Durability of Heat Treated Massive Poplar Plywood

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ABSTRACT

Plywood made of poplar are limited to indoor usages since poplar exhibits a rather low natural durability. Recently, wood heat treatments are applied to improve properties such as decay susceptibility and dimensional stability. Hence, to extend the potential of applications of this engineered wood product to outdoor end uses, and new markets accordingly, this study examines the potential of exposing poplar plywood to heat treatment. Plywood panels were glued with two kind of adhesives to compare their respective ability to resist the heat treatment. Those different plywoods were heat treated in saturated steam conditions at 215 °C for 2 hours following the ThermoWood® process up to a 14% mass loss. The durability improvement brought by the heat treatment was assessed in order to evaluate any possible outdoor uses for such plywoods.

EXPERIMENTAL

Material

Commercial plywood panels made of poplar and provided by Brugère factory (Châtillon-sur-Seine, France) were used in the study. The panels were composed of 21 layers up to a total thickness of 25 mm; each veneer being 1.2 mm thick. Two different adhesives from BASF© Kauramin type had been used to build up the panels: urea-formaldehyde (UF), melamine-urea-formaldehyde (MUF) resins. A total of 64 specimens were sawn from at least 3 different plywood panels into a beam shape with 25 × 50 × 700 mm^3 dimensions; half of the specimen being cut with the external veneers grain direction toward the length of the beams (Parall.) and the other half perpendicularly (Perp.).; The specimens average Equilibrium Moisture Content (EMC) prior to heat treatment was 12.7% ± 0.3% under stabilized 65% RH (Relative Humidity) and 20 °C; under such conditions, their average densities were 549 ± 6 and 502 ± 9 $kg.m^{-3}$ respectively for the MUF and the UF panels

Thermal modification process

The ThermoWood® high-temperature treatment is carried out on the beam shape specimens at 215 ° C for 2 hours (for a total process duration of 29 hours) in a saturated water vapour atmosphere which aims to modify the wood in terms of dimensional stability and fungal resistance) while respecting the environment since no chemicals are added during that high temperature treatment process. Prior to the treatment no dedicated conditioning had been achieved out of the storage at the room conditions for at least 2 months. The heat treatment had been performed up to an average (13.8% ± 0.5%) mass loss assessed from the dimension measurements performed before and after the heat treatment on each specimen as described in the next subsection.

Durability assessment

Fungal resistance

Decay resistance tests were adapted from the guidelines of ENV 12038 (2003), with some adjustments concerning the samples sizes and the choice of wood destroying fungi. For each plywood modality, 2 batches composed by 18 samples from 3 different panels (50 mm × 48 mm × 25 mm, L × R × T) were exposed to *Trametes versicolor* (TV) and *Rhodonia placenta* (RP). Ten solid wood blocks (50 mm × 25 mm × 15 mm; L × R × T) of both beech (*Fagus sylvatica*) and pine (*Pinus sylvestris*) were tested as virulence control (Control-Vir). Six blocks of both beech and pine with the same dimensions as the plywood specimens were exposed to the fungi as size control samples (Control-Dim). After 16 weeks (at 22°C, 75% RH) of the fungal exposure, the block specimens were dried at 103 °C and their final weight (m_2) was recorded. Finally, weight losses (WL %) were determined as a percentage of the initial anhydrous weight (m_1) as $WL = 100 \times (m_1 - m_2)/m_1$. If the average mass losses are greater than 3% (m/m), the Degradation Sensitivity Index (DSI) was determined as $DSI = 100 \times T/S$, where T is the weight loss of a test specimen (in %) and S theaverage weight loss of the series of size control specimens (in %).

