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Suitability of Muli Bamboo (*Melocanna baccifera*) for Making Bamboo Mat Plywood

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Abstract

This paper investigated the potentiality of muli (*Melocanna baccifera*) for making bamboo mat plywood. Bamboo mat plywood with the length, width and thickness of 2.4 m × 1.2 m × 7 mm was made using liquid urea formaldehyde resin. The physical and mechanical properties of such plywood were compared with the existing market plywood. The average density of bamboo mat plywood was much higher compared to the existing market plywood. The modulus of rupture (MOR) of bamboo mat plywood was 3 times and the modulus of elasticity (MOE) was 6 times higher compared to commercial (*Bombax ceiba*) plywood. Interestingly, the specific MOR and MOE were significantly higher than those of market plywood. The high strength values might be due to the long fiber length of the bamboo. Furthermore, the lamination of decorative thin garjan (*Dipterocarpus turbinatus*) veneer did not significantly reduce mechanical properties of the products. Bamboo plywood mat as well as garjan laminated bamboo mat plywood showed better performance in respect to thickness swelling, linear expansion and water absorption. Hence, muli bamboo can be a potential alternative source of raw material for the manufacture of plywood materials.

Key words: Bamboo mat plywood, Density, Dimensional stability, Modulus of elasticity, Modulus of rupture

Introduction

The present day situation has necessitated the utilization of renewable and sustainable non-woody resources like bamboo for wood substitution. This is particularly important for developing countries like Bangladesh where forests have been declining due to increase construction activities and increased demand of population (Hasnin *et al.* 1997). Bamboo and its related industries provide income, food and housing to over 2.2 billion people worldwide (Lopez, 2003). Bamboo is used as an important raw material for various construction works and it has got a significant importance both at the urban and village levels. The global yield of bamboo is estimated to be about 16 million tons. Of this non-industrial uses (such as farm implements, household articles, handicraft items, construction, etc.) account for about 70%. Only 30% of the yield goes for industrial use, mainly for pulp making (Haun-Ming, 2005). Bamboo's fast growth, good strength, straightness, lightness, hardness, varying sizes, easy workability, ease of propagation and quick maturity made it suitable for a variety of purposes (Haun-Ming, 2005; Yuming and Jian, 1994). The tensile strength of the fibers of a vascular bundle of bamboo could be up to 12,000 kg/cm^2, almost twice that of steel (Lopez, 2003). It is not unlikely that bamboo can be used satisfactorily to produce products with qualities equivalent to or better than those of wood (Yuming and Jian, 1994).

Muli bamboo (*Melocanna baccifera*) is distributed in India, Bangladesh, Myanmar and cultivated in many Asian countries (Sattar *et al.,* 1990). It is the most common forest grown bamboo species in Bangladesh with small culm diameter and thin wall. This species constitutes 70-90 percent of total bamboo forests of the country (Banik, 1980; Drigo *et al.,* 1988; Hansin *et al.,* 1997). The species can be easily recognized by diffused clump habit, having culms of 10 to 20 meter height and 3 to 7 cm in diameter. The culms are strong, durable with inconspicuous nodes (Sattar *et al.,* 1990). These clumps are found to regenerate successfully even in heavily burnt and grazed areas and this bioform of muli bamboo might have evolved to adjust and survive in unfavorable conditions of nature (Banik 1989; 1994). Its versatile uses have been described by Lahiri (2001).

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Besides being used in traditional way, at present bamboo is used for manufacturing various structural composites and as a reinforcement material. Studies indicate the use of bamboo based composites with various species (Kumiko *et al.*, 2001) and bamboo in combination with plywood (Heng *et al.,* 1998). The use of this widely grown muli bamboo has not been reported for mat production so far. Hence, the suitability of the species was studied in bamboo mat plywood production. This study was conducted to provide the technical information (i.e. physical and mechanical properties) of *M. baccifera* mat plywood and finally was compared with bamboo-garjan (*Dipterocarpus turbinatus*) mat plywood and shimul (*Bombax ceiba*) plywood.

Materials and Method

Collection and preparation of raw materials

Muli (*Melocanna baccifera*) was used as raw material for making bamboo mat plywood. Defect free and straight mature bamboo culms of approximately 3 years age were collected from Manikgonj district in Bangladesh. The culms were 5 - 6 m long and diameter was 8 - 10 cm. After collection of the culms, small parts from both top and bottom were removed.

Making of bamboo mat plywood

The culms were cut lengthwise to produce 2 m long stick. Defective portions were removed by trimming. The culms were then split into two equal parts in diameter through middle portion and the nodal parts were cleaned. Each portion of bamboo culms was further split into several thin slivers by using traditional hand cutting tools. The outer and inner surface of bamboo slivers were planned with a planner in homogenous thickness of 1 mm sliver.

