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MDP Panels Manufactured with Hevea Brasiliensis Overlaid with Bamboo Foil of Phyllostachys Edulis

Sarah David Muzel[1,a], Maristela Gava [2,b], Juliana Cortez-Barbosa[2,c], Karina Aparecida de Oliveira[3,d], Elen Aparecida Martines Morales[2,e], Victor Almeida De Araujo[4,f]

[1]Undergraduate Engineer of UNESP/Itapeva. Rua Geraldo Alckmin, 519, Itapeva/SP, Brazil

[2]Assistant Professor Doctor of UNESP/Itapeva. Rua Geraldo Alckmin, 519, Itapeva/SP, Brazil

[3]Engineer and Master's Student of UNESP. Av. Ariberto P. Cunha, 333, Guaratinguetá/SP, Brazil

[4]Engineer and Master's Student of ESALQ/USP. Avenida Pádua Dias, 11, Piracicaba/SP, Brazil

[a]sarah.muzel@grad.itapeva.unesp.br, [b]mgava@itapeva.unesp.br, [c]jucortez@itapeva.unesp.br, [d]kari.oliveira@outlook.com, [e]elen@itapeva.unesp.br, [f]engim.victor@yahoo.de

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Abstract. The objective of the present work was to study the use of bamboo foils as structural reinforcement for MDP wooden panels. Four wooden panels of homogeneous layer were produced using particles of GT1 and RRIM 600 clones of *Hevea brasiliensis* (rubber tree), and glued with urea-formaldehyde resin (UF). These panels were also overlaid with foils of *Phyllostachys edulis* (mossô bamboo). The tests were realized to evaluate the physical-mechanical characterization according to European standards (EN). The production of the particleboards with reinforcement of bamboo improves the physical-mechanical characteristics of these commercial wooden panels.

Introduction

Initially, seeking to resolve problems caused by the shortage of wood in Europe, and currently aiming to reduce the waste from timber industry and to achieve a more sustainable production, alternative methods of use of raw materials from waste were studied and solutions to this problem were related to the production of wood-based panels.

Wood-based panels exhibit a number of advantages over solid timber such as: good resistance in bulk density, recyclability, more homogeneity than the sawn wood, possibility of the production of large dimensions parts, ability to immobilize large amount of carbon dioxide from the atmosphere in its mass, and demand of less energy for transportation and installation [1].

Many processed wood products are currently used by the industry: laminated panels, fiberboards and particleboards. Among the popular wood-based products is the Medium Density Particleboard (MDP) [2], which is one of the main materials used in the Brazilian furniture industry, due to its competitive cost and the possibility of a large scale manufacture [3,4].

The MDP production began in the 1940s in Germany during the Second World War, due to the scarcity of wood [5]. In Brazil it began in 1966 in Curitiba-PR, and the first industries used native woods in the manufacturing. Due to the environmental pressures, the increasing of the consumption and the distancing of the natural resources, alternative species from forest plantations started to be used in the process.

Nowadays, chipboard industry in Brazil uses reforestation species, considered of rapid growth such as Pines and Eucalyptus [6]. Aiming the waste reduction and seeking a sustainable production, the use of raw materials from waste and from new species is expanding in the market and it has encouraged the development of several studies.

An example is the rubber tree, a species of great economic importance to the country due to the production of latex, commonly used in the rubber industry. Its planting has considerably increased in recent years, from 85,768 hectares in 2007 to 168,848ha in 2012 [7,8]. This increase can be explained by the projections which indicate that the consumption of rubber will grow faster than its production. Some rubber-experts estimate in 2020 the consumption of natural rubber will be 9.71 million tons for a production about of 7.06 million tons [9].

Rubber tree is the popular name of the species *Hevea brasiliensis*. Its natural dispersal is fixed to the limits of Brazilian Amazon region, but it has shown great adaptability to various environments, such as the regions of Southeast, Midwest, in Bahia state, and more recently in western of Paraná state. *Hevea brasiliensis* is economically exploited for producing good quality latex, and with a high rubber content. In the moment when the latex extraction in a forest field is no more economically viable, characterizing the end of its production life, it is proceeded the trees harvesting to the trees reformulation [10]. In Brazil, the wood obtained at the end of the latex production cycle is used traditionally and exclusively for energy purposes [11].

The current studies have focused on the use of this wood in the industries of furniture, timber, and of wood-based panels, among others. This focus aims to develop new products to increase the value of the *Hevea brasiliensis* wood in the end of the latex production cycle, creating an additional income option to the Brazilian latex producers.

The chipboards are used in the furniture industry, in parts with low structural request. For the use in construction components, whose requests are higher, usually natural or synthetic fibers are added as reinforcement agents.