Termite resistance

Termite resistance tests were adapted from the guidelines of EN 117 (2013), with some adjustments concerning the sample sizes. Five Beech and 5 pine sapwood samples (50 × 25 × 15 mm^3; L × R × T) were also tested against termite as virulence controls. Before exposure to termites, plywood and control samples were dried at 103 °C in order to determine their anhydrous initial weight (m_3), and then re-conditioned at 20 °C, 65% RH until constant weight. For each plywood modality, 3 replicates were tested for non-choice (one plywood samples per test device) as well as choice tests (one untreated and one heat treated plywood samples with the same glue per test device), respectively.
A total of 250 termite workers, 3 nymphs and 3 soldiers (*Reticulitermes flavipes)* were then introduced into each test device (9 cm diameter glass flask containing a 5 cm thick layer of wet sand (4 sand / 1 water, v/v). These test devices were placed for 8 weeks in a dark climatic chamber conditioned at 27 °C and >75% RH, and were regularly checked. At the end of the exposure, the samples were cleaned of sand and the termite survivors were counted. Visual rating were attributed to samples, according to the criteria of EN 117 (2013) (with adjustments to the sample size). Then, the samples were dried at 103 °C to obtain their final anhydrous weight (m_4), and their mass losses (*ML* %) were calculated as $ML(\%) = \frac{(m_3 - m_4)}{m_3} \times 100$.

RESULTS AND DISCUSSION

Physical properties variations

The dimensions and density evolutions of the sample due to the heat treatment are assessed and summed up in Table 2 where the relative difference values between the average values of the treated specimen compared to the control non-treated ones; those measures as mentioned before are obtained after the specimen conditioning at 20°C and 65% RH.
The dimensions measurements are showing that for plywood, by definition being composed of an arrangement of veneers glued perpendicularly to each other, the in plane variations (standing for tangential and longitudinal anatomical directions of the wood) are prevented since below 0.2%; only the thickness (radial direction) of the specimen is quite affected by thermal

modification by almost 2% when compared to the previous thickness of the specimen. Concerning the equilibrium moisture content under normal conditions (65% RH and 20 °C), the EMC reduction by 28.2% between the treated sample and the non-treated ones for the UF glue is slightly more important than for the MUF glue of 24.9%.

Table 2: Evolution of samples physical properties after heat treatment

Glue	Δ Thickness %	Δ Width %	Δ Length %	Δ Mass %	Δ Density %	Δ EMC %
MUF	-1.96 ± 0.32	-0.01 ± 0.14	-0.14 ± 0.05	-14.0 ± 0.3	-12.4 ± 0.2	-24.9
UF	-1.23 ± 0.32	-0.09 ± 0.25	-0.09 ± 0.03	-14.0 ± 0.8	-13.1 ± 0.7	-28.2

Durability against fungi

The average values of weight loss observed on the control samples were 47.69 % (Pine Control-Vir), 33.55 % (Pine Control-Dim), 36.55 % (Beech Control-Vir), 23.56 % (Beech Control-Dim) with *Rhodonia placenta* and 22.26 % (Pine Control-Vir), 28.86 % (Beech Control-Vir), 22.67 % (Beech Control-Dim) with *Trametes versicolor*. These virulence results allow 20%, to validate the decay resistance tests.The significant impact of Thermowood® treatment on the conferred decay resistance of poplar plywood, based on the Weight Loss (WL < 2%) in Figure 1a and the visual aspect of the decayed samples, respectively plotted in Figure 1a and shown and 1b-c, is confirmed.

