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2 **Wettability and color change of thermally treated** 3 **poplar OSB after accelerated weathering test**

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13 **Abstract:** Oriented strand board (OSB) panels are widely marketed for several applications, from
14 building to packaging. The manufacturing of poplar OSB started recently in Northern Italy
15 representing a relevant innovation in the sector since this product is usually made of coniferous
16 wood. The thermal treatment is widely used for reducing the hygroscopicity of wood-based
17 products, nonetheless it influences the mechanical behavior and degrades the main components of
18 wood, which can affect their finishing. Therefore, it is important to know the properties of the
19 treated surfaces. To this purpose, in this study a lot of OSB panels, made of poplar wood, 15 mm
20 thick and with a density of 590 kg/m³, were thermally treated under vacuum conditions at 190 °C
21 for 2 h and then subjected to accelerated weathering. The changes in color and in wettability due to
22 treatment and accelerated weathering were studied. The thermal treatment determined a
23 significant darkening of the color; the accelerated weathering darkened the untreated surfaces and,
24 on the opposite, lightened the thermo-treated surfaces. The wettability decreased after thermal
25 treatment and increased after weathering, more evidently in treated panels. Overall, this study
26 improves the knowledge about the behavior of the surface of thermo-treated poplar OSB, which is
27 relevant for the industrial coating of this product.

28 **Keywords:** accelerated weathering test; color change; poplar OSB; wettability

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30 **1. Introduction**

31 Poplar (*Populus* spp.) is a fast-growing tree with low economic costs in terms of logging and
32 production. The manufacturing of poplar Oriented Strand Board (OSB) started in 2012 in Northern
33 Italy, representing a relevant novelty for the national and European wood sector: OSB, in fact, is
34 typically made entirely or largely of coniferous wood [1]. Production of Poplar OSB has steadily
35 increased from 2014, reaching about the 2% of the overall OSB volume manufactured in Europe [2].
36 In perspective this product it is also expected to contribute in sustaining the poplar cultivation sector
37 in Italy, which in the past decades suffered a sensible reduction in plantations coverage [3,4].

38 The manufacturing process of poplar and coniferous OSB is similar, the main phases being
39 wood stranding, glue spreading and panels pressing. Paraffin is commonly used to detach the
40 panels from the plates of the continuous press adopted for manufacturing and to limit the swelling
41 of the finished panels. Anyway, differences exist in the physical and mechanical characteristics
42 depending on the wood used. Specifically, the density of poplar OSB varies from 500 kg/m³ to 620
43 kg/m³, depending on its thickness; this is about 15% lower than the density of coniferous OSB, which
44 typically ranges from 600 to 680 kg/m³[5]. Further, poplar wood also determines a lighter and
45 whitish color of the panel compared to that of coniferous OSB, which generally presents a yellow
46 tone.

47 According to product standard EN 300 [6], poplar OSB is currently available in OSB-3 type that
48 is for load-bearing use in humid conditions. In general, OSB is intended for final applications in
49 building and packaging, but some end-uses in furnishing are also relevant [7]. Poplar OSB presents
50 several interesting features making it suitable for various uses in the above sectors, nonetheless the
51 low natural durability of poplar wood (Class 'DC 5 – not durable', according to EN 350 [8]) is a
52 limiting factor in case of exposition in conditions that determine the risk of fungal decay.

53 Several methods for improving the natural durability of wood exists [9]. Among these, thermal
54 treatment consists in exposing wood to high temperatures, generally from 160 °C to 230 °C, in a
55 controlled environment. This causes a chemical degradation by heat transfer that modifies several
56 properties of wood. In particular, natural durability and dimensional stability increase, whereas
57 density and mechanical properties decrease; further, the color shifts towards darker tones [10]. Over
58 the past years several processes, mainly differing in inert atmosphere and curing conditions (gases,
59 oil, steam etc.) have been developed; in this context, the thermo-vacuum treatment is performed in
60 vacuum-conditions and is nowadays well-established on the market [11]; recently its potential for
61 extracting chemicals from poplar wood has also been studied [12].

62 Overall, modified wood is adequate for non-structural uses in humid or exterior environments,
63 for instance in furnishing, flooring and facades [13]. Thermal treatment is therefore often proposed
64 as a means for valorizing wood of species with low natural durability or for finding new
65 applications to timber and related materials having few market outlets [14,15].

