International Journal of Composite Materials 2014, 4(3): 157-161
DOI: 10.5923/j.cmaterials.20140403.01

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

Amós Magalhães de Souza[1], Luciano Donizeti Varanda[1], Laurenn Borges de Macedo[1], Diego Henrique de Almeida[2], Marília da Silva Bertolini[1], André Luis Christoforo[3,*], Francisco Antonio Rocco Lahr[4]

[1]Department of Material Engineering, Engineering School of São Carlos (EESC/USP), São Carlos, 13566-590, Brazil
[2]Pontifical Catholic University of Minas Gerais (PUC Minas), Department of Civil Engineering, Campus of Poços de Caldas, Poços deCaldas, 37701-355, Brazil
[3]Centre for Innovation and Technology in Composites – CITeC, Department of Civil Engineering (DECiv), Federal University of São Carlos, São Carlos, 13565-905, Brazil
[4]Department of Structural Engineering (SET), São Paulo University (EESC/USP), São Carlos, 13560-970, Brazil

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].

* Corresponding author:
alchristoforo@yahoo.com.br (André Luis Christoforo)
Published online at http://journal.sapub.org/cmaterials

Resins used in OSB production can be generally divided into two types: resins for outdoor and indoor applications. Outdoor resins are cured under highpressures and at hightemperatures; 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 biding 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-knowninternationally, 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 synthesize polyol, whose combination with a prepolymeris 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 urophilla*, 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 boards for structural use in humid environments (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 into90 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.

Figure 1. Wood particle (Strands)

The strands generated were weighed and confined to a spray chamber, in which the biding 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°Cas described in [23], [26].

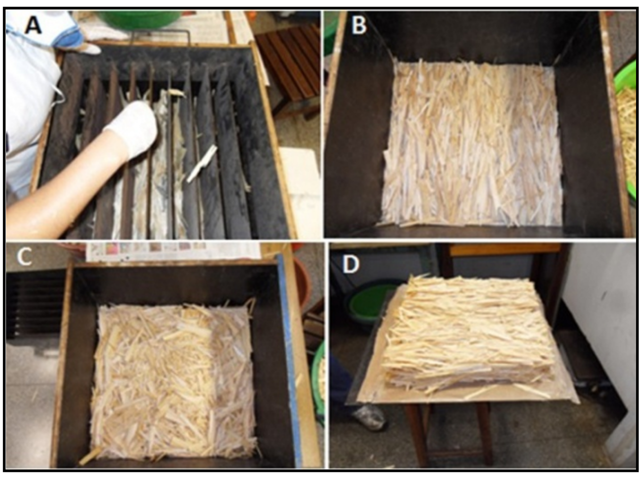

Figure 2. a) Orientation of the particles, b) the outer layer, c) the inner layer d) mattress

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 350×350×10mm 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.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the financial support provided by Fundação para o Amparo à Pesquisa do Estado de São Paulo—FAPESP (Proc: 2012/14352-3) and the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – CAPES.

REFERENCES

[1] European Standard. EN 300: Definitions, classification and specifications. Portugal. 2006.

[2] R. F. Mendes et al. Painéis aglomerados produzidos com bagaço de cana em associação com madeira de eucalipto. Scientia Forestalis, 38, 285-295, 2010.

[3] EPF. O painel derivado de madeira mais versátil dos nossos dias. Available in:<http://www.europanels.org>. Access in 08 aug 2013.

[4] H.Spelter.; D. Mckeever.; M. Alderman. Status and Trends: Profile of Structural Panels in the United States and Canada. Department of Agriculture. For. Prod. Lab. General Technical Report, FPL-636, Madison, United Stated, 2006.

[5] Louisiana-Pacific Corporation Brazi. Como é feito o OSB. Available in: <http://www.lpbrasil.com.br>.Access in 08 aug 2013.

[6] S. Kim. Environment-friendly adhesives for surface bonding of wood-based flooring using natural tannin to reduce formaldehyde and TVOC emission Bioresource Technology, 100, 744–748, 2009.

[7] USEPA. Introduction to indoor air quality, a reference manual, EPA/400/3-91/003, Section 7 [M] US Government Printing Office, Washington, DC, 1991.

[8] Panelwood. EPA Address Formaldehyde. Available in: <http://www.panelworldmag.com>. Access in 08 aug 2013.

[9] G. Costa. A Emissão do formol em painéis de madeira. Available in: <http://ideiascomdigital.blogspot.com.br>.Access in 08 aug 2013.

[10] M. Kuranska. Porous polyurethane composites based on bio-components Comp Sci Technol, 75, 70–76, 2013.

[11] L. C. R. Araújo. Caracterização química e mecânica de poliuretanas elastoméricas baseadas em materiais oleoquimicos. Thesis/Dissertation, The University of São Paulo, Physical and Chemistry Institute of São Carlos, 1992.

[12] F. M.Dias.; F. A. R. Lahr Alternative Castor-Oil Based Polyurethane Adhesive Used in the Production of Plywood Materials Research, 7(3), 413-420, 2004.

