Capillary Water Uptake and Mechanical Properties of Wax Soaked Scots Pine

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ABSTRACT

The impregnation of wood with hydrophobic agents are applied to minimize the speed of water uptake and shrinking of timber and reduce the risk of fungal and insect attack. Scots pine (*Pinus sylvestris* L.) was soaked in hot melting waxes in a vacuum-pressure-treatment. Two different wax types were used, a synthetic amid wax and a montan wax extracted from lignite. The presence of wax in the wood cavities causes a density increase which influences the mechanical properties as well as the uptake of water. The capillary uptake of liquid water was clearly reduced. The MOR was increased up to 28% and the MOE up to 10%. An increase in impact bending strength of approx. 30% compared to the references was shown. The hardness of wood filled with amid wax was improved to 120 N/mm² (lateral). Besides potential applications in those areas, where wood is wetting and drying frequently, the increase of the mechanical properties could be open new application fields for wax treated timbers such as flooring or decking.

INTRODUCTION

The impregnation of wood with hydrophobic agents reduces capillary water uptake. Inhibition of water penetration inside wood occurs by blocking the vessel lumens, ray cells or tracheids by hydrophobic compounds (Sell 1977). Such compounds are oils, silanes or silicones (Borgin and Corbett 1970, Mai and Militz 2004). The use of paraffin emulsions for wood based panels is widely used in order to decrease the swelling. Normally the wax content inside the emulsion does not exceed 2% (Deppe and Ernst 1996). Hot melted waxes are only of minor importance because of the more complex handling, the need of special equipment, higher flammability, costs, etc. (Anonymus 2007). A few companies in the timber sector work with distinct methods based on wax. Conventional methods are Natwood (Austria), Waxwood or Dauerholz (Germany). The products have an increased water repellent effect, improved compression strength or hardness. According to the use of wax in the timber industry in literature only few sources can be found (*e.g.* Rapp *et al.* 2005). The use of pure wax influences the mechanical properties, dependant on the input and type of wax. Besides the non fossil natural waxes (*e.g.* bees wax, carnauba palm wax) and natural fossil waxes such as waxes derived from petroleum or lignite the synthetic types exist, for instance the hydrocarbon waxes (e.g. polyolefin, Fischer-Tropsch) or amid waxes. Modifications via oxidation or with other chemicals are possible (Illmann *et al.* 1983). Various waxes have a wide range of properties such as melting point, surface energy, viscosity or hardnesses. The goal of the project was to find optimum waxes for the treatment of wood due to the high number of wax compounds. After pre-screenings, two waxes were selected for further trials. The aims were the combining of the fixation of a hydrophobic agent with an improvement of mechanical properties.

EXPERIMENTAL

Scots pine sapwood blocks were pressure treated with hot melted waxes (temperature: 120°C, pressure: 12 bar). The blocks were cut into specimens according to table 1. The applied amid wax is based on oxazolin (1), the other type, a lignite based wax (2), is an esterified montan acid (C_{24}/C_{34}). The references were numbered with 0.

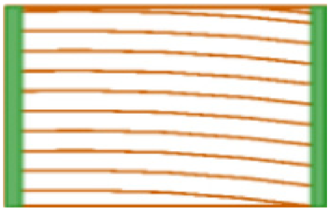

Figure 1: Section through radial water uptake specimen

The lateral water uptake was carried out according to table 1 and figure 1. The sample bodies were sealed in such way that only the two radial or tangential surfaces were open before water exposure. The specimens were packed by using a water resistent tape (Siga). The weighted samples were submerged 2 mm on a totally water saturated sponge surface on one of their unsealed surfaces. The weight was measured after 1h, 3h, 6h, 12h, 24h, 48h, 72h etc. for 17 days. According to the slope of regression line the water transit velocity was calculated by determine the capillary water uptake coefficient (1) by dividing the water uptake through the root of time (1) and compared with the references.

$$k_{WA}\ (kg\ x\ m^{-2}\ x\ h^{-2}) = WA_k / t^{-0,5} \qquad (1)$$

According to table 1 the strength properties, the impact bending strength as well as the hardness were determined. The significances of the results were compared with the t test (level of significance: 0.95).