66 Wetting properties are frequently investigated, usually measuring the contact angle (CA), for
67 assessing several aspects regarding processing and performance of wood and derived products [16].
68 Being wood a porous and hygroscopic material, in fact, its interactions with liquids play a key role in
69 many final applications. These include adhesion, coating, waterproofing, surface modifications,
70 weathering, degradation and liquid absorption [17,18]. For instance, the contact angle is generally
71 considered a fundamental parameter determining penetration of adhesives inside wood [19];
72 spreading and adhesion of coatings on wood strongly depend on CA [20]; changes in the wetting
73 properties have been taken as a major indicator for wood weathering tests [21]. In this context,
74 exposing wood to ultraviolet (UV) light is an effective pretreatment for activation that enables to
75 increase its wettability and it is therefore widely used in the wood coating sector [22,23].

76 Some relatively recent research has been performed on the thermal treatment of OSB panels.
77 Mendes et al. [24] showed that the physical properties of OSB made with *Pinus taeda* wood increased
78 after thermal treatment, while the mechanical properties decreased. Anyway, to this day no detailed
79 studies have been reported about the surface degradation of poplar OSB considering the combined
80 effect of thermal treatment and accelerated weathering test (AWT).

81 To this purpose, in this study the contact angle was recorded on untreated and thermo-treated
82 poplar OSB, exposed and non-exposed to accelerated weathering test. Color change was also
83 determined as an indicator of the intensity of the performed process.

84 2. Materials and Methods

85 2.1. Thermal treatment

86 Ten poplar OSB panels of nominal thickness 15 mm were drawn from the standard
87 manufacturing process of the producer. Panels were subjected to thermal treatment under vacuum
88 conditions using the Termovuoto® process. Treatment temperature of 190 °C was maintained for 2 h.
89 At the end of the process, 30 specimens with dimension of 50x50x15 mm, equally distributed
90 between untreated and thermally-treated panels were randomly cut for sampling and further
91 testing.

92 2.2. Color measurement

93 Surface color of poplar OSB before and after accelerated weathering test, including the
94 corresponding references, was determined on middle spot of each specimens; five replicas have

95 been performed. Color parameters were speedily measured by CR-400 CHROMA METER, which
96 was connected at the Color Data Software SpectraMagic NX for the expression of the results. The
97 color parameters (L^* , a^* , b^* , and ΔE^*) were determined by the CIE- $L^*a^*b^*$ color space system
98 according to ISO 11664-4 [25] (10° standard observer, D65 standard illuminate). The color variations
99 after thermal treatment or UV-exposure were evaluated by overall color change which was
100 calculated according to ISO 11664-4 and ISO 11664-6 [26]:

101

$$102 \quad \Delta E^* = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}}$$

103

104 where: ΔE^* is the overall color change, ΔL^* , Δa^* and Δb^* are the differences between the initial and
105 the final values (between thermo-treated and non-treated panels, before and after accelerated
106 weathering test).

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108 2.3. Contact angle

109 For the analysis of the wettability, contact angle measurements of distilled water on the OSB
110 surface were performed through the sessile drop method by Drop Shape Analyzer System, Krüss
111 software module (Hamburg, Germany). Sessile drops of $2 \mu\text{l}$ have been deposited on each specimen
112 for 5 repetitions. 15 replicas for both treated and untreated OSB panels have been done for a total of
113 150 drops. The contact angle was evaluated for a total duration of 120 s for each drop, while the right
114 and left angle of the drops on the wood surface were collected at intervals of 0.5 s.

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116 2.4. Accelerated weathering exposure

117 AWT of poplar OSB surface was performed by a QUV Accelerated Weathering Tester. The aim
118 was to reproduce the damage caused by sunlight, rain and dew. The exposure of the wood surfaces
119 of the samples lasted for 168 hours. The cycle consisted of a condensation period followed by a
120 sub-cycle of water spray and UV-A 340 irradiation according to EN 927-6 [27].

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122 2.5. Statistical analysis

123 Effects of thermal treatment and AWT on color and contact angle (after 120 sec) of poplar OSB
124 were investigated through two-way ANOVA using the software IBM SPSS ver. 24.

