Medium Density Particleboard Reinforced with Bamboo Laminas

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The objective of this work was to evaluate the effect of the addition of bamboo laminas of the species *Dendrocalamus giganteus* to three-layer medium density particleboard (MDP). These laminas were glued onto both the top and the bottom of each panel. With the manufactured panels laminated with bamboo, mechanical tests based on the Brazilian Standard ABNT NBR 14810 were carried out to determine the modulus of rupture (MOR) in static bending and the tensile strength parallel-to-surface. These mechanical tests were realized in particleboards of eucalyptus and in reinforced particleboard, both produced in the laboratory. The modulus of rupture and tensile strength parallel-to-surface of the laminated MDP had values close to those that have been reported. The reinforcements increased the values of these studied properties. Nevertheless, this fact indicated the possibility to produce a stronger MDP using bamboo lamina as surface layers. These results show the possibility of using coated-bamboo MDP for utilization in large spans, for example, in flooring for mezzanines with finish on both sides, and for robust furniture as bookshelves, beds, tables, *etc*.

Keywords: Medium density particleboard; Lignocellulosic composites; Bamboo; Wood; Reinforced panels

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INTRODUCTION

With the consolidation of the particleboard industry, many companies have invested in equipment to develop their assembly lines. As a result, the evolution of the quality of particleboard is an inherent factor to their success. Furthermore, the acceptance of new products based on this kind of raw material has increased in the global scenario. An example of this is reconstituted wood panel, including medium density particleboard (MDP), developed with alternative reforested wood (Alves *et al*. 2014a,b). Wood particleboards are manufactured as panels from dry wood particles that have been sprayed or dusted (speckled) with a binder resin and are bonded together with pressure and heat (Carll 1986). Modern MDPs are already the most widely used particleboard in the furniture sector, with further prospects for increasing their production in Brazil and for their exportation due to the increase in quality and also the awareness of consumers in purchasing a product from certified human-planted forests (Foelkel 2008).

Bamboo is as renewable as wood and can be efficiently used in building structures (Nogueira 2008). Physical and mechanical characteristics such as bamboo's morphology, easy availability, and low cost make the use of bamboo predominant, especially in tropical and subtropical areas of Asia and Latin America, where bamboo is used as food, shelter, tools, musical instruments, and other objects (Murad 2007). Bamboo has excellent characteristics relating to tension and compression resistance due to its strong walls and low specific weight (Lima Jr. and Dias 2001). This lignocellulosic material has superior resistance to bending, tension, and compression compared to other natural materials, and it can provide more satisfactory results regarding these characteristics if it is combined with adhesives (Moizés 2007).

Innovative research are being carried out with the use of bamboo to reinforce wooden panels. For example, Zhang *et al*. (2014) developed in their study a bamboo-reinforced extruded tubular particleboard with a different concept, as it uses whole culms and exhibits a consistent performance in mechanical tests. For these reasons, the research of particleboards is important to offer new possibilities to industries of composite-boards and furniture, resulting in the need to test new raw materials in MDP production. Brazilian standard NBR 14810 (2006) stipulates the value of 11 MPa for the minimum value of reference to static bending of particleboard.

The objective of this work was to study the influence on modulus of rupture in static bending and the tensile strength parallel-to-surface of the bamboo reinforcement in MDP wooden-based panels, especially for use as stiff components and parts for robust furniture and flooring of mezzanines with finishing on both sides. It is noteworthy that bamboo lamina can offer both structural and aesthetic roles.

EXPERIMENTAL

Materials

The lignocellulosic panels were produced by the technique of gluing bamboo slats onto laboratory-produced MDP specimens. The particles used in MDPs were formed by a homogeneous mixture of two wood *Eucalyptus* species: *E. saligna* and *E. urograndis*.

