PROTECTION OF OAK WOOD (*Quercus conferta* Kit.) FROM LIQUID WATER UPTAKE WITH WATER REPELLENTS

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ABSTRACT

Eight water-repellent formulations based on both a synthetic resin (straight chain hydrocarbon resin) and natural resin were applied to small cross-sectional specimens of broadleaved oak wood. Treated sapwood specimens were protected against liquid water entry to a significant degree, while heartwood specimens exhibited high self-protecting ability and their treatment with water repellents appeared to be less beneficial. By increasing the concentration of hydrophobic substance (paraffin wax) from 1 to 5% in the solution, an increased water-repellent effectiveness was achieved. Simple resin formulations (without paraffix wax) were found to be less effective than resin/wax formulations in sapwood, while in heartwood differences were much smaller. Natural resin from Aleppo pine trees was equally effective to straight chain hydrocarbon resin, and hence it may successfully replace synthetic resins in water-repellent formulations.

Keywords: Water repellents, natural resin, oak wood, rate of swelling.

INTRODUCTION

Water repellents are organic solutions containing as basic constitutents a resin of some type and a small amount of paraffin wax or other hydrophobic substance. By adding a fungicide or insecticide to the solution, the formulations, known as water-repellent preservatives, provide both protection from water and from fungi and insect attack.[1]

Water-repellent treatments reduce the rate of liquid water uptake in treated wood, but they do not reduce the extent of swelling to any degree as dimensional treatments do (Borgin 1961). The degree of reduction of liquid water penetration rate in treated wood is a measure of water-repellent effectiveness (WRE). For the assessment of WRE, several techniques have been proposed and used by the investigators either before or after weathering in laboratory and field experiments. These methods were based on contact angle measurements[2] and mainly on water uptake or swelling data.[3]

For comparative purposes, parameters such as time needed for wafer wood specimens to reach a fraction of maximum swelling and diffusion coefficients

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[1] Banks 1971; Borgin 1968; Feist and Mraz 1978a, b; Miniutti et al. 1961; Purslow and Williams 1978; Rowell and Banks 1985; Verrall 1961; and Voulgaridis 1985.

[2] Banks and Voulgaridis 1980; Borgin 1961; Gray and Wheeler 1959; Rak 1975.

[3] Banks 1970; Banks and Voulgaridis 1980; Borgin 1965; Borgin and Corbett 1973; Browne and Schwebs 1944; Levi et al. 1970a,b; Miniutti et al. 1961; Purslow and Williams 1978; Rowell and Banks 1985; Voulgaridis and Banks 1979.

based on swelling rates were used and regarded as good indicators of WRE.[4] The appearance and the extent of biodegradation of wood have also been used as indexes of WRE or complementary indicators.[5]

The WRE is dependent on a number of parameters. As has been previously reported, the protection of wood with water repellents is due to hydrophobic effects afforded by paraffin wax and to blocking effects provided by resin.[6] The significance of these two effects differs between softwoods and hardwoods and is associated with pore structure and distribution factors.[7] Differences in WRE have been observed between certain resin/wax formulations and attributed to the type of resin or wax incorporated in the solution (Banks and Voulgaridis 1980; Voulgaridis 1985). Improved WRE has been achieved by increasing the concentration of resin and particularly of the hydrophobic substance (usually a type of paraffin wax) in the solution (Banks 1971; Purslow and Williams 1978; Voulgaridis 1985). However, there are limitations of the solution strength if further surface treatment of wood (e.g., overpainting) is needed (Banks 1971). Other factors such as method of treatment (immersion, vacuum treatment), type of carrier solvent, wood species, treatment and test conditions have been found to affect the distribution of water-repellent substances in wood and hence the WRE.[8]

The treatment of wood with water repellents has been internationally established, but more information is needed for their mechanism of protection in order to improve the WRE or to develop new and more effective formulations. In this work, the initial WRE (without exposure of wood to the weather) of various formulations is studied after their application to oak wood (*Quercus conferta* Kit.) which is one of the main species of coppice forests in Greece and, among other uses, it may be used in joinery. Furthermore, a comparison is made between two groups of water-repellent formulations based on a synthetic resin (straight chain hydrocarbon resin) and natural resin collected from Aleppo pine trees (*Pinus halepensis* Mill.), respectively.

