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Properties after weathering and decay resistance of a thermally modified wood structural board

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ABSTRACT

This paper aims to evaluate whether a thermal post-treatment can be applied to enhance the performance of oriented strandboard (OSB). Samples from 42 commercial OSBs were heat-treated at two temperature levels (190 and 220 °C) and for three heating times (12, 16, and 20 min) using a single opening hot-press. For comparison, control boards were kept untreated. These samples were exposed for eight months to outdoor weathering, and then their physical and mechanical properties were evaluated, as was their decay resistance against the brown-rot (*Gloeophyllum trabeum* [Persoon ex Fries] Murrill) and white-rot (*Trametes versicolor* [Linnaeus ex Fries] Pilat Murrill) fungi. The results indicated that the heat-treated samples maintained their mechanical properties at a much higher level after weathering than did the untreated ones. It was determined that the higher the treatment temperature, the better the residual mechanical properties. The proposed thermal treatment also slightly improved the decay resistance against the two evaluated fungi, but it was not enough to change the resistance class of the OSB.

1. Introduction

Oriented strandboard (OSB) is a wood-based board manufactured from wood logs, which are reduced to strands and consolidated using heat, pressure, and adhesive. Their composition, with 3–5 layers of oriented strands, allows the boards to be used in applications that require high strength and low weight. OSB is widely employed in the U.S., Canada, and Japan, practically replacing plywood for many applications in the construction sector. In Brazil, OSB has been manufactured since 2002 and, unlike the case in other countries, has not been used for structural purposes such as roof, wall, and floor sheathing, but mainly for packaging, civil work fence/cover, and internal structure for furniture (Del Menezzi, 2004).

Plywood and OSB panels can be considered similar in conception with regard to wood composites, since the principle of cross lamination is present in both composites. Therefore, they are frequently used for the same purpose, but the main drawback of OSB is its low dimensional stability in comparison to plywood. This means that OSB presents a higher thickness swelling and linear expansion than plywood. To overcome this limitation, a very promising method has been studied in Brazil since 2001. With this method, the consolidated OSB is thermally treated at mild conditions (low temperature, short duration and under dry conditions) using hot-presses. The pressure is applied just to guarantee contact between press plates and surfaces of the board. With this treatment, thermally treated OSB panels present lower thickness swelling and are less hygroscopic (Del Menezzi and Tomaselli, 2006) than untreated ones. Although the treatment is applied at these conditions, some weight loss takes place, mainly due to loss of the hemicelluloses (Del Menezzi, 2004), which is highly desired to improve durability against decay. Okino et al. (2007a) also observed that thermally treated OSB has a lower water absorption rate, and the method worked properly even when a less thermal resistant resin, such as urea–formaldehyde, was used.

In fact, the benefit of the thermal treatment on decay resistance of wood has been reported in works of Welzbacher and Rapp (2007), Kandem et al. (2002), Kim et al. (1998), and Tjeerdsma et al. (1998). According to Weiland and Guyonnet (2003) there are three main reasons for this improvement: the thermal treatment stimulates new substances, which act as a biocide; the treatment chemically modifies the wood substrate so that it cannot be properly identified by the fungus; and it degrades the hemicelluloses,

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the main source of fungus feeding. Hill (2006) stated that the loss of OH groups from the cell wall polymeric constituents may also affect the ability of enzymes to metabolize the substrate. However, ineffective results of thermal treatment on improving decay durability of wood have been obtained (Smith and Sharman, 1971), probably because shorter treatments have been used, limiting the desirable chemical degradation of the wood polymers (Hill, 2006). It has also been found that thermally treated material does not possess durability against marine borers (Westin et al., 2006), termites (Doi et al., 1999), and in-ground contact applications (Welzbacher and Rapp, 2007). In spite of this, Wan et al. (2007) stated that using technologies with a low environmental impact to improve durability of wood material could have advantages over chemical methods.

To improve decay resistance of wood composites, many methods have been studied: impregnation with natural substances (Wan et al., 2007; Nemli et al., 2006); board production with more resistant species/plants parts (Okino et al., 2007b; Yang et al., 2006; Yalinkilic et al., 1998); mixing durable/non-durable species (Shi et al., 2006; Kartal and Green, 2003); chemical modification of raw material (Papadopoulos, 2006; Okino et al., 2004; Timar et al., 1999); coating/overlaying systems (Nemli et al., 2005), and thermal pre-treatment of raw material (Paul et al., 2007).

Furthermore, as dimensional changes and water absorption of treated OSB are reduced, some improvements in the weathering behavior can be expected. According to Williams (2005) free water is not required for weathering to occur, but the presence of the free water can accelerate the process through splitting and checking of the wood. In this context, fluctuating climatic conditions affect the internal structure of reconstituted structural products, once they are prone to swelling and shrinking, which cause strength reduction (Alexopoulos, 1992). As the thickness of the board increases, unrecoverable stresses are released, promoting a permanent thickness swelling (PTS) even if the board is dried again. In this process, adhesive bonds are permanently broken and also strands are ruptured by tension, which considerably reduces the strength (Suchsland, 2004). In addition, the board becomes thicker, which means density reduction, also contributing substantially to reduction in strength. Therefore, the weathering behavior of a wood composite can be suitably evaluated as the amount of residual strength. According to Williams (2005), factors such as mildew growth, checking, splitting, and warping are often more important for boards used in decking applications.

