Mechanical Properties of OSB Wood Composites with Resin Derived from a Renewable Natural Resource

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Abstract OSB (Oriented Strand Board) is the most important development in the industry of wood products in recent years. However, mainly for reasons of cost industries use as adhesive resins that emit formaldehyde. Formaldehyde is considered a hazardous substance and its concentration indoors is restricted in many countries because of its reactivity, toxicity and pungent odor. This study aimed to attest the feasibility of production of OSB from resin with part of your component derived renewable resource (castor oil-based polyurethane) and Pinus sp. The panels were produced technically evaluated by determining their mechanical properties. In comparison to the minimum requirements of the European normative document EN 300 (2006), average values were higher than the panels for structural use in special wet environment (OSB/4) by up to 41% and 58% modulus of elasticity (MOE) and of modulus of rupture (MOR) in bending parallel to the grain, respectively. Adherence internal reached values at least three times higher than OSB/4.

Keywords OSB, Polyurethane resin, Mechanical properties

1. Introduction

According to European standard EN 300 [1], an OSB is defined as a wooden board with multiple layers made of strands, wooden strips of a predetermined shape, with length greater than 50 mm and thickness lesser than 2 mm, bound together by a binding agent. Strands in outer layers tend to align in parallel to the board length, whereas strands in the inner layer or layers can be distributed randomly or aligned normal to the direction of outer layer strands. According to the aforementioned normative document, OSB boards may be classified into four categories according to their physical-mechanical properties.

Opting for a particular type of resin for manufacturing wood strand boards depends on the costs and uses of the final product. Being one of the costliest components, it is very important to define the type and amount of binding agent to be used in order to optimize the cost-benefit ratio [2].

Resins used in OSB production can be generally divided into two types: resins for outdoor and indoor applications. Outdoor resins are cured under high pressures and at high temperatures; they are insoluble and waterproof. Water-soluble resins are mainly used in boards for indoor use, such as dry walls, cabinets, and other furniture [3].

In Europe, it is common to use a combination of binding agents: phenol formaldehyde (FF), isocyanate (MDI) in inner layers and melamine urea formaldehyde (MUF) in outer layers to reduce press cycles as well as to provide a shiny luster to the board surface [3]. Most North American companies manufacturing OSB boards use FF, whereas MDI is used in boards that require better quality, such as those employed as I beam web sand floors or in the inner layers of boards, because its cost is higher [4]. In Brazil, the existing OSB manufacturer, LP Brasil, uses FF in both outer and longitudinal layers and MDI in inner and transversal layers [5].

The biggest problem in employing the aforementioned resins has to do with the use of formaldehyde. Formaldehyde is considered a hazardous substance and its concentration in indoor environments is restricted in many countries because of its reactivity, toxicity, and pungent odor [6]. Epidemiological and clinical studies have shown that...
exposure to formaldehyde can cause numerous health problems, such as irritation of the eyes and respiratory tract, nausea, headache, fatigue, lethargy, and thirst [7].

From 2009 onwards, pressure on the part of the American State of California has forced reductions in formaldehyde emission from wood boards (CARB-California Air Resources Board). In 2010 the U.S. Environmental Protection Agency (EPA) proposed regulations for the first national formaldehyde emission standard regarding wood-based composites, which probably will be enforced in the second half of 2013 [8]. According to [9], these restrictions are giving rise to new terms in the industry, such as ULEF (Ultra Low Emitting Formaldehyde) and NAF (No-Added Formaldehyde), which represent, respectively, very low emission amino-plastic resins and formaldehyde-free resins, such as isocyanates, PVAc, and, more recently, “bio-resins,” among others.

Nowadays, there is growing interest in modern technologies that are based on renewable raw materials. Although the introduction of plant components in polyurethane systems meets the concept of sustainable development, it is a major challenge to the chemical companies [10]. According to [11], the worldwide trend of biodegradable products has advanced development in this field and led to the discovery of polyurethane (PU) resin derived from castor bean (Ricinus communis L.), used in single-component and 2-component formulations.

Well-known internationally, castor bean is an Euphorbiaceae specie, from which castor oil is extracted. This plant is found in tropical and subtropical regions and is very abundant in Brazil. From castor oil it is possible to synthesize polyol, whose combination with a prepolymer is conducive to a polymerization reaction leading to a castor oil-based polyurethane resin [12].

In Brazil, many studies have investigated the use of 2-component type castor oil-based PU resin as binding agent in the manufacture of wood-based composites. This resin was synthesized by the Analytical Chemistry and Polymer Technology Group at University of São Paulo, São Carlos, Brazil, which has its patent [13]. According to [14], it has excellent properties, such as handling at room temperature, water and UV resistance, and high mechanical strength, in addition to being made from a renewable natural resource. Dias [12] states that this PU resin has 100% solids content, consisting of polyol and prepolymer. In addition, it is a cold-curing binding agent, whose cure can be accelerated at temperatures up to 100°C.

Dias [12] conducted a study on the use of castor oil-based PU resin in the manufacture of plywood and hardboard. Plywood boards were manufactured with Eucalyptus saligna wood sheets and wood agglomerates consisting of Eucalyptus grandis, Eucalyptus urophylla, and Pinuselliottii strands. Results showed that boards using this resin display excellent physical-mechanical properties.

