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Reduction By Natural Resin of Water Uptake in Various Wood Species

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Abstract: Straight and clear sapwood specimens of 3x3x1.5 cm were prepared from spruce (*Picea orientalis L.*), pine (*Pinus sylvestris L.*), beech (*Fagus orientalis L.*), and alder (*Alnus glutinosa Geartn. L.*). The specimens were impregnated in solution consisting of 10% natural resin and 90% cellulosic thinner, with dipping for periods of 1/3, 3, and 24 hours. Test and control specimens were soaked in distilled water for periods of 1/4, 1, 4, 16, and of 24 hours. Both tests were carried out under room conditions: 20±2°C temperature, 65±5 percent relative humidity and atmospherical pressure.

Result showed that there were significant differences according to treatment times, wood species, and periods of immersion in water. The solution absorption, retention of resin, and water repellent effect 10.0-34.5 Kg/m^3, 2.0-9.5%, and 10.0-68.0%, respectively. For each treatment, it was determined that solution absorption, retention of resin, and water absorption were highest in alder whereas water repellent efficiency was highest in spruce. Water absorption was lower in treated wood than in untreated, but water repellent effect increased. As a result, natural resin reduced water uptake of wood with air-dryed humidity. It was shown that the degree of improvement varied according to treatment time, wood species, and period of immersion in water.
Key Words: Wood, Water absorption, Natural resin, Water repellent effect.

Değişik Odun Türlerinde Su Alımının Doğal Reçine İle Azaltılması

Özet: Ladin (*Picea orientalis L.*), Sarıçam (*Pinus sylvestris L.*), Kayın (*Fagus orientalis L.*) ve Kızılağaç (*Alnus glutinosa Geartn. L.*) türlerinin diri odunundan 3x3x1.5 cm'lik boyutlarda düzgün ve temiz deneme örnekleri hazırlanmıştır. Test örnekleri, %10 Doğal reçine (kolofan) ve %90 Selülozik tinerden meydana gelen emprenye çözeltisi içerisine 1/3, 3 ve 24 saat daldırmak suretiyle emprenye edilmiştir. Sonra, test ve kontrol örnekleri 1/4, 1, 4, 16 ve 24 saat süreyle saf suya batırılmıştır. Emprenye ve suya daldırma işlemleri oda şartlarında (sıcaklık 20±2°C, bağıl nem %65±5 ve atmosferik basınç) yapılmıştır.

Bulguların karşılaştırılmasında emprenye sürelerine göre ağaç türleri ve suya daldırma periyodlarında çözelti soğurulması, reçine tutulması ve su itici etkinlik arasında anlamlı farklılıklar bulunmuştur. Çözelti soğurulması, reçine tutulması ve su itici etkinlik, sırasıyla, 10.0-34.5 Kg/m^3, %2.0-9.5 ve %10.0-68.0 arasında olmuştur. Her emprenye süresi için Kızılağaç'taki çözelti soğurulması, reçine tutulması ve su alımı en fazla olurken, sadece Ladin'de su itici etkinlik en fazla olmuştur. Bu işlem ile ağaç türlerinin su iticiliği artmıştır. Yani; doğal reçine, hava kurusu rutubetteki ağaç malzemenin su alımını azaltmıştır. Bu durum emprenye süresine, ağaç türüne ve suya daldırma periyoduna bağlı olarak değişme göstermektedir.
Anahtar Sözcükler: Ahşap, Su alımı, Doğal reçine, Su itici etkinlik.

Introduction

As the only renewable organic material, throughout history wood has been used more widely than other structural materials.

The cell cavities and the spaces between the micelles and the fibrils constitute a porous structure in wood. The base components such as cellulose, hemicellulose and lignin are free hydroxyl groups. The micelle structure of wood results in a very extensive internal surface. For these reasons wood, being hygroscopic, swells or shrinks as it takes up or loses moisture (1). The absorbed or evaporated water does not cause any change in the volume of wood and dimensions above the fiber saturation point (FSP, 28-30%). Below this point, changes in moisture content (MC) lead to swelling or shrinking of the wood; thus, this is a highly undesirable property in wood (2). Treatments developed to reduce the tendency of wood to take up water and to reduce its dimension changes below the FSP can be divided into two groups. The first is treatment with water repellent substances (WRS), and the second is treatment with dimensional stablizer substances. Even though these two methods are often used synonymously, they are, in fact, completely different approaches to controlling moisture content in wood. Namely, dimensional stability defines the equilibrium, while water repellency describes the rate of water uptake (3). The aim of the first is to prevent, or to control the rate of moisture uptake. Treatment consist of dipping the wood in a solution of hydrophobic substances such as paraffin, resin, wax or silicon oil, reducing the rate of water uptake since the internal and external surfaces of the cell walls are covered by the hydrophobics. Wood treated in this way takes a longer time to swell, but the extent of swelling is almost the same as in untreated wood. By contrast, the aim of the second treatment is to reduce or to prevent swelling and shrinking resulting from moisture uptake. Dimensional stability is related to the extent of swelling and shrinking rather than the rate of the water uptake. With this treatment, hydroxyl groups in wood components are changed into less hygroscopic groups (4). For this reason, the wood is bulked, and remains so because the inner as well as outer surfaces of the wood cell walls now have a hydrophobic property. Thus, dimensional stabilization is achieved by reducing changes in wood dimensions and volume (5).

