WOOD TREATMENT WITH RESIN-FORMING SYSTEMS

PART 3- - A Study of Size and Species Limitations

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WOOD TREATMENT WITH RESIN-FORMING SYSTEMS: A STUDY OF SIZE AND SPECIES LIMITATIONS[1]

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Introduction

Previous papers in this series (5, 6) have dealt with the treatment of thin cross sections of wood and of 1/16-inch-thick veneer, with which complete treatment of the fibers is simple to obtain. Most of the publicity on the treatment of wood with urea resin-forming systems has been concerned with the treatment of lumber (1, 2, 4). Experience has shown, however, that this treatment is practically impossible to accomplish on the heartwood of any species. Surface treatments and even partial penetration treatments cause little if any change in heartwood properties, and they introduce stress difficulties that promote internal checking. The treated zones swell more than the untreated zones during the treating process. Upon drying and curing, the treated zones shrink less than the untreated zones, and thereby cause damaging stresses. For these reasons, it did not seem worthwhile to make further tests on heartwood.

In order to gain more complete information on the limitations imposed by size and species on the resin impregnation of solid wood, a study was made on the sapwood of nine species in 4- and in 6-foot lengths. Both urea-formaldehyde and phenol-formaldehyde resins were used under treating conditions so chosen as to represent practical commercial practice.

Materials Used

In the preparation of specimens for treatment, freshly cut logs and stock lumber were cut into lengths measuring 2-3/4 by 2-3/4 inches by 8 feet and kiln dried to between 8 and 10 percent moisture content. The dried material was then recut and planed to provide test specimens measuring 2 by 2 inches by 7 feet and with the plane of the annual rings as nearly parallel to two opposite faces as possible. Approximately 10 such specimens were provided for each of nine species, including sugar maple, yellow birch, cottonwood,

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yellow-poplar, black tupelo, sweetgum, ponderosa pine, Douglas-fir, and Sitka spruce. Previous comparative tests had shown that 30-inch lengths of the sapwood of basswood and aspen could be treated quite completely with both types of resin used.

Both commercial dimethylol urea and crystal urea and formalin solution were obtained fresh from the same manufacturer.

The water-soluble phenolic resin used for comparative tests was one of the standard resins for this purpose (3).

As a visual aid in determining the extent of resin penetration, 0.05 percent of a water-soluble red dye was added to the treating solution. Ultraviolet fluorescence studies on partially treated veneer showed that the dye closely followed resin penetration.

Treatment of 4-Foot Specimens

Six specimens of each species, matched as well as possible, were selected for treatment. Each specimen was cut into one 4-foot length for treatment, and into three 1-foot lengths to be used as untreated controls for the swelling data. For each species, two specimens were treated with dimethylol urea (DMU), two with a urea formalin mix (UF), and two with the water-soluble phenolic resin (PF). All solutions were proportioned to provide up to a 20 percent resin-forming-solids content, with the urea resins buffered at a pH of 8 and having a 2:1 formaldehyde to urea ratio, as was reported to be most suitable in a previous publication (5).

Treatment was applied by the pressure-cylinder method, in which an air pressure of 200 pounds per square inch was used for 5 hours at room temperature. Following this treatment, the specimens were stored under nondrying conditions for 48 hours to permit diffusion of the resin through the wood, after which period each specimen was end-coated, stickered in a dry kiln, and dried to a moisture content of about 6 to 8 percent using a mild drying schedule. This kiln schedule started at 140° F. and 85 percent relative humidity and at the end of 10 days had reduced the moisture content to 30 percent, after which 160° F. and 50 percent relative humidity were used for 4 days. Curing of the resin-impregnated specimens was done in a hot-plate press under contact-pressure conditions with the platens at 310° F. A period of 6-1/2 hours was required for the center of the specimens to reach 290° F. This temperature was maintained for an additional 30 minutes to allow for resin cure.

In order to determine the extent and thoroughness of resin distribution, each treated and cured specimen was cut into 6-inch lengths, from each of which were cut two 1/8-inch cross sections for swelling tests. Similar cross sections were cut from the untreated controls. After all edges of the cross sections were sanded to remove loose fibers, the sections were oven-dried for 24 hours at 105° C., measured radially and tangentially with a dial gage, and then immersed in water for 48 hours to allow them to reach equilibrium swelling conditions. Entrapped air was removed after immersion by placing the specimens in a desiccator and subjecting them to a vacuum for about 30 minutes. The water-swollen specimens were again measured, and the percentage of swelling was calculated for both the treated and the control specimens. The difference between the swelling of the control specimens and that of the treated specimens, divided by the swelling of the control specimens and multiplied by 100, gave what has been termed the antishrink efficiency (A.S.E.). Table 1 gives a summary of the data obtained on longitudinal resin distribution in the 4-foot specimens as measured by the antishrink efficiency. The values given are averages of the two treated specimens of each species.