MATERIALS AND METHODS

From normal sapwood and heartwood of broadleaved oak (*Quercus conferta* Kit.) in air-dry condition a number of sticks, 2.5 × 2.5 cm in cross section and 30 cm long, with precise radial and tangential faces, were prepared. Each stick was converted to cross-sectional specimens of 6 mm thickness. These wafer specimens were treated with eight water-repellent formulations (see Table 1), and some of the specimens were used as untreated controls. A total of 108 cross-sectional specimens (54 from sapwood and 54 from heartwood) were used in the experiment.

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[4] Banks 1971; Banks and Voulgaridis 1980; Stamm 1959; Voulgaridis and Banks 1979.

[5] Borgin and Corbett 1973; Feist 1984a, b; Feist and Mraz 1980; Scheffer et al. 1963; Verrall 1959.

[6] Banks and Voulgaridis 1980; Borgin and Corbett 1970; Rowell and Banks 1985; Voulgaridis 1985; Voulgaridis and Banks 1979.

[7] Banks and Voulgaridis 1980; Banks and Carragher 1984; Levi et al. 1970a,b; Voulgaridis 1985; Voulgaridis and Banks 1979.

[8] Banks and Carragher 1984; Borgin and Corbett 1970; Feist and Mraz 1978a,b; Levi et al. 1970a,b; Purslow and Williams 1978; Rowell and Banks 1985; Scheffer et al. 1963; Voulgaridis 1985; Voulgaridis and Banks 1979.

TABLE 1. *Experimental water-repellent formulations, retention of water-repellent substances by oak wood specimens and water-repellent effectiveness (time to 1/4 maximum swelling).**

a/a	Formulation	Retention, Kg/m³		WRE (time to 1/4 max. swell), min	
		Sapwood	Heart-wood	Sapwood	Heartwood
1.	10% synthetic resin	18.71	1.87	60.08 (16.27)	168.00 (20.74)
2.	10% natural resin	16.73	1.67	66.83 (13.36)	162.50 (19.39)
3.	10% synthetic resin + 1% paraffin wax	15.25	1.65	106.50 (14.41)	168.50 (25.10)
4.	10% natural resin + 1% paraffin wax	16.26	1.77	96.16 (9.99)	165.00 (9.40)
5.	10% synthetic resin + 2% paraffin wax	15.25	1.83	126.16 (14.97)	169.33 (7.17)
6.	10% natural resin + 2% paraffin wax	17.24	2.07	127.66 (7.11)	181.00 (6.69)
7.	10% synthetic resin + 5% paraffin wax	21.67	3.25	144.16 (9.43)	191.83 (13.49)
8.	10% natural resin + 5% paraffin wax	22.18	3.31	161.16 (21.16)	201.33 (16.69)
9.	Controls	—	—	8.16 (1.40)	121.25 (14.46)

* Values are means from 6 replicates (in parentheses standard deviations). Statistically (Snedecor and Cochran, 1967), the sample size of each treatment has been found satisfactory ranging from 1 to 9 for $P = 95\%$ and standard error of $\bar{x} = 10\%$ except for treatments 1 and 2 (sapwood only).

The water-repellent solutions were based on a synthetic resin (straight chain hydrocarbon resin) and natural resin produced by Aleppo pine trees. Paraffin wax of melting point 53 C was incorporated in six solutions as hydrophobic substance (Table 1). The water-repellent substances (resin, paraffin wax) were dissolved in an organic solvent (toluene).