Measures of water repellency and dimensional stability are the degree of reduction in the water absorption (WA) rate, and extent of swelling or shrinking, respectively. The water repellent effect (WRE) depends on a number of parameters, such as the formulation of water repellents, the concentration and point of WRS in solution, the contact angle between liquid and solid wood, the pore structure of the wood, the method of treatment, the distribution of WRSs in the wood, and weather conditions during exposure (3). The appearance and the biodegradation-extent of wood have also been used as indexes of WRE (6). The protection process through impregnation with water repellents is an established treatment in use in most countries (7). However, in order to develop new and more effective WRSs or mixtures in this field, and hence to improve WRE or to reduce WA, new techniques and more information are necessary. The aim of the study is to investigate the effects of natural resin on the reduction of water uptake in various wood species.

Materials and Methods

Wood specimens

The spruce (*Picea orientalis L.*), pine (*Pinus sylvestris L.*), beech (*Fagus orientalis L.*), and alder (*Alnus glutinosa Geartn. L.*) used in the experiments were obtained from the eastern Black Sea region (Maçka, Trabzon) of Türkiye. Straight and clear of 3x3x1.5 cm were taken from the sapwood of logs of the above-mentioned species. They were designated test and control specimens. Specimens with imperfections such as knots, cracks, slits, and so forth were eliminated. Before treatment, all the specimens were conditioned from 10 to 12% MC at 20-25°C and 60-65% relative humidity (6).

Ten test and 10 control specimens were taken from the experimental logs of each species. Thus, a total of 3x4x10x2=240 test and control specimens were prepared from the experimental logs four species, for the different treatments (8).

Chemicals

Natural resin was used as WRS and cellulosic thinner as organic solvent. Both chemical substances were of commercial grade. The solution was comprised of 10% resin and 90% solvent (w/w). The solution was prepared as previously reported (7).

Treatments and measurements

Before treatment, oven-dry weights were determined by drying the specimens in a forced draft oven at 105°C until constant weights were achieved, cooling them in a desiccator for 10 min., and weighing them with ±0.01g sensitivity (9). Test specimens were then dipped in the resin solution under room conditions (20±2°C , atmospherical pressure and 65±5% relative humidity) for 1/3, 3 and 24 hours (8).

After the treatment, the specimens were taken out of the solution and, after residual solution was wiped off with paper, they were reweighed to determine weight percent gain (WPG). Solution absorption (SA) was calculated by equation (10):

$$SA=(Wt-Wo)/V$$

Where:

Wt=Weight of the specimen treated for time “t”,

Wo=Oven-dry weight and V Volume of each specimen.

The specimens were then open-stocked for 10-15 days under room conditions to allow solvent evaporation (6). After impregnation to determine oven-dry weight, the specimens were redried, cooled, and weighed, as previously described. The retention of resin (ROR) was calculated by equation (10):

$$ROR=[(Woa-Wob)/Wob]x100$$

Where:

Wob=Oven-dry weight before treatment,

Woa=Oven-dry weight after treatment.

Immersion in water and measurements

In order to determine of water absorption, the specimens were soaked in distilled water for periods of 1/4, 1, 4, 16 and 24 h (8). The weight gain due to water uptake was reported before each immersion period. Residual water was wiped off, and specimens were weighed, as previously described. Water absorption (WA) was calculated by equation (8):

WA=[(Wt-Wo)/Wo]x100

Where:

Wt=Weight of the specimen soaked in water for time "t",

Wo=Oven-dry weight.

The water repellent effectiveness (WRE) acquired by the specimens were then calculated to determine water repellent property or effect of natural resin on reduction of water uptake, by equation (3):

WRE=[(Wc-Wt)/Wc]x100

Where:

Wt=Weight of test specimen soaked in water during time "t",

Wc=Weight of control specimen soaked in water during time "t".