The bamboo slivers were clipped on the both ends and defects were cut off. The size of bamboo slivers was approximately 2.44 m x 6.35 cm. The slivers were wet and had moisture content ranging from 35% to 40%. The slivers were dried in Danvo Drive Motor drier for 30 minutes at 120^{o}C temperature to obtain a moisture content of 8%. Liquid urea formaldehyde adhesive (45% solid content) was used with a glue spreader for bonding the bamboo slivers. The glue coated slivers were placed on edge and bonded together. Seven layers of 1 mm thick bamboo slivers were orientated in an alternative manner as plywood. The glue coated sliver mats were allowed an assembly time of 30 minutes between the spreading of adhesives and the application of pressure. The mats were hot pressed at 14.5 kg/m^3 for 25 minutes at 125^{o}C temperature to produce 2.4 m x 1.2 m x 7 mm sized bamboo mat plywood. After proper surface finishing the panels were stored for 48 hours.

In order to compare the properties of bamboo mat plywood with core plywood, bamboo - garjan mat plywoods were produced. Five bamboo mat layers of 1 mm thickness were placed as core and 1 mm thick garjan (*Dipterocarpus turbinatus*) veneer were assembled as face and back for producing bamboo-garjan mat plywood of similar size as of the bamboo mat plywood. On the other hand, market plywood produced by simul (*Bombax ceiba*) (manufactured in Akij Particleboard Mills Ltd., Manikgonj, Bangladesh) was procured from local market of similar dimensions as of bamboo mat plywood.

Preparation of test samples

In order to prepare the test samples for determining the physical and mechanical properties of the prepared plywood, 2.4 m x 1.2 m sized panels were converted into two parts according to length and the size of the panels was 2.4 m x 0.6 m. Each part of the board was further converted into three parts according to the width as 0.8 m x 0.6 m from which 5.08 x 5.08 cm and 25 x 9 cm samples were prepared for testing physical and mechanical properties respectively. Tests were conducted at room temperature (30^{o} C).

Determination of the physical and mechanical properties

Density was measured according to Desch and Dinwoodie (1996). Thickness swelling and linear expansion were measured by the dimensional changes of test samples after water immersion for 24 hours. The water absorption was measured by weight changes before and after immersion in water for 24 hours (Desch and Dinwoodie 1996). Regarding the mechanical properties, the bending strength of the panel, i.e., modulus of rupture (MOR) and modulus of elasticity (MOE) were measured in a universal testing machine (UTM) according to the standard testing methods (ASTM 1987).

Statistical analysis

Statistical tests were performed by LSD using analysis of variance (ANOVA).

Results and Discussion

The average density of muli bamboo mat plywood and shimul plywood were 939 kg/m^3 and 544 kg/m^3 respectively. The density of this bamboo mat plywood is higher compared to that of other bamboo composites and veneer plywood studied previously. Kumar and Siddaramaiah (2004) reported the density of bamboo laminates (*Bambusa bambose*) was 715 kg/m^3. Densities of 809 kg/m^3, 890 kg/m^3, 711 kg/m^3 and 766 kg/m^3 have been found in bamboo mat board manufactured from *Dendrocalamus strictus, B. balcooa, B. bambose* and *M. baccifera respectively* (Bansal and Damodaran, 1999).

The average values of the strength properties of the bamboo mat plywood and shimul plywood are shown in Table I. The mechanical properties of the bamboo mat plywood were much higher compared to shimul plywood. The MOR and MOE of the bamboo mat plywood were 89 N/mm^2 and 8110 N/mm^2 respectively. On the other hand, the values of MOR and MOE of the shimul plywood were 31 N/mm^2 and 1217 N/mm^2. The MOR and MOE values of bamboo mat plywood were almost 3 times and 6 times higher than that of shimul plywood (Table II). As there is a close relation between density and mechanical properties, it is expected that such high mechanical properties in bamboo mat plywood is mainly related to the density of the composites. The mean value of MOR of bamboo mat board is comparatively higher than bamboo laminate (75 N/mm^2) of *B. bambose* and bamboo mat board (59.35 N/mm^2) (Kumar and Siddaramaiah, 2004; IPIRTI 2001). According to ASTM Standard, modulus of rupture of standard plywood varies from 20.7 to 48.3 N/mm^2 (ASTM, 1987). Thus, bamboo mat plywood satisfies the requirement of standard plywood.

