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INFLUENCE OF THERMAL MODIFICATION SCHEDULES ON THE NATURAL WEATHERING OF MAPLE AND ASH WOOD

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ABSTRACT

This study aimed to compare the influence of two thermal modification (TM) schedules—with short (65 h) and long (112 h) heating phases—on the natural weathering of maple (Acer pseudoplatanus L.) and ash (Fraxinus excelsior L.) wood. Over a duration of almost 21 months (October 2021–June 2023), the changes in wood colour and moisture content (MC) were monitored. The samples were exposed to all weather conditions facing south, positioned 1 m above ground level under a 45-degree slope with horizontal grain orientation. As the weathering process progressed, a pronounced alteration in the inherent colouration of the control and TM samples (both schedules) was observed in both wood species. At the end of the weathering process, the colour of all samples, whether treated or untreated, had reached a similar appearance. In the initial phase of the experiment (first winter—from October ’21 to March ’22), MC variations were more pronounced, but the extent of these changes diminished with time. The control samples were found to be the most responsive to weather condition changes, while TM (fast schedule) samples exhibited slightly higher MC variations compared to samples modified under a slow schedule. Throughout the duration of the experiment, the MC of the maple control samples was mostly between 15% and 45%, whereas the MC of the maple TM samples ranged from 8% to 25%. The ash control samples had a MC ranging from 12% to 27%, while the ash TM samples had MC mainly between 5% and 15%.

Keywords: weathering, thermal modification schedule, maple wood, ash wood

1. INTRODUCTION

Wood is a versatile and widely used material in various applications, including outdoor structures, furniture, and decorative elements. However, when exposed to outdoor conditions, wood is subjected to a range of abiotic and biotic factors, such as weather conditions and biodegradation, which can adversely affect its physical, biological, chemical, and mechanical properties [Marais et al., 2020]. One prominent advancement in wood treatment technology is thermal modification (TM), an approach that offers chemical-free enhancements in both dimensional stability and durability of wood. Through reduced hygroscopicity, TM wood products have found their niche in outdoor applications, particularly in situations involving demanding weather conditions.

Weathering of wood is a combination of biotic and abiotic degradation mechanisms acting on the wood surface (Hill et al., 2022). The effects of weathering can manifest differently depending on wood species, treatments, exposure setup, exposure duration, and location (Kropat et al., 2020).

The goal of this study was to examine the influence of thermal modification schedules on the natural weathering of maple and ash wood.

2. MATERIAL AND METHODS

The study was conducted using kiln-dried maple (Acer pseudoplatanus L.) and ash (Fraxinus excelsior L.) timber that was free of defects. Following the drying process, the boards from both species had dimensions of approximately 28 mm thickness, 120 mm width, and 2.4 m length. Fourteen boards were chosen for each species, and these boards were divided into halves for the purpose of thermal modification (Milić et al., 2023). The modification was carried out in an industrial chamber using a superheated steam atmosphere achieved through water spraying with high- and low-pressure nozzles. This process was performed on a subset of a larger batch of 20 m^3 of maple/ash timber.

Two different methods of thermal modification were used: slow (TMS) and fast (TMF). The only difference between these treatments (peak temperature 200°C, 3 hours) was the duration of the heating phase: for the TMS process, the heating took 112 hours (heating rate 1.1°C/h); the TMF method had a shorter heating phase of 65 hours (2.5°C/h).

After conducting standard laboratory tests on TM samples and allowing for long-term acclimatisation under room conditions, four samples (2xTMS and 2xTMF) were selected for each wood species. Together with two control (unmodified) samples, a total of 12 samples were used for the weathering test (6 for ash and 6 for maple). The samples were exposed to all weather conditions facing south, positioned 1 m above ground level under a 45-degree slope with horizontal grain orientation (Fig. 1). The test began on October 19, 2021, and measurements were conducted until July 4, 2023.

Figure 1: *The setup for weathering test*

Depending on weather conditions, the colour of the samples was assessed 1 or 2 times each month. In total, 30 measurements were conducted for each sample, consistently at a designated measuring point. The colour was measured using the Easyco colorimeter, manufactured by Erichsen. The diameter of the lenses was 10 mm, the device was set at the observing angle of 10˚, and illumination was D65 for daylight. This colorimeter displays colours in CIELAB colour space, and the colour difference was determined using the corrected value of the colour change (CIEDE2000–ΔE00), which, according to numerous authors (Hauptmann et al., 2012), is closer to the human perception of the difference in wood colour.

