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Section 4 **Processes and properties**

Thermally modified wood treated with methacrylate

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Thermally modified timber treated with methacrylate

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ABSTRACT

Thermally modified timber (TMT) from Scots pine sapwood similar to Thermo-D quality was impregnated with methacrylate resin by the hot-and-cold method and subsequently cured at elevated temperatures. The results showed that methacrylate resin could be used to reduce colouring of painted TMT wood during accelerated weathering probably by hindering the migration of extractives. The resin itself did not reduce greying of the unpainted wood. Hardness was only slightly improved by treatment with the resin probably due to a higher density of the material. Formation of blisters occurred but was reduced by treatment with the resin. Resistance to mould growth by a mixture of *Aureobasidium pullulans, Cladosporium cladosporioides, Aspergillus versicolor, Penicillium purpurogenum* was performed by applying EN-15457:2014. Treatment with methacrylic resin hindered the colonisation of the three last mould fungi.

Keywords: TMT, Scots pine, methacrylic resin, mould, bulking, extractives.

1. INTRODUCTION

Thermal modified timber (TMT) is in many ways ideal for use in out-door conditions and its durability could be compared with other common preservative or modification methods as long as it is not exposed to extended periods of water or in ground contact. Mould growth is to a great extent related to the moisture in wood and will lead to undesired colour changes and a lower quality of wood. Leaching or migration of extractives (native or formed in the modification/drying process) during production and end-use may lead to undesired colour changes of wooden facades. Such behaviour could influence the ability to attract or repel colonisation of microorganisms on wood (Karlsson *et al.* 2014, 2017). In this paper we study the influence of treatment of thermally modified wood from Scots pine (*Pinus sylvestris*) sapwood with methacrylic resin against a series of properties including leaching of extractives through a painted surface as well as colonisation by moulds. Previous results have shown that a hot and cold process in which a heated wood is immersed in a cold liquor could be used for impregnation of wood with vegetable oil derivates (Elustondo *et al.* 2017) and a similar approach was applied for impregnation with methacrylic resin (MA) followed by curing at elevated temperatures.

2. MATERIAL AND METHODS

Scots pine was kiln dried to a moisture content (MC) of 10-15% and thermally modified under saturated steam conditions in an autoclave at 170°C only adjusting to keep constant climate (Dagbro *et al.* 2010). Samples containing sapwood were carefully sawn (130*74*18 mm) and conditioned at 20°C and RH 65%. Samples were dried in oven at 103°C and directly transferred into a metal net basket in a 5°C solution of methacrylic resin and accelerator (Cactus Juice, Turntex) and kept under liquid surface by application of some weights at the top of samples (Fig. 1). The vessel was equipped with a magnetic stirrer to facilitate heat and mass transfer of liquid

into the sample. Samples were taken up after 30 min at a temperature of ca. 12°C and excess of liquid was wiped off with paper. Samples were heated standing on their cross-cut ends at 70°C for one hour and then 90°C for one hour in a ventilated oven to reduce smoke formation during the hardening process. During this period, any resin that migrated out of the board during the heating was collected on the plate on which the sample is standing on. It could be added that by touching the hardened samples, the feeling of a wooden (and not plastic) surface was apparent and a droplet of water applied on MA treated wood was absorbed rather quickly into the material. Separate experiments were performed by mixing either acetic acid, furfural or dried methanol extract from the thermally modified wood with the resin, but these substances did not seem to reduce the hardening rate of the resin. Samples were dried until constant weight at 103°C and stored at 20°C and RH 65%.

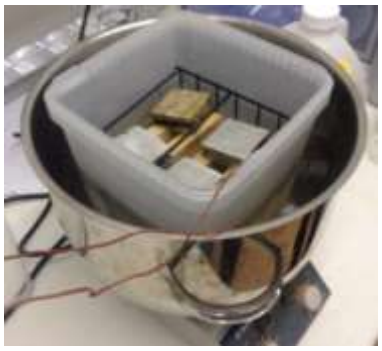

Figure 1: Hot and cold batch of methacrylate and samples of wood.