Using bamboo culms of *Dendrocalamus giganteus*, laminas were obtained by machining at the Wood Processing Laboratory of São Paulo State University (UNESP) at Campus of Itapeva as follows: (a) Cutting with a circular saw bench to provide cross sections; (b) cutting with a table saw to provide longitudinal sections; (c) cleaning of the culm diaphragms using a band saw; and (d) standardizing the thin slats (or clefts), in a double planer, to remove the bark and provide a 3 mm thickness.

Lignocellulosic panels were produced with a standard MDP coated with two layers of bamboo lamina. These layers were glued using polyvinyl acetate (PVA) diluted in the ratio of 75% adhesive and 25% water. The adhesive was applied in an amount of 200g/m^2 with a ½ inch brush, and the bamboo laminas were glued parallel to the longitudinal direction of the panels on both sides (top and bottom).

Methods

Laboratory-produced MDP has a three-layer wood composition, with two external layers with particles of smaller sizes and an inner layer with larger size particles. Panels were glued with urea-formaldehyde and dried at acclimatized room for 48 h (65±5% relative humidity and 20±3 °C temperature).

The bamboo laminas were cold-pressed in the panel with C-clamps, and the boards were dried in a controlled room for 48 h (65±5% and 20±3 °C). The boards were then machined to reach a thickness of 18 mm, using a surface planer to standardize the samples.

After this manufacture process, six boards were cut in the final dimensions of the samples (400 mm × 400 mm × 18 mm, including two layers of bamboo lamina with 1.5 mm of thickness *per* layer) for the mechanical tests. Standardization was verified with a digital caliper. Finally, the panels were taken to a planer to regularize the lateral surfaces.

In this research, two mechanical tests with the panels were performed based on standard NBR 14810 (2006) for modulus of rupture (MOR) in static bending and tensile strength parallel-to-surface. Two different laboratory-produced board treatments were considered: standard MDP without bamboo laminas (Tr 1) and MDP reinforced with bamboo laminas (Tr 2). To verify the influence of the bamboo addition in mechanical properties of the produced MDP, an average of the samples, the standard deviation, and the coefficient of variance were recorded in the results.

RESULTS AND DISCUSSION

All tests performed respected the prescriptive requirements of Brazilian Standard (ABNT) NBR 14810 (2006), giving a satisfactory return in relation to the reliability of the application of bamboo *Dendrocalamus giganteus* as for utilization in large spans. Some examples of such applications are in flooring for mezzanines with finishing on both sides and robust furniture as tabletops and table frames, beds, bookshelves, *etc*.

Figure 1 shows two steps in the manufacturing of the particleboard reinforced with bamboo laminas. Figure 1a shows the board after the gluing and pressing stages, and Fig. 1b illustrates machining stage to finish and to standardize the board dimensions.

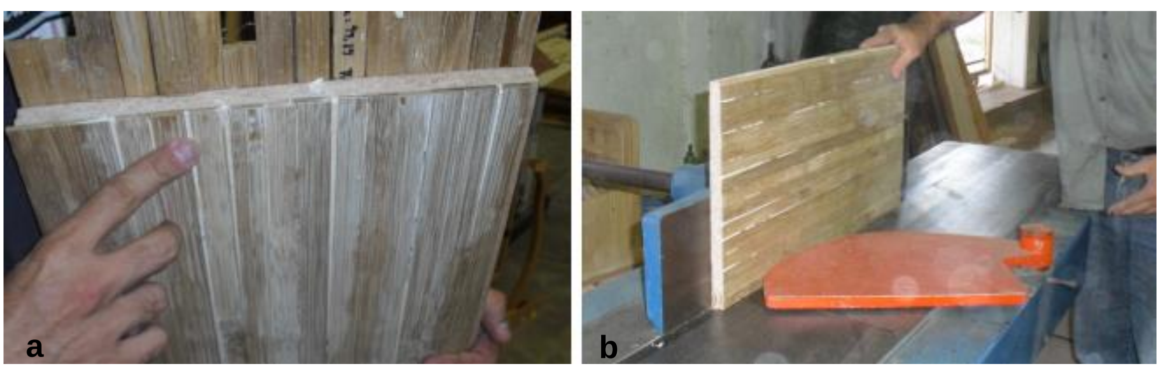

Fig. 1. Manufacturing of the MDP (a) reinforced with bamboo and (b) the machining for finishing

Table 1 shows the values obtained in the static bending test of the MDP without bamboo laminas and MDP with two layers of bamboo lamina (top and bottom).

