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Utilization of *Bambusa bamboo* for the manufacture of cement bonded particle board

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Abstract

Bamboo is considered to be economically and industrially important plant species due to its multipurpose uses. The soluble sugar (leachable type) and tannin content is low in bamboo; therefore, the heat of hydration is less and it can easily bind with Portland cement. Present work was carried out to examine the compatibility of Bamboo particles bonding with Portland cement of varying composition. These cement bonded particle boards (CBPB) are suitable for various end uses because of their fire, termite and all-weather resistance abilities. Pozzolana Portland cement used as a sizing agent. The ratios of bamboo particlesand cement were taken on air-dry basis in proportion of 2:1, 2.5:1, and 3:1.2% of Sodium silicate (Na_2SiO_3) and 2% Aluminiumsulphate [$Al_2(So_4)_3$] were used to prevent heat of hydration and increase the rate of cement setting. 28Kg/cm^2 specific pressure was maintained in cold press for preparation of 1 0mm thick board. After pressing, the board was conditioned at room temperature for board setting. The physical and mechanical properties of cement bonded particle boards produced from *Bambusa bamboo* particles were evaluated. The density of the boards varies between 1.28 g/cm^3 to 1.36 g/cm^3 in 2:1 and 3:1 cement: particle ratios respectively. It was observed that the moisture content of the boards was 9.96 %, 6.98 % to 6.62 % 2:1, 2.5:1 and 3:1ratios cement bonded particle boards respectively. The physical properties of board such as Moisture Content, Water Absorption, Thickness Swelling were decreasing with increase in Cement: Bamboo particle ratios. The maximum MOR and MOE of 9.17 N/mm^2 and 4884 N/mm^2 respectively were obtained for 3.0:1.0 Cement: Bamboo particle ratio. The mechanical properties of the boards such as Density, Tensile Strength, Modulus of Rupture (MOR), Modulus of Elasticity (MOE), Screw Withdrawal were increasing with increase in Cement: Bamboo particle ratios. The 2.5:1 and 3:1Cement: Bamboo particle ratios performed better for cement bonded particle board and also passed the IS: 14276. These cement bonded particle board may be used for partitioning, wall cladding, flooring, false sealing, kitchen cabinet etc.

Keywords Bamboo; Portland Cement; Particle Board; Physical and Mechanical Properties

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1. Introduction

The high rate of deforestation, which has a serious impact on the environment and contributes to global warming, is thought to be largely due to the rising demand for timber use (Atoyebiet al. 2018; Sotannde et al. 2010). Additionally, this has resulted in unchecked tree-felling and over-exploitation in plantation and natural forests, rekindling interest in lesser-known timber species. Unfortunately, there is still a gap between demand and supply for wood products, which forces tree harvesting without replacement (Elias, and Boucher 2014). The future availability and supply of raw materials to these sectors would be challenged as a result of the rising demand. Wood based composite products refer to the engineered panels prepared from wood components and adhesive with the help of heat and pressure. These composite panel shave lot of variety, which opens world of endless possibilities and options, either to set out a design for a home, and an office or any other use. These materials are found better then original substrates due to large dimensions, homogeneity, durability, price or aesthetic values and good mechanical properties (Vidrine 2008). Wood-cement boards, fibre-cement boards, gypsum fibreboards, and gypsum particleboards are now manufactured in various parts of the world. Industries have an opportunity to use chief raw material, which is locally available for strong and durable building products. Now a day, customer is so concerned about environmental health and economy which demand a value-added product from the waste material. Many studies were done to achieve these objectives (Erakhrumen et al. 2008). These boards possess the advantage of inorganic and organic materials. Other desirable characteristics include fire resistance and durability in warm, humid climate where decay and termites are a major concern (Jorge et al. 2004).The concept of replacing glue bond by cement bond is another area of great interest owing to added dimensions of formaldehyde emission free, fire retardant, stiffness to structural housing material, carbon locking, and greater performance life and is expected to be a real composite product of future as demand is increasing of solid wood and panel products continuously. Bamboo is one of the most sustainable and versatile materials and it can be used for various purposes like construction, artefacts, flooring, home decor, etc. Therefore, an approach was done in the present study to use bamboo (*Bambusa bamboos*) as a raw material for cement bonded particle board, which is easily available in India. Compatibility of wood particles with cement is a big issue in line to develop cement bonded board of optimum strength. Hence, present work was also carried out to examine the compatibility of fast-growing Bamboo particles for bonding with cement

of varying composition. Their properties will also be tested in order to assess the suitability of formed boards for structural purposes.