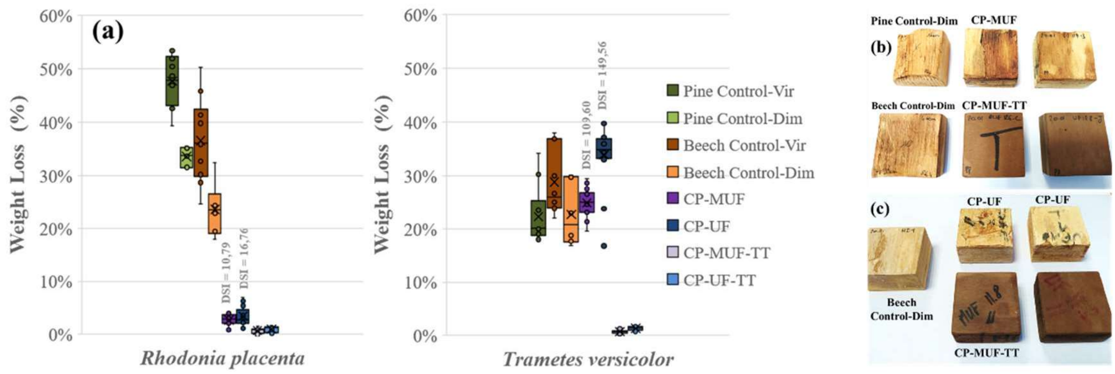

Figure 1: (a) Weight Loss and visual aspect of samples after 16 weeks exposure of (b) Rhodonia placenta and (c) Trametes versicolor

Durability against termites

As shown in Table 1, the control samples were degraded up to 6.12% (pine control) and 3.88% (beech control) with an average termite survival rate greater than 62.67%; all control samples reaching a visual rating 4. These results confirmed the high termite virulence and the validity of the tests. According to the non-choice and choice tests, it appeared that thermally modified plywood samples are a little more degraded than their respective untreated samples. As observed in this study the impact of heat-treatment on wood samples seems generally to be very poor and it appeared that the termite resistance of heat-treated wood was impacted in a random way, was indiscriminate and even reduced in many cases, according to modification process.

Although in terms of mass loss, all the plywood samples are less degraded than the control samples, all plywood samples show visual rating 3 or 4 reflecting moderate and severe attacks, respectively. In other word, heat-treatment process and glue type have not a high impact in plywood termite resistance improvement.

Table 1: Termite durability of untreated and heat-treated (-TT) samples

	Sample references	Mass Loss in %	Survival rates in %	Visual rating*
Non-choice tests	CP-UF	1.14 ± *0.78*	0.67 ± 1.15	3 (2) - 4 (1)
	CP-UF-TT	1.65 ± *0.61*	2.40 ± 4.16	3 (2) - 4 (1)
	CP-MUF	0.94 ± *0.19*	3.07 ± 5.31	3 (3)
	CP-MUF-TT	1.17 ± *0.09*	0.00 ± 0.00	3 (3)
	Pine Control	6.12 ± 0.80	65.68 ± 3.89	4 (5)
	Beech control	3.88 ± 0.57	62.67 ± 3.11	4 (5)
Choice tests	CP-UF	0.86 ± 0.37	11.60 ± 19.75	2 (1) - 3 (1) - 4(1)
	CP-UF-TT	1.82 ± 0.79		4 (3)
	CP-MUF	1.61 ± 0.68	45.47 ± 12.29	3 (1) - 4 (2)
	CP-MUF-TT	1.71 ± 0.39		4 (3)

0, no attack; 1, attack attempt; 2, slight attack; 3, medium attack; 4, severe attack. The numbers in parenthesis indicate the respective number of replicate

CONCLUSIONS

The ThermoWood® process allows improving considerably the decay resistance of MUF and UF poplar plywood. Nevertheless, it is not effective against termites; the improvement of termite resistance between untreated or heat-treated plywood and control samples is essentially due to the glue by the presence of formaldehyde that has a high level of termicidal activities. These results are particularly interesting, because poplar wood is not naturally durable and thermal modification process makes it suitable for use in humid conditions, offering new perspectives of valorisation for poplar plywood materials. Those outcomes have to be mitigated with physical and mechanical degradations assessments to complete this study to ensure the potential for structural exterior uses.

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REFERENCES

ENV 12038 (2003). *Durability of wood and wood-based products - wood-based panels - method of test for determining the resistance*. European committee for standardization.

EN 117 (2013). *Wood preservatives – Determination of toxic values against Reticulitermes species* (European termites) (laboratory method). European committee for standardization.