International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(1): 670-672

Received: 13-11-2017
Accepted: 18-12-2017

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Comparison of physical and mechanical properties of particle boards of bamboos bonded with urea formaldehyde resin

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Abstract
The objective of the study was to compare the physical and mechanical properties of the particle boards of *Dendrocalamus strictus* and *Bambusa polymorpha* by using 8% urea formaldehyde (UF) resin at different specific pressures i.e. 21, 17.5, 14 kg/cm^2 for the 15 minutes hot pressing and using the temperature of 110-120 ^{0}C. The results obtained in mechanical tests meet the Indian Standard specification IS: 3087 for medium density particle boards. The results also revealed that the particle boards of *B. polymorpha* showed the better results in comparison to the boards made from *D. strictus.* Among these three pressures the boards prepared with 21 kg/cm^2 pressure shown the best results for all the mechanical properties for both the species but the physical properties were not in the set criteria. However, physical properties can be improved by adding seizing material like paraffin wax. The results of mechanical properties indicate that the particles of bamboo are feasible raw material alternative for particleboards produced for non-structural purposes. It can also be observed that boards prepared with higher pressure (21kg/cm^2) shown the best result with compare to 17.5 and 14 kg/cm^2 respectively.

Keywords: *Dendrocalamus strictus*, *Bambusa polymorpha*, Particle board, Urea formaldehyde, Specific pressure.

Introduction
The activities of forestry based industries generate a significant volume of waste which can be reused or recycled. The recycling of waste from this sector presents a viable alternative to prevent the valuable raw material to have an inappropriate final disposal in landfills, which can cause negative environmental consequences. Agricultural residues, e.g. cereal straws, or dedicated annual fibre crops grown using intensive agricultural management practices, e.g. flax (*Linum usitatissimum* L.) and hemp (*Cannabis sativa* L.), the fast growing bamboo represent potential alternative sources of lingo-cellulosic raw materials which could supplement wood from natural and plantation forests. The mechanical properties of bamboo are directly related to the amount of moisture in the stems, age and density, but mostly by the amount of fibers that ensure its resistance. For the expansion of the raw material base, extensive studies have demonstrated the feasibility of various lignocelluloses material for producing particle boards (Ranjan *et al.* 2017, Metti *et al*., 2017) [11]. Bamboo waste for single-layer particleboard was evaluated by Vanchai (2010) [13] for its technical feasibility. Arruda *et al*., (2011) [3] evaluated the utilization of Brazilian giant bamboo. Sihag *et al.* (2016) [12] evaluated *Bambusa polymorpha* for particle boards using 10% PF at specific pressure 17.5 Kg/cm^2 meeting the relevant IS specification.
In this study *Dendrocalamus strictus* and *Bambusa polymorpha* was evaluated for suitability of particle board using 8% urea formaldehyde (UF) resin.

Materials AND methods
Materials
The raw material used as lingo-cellulosic materials are *Dendrocalamus strictus* and *Bambusa polymorpha* i.e. harvested from Forest Research Institute (latitude: 30^{0}19'N and longitude: 78^{0}04'E), Dehradun.
The raw material used as chemical was urea formaldehyde (UF) resin at 35% solid content, which acts as a binding material in the preparation of board.

Manufacture Process of Particleboard

The air dried bamboos culms were converted into small chips/particles by help of condux mill. The particles of *D. strictus* and *B. polymorpha* were screened through a 20 mesh screen to obtain uniform sized particles by removing the dust from the particles. The accepted particles were dried in an oven at temperature of 50-60^{0}C to achieve moisture content of particles to 6 to 8%. The particle board were made according to IS: 3087 (1985) by using following parameters:

Species: *D. strictus* and *B. polymorpha*

Binding agent: Urea formaldehyde resin (35% solid content).

Resin content: 8%

Specific Pressure: 14kg/cm^2, 17.5kg/cm^2 and 21kg/cm^2

Press condition: Hot press (110-120^{0}C)

Pressing Time: 15 min

Replicates: Six in each test

After hot-pressing, these particle boards were conditioned for 24 hrs at ambient room temperature and humidity prior to properties evaluation. The physical and mechanical properties of the particleboard such as thickness variation, density, moisture content, water absorption, thickness swelling, swelling due to surface absorption, modulus of rupture, Internal bonding (IB) and screw withdrawal strength were determined in accordance with IS: 2380 (Anon., 1977) and IS: 3087 (Anon. 1985).

Results and Discussion

The mean values of different physical and mechanical properties of particle boards prepared from *D. strictus* and *B. polymorpha* with 8% UF 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.

The moisture content of particle boards made from D. *stricus* and B. *polymorpha* varies from 5.2% to 6.3% and 5.70 to 6.30% respectively, it showed the trend of decreasing with increase in pressure. Density of particle boards from D. *stricus* and B. *polymorpha* varies from 0.72 to 0.79 g/cm^3 and 0.72 to 0.84 g/cm^3 respectively, it is noticed that density increased with increase in the applied pressure bonded with 8% UF resin. All the boards in respect of moisture content met the requirement of the IS specification. Similar type of result has been reported by Nimkar and Singh (2000) [9], Nimkar *et al*. (2003) [10] in the board prepared from *Bambusa polymorpha*. Bhaduri and Majumder (2008) [4] have revealed that moisture content of the board found within the limit of IS specification.