The air-dried cross-sectional specimens were impregnated in groups by immersion for 3 min in the water-repellent solutions described in Table 1. The specimens were weighed before and after treatment for calculation of solution absorption and the amounts of solid substances deposited in wood. After treatment, the specimens were open-stacked for two months to allow complete solvent evaporation in room conditions (20–23 C, 50–55% RH).

The WRE was assessed by measuring the tangential dimensional change of the wafer specimens. According to a technique used previously (Voulgaridis and Banks 1979), each specimen was mounted on the jig of a dial micrometer and immersed in distilled water at 20 C. The rates of tangential swelling were taken as the time needed to reach the quarter maximum swelling from the air-dry condition. At maximum swelling, the total swelling of controls from air-dry to full saturated condition was taken.

RESULTS AND DISCUSSION

The results are shown in Table 1 and Fig. 1.

Table 1 shows that the retention of water-repellent substances (resin, wax) by wood specimens is very low in heartwood when compared to sapwood specimens probably because of formation of tyloses or other pore-blocking occlusions and deposition of high amounts of extractives in heartwood. Relatively high retentions were calculated for solutions of higher concentrations.

The initial WRE in terms of time needed for the specimens to reach the quarter maximum swelling for all water-repellent formulations tested is shown also in Table 1. It can be seen that the WRE of formulations based on natural resin (solutions 2, 4, 6, 8) is comparable to that of formulations based on synthetic hydrocarbon resin (solutions 1, 3, 5, 7, respectively) which is usually used as the basic water-repellent constituent. Hence, natural resin from Aleppo pine trees

