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Physical and Mechanical properties of MDF board from Bamboo (*Dendrocalamus strictus*) using Needle Punching Technique

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Abstract
Medium density fibre board has unique properties like uniform, dense, smooth, and free of knots and grain patterns, it may be an excellent substitute for solid wood in many applications. MDF boards are prepared using different ligno-cellulosic materials. Bamboo is being utilized in handicrafts, flooring, doors, fences, housing roofs, and rafters. In the present study fibres from bamboo was used for manufactured of board. The aim of the present study was to find out the effect of needle punch technique on the physical and mechanical properties of MDF boards i.e. density, moisture content, water absorption, general swelling, surface absorption, modulus of rupture, tensile strength perpendicular to grain (internal bond strength) and screw withdrawal strength. Needle punch technique was used on resin blended bamboo fibres during the mat formation for reorientation of fibres for increasing the tensile strength perpendicular to grain (Internal bond strength) of the board. The needle punched MDF Boards were prepared using 6, 8 and 10% phenol formaldehyde resin at three different pressures i.e. 14, 17.5 and 21kg/cm^2 respectively for 15 minutes hot pressing at 150^{0}C temperature. Physical and mechanical properties of MDF boards were evaluated as per IS specification 12406:2003. Results indicated that suitable medium density fibre boards made from bamboo (*Dendrocalamus strictus*) can be prepared using three time needle punching the 8% resin treated bamboo fibres during the mat formation and pressed at 21kg/cm^2 specific pressure and with 10% resin content at 17.5 and 21kg/cm^2 specific pressures which meet most of the requirements as per Indian Standard specification IS: 12406:2003. Some of the properties i.e. water absorption and general swelling of board were found higher than the required value of Indian Standard specification (IS: 12406) which can be controlled by suitable treatment of fibres.

Keywords: MDF Board, *Dendrocalamus strictus*, Bamboo fibres, Phenol formaldehyde.

Introduction

Wood as a material was used for manufacturing of building, tools, weapons, furniture and transportation. This dependency on wood increased with time, since the understanding about the unique nature of wood has developed initially with experience and then through the fundamental research. Wood is having the superior qualities and versatile nature such as strength, thermal insulation and electrical resistance. It still holds a prime position as industrial and consumer raw material. Indian industrial demand for wood jumped from 58 million cubic meters in the year 2000 to 85 million cubic meters in 2008 and is expected to exceed 150 million cubic meters by 2018. Indian manufacturers prefer to import timber in log form to feed the domestic industry and are second-largest importer of tropical logs in the world (Anon. 2016) [3]. The plantation and agro-forestry timber are also fulfilling the industrial demand as per the present requirement. However, the imported and the plantation forest both have its own limitations, so it is need of hour to search an alternate in the direction to save the wood raw material.

Composite wood which can be used from structural and non-structural purposes such as in cabinets, furniture, flooring and siding etc is one of the substitute with better homogeneous engineered material to solid wood. These materials are superior to the original substrate due to large dimensions, homogeneity, durability, price or aesthetic values and good mechanical properties (Vidrine, 2008) [15]. Composite wood includes plywood, particle board, oriented strand board, MDF board and block board etc. (Youngquist, 1999) [17]. Demand is a consistently increasing for such composites since they have advantage over solid wood with reference of improved physical and mechanical properties. The maximum amounts of wood or raw material obtained from plantation timber are used for making residue, agricultural residue

composite wood. Medium density fibre board is composite product with properties similar to solid wood. Medium Density Fibre Board was first developed in the United States during the 1960s, with production starting in Deposti, New York. In India the history of fibreboard industry begins in 1959-60 with the set up of two plants producing hard board by defibrator system one M/s Western India Plywood Ltd. Baliapatam, Kerala and other M/s Jolly Boards, Bhandup, Mumbai, Maharastra with installed capacity of 15000 tonnes and 18000 tonnes, respectively (Shukla and Singh, 1994) [12]. The current usage of bamboo is for paper (2.5 million tons), domestic consumption (1.35 Million tons), scaffolding (3.40 Million tons), handicraft (2.55 Million tons) and miscellaneous (1.97 Million tons) (Anon. 2017). According to Suchsland and Woodson (1991) [13] bending strength tends to be higher in panels where the density is not evenly distributed, i.e. high surface density and lower core density. The density profile has a significant influence on most panel properties and can be altered by press parameters such as temperature, pressure and time (Platin & Schnitzler, 1974) [11]. Panels with such density profiles have been found to be suitable for structural applications (Xu *et.al,* 1996) [16]. The bending properties of most wood based panels can also be improved by reinforcing the surface layers of the panels with natural fibres (Barbu & Trogen, 1996; Trogen & Wegener, 1997) [5, 14].