Nascimento [15] manufactured OSB boards with tropical timber strands and castor oil-based PU resin. The average values and variability of properties were equivalent to those of boards manufactured on industrial scale, and the values of modulus of elasticity (MOE) and modulus of rupture (MOR) in bending parallel to the grain were higher than those recommended by EN 300 [1].

Ferro [16] assessed the technical feasibility of manufacturing OSB boards from Paricá wood strands (Schizolobium amazonicum) and castor oil-based PU resin. In comparison to EN 300 [1] minimum requirements, average MOE and MOR parallel values obtained were 26% and 31% higher, respectively, than those recommended forboards for special structural use in humid environments (OSB/4). Internal binding reached values above those of OSB/3 and OSB/4. In addition, results of swelling in thickness met the requirements for general-use boards and components for use in dry environments (OSB/1) and for structural use in dry environments (OSB/2).

As aforementioned, the efficiency of castor oil-based PU resin has been attested in various types of wood boards. Notwithstanding, studies on OSB boards made of Pinus wood strands and castor oil-based PU resin are lacking, despite the importance of this wood in the manufacture of boards. According to [17], the area of planted forests in Brazil has totaled 6.66 million hectares; of which 1.56 ha pertain to Pinus, i.e., more than 20% of the total area, which makes Pinus second only to Eucalyptus.

In light of this worldwide trend of developing sustainable products and use of wood waste, our study aimed to investigate the feasibility of manufacturing OSB boards from Pinus sp. and resin partly consisting of castor oil-based polyurethane. The produced boards were evaluated technically by determining their mechanical properties and comparing the values obtained to those found in EN 300 [1].

2. Materials and Methods

The experimental OSB boards were manufactured and tested at the Wood and Timber Structures Laboratory (LaMEM), São Carlos School of Engineering, University of São Paulo (EESC/USP).

In order to manufacture OSB boards, this study employed strands obtained from tailings of Pinus sp structural parts. According to [18], [19] and [20], the density of this wood is close to that recommended for use in the manufacture of OSB boards [21]. Castor oil-based polyurethane resin was used as a binding agent due to its excellent performance in boards, as observed in previous studies [12], [15], [16] and [22].

The composites were manufactured with the aid of the following equipment: circular saw (a); chipper (b); strand generator (c); oven (d); analytical balance (e); spray chamber(f); strand separator (g); mixer (h); digital caliper (i); heated hydraulic press (maximum load of 80 tons and capacity of 200°C).

The manufacturing process was conducted according to [23]. At first, Pinus sp wood scraps with apparent density of
0.49 g/cm³ and with moisture content close to 12% were forwarded to carpentry, where they were sectioned into 90 mm wide and 45 mm thick pieces (Figure 1). These dimensions defined the length and width of strands. The strands were generated in a disc chipper, whose knives had been adjusted to generate strands with thickness ranging from 0.40 to 0.90 mm.

The strands generated were weighed and confined to a spray chamber, in which the binding agent was sprayed onto them with the aid of an air compressor and two pistols. First, polyol was applied, followed by the prepolymer [24] and [25]. Based on Bertolini [22], the adopted polyol/prepolymer weight ratio was 1:1. In accordance with [12] and [15], the resin concentration was 12% for all boards, based on dry weight of strands. Once sprayed with the binding agent, strands were placed in the separator.

A pre-pressing operation was carried out, aiming to improve the cushion conformation and avoid waste of strands. Then, the cushion was taken to a hydraulic press and submitted to a specific load of 4.5 MPa for ten minutes at 100°C as described in [23], [26].

After manufacture, the boards underwent cure for 72 hours so as to optimize the binding agent performance. As regards the direction of strands on the board surfaces and inside, we opted for three layers: strands were placed in the same direction in both outer layers and randomly placed in the inner layer. In accordance with [20], the adopted surface/core/surface ratio was 20:60:20, based on the dry weight percentage of strands sprayed with binding agent (Figure 2). Four 350×350×10 mm boards were manufactured.

3. Experimental Results and Discussion

Internal Binding

The average value for internal binding was 1.55 MPa (VC = 19.5%). In comparison to boards for special structural use in humid environments (OSB/4 from EN 300[1]), the result obtained in our study is at least three times higher.

Static Bending Parallel to the Grain

The average modulus of elasticity for the manufactured boards was 8,126 MPa (VC = 9.6%). MOE values obtained for the boards in question are at least 41% and 38% higher than those of OSB/4 boards (EN 300[1]) and plywood for use in reinforced concrete molds (DIN 68792[36]), respectively.

The average module of rupture was 56.5 MPa (VC = 13.5%). As compared to MOR values found in norms such as OSB/4 regarding boards (EN 300[1]), plywood for civil construction (DIN 68705-3 [37]) and five-layer plywood (DIN 68792[36]), this value is at least 58%, 24%, and 14% higher, respectively.

4. Conclusions

Based on the methodology used and results obtained for our OSB boards the following conclusions can be drawn:

In static bending tests, average MOE and MOR values for the boards under investigation are higher than those found in normative documents regarding OSB and plywood, indicating the efficiency of their mechanical strength.

The average internal binding value is three times higher than that recommended by EN 300 [1], which attests to the efficiency of the resin employed.

In light of the above results, it can be concluded that the manufacture of OSB boards with Pinus sp. and castor oil-based PU resin is viable.

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