A study of table 1 shows that the treatment of the 2- by 2-inch by 4-foot specimens of sweetgum, black tupelo, cottonwood, yellow-poplar, and yellow birch was exceptionally uniform throughout their length. Sugar maple, Douglas-fir, and ponderosa pine showed only a slight falling off of resin content toward the center of the specimens but these species would probably give satisfactory results if they were given a somewhat longer treating time. The urea resins showed only one-fourth to one-half the reduction in swelling and shrinking obtained with the water-soluble phenolic resins. This difference is greater than the difference obtained on thin cross sections where treatment was complete (5). It can be accounted for in part on the basis of the smaller take-up of the urea than that of the phenolic resin-forming materials.

Treatment of 6-Foot Specimens

In view of the more or less uniform results from treatment of the 4-foot specimens, it was decided to treat longer specimens of the same species in an attempt to learn whether additional length would limit resin penetration in material of the same cross section. Because the test specimens, as prepared from the logs, were only 7 feet in length, the maximum specimen length for this new treatment was limited to 6 feet, and the remaining 12-inch lengths were used as controls. Owing to lack of sufficient material on hand in some species, only one specimen of each species was treated, and only the urea-formalin mix and the phenolic resin were studied. Treating, drying and curing procedures were similar to those used with the 4-foot specimens. In addition to antishrink-efficiency measurements for determining the resin penetration, however, specific gravity and standard ball-hardness data were obtained from various positions from the ends and from the surfaces of the 6-foot sections. Table 2 shows the results obtained.

While the three different methods of determining the resin penetration in the 6-foot lengths gave conflicting results for some of the species, the following general conclusions may be reached from a study of table 2:

(1) The sapwood of sweetgum, yellow-poplar, yellow birch, cottonwood, and sugar maple can be treated in 6-foot lengths with a water-soluble phenolic resin to give reasonable uniformity in antishrink-efficiency values. The values will not be so high, however, as those obtained with veneer (3, 7, 8).

(2) The antishrink values obtained with the urea resin were considerably lower than those obtained on the 4-foot lengths and were too low to be of any practical value for stabilization purposes. The negative values obtained for the yellow birch and yellow-poplar specimens seemed to indicate that the resin was not fully cured and that the uncured resin constitutents caused swelling beyond water-swollen dimensions. The ponderosa pine sample checked so badly during drying that swelling cross sections could not be obtained.

(3) Yellow birch showed a maximum increase in hardness, due to resin treatment, of about 60 percent; however, the over-all average for all eight species was only 20 to 25 percent. In general, the increase in hardness paralleled specific gravity increases.

(4) In no case was the increase in hardness sufficient to warrant resin treatment for this purpose.

(5) The penetration values shown by the antishrink-efficiency and hardness increases in the phenolic-resin-treated specimens were sufficiently higher than the corresponding penetration values shown for the urea resin to more than make up for the higher cost of the phenolic resin.

Summary

Solid wood specimens measuring 2 by 2 inches by 4 feet and 2 by 2 inches by 6 feet, taken from the sapwood of nine species of common commercial woods, were treated by the pressure-cylinder method with solutions of dimethylol and urea-formalin resins and of a water-soluble phenolic resin, all at a resin-forming-solids content of 20 percent. After 2 weeks of kiln drying to a moisture content of about 8 percent, the treated specimens were cured under contact pressure in a hot-plate press at 310° F. for 7 hours. Antishrink-efficiency measurements were then taken on 1/8-inch cross sections cut from each specimen at intervals of 6 to 12 inches along its length. Data on specific gravity and hardness increases due to resin treatment were also obtained at various positions from the ends and surfaces of the 6-foot specimens.

The data indicated that reasonably uniform resin penetration is possible for the sapwood of such species as cottonwood, sweetgum, black tupelo, yellow-poplar, yellow birch, and maple in lengths up to 6 feet. In the 4-foot lengths, urea resins showed one-fourth to one-half of the antishrink values of the phenolic resin, while in the 6-foot lengths, these values were considerably lower; too low, in fact, to be of any practical value. The average hardness increase obtained in the 6-foot specimens was approximately 20 percent.

In all cases, resin treatment of these solid wood specimens showed appreciably less improvement in hardness and moisture resistance than has been obtained from panels made from individually treated plies of veneer. Moreover, the treating, drying, and curing of solid wood takes considerably more time than

would be required for making the same size specimens from glued, treated veneer. The test results indicate that the treatment of larger solid wood specimens would not be practical from a commercial standpoint, even for the relatively easy treatment of sapwood.