During the experiment, the mass of all samples was measured 1 to 3 times per month (in total 50 measurements), and after the completion of the weathering test, the samples were dried to their oven-dry state and then reweighed in order to determine moisture content (MC).

3. RESULTS

At the beginning of the weathering test, the initial MC of the control samples varied between 11.5% and 13.4%. For the TMF samples, the MC ranged from 7.0% to 12.8%, while for the TMS samples, the MC was within the range of 5.0% to 6.4%.The outdoor temperature during the experiment varied from -12°C to 43.8°C, while the air relative humidity ranged from 24% to 100%

(Fig. 2). The MC of the control samples for maple consistently remained significantly higher than that of the TM samples. Additionally, it can be noticed that climate parameters (temperature-T and relative humidity-RH) had a more significant impact on the MC variation in control samples as compared to the TM samples (Fig. 2, top). Unexpectedly, this was not entirely the case for ash, where the differences in MC between control and TM samples were considerably smaller, accompanied by minor fluctuations. (Fig. 2, bottom).

The control samples of maple exhibited higher moisture content and absorbed moisture more rapidly than the ash samples. This is in line with expectations, as high permeability of maple wood enables MC changes even in the inner sections of the wood during the rainy or snowy days. Certain measurements, especially from Nov. '21 to Jan. '22, depict notably higher moisture levels. This is attributed to the fact that the measurements were taken under various weather conditions, including rain and snow. It can be observed from the graphs that there are time intervals when the RH is at 100%, during which the samples were entirely covered with snow.

