Cement Bonded Boards from *Bambusa vulgaris*

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Abstract

Bambusa vulgaris culms sampled from the riverside of Bentong, Pahang, Malaysia were found to be suitable in the manufacture of cement bonded boards. The relatively high sugar content of the culms, however, was found to give a retarding effect on cement setting. In this study, cement ratio (1:3) was found to give better board properties. Board with a bamboo - cement ratio of 1 : 2.75 with the addition of 2% chemical additives produces an acceptable board which meet the requirements of the Malaysia Standard MS 934.

সারসংক্ষেপ

মালয়েশিয়ার পাহাং এলাকার বেন্‌টং নদী তীরবর্তী এলাকা থেকে আহরিত *Bambusa vulgaris* প্রজাতির বাঁশ সিমেন্ট বণ্ডেড বোর্ড প্রস্তুতে উপযুক্ত বলে প্রতীয়মান হয়। বাঁশের কাণ্ডের তুলনামূলক বেশি চিনির উপাদান অবশ্য সিমেন্ট জমা হওয়ার উপর কিছুটা প্রতিবন্ধকতার সৃষ্টি করে। আলোচ্য পরীক্ষণে দেখা যায় যে, সিমেন্টের পরিমাণ বেশি হলে বোর্ডের গুণগত মান বৃদ্ধি পায়। ১ : ২.৭৫ অনুপাতে বাঁশ ও সিমেন্টের সাথে শতকরা দুই ভাগ রাসায়নিক পদার্থ সংযোজনে মালয়েশিয়া ষ্ট্যাণ্ডার্ড এম এস ৯৩৪ মানের বোর্ড প্রস্তুত সম্ভব।

Key words : *Bambusa vulgaris*, bamboo, bamboo-cement board, sugars

Introduction

The uses of bamboo are unlimited, but proper utilization of this resource would be greatly beneficial especially to the rural community. Malaysia has a long tradition in the use of bamboo. The degree of bamboo utilization within the country, however, is yet to reach the level of sophistication like other agricultural products. In the industrial sector, it may be used as a supplement for timber in the near future. This paper highlights the possibility of using bamboo as a raw material for the building industry in the form of bamboo-cement bonded boards.

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Materials and methods

Bamboo sample

About 300 kg of *Bambusa vulgaris* was taken from Bentong in Pahang, Malaysia. The stem of about 2 m in length was chipped with a Taihei chipper at the Forest Research Institute Malaysia (FRIM) laboratory. The chips which passed through a 2 x 2 cm screen were taken for flaking before further screened to various particle sizes. The bamboo flakes retained at 0.5 mm screen were used as fine materials while those at 1.0 mm screen were utilized as core materials for manufacturing cement-bonded particleboard.

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Particle size analysis

Bamboo particles in flakes form were randomly taken for particle size analysis. The particle size distribution of the flakes was determined by using the lab-siever with the screen size of 0.25 to 3.35 mm. The average thickness and length of the flakes were determined based on at least 100 specimens.

Sugar content analysis

Sugar content analysis was carried on random sampling of the bamboo flakes. The flakes were grounded with Fritz-Pulverizer to about 200 mesh size; and 12 determinations were carried out. About 400 mg of fresh bamboo samples (200 mesh) were soaked in about 40 ml MeOH : H_2O (75 : 25) overnight with regular shaking. After 24 hours, the volume was made to 50 ml and filtered with a crucible glass no. 3. About 25 ml of the filtrate was evaporated to dryness before being dissolved with 3 ml distilled water. The aqueous solution was then filtered by 0.45μ prep-disc membrane filter into a sampling bottle before being injected into HPLC system (Model HP 1048 B). The sugars were detected by RI detector with Aminex HPX-87 P column and doubled distilled water as the mobilizer.

Board making

Several series of 3-layered bamboo cement boards (BCB) were made based on the variation of bamboo to cement ratios and with the inclusion of various types of chemical additives. Five pieces of boards were produced for each series. The size of the boards was 45 cm x 45 cm and 10 mm thick. The target density of the board was 1250 kg/m^3. The bamboo-cement admixtures were mat formed on a caul plate by using a wooden mould. Every mat was stacked on top of the other, pressed up to the required thickness and clamped for overnight in a hardening chamber set at a temperature of 60-65°C. After 24 hours, the pressure was released and the boards were allowed for further curing process at room temperature. The boards were then subjected for testing after 28 days of curing.

Board testing

The boards were tested for bending strength (BS), tensile strength (IB), water absorption (WA) and thickness swelling (TS) thus made according to the Malaysian Standard Specification for Wood Cement Boards MS 934 (Anon. 1986).