The water absorption of particle board after 2 hours varies from 53% to 55% and 58.95% to 67.75% after 24 hours for *D. stricus* while in case of, *B. polymorpha* the water absorption after 2 hours varies from 44% to 57% and i.e., 56% to 69% after 24 hours, the results indicating decrease in water absorption with increase in pressure.

Surface swelling of particle boards made from *D. stricus* and *B. polymorpha* varies from 13.6% to 16.4% and 9% to 21% respectively, it also showing the trend of decrease in swelling with increased applied pressure. General Swelling percentage of particle boards of *D. stricus* after 2hrs varies from 19% to 22% whereas, *B. polymorpha* shows 14.4% to 20%, the results shows the trend of decrease in absorption with increase in applied pressure.

Modulus of rupture (MOR) and Modulus of elasticity (MOE) of particle boards of *D. stricus* varies from 15 N/mm^2 to 12.68 N/mm^2 and 1438.81 N/mm^2 to 1810.32 N/mm^2 respectively. It is observed that the boards prepared from 17.5kg/cm^2 pressures showing good result then other two pressures in both MOR and MOE. Modulus of rupture and modulus of elasticity for *B. polymorpha* various from 25.6N/mm^2 to 15N/mm^2 and 2444 N/mm^2 to 2443.98 N/mm^2 respectively. Internal bonding strength of particle boards from *D. stricus* and *B. polymorpha* varies from 1.05 N/mm^2 to 0.47 N/mm^2 and 0.86 N/mm^2 to 1.34 N/mm^2. It can also observe that the MOR and MOE increases with increase in applied pressure for both the species. Maloney (1993) [8] reported that there are several factors that influence of MOE value such as resin type, resin content, adhesive bonding, and fiber length. Malanit *et al*. (2009) [7] reported that the high temperature and pressure caused of increasing resin bonding for resulting better strength.

It is observed that screw withdrawal strength for Face and Edge of particle board varies from 1561.72N to 1958.89N and 1296.94N to 1529.85N respectively for *D. strictus* and screw withdrawal strength for Face and Edge of particle board varies from 2336.5N to 2243.3N and 1775.01N to 1897.60N respectively for *B. polymorpha.* It increased with increase with pressure applied to the board. Present result are supported with the findings given by Nimkar and Singh (2000) [9], Nimkar *et al* (2003) [10], Bhaduri and Mojumder (2008) [4] Kshirsagar *et al* (2012) [5] and Sihag *et al.* (2016) [12].

From the above investigations, it is concluded that *D. strictus* and *B. polymorpha* is a suitable raw material for making particle board. The boards prepared with 8 per cent resin content and 21 kg/cm^3 specific pressure in both the species were meets the requirement of the IS: 3087 (1985) specification for medium density particle board. As per comparison the particle board made from *B. Polymorpha* showed better results as compare to *D. strictus.*

Table 1: The mean values of different physical and mechanical properties of particle boards made from *D. strictus* and *B. Polymorpha* with 8% UF resin content at different specific pressures.

Species	Pressure (kg/cm^2)	Moisture content (%)	Density (g/cm^3)	Water absorption (%)		Swelling due to surface Absorption (%)	General swelling (%)	MOR (N/mm^2)	MOE (N/mm^2)	IB (N/mm^2)	crew withdrawal (N)	
				2h	24h						Face	Edge
D. strictus	21	5.23	0.79	53	59	13.60	19	15	1695	1.05	1959	1530
	17.5	6.05	0.76	50	63	13.80	20	16.25	1810	0.76	1738	1336
	14	6.25	0.72	55	68	16.40	22	12.68	1439	0.47	1562	1297
B. polymorpha	21	5.70	0.84	44	56	9.00	14.40	25.60	2444	1.34	2336.5	1897.6
	17.5	6.30	0.81	48	61	16.00	19.00	15.20	2443.98	0.86	2243.3	1876.02
	14	6.25	0.72	57	69	21.00	20.00	15.00	2443.98	1.34	2289.87	1775.01
As per IS 3087		5-15	0.5-0.9	25	50	9.00	10	11.00	2000	.80	1250	850

Conclusion

In this study *D. strictus* and *B. polymorpha* were used for preparation of particle boards pressing at different specific pressures and prepared particle boards were tested to compare the physical and mechanical properties and it is observed that all particle boards using different ratios meet all mechanical properties as per Indian standard specification 3087. Particle boards of *B. polymorpha* showed the better results in comparison to the boards made from *D. strictus.* However, the physical properties like water absorption and swelling due to surface did not meet the IS requirements and these can be improved by using seizing material like paraffin wax.

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