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126 3. Results and Discussion

127 3.1. Color change

128 Table 1 shows the average color coordinates measured for untreated (NT) and treated (T), non
129 subjected to wethering test (Pre AWT) and after wethering test (Post AWT) specimens groups,
130 whilst color changes (ΔE^*) are shown in Table 2.

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Table 1. CIELab* coordinates measured for tested specimens.

group code	CIELab* coordinates		
	L*	a*	b*
NT Pre AWT	77.52	4.45	21.61
T Pre AWT	52.16	10.28	21.38
NT Post AWT	68.55	6.82	18.78
T Post AWT	60.66	5.02	11.42

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Table 2. ΔE^* measured among group code

group code	ΔE^*		
	NT	T	NT Post AWT
NT Pre AWT	-	-	-
T Pre AWT	26.07	-	-
NT Post AWT	9.90	16.95	-
T Post AWT	11.11	14.14	10.94

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Thermal treatment determined a significant darkening ($p < 0.01$) of the surfaces ($\Delta L^* = -25.35$); color also shifted towards red ($\Delta a^* = 5.83$), whereas changes on the blue-yellow axis were limited ($\Delta b^* = -0.23$); overall, the color change ($\Delta E^* = 26.07$) resulted mainly related to ΔL^* . The darkening of wood color is a typical consequence of thermal treatment, which determines the formation of degradation products from hemicelluloses, the build-up of oxidation products and the modification of extractives [10]. Further, it has been recognized that color and treatment temperature are closely related [28,29].

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Accelerated weathering determined a significant ($p < 0.01$) darkening of untreated specimens ($\Delta L^* = -8.97$); changes in a^* and b^* coordinates turned out limited ($\Delta a^* = 2.37$, $\Delta b^* = -2.83$), therefore the color change ($\Delta E^* = 9.90$) still resulted mainly due to ΔL^* . On the opposite, the color of thermally modified specimens was significantly lighter ($p < 0.01$) after AWT ($\Delta L^* = 8.42$); in this case the changes in a^* and b^* resulted higher ($\Delta a^* = -5.26$, $\Delta b^* = -9.96$), for a more relevant contribution in color change ($\Delta E^* = 14.14$). Similar trends have already been reported [30] and show how UV irradiation omogenizes the color of wood. In particular, the lightening of thermo-treated wood is similar to that occurring in dark colored woods exposed to UV for long time. Overall, the color change of untreated and treated specimens can be mainly attributed to the degradation of lignin, which is extremely susceptible to UV irradiation [30,31].

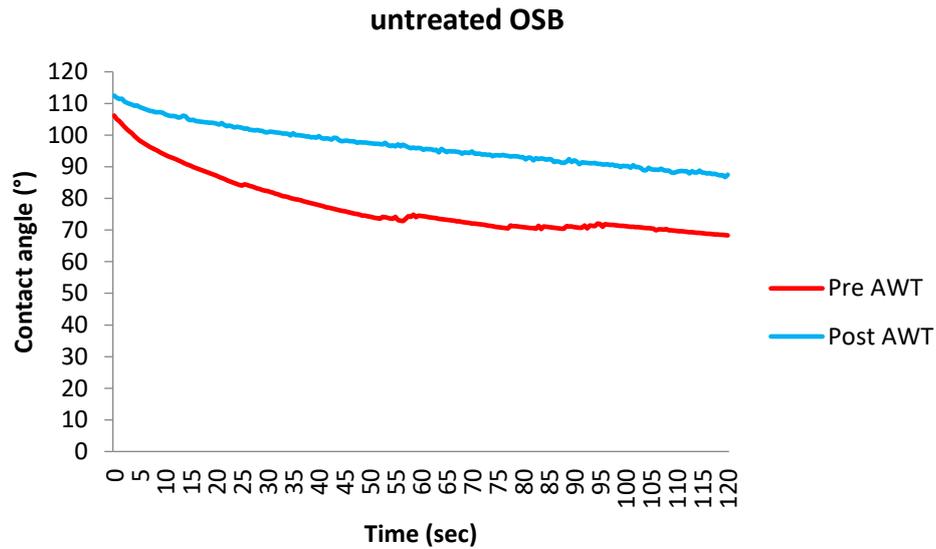
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3.2. Contact angle