Samples were brush painted with white acrylate paint: by primer (Tinova primer exterior, AkzoNobel) and two top coats (One super tech, Akzo Nobel) according to manufacturer's guidance. Samples were also brush painted twice with white polyurethane paint (two-component, perfection AkzoNobel). The samples were allowed to dry in air as described by the manufacturer and then conditioned at 20°C and RH 65%. Dimensions of samples were measured with a caliper and used for density calculations. Brinell hardness was measured essentially following EN 1534 by using Zwick Roell ZwickiLine 2.5 TS universal testing machine (Neyses *et al.* 2016). Accelerated weathering test was performed according to Q-Lab corporation with UV lamps operating at 340 nm according to ISO 927-6; condensation 24 h at 45°C followed by UV-irradiance of 0.89W/m^2 at 60°C for 150 min and spraying for 30 minutes (7L/min distributed over 8 nozzles reaching 48 samples) the irradiation and spraying was repeated 48 times and samples were then conditioned for 24 h at 45°C. The whole cycle was repeated until the end of the experiment, after which the samples were taken out, conditioned at 20°C and RH 65% and studied using colorimeter (Chroma meter CR-410, Konica Minolta). L*, a* and b* coordinates were recorded and ΔE was calculated as $\Delta E=((\Delta L^*)^2+(\Delta a^*)^2+(\Delta b^*)^2)^{-1}$. Gloss was studied at 65° using glossmeter (ZGM 1110, Zehntner testing instruments). Pictures of wood samples were taken using Iphone 4s. The ability of the MA-resin to hinder colonisation by fungi was studied by soaking the filter paper in the resin heat for 30 min. at 103°C followed by inoculation of 0.3 ml of a mixture of fungi (*Aureobasidium pullulans, Cladosporium cladosporioides, Aspergillus versicolor, Penicillium purpurogenum*) on filter paper (00K) applying EN-15457:2014.

3. RESULTS AND DISCUSSIONS

Mass and dimensions of boards samples were measured before and after treatment with the methacrylate resin (MA) (Table 1). Mass increase was found to be slightly larger for untreated than thermally modified wood. The density was fairly similar for the untreated material after treatment with MA, probably due to losses during the curing. Swelling of the TMT-material

(2.4%) was observed by the treatment with the resin (Rowell and Ellis 2007). This could be due to its penetration into cell wall of TMT favoured by a less hygroscopic wood which more readily interacted with the organic resin than the untreated pine.

Table 1: Properties of pine sapwood (PS) and thermally modified wood (TMT) treated with methacrylate (MA) resin.

Specimen	Mass [m]	Volume [$10^{-4}m^2$]	Dry density [kg/m^3]	Hardness [HB]
PS	76.5	1.66	462	1.03
PS+MA	86.8	1.66	521	1.17
TMT	76.4	1.703	453	0.88
TMT+MA	84.1	1.744	483	0.79

Hardness of the boards was studied and found to be slightly lower for the thermally modified samples than the untreated samples (Table 1). Any increase in hardness of TMT when treated with methacrylic resin may be related to the density of the material, which was higher in the resin treated material (Table 1). Inspection of the impact on the wood created during the hardness test showed that finer edges were produced for TMT treated with MA, indicating a less brittle material was formed by the treatment with the resin.

Board samples were painted with white acrylic as well as with white two-component polyurethane paint followed by exposure to accelerated weathering conditions according to ISO 927-6. It could be seen that after 4 weeks of exposure, the gloss was practically unchanged for the TMT and untreated pine samples painted with PUR paint, whereas the gloss of acrylic paint decreased at an observing angle of 65 degrees (Fig. 2b).