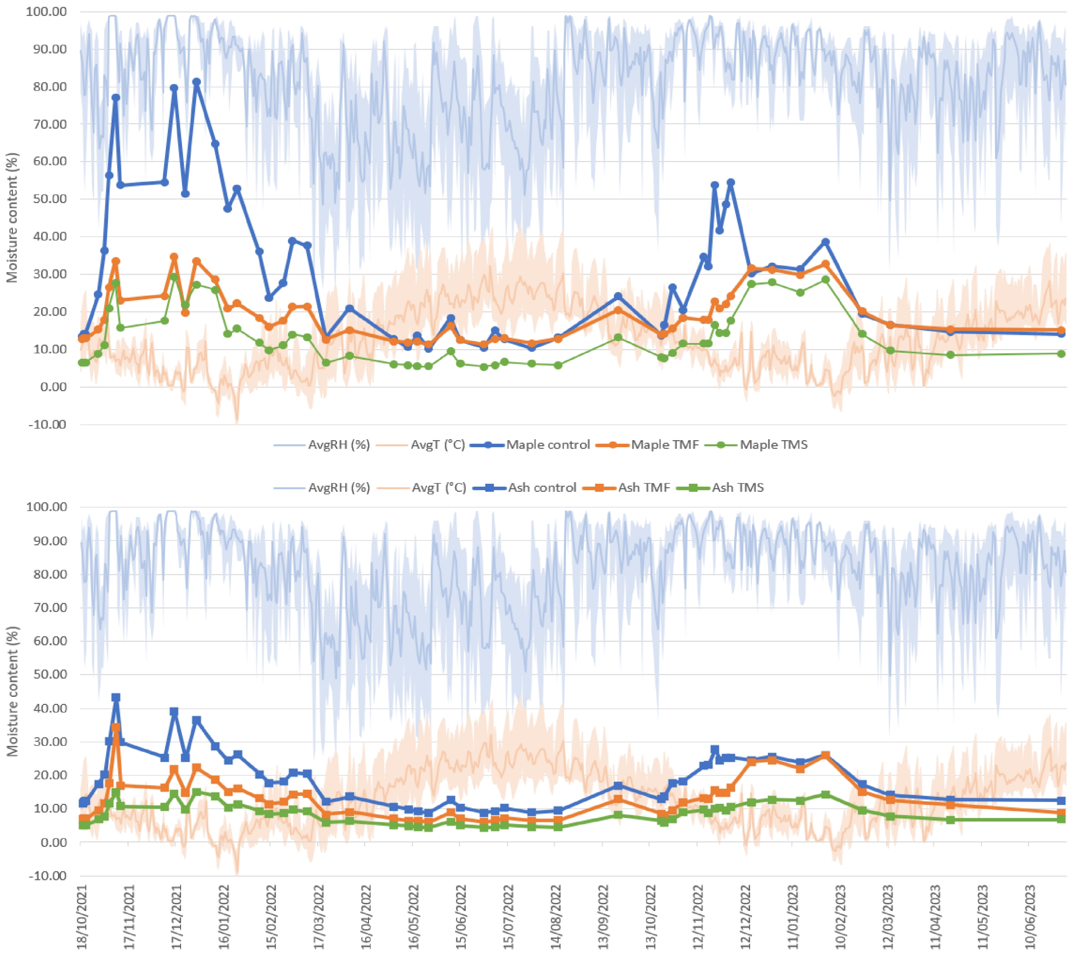

Figure 2: *Wood moisture content, temperature and relative humidity of air during the weathering test*

During the experiment, MC of maple control samples was mostly between 15% and 45%. On the other hand, maple TM samples mainly had MC ranging from 15% to 25% (TMF) and 8% to 18% (TMS) (Fig. 3). Moisture content of the ash control samples was in the range from 12% to 27%. TM samples were mainly between 7% and 15% (TMF) and 5% and 12% (TMS) of moisture content (Fig. 3). A clear trend can be observed where TMS samples exhibited the lowest MC, with the maximum MC of 29.2% for maple samples and 15.1% for ash samples. This is in agreement with previous results obtained under indoor conditions (also in a climate chamber), which demonstrated that the slow heating process during TM leads to the lowest equilibrium moisture content (EMC) values for both maple and ash wood (Milić et al., 2023). This further confirms the significant influence of heating duration on the intensity of thermal degradation of wood (Allegretti et al., 2021).

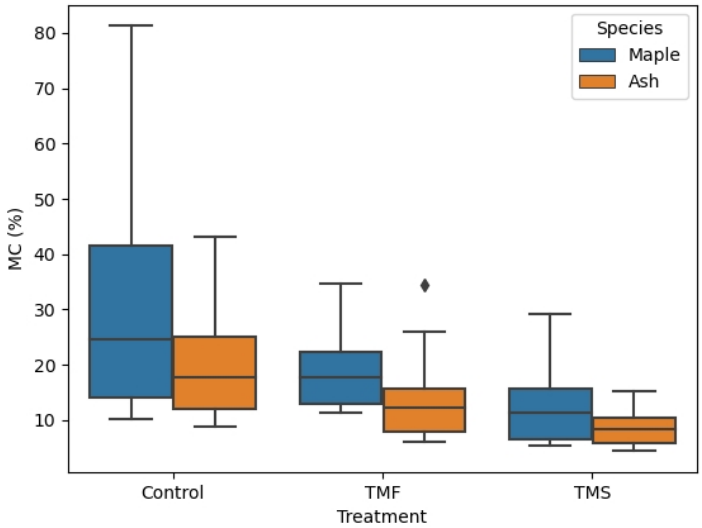

Figure 3: *Moisture content of maple and ash (unmodified and TM) samples during weathering test*

At the beginning of the weathering test, unmodified samples exhibited a natural, light colour, while TM samples displayed a dark brown hue, with small differences between TMF and TMS (Fig. 4). The primary colour difference arises from the lightness component, L*. For unmodified samples, the L* component at the start of the experiment ranged from 72 to 78, whereas for TMF and TMS samples, it ranged from 34 to 46. The a* component (representing the redness) showed approximately 3-5 higher values in TMF and TMS samples compared to control samples, while differences in the b* component were minimal. Throughout the weathering process, a pronounced alteration in the inherent colouration of the control and TM samples (both schedules) was observed in both wood species. Visually observed, in the twelfth month of the experiment, there was a relative equalisation of the colour of all samples, where the predominant colour was grey.