To reduce the effects of weathering and improve the service life of wood composites, strategies such as surface/edge coating, overlaying, and special adhesive formulations have been used. Carll and Feist (1987) evaluated five pre-treatments and four finish systems and observed that painted waferboards performed better than stained ones, while pre-treatment had an inconsistent effect. Cremonini and Pizzi (1999) observed better exterior performance for tensile strength of plywood glued with urea–formaldehyde modified resin in comparison with plywood bonded with ordinary melamine–urea–formaldehyde resin. Some studies have evaluated weathering behavior of untreated and unstained wood composites. Untreated plywood from six species was manufactured by Biblis (2000) and the weathering behavior was affected by the wood species. Commercial long strand waferboards were evaluated by outdoor weathering for five years by Alexopoulos (1992). It was observed that most of the total thickness swelling and bending stiffness decline took place during the first year of exposure.

In this context the present work aims to increase knowledge about thermal post-treatment (Okino et al., 2007a; Del Menezzi and Tomaselli, 2006) by evaluating decay resistance against brown- and white-rot fungi and weathering behavior of the treated and untreated OSB panels.

2. Materials and methods

2.1. Wood composite material and thermal treatment

One sample ($50 \times 50 \times 1.25$ cm^3) was cut from each of the 42 commercial OSB panels of the same composition and manufactured by the same company. They were manufactured according to the following characteristics: made from *Pinus* sp., nominal density of 0.64 g/cm^3, three layers, 19.04 kg of solid resin/m^3 (40% diisocyanate on the core and 60% phenol–formaldehyde on the surface layers). The samples, now referred to as boards, were kept in a conditioning room (65% RH; 20 °C) until equilibrium. From each board a $5 \times 5 \times 1.25$-cm^3 specimen was cut to determine moisture content.

The thermal treatment was applied using a laboratory single opening press, where pressure and heat were applied, but without a high level of compression stress. The pressure was applied simply to have contact between the press plates and both surfaces of the boards (<17 kPa). In the industrial OSB plant the pressing temperature varies from 190 to 210 °C, which is the range needed to promote the resin polymerization. Thus, two temperatures were chosen: 190 °C, the industrial minimum; and 220 °C, slightly above the maximum. A preliminary study was done to evaluate the time needed to heat the boards above 170 °C (glass transition temperature, T_g). According to Hsu et al. (1989), at this temperature the compression stresses can be released from the board. The results indicated that at least 590 s were necessary for the boards to reach T_g at 190 °C and at least 400 s at 220 °C. This meant that the minimum treatment should be 8 min, with an additional time of 4 min needed to release the compression stress. The boards were treated according to the following schedule: two temperature levels, 190 and 220 °C, during 12, 16, and 20 min. For each temperature–time combination six boards were thermally treated and six additional boards were kept untreated (control samples), totaling 42 boards (Table 1). After the thermal treatment the boards were reconditioned once more to reach equilibrium.

2.2. Natural weathering test

For the natural weathering test, 28 uncoated boards ($26 \times 29 \times 1.25$ cm^3) were exposed to natural climatic conditions (humidity, wind, rain, and sun) from November 2004 to July 2005 at Forest Products Laboratory (LPF) in Brasília, DF, Brazil. The city is located at 15°46′11″ South and 47°51′37″ West and its elevation is 1030 m above sea level. The boards were oriented South at the 45° angle. During the exposure period air humidity (as a percentage), rain (in millimeters), maximum and minimum temperatures (in degrees celsius) and sunlight (hours) data were obtained daily from the Brazilian National Institute of Meteorology (www.inmet.gov.br). After eight months of exposure, the boards were once again placed in the conditioning room as explained previously. After reconditioning, the thickness of the boards was measured and compared to the value before weathering exposure to calculate the permanent thickness swelling (PTS) according to Eq. (1).

$$\text{PTS} = \frac{T_f - T_i}{T_i} \times 100\ (\%) \quad (1)$$

where T_f is the final board thickness after eight months of exposure; and T_i is the initial board thickness before weathering.

Modulus of rupture (MOR) as well as modulus of elasticity (MOE), both tested perpendicularly to the outer layers axis, were determined according to EN 310 (1993), while internal bonding (IB), compression strength (COMP), and density (D) were determined as stated by ASTM D 1037 (1999). These mechanical evaluations were carried out in a universal testing machine, INSTRON 1127. The results obtained for these properties were compared to those previously obtained to determine the residual property (RP) according to Eq. (2).

$$\text{RP} = \frac{V_f}{V_i} \times 100\ (\%) \quad (2)$$

where V_f is the final value of the property after eight months of exposure; and V_i is the initial value of the property according to Del Menezzi (2004).

Before the exposure a $5 \times 5 \times 1.25$-cm^3 sample was cut from each board to determine the initial moisture content required for calculating the estimated dry weight of the board (W_d) according to Eq. (3). During the exposure period, every two weeks the boards were weighed and the current moisture content (MC_c) calculated according to Eq. (4).

Table 1
Experimental design

Treatment code	Temperature (°C)	Time (min)	Number of boards (n)
Control	–	–	6
T1	190	12	6
T2		16	6
T3		20	6
T4	220	12	6
T5		16	6
T6		20	6