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Table 1.--Longitudinal resin distribution in 4-foot specimens of eight species, as measured by their antishrink efficiency

Species	Resin	Gross resin content	Antishrink efficiency[1]				
			Ends	6 inches from ends	12 inches from ends	18 inches from ends	Center
		Percent	Percent	Percent	Percent	Percent	Percent
Sugar maple	DMU[2]	15.5	5.0	10.0	10.5	10.0	11.0
	UF[3]	11.0	6.5	7.0	4.5	4.0	3.6
	PF[4]	11.1	47.5	41.5	35.5	37.0	31.5
Yellow birch	DMU	16.2	11.0	16.0	16.5	15.5	14.0
	UF	14.6	13.5	13.0	15.0	13.0	12.5
	PF	20.8	60.5	58.0	57.0	55.5	55.5
Sweetgum	DMU	16.2	29.5	30.5	30.0	30.0	30.0
	UF	15.6	27.0	25.0	26.0	26.0	25.0
	PF	25.3	62.0	61.5	61.5	62.0	62.0
Black tupelo	DMU	15.2	19.0	22.5	21.5	22.5	21.0
	UF	16.2	20.0	21.0	24.0	23.5	23.0
	PF	25.8	62.0	60.0	60.0	60.0	61.5
Yellow-poplar	DMU	14.5	9.5	6.5	5.0	4.5	4.0
	UF	16.5	8.5	8.5	9.0	7.5	9.5
	PF	27.1	55.5	45.5	43.5	39.0	45.0
Cottonwood	DMU	17.0	20.0	21.5	22.0	22.0	23.0
	UF	16.3	19.0	22.0	23.0	22.0	20.0
	PF	25.6	69.5	66.5	67.0	67.0	67.5
Douglas-fir	DMU	10.5	18.5	25.0	29.0	33.0	31.0
	UF	7.2	14.5	14.5	22.0	21.5	22.5
	PF	12.5	48.5	38.5	32.0	36.0	40.0
Ponderosa pine	DMU	30.2	15.0	20.5	34.0	26.5	27.0
	UF	28.5	14.0	27.0	31.5	27.0	27.5
	PF	22.5	66.0	56.5	53.5	47.0	45.0

[1] Values are average of two treated specimens of each species.

[2] Dimethylol-urea resin.

[3] Urea-formalin resin.

[4] Water-soluble phenolic resin.

Table 2.--Longitudinal resin distribution in 6-foot specimens of eight species, as measured by their antishrink efficiency, specific gravity, and standard ball hardness[1]

Species	Type of resin	Gross resin content	Antishrink efficiency: Ends	Antishrink efficiency: 12 inches from ends	Antishrink efficiency: 24 inches from ends	Antishrink efficiency: Center	Specific gravity increase: Surface of end section	Specific gravity increase: Center of end section	Specific gravity increase: Surface of center section	Specific gravity increase: Center of center section	Hardness increase: Surface of end section	Hardness increase: Center of end section	Hardness increase: Surface of center section	Hardness increase: Center of center section
			Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Sugar maple	Urea	10.6	9.0	6.5	7.5	6.5	9.0	6.5	12.0	5.5	24.0	5.5	17.0	16.0
	Phenolic	15.7	53.0	41.0	37.0	42.0	7.0	4.0	7.5	1.0	30.5	19.0	20.0	12.0
Yellow birch	Urea	15.8	-11.0	-4.0	0.0	-1.5	15.5	13.0	17.0	13.0	39.0	26.5	48.0	33.5
	Phenolic	23.8	59.5	45.5	42.0	51.0	16.0	8.0	15.0	6.5	62.0	27.5	44.5	8.0
Sweetgum	Urea	15.3	14.5	5.5	4.0	7.0	17.5	1.0	19.5	5.5	21.0	14.0	10.0	3.0
	Phenolic	23.2	70.0	64.0	63.5	64.0	6.5	4.0	7.0	2.5	2.0	11.5	8.5	4.0
Yellow-poplar	Urea	13.8	-11.0	0.0	4.5	0.0	21.0	8.0	20.5	0.0	21.0	19.0	27.5	12.5
	Phenolic	30.8	61.0	52.0	51.5	52.0	25.5	28.0	23.5	28.0	49.5	49.5	15.5	14.5
Cottonwood	Urea	16.6	1.0	2.0	2.0	1.0	27.0	13.0	26.5	10.0	32.0	5.0	18.0	0.0
	Phenolic	31.5	63.5	59.0	57.5	57.5	18.0	24.5	20.0	12.5	30.0	46.0	38.5	21.0
Douglas-fir	Urea	7.4	10.5	13.0	13.0	15.0	5.0	3.5	5.5	5.0	9.0	3.0	1.5	1.5
	Phenolic	11.0	50.5	13.5	15.0	21.0	9.0	4.0	4.0	2.5	7.5	3.5	1.0	0.0
Ponderosa pine	Urea	22.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	Phenolic	26.6	57.0	45.5	39.5	37.5	26.5	9.5	20.5	0.0	39.5	6.0	17.5	0.0
Sitka spruce	Urea	11.5	12.5	16.5	22.5	23.0	14.5	3.0	9.0	2.5	11.5	0.0	3.0	0.0
	Phenolic	19.5	65.0	33.0	32.5	31.0	13.5	14.5	9.5	7.0	14.5	30.5	16.5	23.0

[1]Values are for one specimen of each species.

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