

Performance Testing of Plywood from Beech Veneers Treated with Melamine-based Compounds

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ABSTRACT

Beech (*Fagus sylvatica* L.) veneers were treated with two formulations based on N-methylol-melamine-(NMM): 1. NMM solution (NMM-1, 10% solid content), 2. fatty acid modified NMM dispersions containing paraffin (with an aluminium salt as catalyst, mNMM-2, 5% solid content). Five treated veneers were glued with a phenol formaldehyde adhesive to produce plywood. Plywood specimens from water-treated veneers served as controls. The plywood was subjected to 6 cycles of water submersion and oven-drying. In the submersion test over 24h, water uptake and thickness swelling of the treated plywood were reduced up to 66.8% and 59.5%, respectively, through mNMM-2 in comparison to the controls. Mechanical properties of plywood treated with NMM-1 displayed increased values compared to the controls, such as Brinell hardness (23.2% increment), modulus of elasticity (7.9–12.4 %) and bending strength (7.4–15.9%). The plywood treated with mNMM-2 showed minor decrease of these mechanical properties compared to the control plywood. Moisture content of the treated plywood was clearly reduced during 18 months weathering. As a consequence, the treated plywood displayed higher form stability and less delamination than the control plywood. In addition, the treatment with melamine-based compounds led to reduced surface colonization of staining fungi on the indirectly weathered sides of plywood panels.

INTRODUCTION

Many efforts have been undertaken in order to improve the dimensional stability of wood as well as its decay and weathering resistance and thereby to prolong the service life in outdoor application. Treatment with melamine-based compounds brought about remarkable improvements of solid wood such as enhanced water repellence and dimensional stability, increased hardness, modulus of elasticity and bending strength (Gindl *et al.* 2004). In addition, the treatment with water-based melamine increased the resistance of wood against wood destroying fungi (Lukowsky *et al.* 1999) and weathering (Rapp and Peek 1999). In Germany, beech is the most important wood species used in the veneer industry. It is easily treatable; however, its low durability limits the area of application. Hence, the objective of this work is to investigate the influence of the two melamine-based compounds on several water-related and mechanical properties as well as on the weathering resistance of beech plywood.

MATERIALS AND METHODS

Rotary cut beech (*Fagus sylvatica* L.) veneers with the dimension of $1.5 \times 400 \times 400$ mm³ (thickness × width × length) were impregnated in an autoclave at 60mbar vacuum for 30 min and at 12 bar pressure for 2 h with the following solutions: 1. N-methylol-

melamine (NMM) solution (NMM-1, 10% solid content), 2. fatty acid modified NMM dispersions containing paraffin (mNMM-2, 5% solid content) with an aluminium salt as catalyst (1.7%). The impregnated veneers were pre-dried at 40°C to a moisture content of 3-8% and subsequently 160 gm⁻² phenolic resin (Prefere 4976, Dynea, Norway) was applied per veneer. Afterwards, 5-layer-plywood was produced in a hot press (130 °C) at 1.5 Nmm⁻² (10 min pressing time).

Dimensional stability

The dimensional stability tests were performed according to a modified EN 317 (1993). Ten plywood specimens of 7.5 × 50 × 50 mm³ (thickness × width × length) from each treatment were oven-dried before the submersion/oven-dry cycling test. Each cycle consisted of 6 steps: 1. submersion in water (24 h), 2. water soaking under vacuum (60 mbar, 1 h) and storing under water (20 h), 3. air-drying (24h), 4. oven-drying (50°C, 24h), 5. oven-drying (80°C, 24h); 6. oven-drying (103°C, 24h) and cooling to room temperature over silica gel in a desiccator. The cycle was repeated 6 times. The specimens were totally dry after the last steps. Mass and thickness of the specimens were determined after the steps 1, 2 and 6. Water uptake and thickness swelling was calculated from the ratio of the values at the wet state and the dry state from each cycle.

Mechanical properties

The determination of Brinell hardness was carried out according to the EN 1534 (2000). Twelve plywood specimens of 7.5 × 50 × 50 mm³ (t × w × l) from each treatment were conditioned at 20±2°C and 65±5% RH before the test. Brinell hardness was measured at 5 different points on each specimen. Modulus of elasticity (MOE) and bending strength (MOR) were determined according to the EN 310 (1993). Two sets of 10 specimens of 7.5 × 50 × 200 mm³ (t × w × l) per treatment were cut from the plywood: specimens with the grain of the middle layer parallel to the longitudinal axis and specimens with the grain of the middle layer perpendicular to the longitudinal axis. The specimens were conditioned at 20±2°C and 65±5% RH prior to the test.

Weathering test

Outdoor weathering was performed according to the EN 927-3 (2006) using plywood panels of 7.5 × 100 × 375 mm³ (t× w × l). The edges of the panels were sealed with the coating Wapex 660 (Akzo Nobel Decorative Coatings, Wunstorf, Germany). The specimens were placed on the weathering racks in the test field of the Georg-August University, Göttingen (Germany) for 18 months. Four replicates were used per treatment. The moisture content, delamination, deformation, cracking and fungal staining of the specimens were evaluated every 3 months during the test.

RESULTS AND DISCUSSION

Water uptake and thickness swelling

Treatment with both types of melamine clearly reduced the water uptake and thickness swelling of plywood during 24h submersion compared to the controls (Figure 1). This effect was stable over 6 cycles of submersion and drying. Despite of its lower concentration, the modified melamine (mNMM-2) was more efficient than NMM-1 in reducing both water related properties. This is attributable to the additional hydrophobic effect of the fatty acid residue and the paraffin in the stock formulation of mNMM-2. The reduction of water can be explained with occlusion of the main penetration paths

for water such as ray cells by both melamine types (Nguyen *et al.* 2007, Gindl *et al.* 2004) and by partial incorporation of NMM-1 into the cell wall (Gindl *et al.*, 2004).