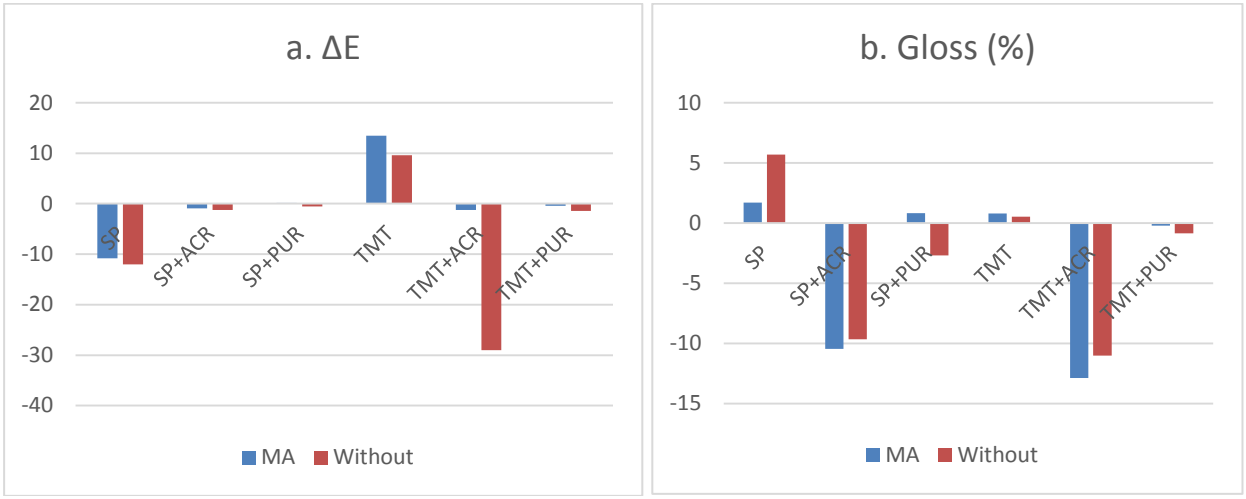

Figure 2: Change in a) colour (ΔE) and b) gloss (65^o) during accelerated weathering.

Changes of colour was estimated as ΔE and can be seen Fig. 2a. Treatment with methacrylate resin seems not to have an effect of colour of TMT and untreated painted samples painted with PUR when exposed to the accelerated weather conditions. Boards that had not been treated with MA-resin and painted with acrylic paint obtained a loss in colour, but not those that had been treated with the resin as well as for untreated wood (Fig. 2). This could be due to presence of coloured water-soluble material in TMT (Karlsson et al. 2014) that migrates through the more porous acrylic coating during the wet exposure conditions. Both the unpainted boards that had been treated with MA-resin and the ones without this treatment started to grey, thereby changing the ΔE. Greying was more apparent in earlywood than latewood (Fig. 2). Blisters were formed

both in samples treated with the MA-resin as well as the one that was not treated, but at a lower extent for samples treated resin (Fig. 3). Formation of blisters was not observed for the painted samples.