2. Material and Methods

Bambusa bamboos species was procured from IPIRTI Campus, Bangalore, India. Bamboo was cut into small pieces, chipped out manually and dried to get better quality particles. These chips converted cutter type particle in condux mill. The Particles were sieved through 20 and 40 mesh screens to get uniform size of coarse and fine particles. The coarse and fine particles were separated in 2:1 ratio for board preparation. The quantity of water depends on the quantity of cement used for cement bonded particle board. The quantity of water added was calculated using a relationship developed by Simatupang (1979). The dried coarse and fine particles were soaked in water for 48 hrs before mixing with cement. This was mainly done to reduce soluble sugar content in wood particles and also to prevent heat of hydration after mixing cement (Mohamed et al. 2011). 2% Sodium silicate (Na2SiO3) and 2% Aluminium sulphate [Al2(So_4)3] was added by weight of cement to reduce heat of hydration and accelerate cement setting (Badejo, 1989). Pozzolana Portland Cement (Type IV) was used for board preparation. Three different proportion of cement/particles were used 2:1, 2.5:1 and 3:1 for board preparation. After mixing of coarse and fine particles with water, additives and cement, three layered mat formation was made. The fine particle mixture was on the top and bottom layer and the coarse particle mixture was on the middle layer. The moisture of the mat before cold press should not exceed more than 48%. After mat formation the entire iron frame was kept in cold press for boardpressing. The specific pressure was kept in cold press 28 kg/cm^2 for 6 hrs. The boards were then kept on room temperature for 7 days for conditioning. After 7 days, the boards were removed from cellophane sheet and kept under dryer to reduce moisture content up to 9%. After conditioning, the boards were trimmed and sized for testing. The number and size of the test samples from each prepared cement bonded particle board for various tests as per IS: 2380 (1998).

3. Result and discussion

In order to develop material for cement bonded particle board, *Bambusa bamboo* species was selected for this study. Cement and bamboo in three different ratios of 2:1 (CB1), 2.5:1(CB2) and 3:1 (CB3) was used. The boards of 10 mm thickness were pressed in all the three ratios at specific pressure of 28 kg/cm^2 (400 lbs/sq. inch) for 6 hours at room temperature. This Cement Bonded Bamboo Board (CBBB) was tested for physical properties such as density,

moisture content, water absorption. Table 1 presents mean observations of physical properties of CBBB and its comparison with IS: 14276 (2009).

Mean density of CBBB's CB1, CB2 and CB3 were found to be 1.28, 1.33 and 1.36 g/cm^3 respectively. It was noted that density of the board significantly increased with increasing cement particle ratio in boards. Although it is fulfilling the criteria of desired density as per IS: 14276 (2009) at all ratios and results are supported by previous studies (Zhou and Kamdem, 2002). It is because of high weight of cement particles as compared with bamboo particle or high density of cement than wood. Therefore, the high ratio of cement in boards increased the aggregate air-dry density. The mean moisture content of 9.96, 6.98 and 6.62 % was recorded in CBBB for CB1, CB2 and CB3 respectively. Similarly, water absorption for CB2 and CB3 were found to be 13.46 and 12.15% respectively after 2 hrs and 25.28 and 18.05 % respectively after 24 hrs soaking in water. CB3 does not satisfy the criteria as per IS: 14276 (2009).

It was observed that moisture content and water absorption after 2hr and 24hrs decreased with increasing amount of cement in wood particle. Results are in conformity with the finding reported by Savastano et al. (2000) and Eusebio et al. (1998). It is well known that wood is hygroscopic in nature, so high content of wood particle in CBBB tends to absorb more water as compared to cement particles (Wei et al. 2003). Cement particles also provide coating to wood particles, which prevents them from absorbing water. Therefore, from the results it can be concluded that higher quantity of cement particle in CBBB will help to prevent moisture/water absorption in boards.

Table 1: Physical properties of CBBB

Cement: Particle Ratios		Density (g/cm^3)	Moisture Content (%)	Water Absorption 2hr (%)	Water Absorption 24hrs (%)
2:1 (CB1)	**AVG**	**1.28**	**9.96**	**13.46**	**25.28**
	SD	*0.02*	*0.16*	*0.63*	*0.64*
	CV	1.61	1.58	4.69	2.52
2.5:1(CB2)	**AVG**	**1.33**	**6.98**	**12.77**	**18.91**
	SD	*0.01*	*0.63*	*0.36*	*0.75*
	CV	1.11	9.02	2.84	3.95
3:1(CB3)	**AVG**	**1.36**	**6.62**	**12.15**	**18.05**
	SD	*0.01*	*0.31*	*0.56*	*0.62*
	CV	0.96	4.73	4.6	3.43
IS: 14276 (2009)		**1.25 (Min)**	**6- 12**	**13 (Max)**	**25 (Max)**