[13] R.V. Silva. Fracture toughness of natural fibers/castor oil polyurethane composites Comp Sci Technol, 66, 1328–1335, 2006.

[14] J. M. H. Jesus.; C. Calil Júnior. Estudo do Adesivo poliuretano á base de Mamona em Madeira Laminada Colada MLC. Madeira, 3(8), 2002.

[15] M. F. Nascimento.; E. A. M. Morales.; F. A. R. Lahr.; A. L. Christoforo.; A. Carvalho. Chapas de OSB com Uso de Madeiras Nativas Revista da Madeira, 1, 1- 4, 2001.

[16] F. S. Ferro. Painéis OSB com madeira *Schizolobium amazonicum* e resina poliuretana à base de óleo de mamona: viabilidade técnica de produção. Thesis/Dissertation, The University of São Paulo, São Carlos Engineering School, The Chemistry Institute of São Carlos, The physical Institute of São Carlos, 2013.

[17] Brazilian Association of Planted Forest Producers (ABRAF). Available in:<http://www.abraflor.org.br>.Access in 08 aug 2013.

[18] G. Bortoletto Júnior.; J. N. Garcia. Propriedades de resistência e rigidez à flexão estática de painéis osb e compensados Materials Research, 28, 563-570, 2004.

[19] L. M Mendes.; S. Iwakiri.; J. L. M. Matos.; S.Keinert JR.;L. K.Saldanha. Efeitos da densidade, composição dos painéis e teor de resina nas propriedades de painéis OSB Floresta e Ambiente, 10, 57- 67, 2003.

[20] S. Iwakiri.; L. M. Mendes.; L. K. Saldanha. Produção de chapas de partículas orientadas "OSB" de *Eucalyptus grandis* com diferentes teores de resina, parafina e composição em camadas Ciência Florestal, 13, 89-94, 2002.

[21] A. M. Souza Productionand performance evaluation of*Pinus* sp oriented strandboard(OSB) with metallic gauze inclusion. Thesis/Dissertation, The University of São Paulo, São Carlos Engineering School, The Chemistry Institute of São Carlos, The physical Institute of São Carlos, 2012.

[22] M. S. Bertolini.; M. F. Nascimento.; K. A. Blecha.; F. A. Rocco Lahr. Eco-panels Based on Wastes from Urban Trees and Castor Oil Polyurethane Resin International Journal of Agriculture and Forestry, 3, 12-15, 2013.

[23] L. M. Mendes et al. Influência da densidade do painel e da composição em camadas nas propriedades físico-mecânicas de painéis OSB de clones de *Eucalyptus spp*. Cerne, 14, 379-385, 2008.

[24] A. J. P. Silva.; F. A. L. Rocco.; A. L. Christoforo.; T. H. Panzera. Properties of Sugar Cane Bagasse to use in OSB International Journal of Composite Materials, 2, 50-56, 2012.

[25] S. A. M. Silva.; A. L. Christoforo.; S. L. M. Ribeiro Filho.; L. D.Varanda.; F. A. L. Rocco. Particleboard Manufactured with Bicomponent Polyurethane Resin base on Castor Oil International Journal of Composite Material, 2, 115-118, 2012.

[26] M. F. Nascimento.; F. A. Rocco Lahr.; A. L.Christoforo. Painéis tipo OSB fabricados com madeiras brasileiras: produção e avaliação de desempenho. In: CIMAD 11 – Congresso Ibero-Latino Americano da Madeira na Construção, Portugal, Universidade de Coimbra. 2011.

[27] European Standard. EN 310: Determination of modulus of elasticity in bending and of bending strength, Bruxelas. 1993.

[28] European Standard. EN 317: Determination of swelling in thickness after immersion in water.Bruxelas.1993.

[29] European Standard. EN 319: Determination of tensile strength perpendicular to the plane of the board. Bruxelas. 1993.

[30] European Standard. EN 323: Determination of density. Bruxelas. 1993.

[31] L. M. Mendes.; S. Iwakiri.; J. L. M. Monteiro.; S. Keinert.; L. K. Saldanha. Pinus spp. na produção de painéis de partículas orientadas (OSB) Ciência Florestal, 12(2), 135-145, 2002.

[32] M. F. Nascimento et al. Chapas de OSB com uso de madeiras nativas. Available in:<http://www.remade.com.br>.Access in 08 aug 2013.

[33] M.W. Kelly.A critical literature review of relationships between processing parameters and physical properties of

particleboards U.S. For. Prod. Lab. General Technical Report FPL-10, Madison, p. 66, 1977.

[34] A. A. Moslemi Particleboard Materials London: Southern Illinois University Press, p. 244, 1974.

[35] T. M. Maloney Modern Particleboard & Dry Process Fiberboard manufacturing San Francisco, M Freeman, p. 672, 1977.

[36] Deutsches Institutfür Normung. DIN 68792: Large area shuttering panels of veneer plywood for concrete and reinforced concrete. 1979.

[37] Deutsches Institutfür Normung. DIN 68705-3: Plywood: building-veneer plywood. 1981.