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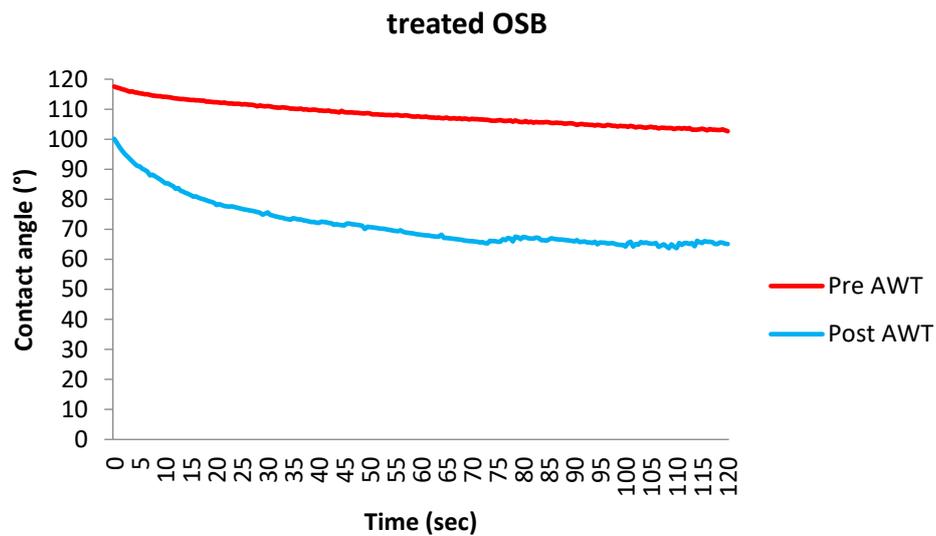
Figure 1 and 2 show the average values of contact angle, determined using water as liquid test, for untreated and treated specimens, pre- and post-weathering.



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Figure 1. Contact angle variation in untreated OSB panels before and after weathering.



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Figure 2. Contact angle variation in treated OSB panels before and after weathering.

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161 The thermal treatment determined a significant ($p < 0.01$) decreasing in wettability. In fact, after
 162 120 sec the pre-AWT CA of thermo-treated OSB (120.7°) resulted almost twice the pre-AWT CA of
 163 untreated OSB (68.3°). The lower wettability of the panels surface after thermal treatment can be
 164 mainly ascribed to the phenomena of degradation occurring during the process, which modifies
 165 some chemical features of wood. In particular, the main reason are the migration of non-polar
 166 extractives to the surface during heating [32] and the cross-linking between the lignin and
 167 polysaccharides, with a consequent reduction in free hydroxyl groups among the hemicelluloses
 168 that changes during heating and may undergo oxidation reactions [33].

169 For untreated OSB, after 120 sec the pre-AWT CA (68.3°) resulted significantly lower ($p < 0.01$)
 170 than the post-AWT CA (87.5°). On the contrary, for treated OSB after 120 sec the pre-AWT CA
 171 (120.7°) is significantly higher ($p < 0.01$) than the post-AWT CA (65.1°), highlighting a loss of the effect

172 previously gained through thermal treatment. It can also be noted that, after weathering, the CA line
173 of untreated OSB shows a constant trend in time (Fig. 1), which could further decrease, whereas that
174 of thermo-treated OSB becomes rather stable after about 70 sec (Fig. 2). Overall, the exposure to UV
175 irradiation can represent a method for reactivating the surface of thermo-treated poplar OSB in view
176 of industrial coatings and finishing processes.

177 4. Conclusions

178 The aim of the present work was to evaluate the wettability and the color change of poplar OSB,
179 taking into account the effects of heating and accelerated weathering test. The results obtained give
180 some evidence in terms of color and wettability change. In this regard, the hydrophobicity of poplar
181 OSB increased after thermal treatment, whereas the surface degradation due to weathering test
182 caused a decreasing slightly stronger in thermally treated panels, at least after 120 sec. The results
183 are interesting for several industrial applications in which it is essential to take into account any
184 change in wetting properties. In particular, the weathering enabled to increase the wettability of
185 thermally treated OSB and this effect can be further evaluated or exploited for improving the coating
186 of this panel and similarly treated wood materials whose use is recently recording a wide market
187 diffusion.

188
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197 Cremonini, Luigi Todaro and Roberto Zanuttini conceived and designed the study, and revised the paper
198 contributing to its drafting; all authors participated to the discussion of the work.

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200 design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in
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