The reinforced MDP with bamboo laminas (Tr 2) was found to be 2.4 times stronger than a MDP without reinforcement (Tr 1), according to the base value identified by the Brazilian standard NBR 14810 (2006), resulting in a resistant lignocellulosic panel. This treatment 2, with bamboo reinforcement, increased the MOR values and also decreased the coefficient of variation.

Table 1. Static Bending Test Values

Static Bending test values – MOR		
Condition	Treatment 1 – without bamboo	Treatment 2 – with bamboo
Average of Samples (MPa)	16.20	39.22
Standard Deviation (MPa)	1.60	0.47
Coefficient of Variation (%)	9.9	1.2

No similar study has investigated particleboard reinforced with bamboo laminas, however, some research about other kinds of lignocellulosic particleboards can be cited to emphasize the obtained results. McNatt (1973) obtained an average value of 16.2 MPa for MOR values of industrial wooden particleboards. At the same time, Papadopoulos (2006) produced a particleboard from a mixture of softwoods (fir and pine species) glued with urea-formaldehyde resin, achieving a MOR value of 13.10 MPa. Warmbier *et al.* (2014) evaluated the effect of willow particle contents (*Salix viminalis*) in particleboards, and obtained MOR values of 14.5, 14.0, and 13.1 MPa for the willow contents of 0, 50, and 100%, respectively. In comparison with all these composites, the reinforced boards produced in the present study showed a higher MOR average value.

Table 2 shows the values obtained in the tensile strength parallel-to-surface test of MDP without bamboo and MDP with two-layers of bamboo lamina (top and bottom).

Table 2. Tensile Strength Parallel-to-Surface Test Values

Tensile Strength Parallel-to-Surface test values (MPa)		
Condition	Treatment 1 – without bamboo	Treatment 2 – with bamboo
Average of Samples (MPa)	9.17	31.67
Standard Deviation (MPa)	0.42	2.70
Coefficient of Variation (%)	4.6	8.6

Tensile strength parallel-to-surface test values of MDP with the double surface layering with bamboo exhibited an increase in tensile strength, from approximately 9 MPa up to 32 MPa, which represents an increase by more than 245% in relation to MDP samples without bamboo (produced in laboratory, similar to commercial MDP). The treatment 2, with bamboo reinforcement, increases the tensile strength parallel-to-surface values; nevertheless, the treatment negatively influenced the coefficient of variation, despite a coefficient of variation below of 10%, which is considered small. McNatt (1973) obtained an average value of 8.0 MPa for the tensile strength parallel-to-surface for industrial wooden particleboards. In comparison with this standard composite, the reinforced boards produced in this study showed a higher MOR average value, indicating a good perspective for strength in the bottom region of elements on static bending. The specimens presented shearing failures within MDPs, and in no case did the failures arise in the glue line among MDP and lamellas.

CONCLUSIONS

1. In the use of bamboo (*Dendrocalamus giganteus*) as a surface layer to reinforce the bottom and top surfaces of MDP, it was found in the performed tests to have a big

advantage as an alternative material to strengthen MDP resistance. In addition, the surface layer can offer a finish of excellent quality that is aesthetically beautiful.

2. The samples of reinforced MDP with bamboo lamina were stronger than a common MDP (for commercial uses), according to the Brazilian standard. This indicates that bamboo possesses characteristics of high mechanical strength, especially in relation to static bending and tensile strength parallel-to-surface.
3. This panel demonstrates a high potential for application as a double coating in situations where mechanical stresses are applied, for example in large spans, such as in flooring for mezzanines and in furniture components for bookshelves, tables, *etc*.

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