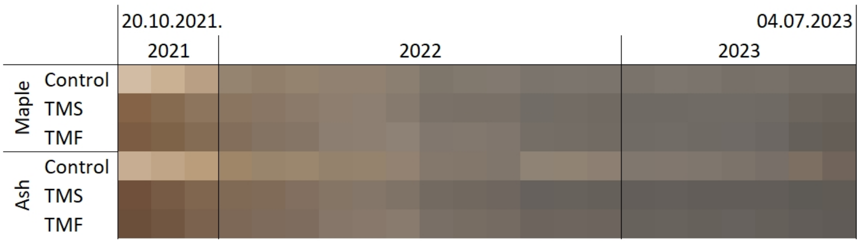

Figure 4: *Heatmap visualization of colour change during the weathering test*

At the end of the experiment, all samples underwent significant colour changes compared to the initial state. The greatest colour difference was recorded in the control sample of ash (ΔE00=31.4), while the sample of ash TMS underwent the least colour change (ΔE00=11.5). The colour difference between TMF and TMS samples at the end of the experiment was small, with values of ΔE00=2.1 for maple and ΔE00=0.2 for ash.

The most significant changes in control samples occurred within the initial two months, during which the L* component decreased significantly to a level between 50 and 60, which is in line with the results reported in Kropat et al. (2020). In the case of the TM samples, the L* component initially increased (over the first 2-3 months) and then began to decrease until the end of the experiment, eventually returning to a state approximately resembling the initial condition (Fig. 5). For the unmodified ash samples, a significant variation in the L* component can be observed, emerging around the midpoint of the experiment. This phenomenon is a result of localised peeling of the wood's surface layer (caused by surface checks), unveiling an underlying surface that has not yet undergone the greying process.

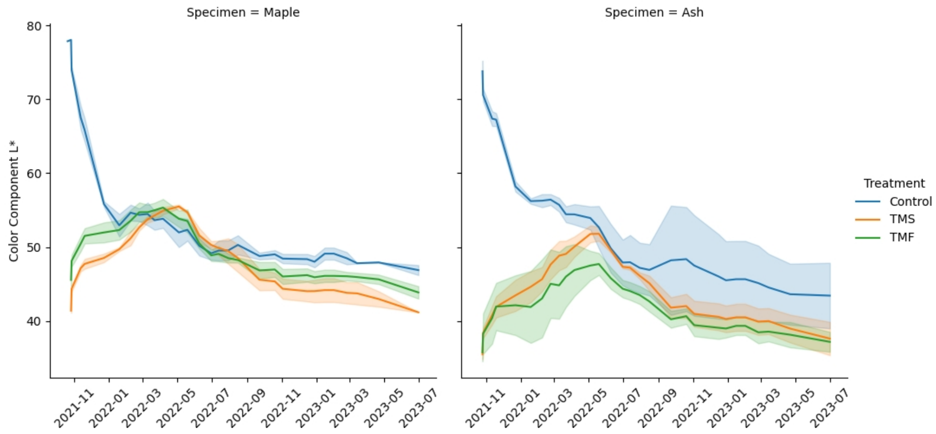

Figure 5: *Change of colour component L* during weathering test*

4. CONCLUSIONS

In this study, the effects of diverse thermal modification schedules on the natural weathering of maple and ash wood were investigated. All samples were subjected to natural weathering over a period of almost 21 months. During exposure to various outdoor conditions, the moisture content and colour change of wood were measured.

Notably, the moisture content (MC) of control maple samples consistently exceeded that of TM samples, while this distinction was less pronounced for ash wood. This differential MC behaviour can be attributed to the different permeability of the wood species. Additionally, a distinct trend emerged, with TMS samples exhibiting the lowest MC levels. This pattern aligns with prior indoor results, underscoring heating duration's impact on wood hygroscopicity, both in dry and wet climate conditions.

Moisture content of unmodified maple samples was mostly between 15% and 45%, but TM samples mainly had moisture content ranging from 8% (TMS) to 25% (TMF). Unmodified ash samples had moisture content in the range from 12% to 27%, while the MC of TM samples saw mainly between 5% (TMS) to 15% (TMF).

Colour alterations were evident in all samples during the weathering process. Among the control samples, the most notable change was identified in the L* component (decreased by about 41%), whereas in the case of TM samples, the greatest impact on colour variation had changes in both components a* and b*, which decreased by about 87% and 81%, respectively. Within the initial two months, the L* component decreased in control and increased in TM samples, eventually reaching similar values. A grey hue prevailed in all samples after approximately 12 months of weathering.

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