One of the ligno-cellulosic residues materials like bamboo is important for making of composite products. It is available in India abundantly. It is an inexpensive and fast-grown resource with favorable physical and mechanical properties comparable to some common wood species. Bamboo has great potential as an alternative to wood for many applications (Lakkad and Patel 1981; Jain *et al.*1993) [7, 6]. Marinho *et al.*, (2013) [8] evaluated the physical and mechanical properties of Medium-Density Fiberboard made from giant bamboo and its fiber has potential for MDF production.

Effort had been made to improve the internal bond of MDF board by using various techniques. However, the industries are still waiting for new innovations. It was assumed that the orientation of fibres is one of the important factors responsible for the strength of the product. The control over the fibre orientation can give some fruitful results

In the present study the physical and mechanical properties of MDF board prepared from bamboo using 6, 8 and 10% PF resin at 14 kg/cm^2, 17.5 kg/cm^2 and21 kg/cm^2 specific pressures with three time needle punching for changing the orientation of fibres during the mat formation has been evaluated.

Material and Methods

Materials

The raw material used as a ligno-cellulosic material is bamboo *(Dendrocalmus strictus)* i.e. harvested from Forest Research Institute, Dehradun (latitude: 30^{0}19'N and longitude: 78^{0}04'E). Bamboo culms were converted into chips.

The raw material used as chemical is Phenol Formaldehyde. Phenol formaldehyde resin was prepared using phenol, formalin and sodium hydroxide which act as a binding material in the preparation of MDF board.

Manufacture of MDF

The air dried bamboos culms were converted into small chips. These chips were converted into fibres in a condux mill. The fibres were separated from each other by refining them in a refiner. Washing was carried out to maintain the pH of fibres. Fibres were air dried for 24hrs in room temperature and passed through the pulveriser machine. Fibres were sieved through 60 mesh screen to get uniform size of the fibre. The drying process is one of the most important operations in a fibre board preparation. The fibres were dried in the range of 6-8% moisture content in a laboratory oven. Oven dried fibres (2kg) were used for the preparation of MDF board.

MDF Boards were made up of 6, 8 and 10% resin content of the dry weight of bamboo fibres. The resin was coated uniformly on the fibres in a rotary blender by spray gun. The resin blended fibres were then air dried to attain moisture content of about 6-8%. After resin blending and fibre drying, process of mat formation was carried out. After mat formation the needle punch technique was used for the reorientation of fibres in mat. Needle punch frame of size 21" x 21" was prepared at Composite Wood Discipline, FRI by wood having numbers of needles on it. The mat was punched by needles for three time. Caul plates with applied wax were then placed over the mat. The mat was pressed in a hot press at different specific pressure i.e. 14, 17.5, and 21kg/cm^2 at temperature 150°C for 15 minutes. After hot-pressing, MDF boards were conditioned for 24hrs at ambient room temperature and humidity prior to properties evaluation.

The number of samples and the size of test sample from each MDF board were prepared as per IS: 2380 (1998) and the physical and mechanical properties of MDF board were tested as per IS: 12406 (2003).

Results and Discussions

The values of different physical and mechanical properties of MDF board prepared from *Dendrocalamus strictus* with 6, 8 and 10% PF resin content at 14, 17.5 and 21kg/cm^2 specific pressure are shown in table-1. The values are evaluated as per IS specification (12406:2003).