Although the manufacturing procedure of the both bamboo mat plywood and shimul plywood is similar, the density of the final products differs. The high density of the bamboo mat plywood is due to the higher initial density of the raw materials. For example, the specific gravity of bamboo lies between 0.55-0.75 (on the basis of green volume and oven dry volume) (Sattar *et al.*, 1990) whilst the value of shimul is 0.34. Hence, the specific values of MOR and MOE (The ratio of MOR and MOE to specific gravity) were evaluated for both the bamboo mat plywood and shimul plywood. The specific MOR values of bamboo mat plywood and shimul plywood were 0.095 and 0.056 Nm^3/ kg mm^2, respectively. On the other hand, the specific MOE of bamboo mat plywood and shimul plywood was 8.62 and 2.23 Nm^3/ kg mm^2 respectively. This result clearly indicates that at the same density level, bamboo mat plywood was much stronger than shimul plywood. This result corresponds to the previous findings by Chen (1987). The author reported that bamboo plywood had higher MOE and MOR. These values are much higher compared to the plywoods from high density commercial timbers. It is expected that this high value of

Table I: Physical and mechanical properties of three different boards (bamboo mat, bamboo-garjan mat and shimul plywood). Data in parenthesis indicates mean (for density n=12, for MOR and MOE n=9). Different letters indicate significant differences at P = 0.05

Plywood types	Density kg/m^3	Modulus of rupture (MOR) N/mm^2	Specific Modulus of rupture (MOR/specific gravity) N/mm^2	Modulus of elasticity (MOE) N/mm^2	Specific Modulus of elasticity (MOE/specific gravity) N/mm^2
Bamboo mat plywood	939.96 (14.62) A	89.62 (4.68) A	0.095	8110.02 (313.71) A	8.62
Shimul plywood	544.86 (38.27) B	31.04 (1.85) C	0.056	1217.83 (79.35) B	2.23
Garjan bamboo plywood	938.89 (19.06) A	67.16 (7.60) B	0.071	8041.09 (334.80) A	8.56

Table II: Physical properties of three different boards (bamboo mat, bamboo-garjan mat and shimul plywood). Data in parenthesis indicates mean (n=12). Different letters indicate significant differences at P = 0.05

Plywood types	Moisture content (%)	Water absorption (%)	Thickness swelling (%)	Linear expansion (%)
Bamboo mat plywood	10.73 (0.27) A	37.03 (1.43) A	5.73 (0.65) A	0.24 (0.09) A
Shimul plywood	17.92 (2.68) B	73.67 (7.33) B	7.23 (1.45) B	0.21 (0.07) A
Garjan-bamboo plywood	10.51 (0.30) A	34.24 (1.65) A	5.46 (1.45) A	0.22 (0.07) A

mechanical strength of bamboo is attributed to larger fiber length of bamboo, as mechanical properties of products are influenced by the long and thick wall fibers (Findlay, 1975). Since bamboos consist of cellulose fibers embedded in a lignin matrix, these fibers are aligned along the length of the bamboo providing maximum strength and rigidity (Lakkad and Patel, 1980).

On laminating the thin sheet of garjan veneers on the face and back of the bamboo mat plywood, the density and mechanical properties of the final products did not vary significantly. The average MOR and MOE of garjan laminated bamboo mat plywood were 67.16 N/mm^2 and 8041 N/mm^2 respectively. Thus, lamination of wooden thin sheets can be another way to manufacture the bamboo wood laminated plywood.

Water absorption and thickness swelling properties are directly related to moisture content. The average moisture content of the bamboo mat plywood and garjan laminated bamboo mat plywood are much lower compared to the shimul plywood. The average water absorption, thickness swelling and linear expansion of these three types of plywood were shown in Table II. The water absorption and thickness swelling of the bamboo mat plywood and garjan laminated bamboo mat plywood were much lower compared to shimul plywood. In bamboos culms, older than one year, the percentage of holocellulose and alpha cellulose tends to decrease but the lignin content remains unchanged or increases slightly (Chen *et al.,* 1987). Cellulose and hemicellulose are responsible for water absorption due to their free -OH groups which has been reported by Wardrop (1957). This low holocellulose content of 3 years old mature bamboo was probably responsible for low water absorption than shimul plywood. Franz *et al*. (1975) described the moisture content of the standard plywood after storage in normal climate to be in the range of 7.3% to 12.7%. The moisture content of shimul plywood was found to be above the average range (Table II). However, insignificant variation of the percentage of mean linear expansion among bamboo mat plywood, bamboo-garjan mat plywood and shimul plywood has been observed (Table II).

Conclusion

Three years old muli bamboo has proven to be a potential source for the manufacture of bamboo mat plywood. The average density of the products was much higher comparedto the commercial plywood. The modulus of rupture (MOR) and the modulus of elasticity (MOE) of the bamboo mat plywood were 3 times and 6 times higher respectively comparedto commercial plywood. The specific MOR and MOE were also significantly higher than that of commercial plywood. On the lamination with decorative garjan veneer, did not reduce significantly the mechanical properties of the product. Bamboo mat plywood as well as garjan laminated bamboo mat plywood showed better performance in respect to thickness swelling, linear expansion and water absorption. Hence, bamboo can be a potential alternative source of raw material for the manufacture of plywood based materials.

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