Statistical analysis

Analysis of the results was performed using the statistical graphics system "STATGRAPHICS". The values calculated for 120 (3x4x10) test specimens were used as data for this computer program. Multifactor analysis of variance was used to determine whether treatment time, wood species, and period of immersion in water had significant effects on SA, ROR, WA, and WRE. The multiple range tests were used to analyse homogeneous groups of these factors, and hence to determine statistically significant differences. Furthermore, interactions for treatment time by wood species, treatment time by immersion in water-period, and immersion in water-period by wood species were studied. Analyses and tests were conducted separately for each property, with all of the factors taken into consideration in order to determine the one with the greatest effect.

Results and Discussion

The solution absorption (SA) and retention of resin (ROR)

Tables 1 and 2 show the average values of SA and ROR of treated wood species, respectively. The SA and ROR increased for all of the species with the elapse of treatment time. WPG was almost equal in all of the species at 1/3 and 3 h, but was highest at 24 h. Both SA and ROR were higher in hardwoods (beech and alder) than in softwoods (spruce and pine). Furthermore, at all the times, the SA and ROR in beech and the SA in spruce were lower than those in alder and pine, respectively.

Table 1. The values of SA (Kg/m3) of various wood species treated at various times.

Treatment	Wood Species *			
Times (h)	Beech	Pine	Alder	Spruce
1/3	12.01	8.99	22.76	6.98
3	13.18	9.78	23.79	9.42
24	17.44	17.37	34.39	14.67

* These values are means calculated for 10 test specimens.

Table 2. The values of ROR (%) of various species treated at various times.

Treatment	Wood Species *			
Times (h)	Beech	Pine	Alder	Spruce
1/3	2.71	1.85	6.09	2.83
3	3.97	2.15	6.13	4.05
24	4.63	3.53	9.33	5.37

* These values are means calculated for 10 test specimens.

For each treatment time, SA and ROR were highest in alder, but the first and the second were lowest in spruce and pine, especially at 1/3 h, respectively. This excess can be attributed to the anatomical properties of the wood of the species, because the cell cavities are larger in hardwoods, the cell walls are thinner and more permeable, there are more between the cells, and the openings of the pits are larger than in softwoods (11).

When compared with the values reported by Voulgaridis the SA values obtained in this experiment, especially in spruce and pine at 1/3 h, were some what lower than those reported by Voulgaridis (1988) under the same conditions, but the values in the beech and alder were nearly the same. This can be attributed to the anatomical properties of the spruce and pine are different from those of the oak, as fluid liquid absorption and flow in the vessels and the fibres of hardwoods were more excessive and faster than in softwoods (11). There were no significant differences between the results of the two studies, other than treatment time, wood species, and paraffin wax. Sapwood and hardwood specimens of oak (*Quercus conferta Kit.*), natural resin/paraffin wax mixtures included paraffin at various content, and 3-min dipping were used in the taken about paper, whereas parameters described previously were used.

The water absorption (WA) and water repellent effectiveness (WRE)

Tables 3 and 4 show the average values of WA and WRE for wood samples soaked in water after treatment. In all the species, WA generally increased with the elapse of treatment time and immersion period while WRE decreased. Although WA increased at nearly the same rate for all treatment times and immersion periods, WRE decreased at different rates for all times and the periods of 1/4 h and 1 h, but was about the same for the other periods. Moreover, while the highest WA was obtained with 3-h treatment time and 24 h immersion period, the lowest was obtained with 1/3 h and 3 h treatment times and a 1/4 h immersion period. Whereas the WRE became vice versa of this with 3 h-treatment and the same periods. The WREs of spruce and pine were greater than those of beech and alder, although the WA of spruce was lower than that of pine for all periods. Namely, the WA obtained in softwoods was lower than in hardwoods, and hence the WRE was greater. For all treatment times, WA was highest and WRE was lowest for the 24-h period in alder, whereas in beech, WA was lowest and WRE was lowest for the 1/4-h period.

Table 3. The values of WA (%) of various species of wood immersed in water for various periods after treatment for various times.