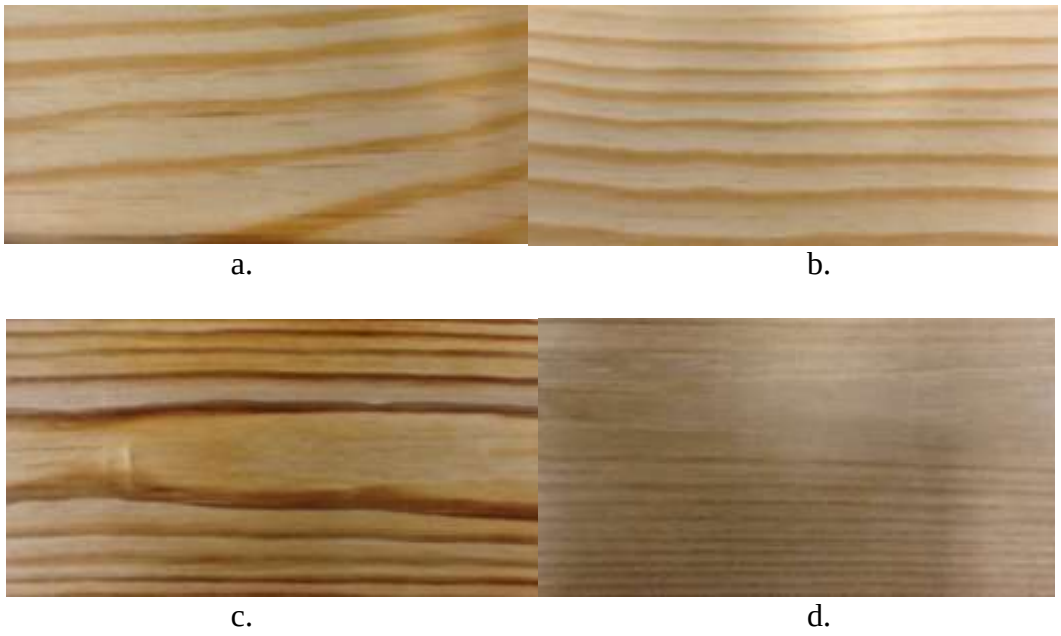

Figure 3: Accelerated weathering of sapwood of pine (PS) and thermally modified timber (TMT) treated with methacrylic resin (MA): a) PS, b) PS+MA, c) TMT, d) TMT+MA.

Finally, we studied whether the methacrylate resin could have an influence on stability of cellulosic material against mould attack using filter paper that had been soaked in the MA-resin and heated in an oven (Fig 4). The filter paper absorbed 2.5 times its weight of resin but most of it evaporated during heating in oven and only 10% remained after heating for 40 min at 103°C. As could be seen, the sample treated with resin was not attacked after exposure for three days to mould fungi in contrast to what is observed for the untreated filter paper. Mould fungi *Cladosporium cladosporioides, Aspergillus versicolor, Penicillium purpurogenum* could be identified after the test. This indicates that methacrylic resin could be efficient in reducing the mould growth of wooden panels without severely influencing the appearance of the wood structure.

4. CONCLUSIONS

The results from the test showed that methacrylate resin could be used to reduce colouring of painted TMT wood during accelerated weathering probably by hindering migration of extractives. The resin itself did not improve greying of the unpainted wood. Hardness was only somewhat improved by treatment with the resin probably due to a higher density of the material. Formation of blisters occurred but was reduced by treatment with the resin. Resistance to mould could be largely improved, however, for outdoor conditions the resin may be protected from degradation reactions.

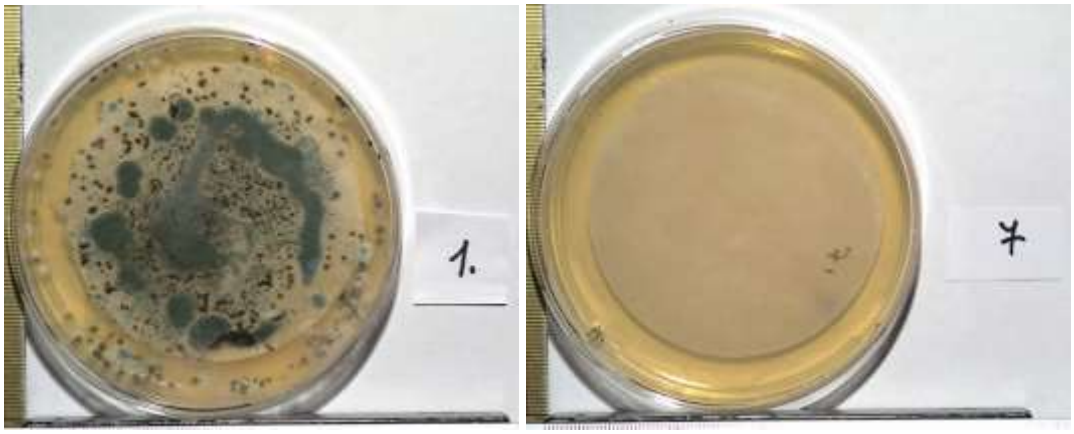

Fig. 4. Filter paper treated without (1) and with methacrylic resin (7) after mould test.

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