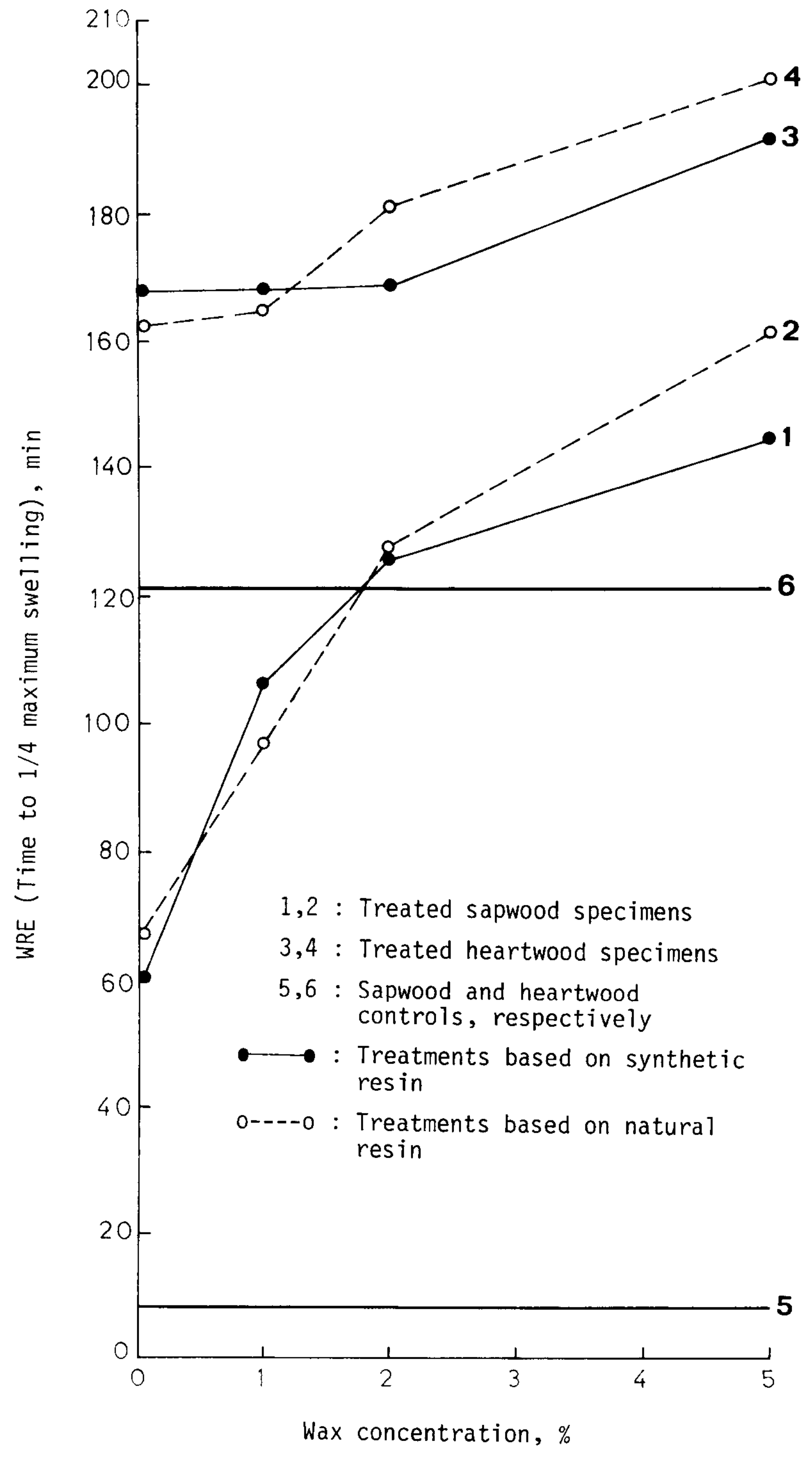

FIG. 1. Water-repellent effectiveness (WRE) in sapwood and heartwood oak wood specimens treated with water-repellent formulations of varying wax content.

grown in Mediterranean regions can successfully replace synthetic resins used for water-repellent formulations.

The WRE of various water-repellent formulations tested is shown graphically in Fig. 1 for comparison. Comparison between sapwood and heartwood control oak specimens shows that the heartwood has significant ability to reduce by itself the rate of moisture absorption when it is in contact with water. The time needed for heartwood control specimens to reach the quarter maximum swelling was 15 times greater than that of sapwood specimens. Figure 1 also shows that this inherent WRE of untreated heartwood specimens offers significant protection to wood against water entry when compared to WRE of treated sapwood. After treatment of heartwood with water repellents, its ability to resist the entry of water is strengthened but to a lesser extent than in sapwood specimens. The WRE in treated heartwood specimens increased only 1.34–1.66 times, while in treated sapwood specimens about 7–20 times.

The WRE is increased as the concentration of paraffin wax in the solution increases and this tendency is much more clear in sapwood than in heartwood (Fig. 1); hence, the solutions incorporating 5% paraffin wax were the most effective. Simple resin solutions (without paraffin wax) are less effective than resin/wax solutions in sapwood because resin does not provide strong hydrophobic properties to wood (contact angle lower than 90°), and the protection against water entry in this instance is based mainly on blocking mechanisms. In heartwood, the WRE of simple resin solutions is not much lower than for resin/wax solutions and, in general, differences between treatments are small. This is because in heartwood specimens blocking effects play the principal role in the protection of timber from liquid water penetration.

CONCLUSIONS

The conclusions of this study may be summarized as follows:

1. A significant degree of protection against liquid water uptake is afforded by application of a number of water-repellent formulations to sapwood of broad-leaved oak (*Quercus conferta* Kit.) when it is exposed to water action. Heartwood is protected by itself to an adequate degree against water entry.

2. The water-repellent effectiveness (WRE) in treated oak wood specimens is improved by increasing the concentration of paraffin wax in the solution from 1% to 5%. Simple resin solutions applied to oak sapwood specimens appeared to be less effective than resin/wax treatments, but in heartwood no substantial differences between the treatments occurred.

3. Natural resin collected from Aleppo pine trees (*Pinus halepensis* Mill.) was found to be a successful substitute for synthetic resins incorporated as basic constituents in water-repellent formulations.

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