The fibers can be continuous or discontinuous, aligned or randomized, and they can be obtained from many possibilities. Reinforced panels with continuous fibers exhibit the best mechanical performance [12].

Bamboo is a fibrous material of natural origin, which has high mechanical strength and low specific weight. It constitutes an excellent material for use as a structural reinforcement for wood-based panels [13, 14]. Bamboo is gramineous, whose mechanical properties indicate great potential to be exploited in the engineering. It has long stalks, internally hollow with diaphragms in regular intervals in the regions of the nodes. Its walls have excellent tension and compression resistances if it is compared to hardwoods, emphasizing its low specific weight [15, 16].

Even with excellent mechanical properties, bamboo is rarely used as a material in construction, due to its cylindrical geometry and its low shear stress strength [15].

Due to the environmental pressures for a more sustainable use of the natural resources, many studies have been performed in order to develop a technology for bamboo uses, such as: application of bamboo foils or laminas as reinforcement in wood and wood-based products, to the creation of high performance products for structural purposes [16].

The use in wooden structures of reinforcements with bamboo foils glued has shown satisfactory results in order to improve the mechanical characteristics of softwoods and low density woods [17]. Several studies have pointed to the improvement of resistance in wood-based panels as EGP, OSB and plywood.

Objective

The objective of this work was to study the use of bamboo foils of *Phyllostachys edulis* species as structural reinforcement for MDP panels manufactured with wood of the species *Hevea brasiliensis.*

Materials and Methods

Homogeneous layer MDP panels were produced using particles from the residues of wood clones GT1 and RRIM600 of *Hevea brasiliensis,* from na experimental planting located in the Brazilian city of Piracicaba-SP.

For particles bonding it was used the urea-formaldehyde resin, popular in Brazilian industries, in the proportion of 12% in dry basis.

For the formation of each board, 2 kg of particulates were used, glued and arranged in a single layer in the forming box. The panels were pressed at a temperature of 140ºC and specific pressure of 40kgf/cm² for 12 minutes. After the cooling, the panels were coated with bamboo foils of

Phyllostachys edulis, with nominal dimensions of L x C x 2.8 millimeters, glued with adhesive of polyvinyl acetate (PVA) and cold pressed.

Characterization of panels. After 48 hours specimens were produced to determine the thickness swelling and the static bending, according to the standards EN323 [18], EN310 [19], respectively.

Analysis of results. The obtained results for MDP boards with bamboo reinforcement produced in this study were compared with the values found for [30] MDP boards produced with *Hevea brasiliensis* and urea-formaldehyde resin. For statistical analysis, it was realized a hypothesis test using software R (version 2.15.2-1 of 2012). Through the analysis of variance (ANOVA) using the Student's t-test to determine the existence of differences among the averages, at a significance level of 5%. The average results were also compared with pre-established values by the [20] technical standard.

Results and Discussion

For the thickness swelling after 24h of immersion (Table 1), significant differences among the treatments were verified. The bamboo bonding in both surfaces (top and bottom) of panels prevents the expansion of the swelling of the board thickness, reducing it in 47.08%.

The bamboo reinforcement obtained a positive point for the application of this kind of board in construction, since the MDP panels are currently used in furniture industry, where the use is internal because of the susceptibility to moisture.

Table 1. Average values of thickness swelling (TS), modulus of rupture (MOR) and modulus of elasticity (MOE)

Panel	TS(%)	CV (%)	MOR (MPa)	CV (%)	MOE (MPa)	CV (%)
Without Rreinforcement	29.35 b1	4.98	10.52 b2	24.72	1,746.83 b3	22.07
With Reinforcement	17.09 a1	5.02	55.91 a2	9.47	4,236.00 a3	39.69

Averages with the same character do not differ each other (Tukey; $p > 5\%$); CV = Coefficient of Variation.

Analyzing the obtained results for the static bending test, it was observed that the bamboo foil reinforcement generated increases of 431 % in MOR and of 143% in MOE, significantly increasing the mechanical strength of the MDP boards of rubber trees.

In the comparison of the values obtained in the EN312 [29], the values found in this study, and associated with the evaluated properties, qualify the produced boards for both treatments, suitable for general uses and in technical facilities as indoor furniture. In both cases, the boards are restricted to use in dry rooms. The boards with reinforcement could be further classified into non-structural use in humid spaces, and for the supporting of high loads in dry spaces where dry-bulb temperature for both applications is 14%, as well as in structural use in dry conditions, and special structural, in other words, supporting high loads in humid conditions, admitting maximum values of dry-bulb temperature after 24h of immersion in water of 15% and 10%, respectively.

Conclusions

The production of particleboards with bamboo reinforcement improves the physical-mechanical characteristics of the wooden panels.

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