Table 1: Overview about the sample sizes and applied standards

Parameter	Block size [mm³]	Specimens [mm³]	Test clima [s]	Standard
Capillary water uptake	40 x 40 x 20	40 x 40 x 20	-	EN 15 148
Density	variable	variable	variable	DIN 52 182
Compression strength	400 x 22 x 22	30 x 20 x 20	20°C / 65%[a]	DIN 52 185
Bending properties	400 x 12 x 12	180 x 10 x 10	oven dried	DIN 52 186
Brinell-Hardness	400 x 22 x 22	30 x 20 x 20	20°C / 65%[a]	EN 1534
Impact bending strength	400 x 12 x 12	150 x 10 x 10	20°C / 65%[a]	DIN 52 189

[a]*relative humidity*

RESULTS AND DISCUSSION

Capillary water uptake

Figure 1 shows the capillary water uptake as a function of root of time. The wax treated wood shows a reduced water uptake compared to untreated wood specimens. The capillary water uptake velocity averages between 16 times (wax 1) and 11 times (wax 2) under the references in radial direction. Both treatments cause a minimization of water uptake up to 5 times under the references in tangential direction. Over a period of time more water penetrates the radial than the tangential direction of the references due to the water conduction effect of rays (Bosshard 1984). However, the difference between the capillary water uptake against the direction in space are marginal. That could be explained by blocking the ray cell lumens with penetrated wax deposits. The low water uptake will positively contribute to the behaviour of wood under use conditions, where wood frequently will undergo climate changes (*e.g*. terraces or floorings).

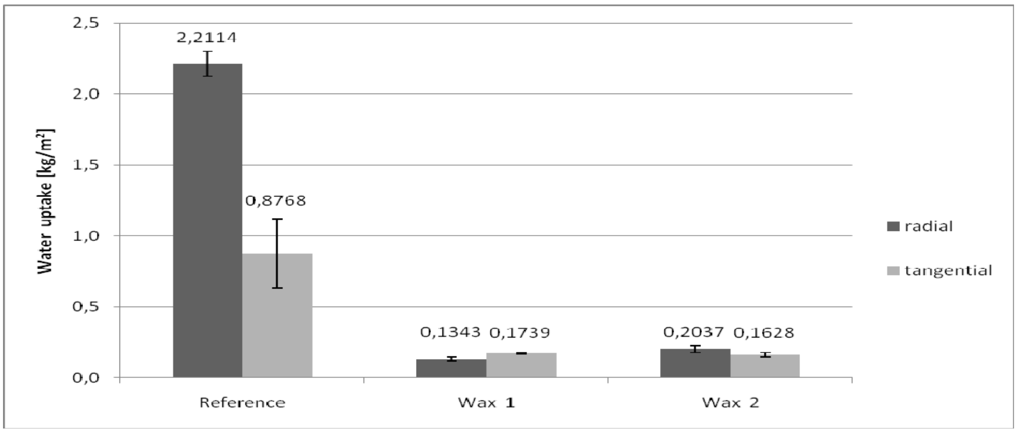

Figure 1: Lateral capillary water uptake of Scots pine within 17 days

Mechanical properties

The average density of wax soaked timber increases from approx. 460 kg/m³ up to 1,050-1,090 kg/m³ (wax 1) and 860-1,040 kg/m³ (wax 2), respectively. In terms of a very similar density of the two wax types, the upload of timber is more effective with wax 1. Table 2 shows an increase in hardness as well as higher strength properties. The calculated results of the wax treated specimens are significant higher than the references. Wood impregnation with wax increases the compression strength up to 29% (wax 1) and 24% (wax 2). The average MOR increases up to 20% (wax 2) as well as up to 28% (wax 2) and 10% more stiffness referred to untreated specimens, respectively. The lateral hardness accelerates up to average 445% (wax 1) and 200% (wax 2). The axial hardness increments range between 180% (wax 1) as well as 57% (wax 2). The impact bending strength increases up to 30% (wax 1) and 34% (wax 2), respectively. The increment of the density provokes the increase of the strength properties. The hardness of tropical timbers increases due to incorporated tannins or minerals amongst others (Scheiber 1965, Lohmann 1991). During compression stress etc. the ruptures in wood occur via a collapse of the fibres in the wood cavities (Niemz 1993). The in the lumens coagulated wax deposits minimize the wood cavities and increases the resistance against penetrating objects as well as it reinforces collapsing fibres.

Table 2: Increase of strengths and hardness by wax soaking of wood (mean ± standard deviation)

Wax	σ_D [a]	*MOR*[a]	*MOE*[a]	$HB_{\perp}$ [a]	$HB_{\parallel}$ [a]	ω [b]
0	49 ± 3	138 ± 15	12,560 ± 960	22 ± 9	51 ± 11	27 ± 4
1	63 ± 11	165 ± 23	13,780 ± 1,720	120 ± 29	143 ± 29	36 ± 8
2	61 ± 4	176 ± 24	13,600 ± 1,470	66 ± 9	80 ± 6	37 ± 11

[a]*N/mm²*, [b]*kJ/m²*

CONCLUSION

Wax refined wood could be suited for outdoor uses under varying climate conditions. With an increasing wax uptake the hardness and strength properties are increasing significantly. The aim of combining hydrophobising and reinforcement treatments of timber is feasible with a wax treatment. Certainly other aspects for practical applications are important, too, such as flammability, weathering etc. Further research is under way to clarify these aspects.

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