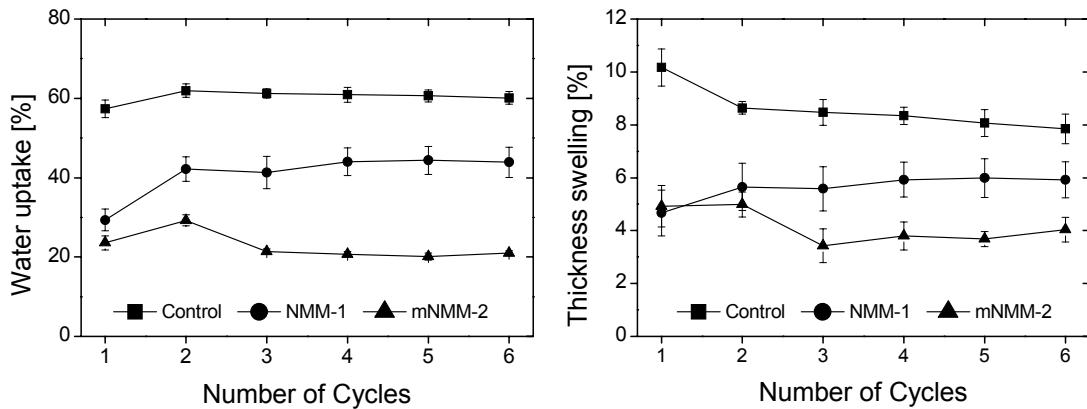


Figure 1: Water uptake and thickness swelling of treated plywood and the controls after 24h submersion in water

Mechanical properties

The Brinell hardness of NMM-1-treated plywood was clearly higher than that of mNMM-2-treated plywood and of the controls. The same tendency was observed with respect to MOE and MOR, but less pronounced. It should be noted that mNMM-2, as a water repellent, was applied in lower concentration than the NMM-1 solution. The diffusion and polymerization of molecules of NMM-1 into the cell wall could be a reason for the increasing of the hardness, as well as of the MOE and MOR (Gindl *et al.* 2004).

Table 1: Brinell hardness, MOE and MOR ($N \text{ mm}^{-2}$) of treated plywood and the controls

Specimens	Brinell-hardness	MOE		MOR	
		parallel	Perpendicular	parallel	perpendicular
Control	41.2 ± 3.0	11066 ± 1089	3692 ± 248	98 ± 8.8	55.9 ± 3.6
NMM-1	50.7 ± 3.5	12440 ± 377	3985 ± 121	105.3 ± 8.2	64.8 ± 2.8
mNMM-2	37.2 ± 2.2	10806 ± 554	3013 ± 479	92.2 ± 3.2	48.9 ± 3.3

Natural weathering

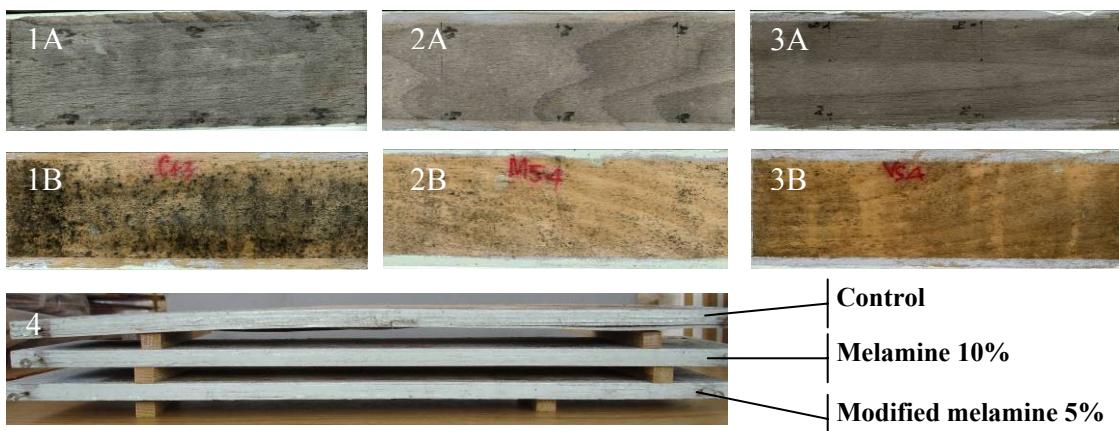


Figure 2: Photos of uncoated beech plywood after 18 months weathering in Goettingen, Germany. 1: control, front side (A), rear side (B), 2: NMM-1-treated, front side (A), rear side (B), 3: mNMM-2-treated, front side (A), rear side (B), 4: Delamination and deformation of plywood specimens after exposure.

The treatment with melamine formulations clearly reduced the moisture content as well as swelling and shrinking of the plywood specimens during 18 months outside exposure (not shown). As a result, less cracking was observed on the front sides of the treated specimens as compared to the controls (Figure 2-1A, 2-2A, 2-3A). NMM-1 was the most efficient agent in reducing fungal staining on the rear sides of the exposed plywood specimens (Figure 2-2B), followed by mNMM-2 (Figure 2-2C), while the controls showed the highest degree of staining (Figure 2-2A). In addition, the treated plywood specimens displayed greater form stability and less delamination than the control specimens (Figure 2-4).

CONCLUSIONS

Both melamine formulations caused high water repellence and dimensional stability of plywood specimens during a cyclic water submersion and drying procedure. The melamine solution (NMM-1) imparted increased Brinell hardness compared to the control panels. The performance of the plywood panels exposed to weathering revealed that both melamine formulations reduced surface cracking, fungal staining, deformation as well as delamination and do, thus, prolong the service of outside exposed plywood.

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