The density of MDF board varies from 0.598 to 0.844gm/cm^3. The moisture content of the boards was observed from 9.84 to 6.48%. The water absorption of boards after 2hrs and 24hrs soaking were higher in MDF board. Minimum 45.03% and 54.09% water absorption after 2hrs and 24hrs soaking were observed with 10% PF resin at 21 kg/cm^2 specific pressure among all the MDF boards prepared. However, the values of water absorption was higher than the required IS specification. Minimum general swelling percentage after 24 hours water soaking i.e. 18.5% in thickness, 0.4% in length and 0.3% in width were observed in MDF boards prepared with 10% resin content at 21 kg/cm^2. The surface absorption of MDF boards were varies from 9.19 to 5.79% among all boards. The modulus of rupture of MDF board varies from 14.31 N/mm^2 to 28.34 N/mm^2 and maximum value i.e. 28.34 N/mm^2 was observed in the board prepared at 21 kg/cm^2 specific pressure for 15 minutes with 10% resin content. Tensile strength perpendicular to the grain (Internal bond strength) value was in general less than the Indian Standard Specification among all boards except board prepared with 8% resin content at 21kg/cm^2 specific pressure and 10% resin content at 17.5 kg/cm^2 and 21kg/cm^2 specific pressure which meet the requirement as per Indian Standard. The main reason for increase in internal bond strength of MDF boards is due to needle punch technique used during the mat formation which changes the orientation of some of the fibres into vertical direction. The Screw withdrawal strength of MDF board prepared with 8% and 10% resin content at 17.5 kg/cm^2 and 21kg/cm^2 meet the requirement of Indian Standard IS: 12406-2003.

Table 1: The physical and mechanical properties of MDF board prepared from Dendrocalamus *strictus*at at different resin content and pressure.

Physical and Mechanical properties			6% Resin Content at different pressure			8% Resin Content at different pressure			10% Resin Content at different pressure		
			14 kg/cm^2	17.5 kg/cm^2	21 kg/cm^2	14 kg/cm^2	17.5 kg/cm^2	21 kg/cm^2	14 kg/cm^2	17.5 kg/cm^2	21 kg/cm^2
1	Density		0.599	0.645	0.686	0.678	0.759	0.817	0.678	0.766	0.844
2	Moisture Content		9.84	8.44	7.72	7.31	7.08	6.55	6.99	6.75	6.48
3	Water Absorption (%)	2 hrs	94.39	83.83	75.74	62.32	57.7	47.43	61.11	52.8	45.03
		24 hrs	108.42	94.08	86.73	69.68	66.94	57.65	68.13	61.81	54.09
4	General swelling (%) after 24 hrs	Thickness	46.2	39.9	34.2	34.8	26.3	20.0	33.0	25.0	18.5
		Length	0.6	0.5	0.4	0.6	0.5	0.4	0.6	0.5	0.4
		Width	0.6	0.5	0.4	0.6	0.5	0.3	0.6	0.5	0.3
5	Surface Absorption (%)	2 hrs	9.19	7.57	6.41	8.58	7.84	6.13	7.38	6.92	5.79
6	Internal Bond (N/mm^2)		0.322	0.362	0.411	0.391	0.602	0.710	0.428	0.704	0.812
7	MOR (N/mm^2)		14.31	19.54	23.26	17.56	23.28	25.86	20.79	25.12	28.34
8	Screw Withdrawal strength (N)	Face	1023.2	1175.9	1318.0	1399.6	1561.2	1665.1	1497.8	1636.7	1830.7
		Edge	768.05	885.45	940.41	1114.2	1288.0	1405.0	1316.2	1403.8	1485.2

Conclusion

The present study was carried out to evaluate the physical and mechanical properties of MDF board prepared from bamboo with three different percentage of PF resin at three different pressures with three time needle punching during the mat formation. The results indicate that suitable MDF board can be prepared using three time needle punching the fibre mat treated with 8% resin content at 21kg/cm^2 specific pressure and 10% resin content at 17.5 and 21kg/cm^2 specific pressure me *et al* most all the requirement as per Indian Standard specification IS: 12406:2003. Water absorption and general swelling of board were higher than the required value of Indian Standard specification (IS: 12406) which can be controlled by suitable treatment.

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