		Wood Species *							
Treatment	Immersion	Beech		Pine		Alder		Spruce	
Times (h)	Periods (h)	Test	Control	Test	Control	Test	Control	Test	Control
	1/4	9.39	14.61	26.23	47.47	34.47	58.45	14.00	44.15
	1	16.93	24.80	37.71	62.70	46.02	66.01	25.69	57.95
1/3	4	27.12	35.80	49.42	65.99	58.99	73.88	43.74	69.35
	16	43.10	51.28	55.84	71.44	74.44	81.02	62.35	76.72
	24	48.50	56.18	58.37	74.00	80.33	86.04	68.32	82.46
	1/4	10.69	14.42	26.51	47.10	35.56	58.00	15.90	45.02
	1	18.17	24.05	38.97	62.45	47.14	66.00	26.15	57.51
3	4	28.21	35.41	50.14	65.43	59.20	73.79	46.19	68.39
	16	44.71	51.09	56.08	71.00	75.00	81.00	63.55	77.15
	24	49.20	56.08	59.60	74.16	81.11	86.11	70.00	82.90
	1/4	13.10	14.13	26.90	47.74	38.36	58.21	16.63	45.00
	1	20.37	24.55	39.46	62.64	48.61	66.28	26.65	57.25
24	4	30.12	35.15	51.42	65.12	60.51	73.08	46.91	69.00
	16	45.17	51.00	58.79	71.02	75.40	81.31	69.43	77.66
	24	50.23	56.38	61.83	74.06	81.69	86.00	75.73	82.36

* These values are means calculated for 10 test and control specimens.

The WA values obtained in this experiment were slightly different from those reported by Rowell and Banks (1985). We think that this differences are attributable to treatment time, period of immersion in water, types of resin and paraffin wax, and their mixture rate. Rowell and Banks used modified resin and resin ester mixed with refined wax and unrefined wax at various contents, whereas we used the above-mentioned parameters.

WRE values recorded in this experiment for spruce and alder at periods of 4 and 24h were somewhat lower than those reported by Yıldız and Hafızoğlu (1990) for the same species and the same periods. This difference may be due to the WRS, the mixture rate, and means of impregnation. We used the previously described parameters, whereas they used paraffin wax, alkyd resin and linseed oil mixed in different amounts with paraffin wax, and they employed the hot-cold open tank process, and the stepwise increasing pressure method.

In addition, no significant difference was found between the WRE of beech at for a 1/3-h treatment time and the WRE of alder for all three treatment times between the WREs of spruce and pine for 3-h-treatment time, or between the WRE of spruce at 1/3-h and 24-h treatment times. However, while the WRE values of beech, spruce, and pine at 16-h and 24-h periods were almost the same, the WRE values of pine and alder at a 16-h period were

Table 4. The values of WRE (%) for various species of wood immersed in water for various periods after treatment for various times.

Treatment Times (h)	Immersion Periods (h)	Wood Species * ** Beech	Pine	Alder	Spruce
	1/4	35.75	44.74	41.03	68.29
	1	31.73	39.86	30.28	55.67
1/3	4	24.25	25.11	20.15	36.93
	16	15.95	21.84	8.12	18.73
	24	13.63	21.12	6.64	17.15
	1/4	25.87	43.72	38.69	64.68
	1	24.45	37.60	28.58	54.53
3	4	20.33	23.37	19.77	32.46
	16	12.49	21.01	7.41	17.63
	24	12.27	19.63	5.81	15.56
	1/4	17.29	43.65	34.10	63.04
	1	17.03	37.01	26.66	53.45
24	4	14.24	21.04	17.20	32.01
	16	11.43	17.22	7.27	10.60
	24	10.91	16.51	5.01	8.05

*These values are means calculated for 10 test and control specimens.

** The values WRE of control specimens are 0.

nearly the same as those of beech at 1/4, 1, and 4-h periods.

Conclusions

The conclusions of this study may be summarized as follows according to the analysis:

1-Water uptake of wood specimens impregnated with natural resin decreased in comparison with the untreated specimens; hence, the WRE of the wood increased. Namely, the natural resin reduced WA between 10.0% and 68.0% in wood having air-dry humidity. This differed according to treatment time, species of wood and period of immersion in water.

2- SA and ROR increased with the elapse of treatment time. WA increased with the period of immersion in water but WRE decreased. This resulted from further increase of hydrophilic groups and decrease of hydrophobic groups during operations.

3- For periods of immersion in water and wood species, while treatment times had almost the same effect on the WA, the effects on WRE were different.

4- SA, ROR, and WA were highest while WRE was lowest in alder. The highest WRE and the lowest SA were found in spruce. The ROR and the WA were lowest in pine and beech, respectively.

5- Wood species, treatment time, and period of immersion in water were effective on water uptake and water repellency. Statistically significant differences were established among these effects. This was due to the anatomical properties of the species and the composition of the resin.

6- When various types of resins and impregnation processes are used for the prevention or moderation of moisture absorption, the amount of solution and retention of resin in the wood may vary since the chemical components of resins and the conditions of the processes

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