The mechanical properties of the boards such as modulus of rupture (MOR), modulus of elasticity (MOE) both dry and wet condition, screw withdrawal (Face) and internal bonding (tensile strength) were determined and presented in Table 2.Mean MOR of CB1, CB2 and CB3 exhibited 5.40, 9.01 and 9.17 N/mm^2 dry and 4.86, 7.49 and 7.64 N/mm^2 respectively (Table 2) in dry and wet conditions. Mean MOE of 3204, 4805 and 4884 N/mm^2 respectively was recorded CB1, CB2 and CB3. It was observed that MOE and MOR of the boards significantly increased with increasing cement ratio in CBBB. Lee (1984) also reported that the mechanical strength of cement wood particle board is directly proportional to the cement/wood ratio.

Mean screw withdrawal in face of board was 1331, 1451 and 1460 N respectively all three ratios of 2:1, 2.5:1 and 3:1. It shows that alignment of particles in board is important in case of screw withdrawal strength, since it is hard to withdraw screw across the grain than along the grain. However, board manufactured at all the three ratios meets screw withdrawal strength face as per IS: 14276 (2009). It indicates that high mechanical strength is obtained at high cement/wood particles ratio in board, which is significantly different from the lower ratios. Similar results were reported by Alhedy et al. (2006), where all the strength values increased as cement/bamboo ratio increased. In previous studies Zhou and Kamdem (2002), Manish et al. (2017) reported that board with higher cement wood ratio is difficult to nail. Mean Internal bonding of CBBB was determined 0.35, 0.41 and 0.43 N/mm^2 at different cement/wood ratios i.e. 2:1, 2.5:1 and 3:1 respectively. It was observed that cement particles in board developed strong internal bonding and further improved the tensile strength of board.

Papadopoulos (2008) stated that all mechanical properties increased with increasing cement wood ratios up to a certain limit. The other reasons for improved mechanical properties may be chemical present in wood. Meneeis et al. (2007) reported that internal bonding is associated with lower water absorption which is responsible for higher MOR or compressive strength. In another study reported by Chen et al. (1998), it is observed that when the soluble sugar and tannin content is more in wood, it can directly affect the mechanical properties of the wood. Abdelgadir and Ibrahim (2003) stated that compressive strength of wood cement mixture increased as cement wood ratios increased.

Table 2: Mechanical properties of CBBB

Cement: Particle Ratios		MOR_Dry (N/mm^2)	MOR_Wet (N/mm^2)	MOE_Dry (N/mm^2)	MOE_Wet (N/mm^2)	SW Face (N)	IB (N/mm^2)
2:1(CB1)	**AVG**	**5.4**	**4.86**	**3204**	**3069**	**1331**	**0.35**
	SD	*0.6*	*0.68*	*392.57*	*395.03*	*55.25*	*0.05*
	CV	11.1	14.03	12.25	12.87	4.15	14.39
2.5:1(CB2)	**AVG**	**9.01**	**7.49**	**4805**	**4642**	**1451**	**0.41**
	SD	*0.31*	*0.89*	*466.9*	*502.05*	*59.39*	*0.02*
	CV	3.42	11.94	9.72	10.82	4.09	5.85
3:1(CB3)	**AVG**	**9.17**	**7.64**	**4884**	**4721**	**1460**	**0.43**
	SD	*0.19*	*1.01*	*519.2*	*488.63*	*40.27*	*0.03*
	CV	2.1	13.25	10.63	10.35	2.76	6.12
IS: 14276 (2009)		**09 (min)**	**5.5 (min)**	**3000 (min)**	**2200 (min)**	**1250 (min)**	**0.40 (min)**

Conclusion

Cement Bonded Bamboo Board prepared with *Bambusa bamboo* species in three different cement particle ratios of 2:1, 2.5:1 and 3:1. Density of the boards increases with increasing cement proportion. Moisture content of bamboo cement board was recorded highest at 2:1 ratio. Apart from this, the moisture content of board decreased with increasing cement particle ratios. The minimum water absorption of cement bamboo bonded board was recorded in 3:1 cement particle ratio. In case of mechanical properties Modulus of Rupture, Modulus of Elasticity (both dry and wet), Internal Bonding and Screw Withdrawals strength increases with increase in cement ratio in the board. All these physical and mechanical properties of cement bonded bamboo boards 2.5:1 and 3:1 cement particle ratio board fulfil the requirement of IS 14276 (2009) but no significance difference was observed in between two cement particle ratios.

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Conflict of Interest

The authors declare there is no conflict of interest.

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