Results and discussion

Particle size analysis

The particle size distribution of the flakes is given in Table 1. Most of the particles belong to the particles retained at the screen size of 0.5 to 2.0mm.

The amount of bigger particles that retained at 3.35 mm sieve size was fed once again into the flaker to produce smaller particles suitable for BCB manufacture. The average thickness and length of the flakes are found to be within the range of 0.39 to 0.61 mm and 14.0 to 17.1 mm respectively.

Sugar content analysis

Sugar content of the freshly felled bamboos showed that glucose, fructose and sucrose were the main sugar components in this species (Table 2). Glucose and fructose are basically the major components compared to sucrose. The average total sugars in this bamboo species is about 2 - 4 times higher than rubber wood (Azizol and Rahim 1989) and half of those reported in oil palm trunk (Halimahton and Abd. Rashih 1990). The amount of sugars (4.92%) in *B. vulgaris* is higher than the allowable amount of sugars (less than 0.5% based on dry weight of wood) in wood aggregate (Bever 1986, Arturo 1989, Schwarz 1989).

The hydration test carried out by incorporating the particles of *B. vulgaris* into the cement matrix confirmed that this admixture had delayed the hydration time and reduced the hydration temperature of Portland cement. The hydration properties of bamboo-cement mixtures improved to almost neat cement when the extracted bamboo particles were added into the cement matrix. The utilization of water extract mixed with cement was also observed to prolong the hydration time of the ordinary Portland cement to about 10 hours compared to about 8 hours with neat cement. This study confirmed that water extracts from *B. vulgaris* had set-retarding effect on cement setting.

Physical and mechanical properties

The bending strength (BS), internal bond (IB), water absorption and thickness swelling (TS) of cement boards manufactured from *B. vulgaris* are given in Table 3. The data was analyzed by SAS for ANOVA and Duncan Multiple Range T-test for the effect of bamboo : cement ratio and chemical additives on the board properties.

Table 1 : Particles size distribution of *Bambusa vulgaris*

Sieve size (mm)	Percent by weight (%)
< 0.25	2.06
0.25	5.19
0.50	15.89
1.00	16.90
1.40	20.42
2.00	20.88
2.80	5.87
3.35	12.78

Note : Analysis are based on three determinations

Table 2 : Sugar content analysis of *Bambusa vulgaris* (% dry wt.)

Analysis	Fructose	Glucose	Sucrose	Total sugars
Min.	1.95	2.24	0.42	4.73
Max	2.23	2.41	0.55	5.13
Mean	2.07	2.35	0.50	4.92
SD	0.07	0.05	0.03	0.11

Effect of bamboo : cement ratio

Variation in board properties among the bamboo : cement ratio is given in Table 4. The ratio of 1 : 3 indicated the highest board properties for BS (5.04 MPa), IB (0.23 MPa) and lowest WA (20.40%). However, according to Moslemi and Harmel (1988), too high of the cement ratio might cause cement-bonded particleboard to be brittle and increases the cost of materials unnecessarily. Depending on the species, density and retardation effect within woody materials, the common wood : cement ratio suggested to be used by the mill is within the range of 1: 2.2 to 1: 2. 75. (Bison and Greten 1977)

Effect of chemical additives

All board properties showed a remarkable improvement when 2% chemical additives were added into the bamboo-cement ratio (1 : 2.75) as shown in Table 5. In BCB manufacture, chemical additives (so called mineralizing fluid) is normally added in small quantities to counter the poisoning effect on cement; and also to boost the grown in polythene bags of various sizes. Both organic and chemical fertilizers are commonly used to raise good quality seedlings. However, information related to growth response of *A. mangium* seedlings to fertilizer is lacking in Bangladesh. The present study reveals the effect

Table 3 : **Bending strength (BS), internal bond (IB), water absorption (WA) and thickness swelling of cement boards from *Bambusa vulgaris*.**

Bamboo Cement ratio	Chemical additives	BS (MPa)	IB (MPa)	WA (%)	TS (%)
1 : 2.50	-	2.43	0.07	29.00	2.15
1 : 2.75	-	3.87	0.12	26.10	1.17
1 : 3.00	-	5.04	0.23	20.40	1.26
1 : 2.75	$CaCl_2$	5.48	0.19	24.64	2.26
1 : 2.75	$MgCl_2$	6.93	0.43	15.97	1.11
1 : 2.75	$Al_2(SO_4)_3$	9.25	0.63	14.40	0.76
1 : 2.75	$Al_2(SO_4)_3 + Na_2SiO_3$	9.41	0.77	12.57	0.82
MS 934	-	9.00	0.50	–	< 2.00

Table 4: Duncan's Multiple Range T-test on the effect of bamboo-cement ratio for bending strength (BS), internal bond (IB), water absorption (WA) and thickness swelling (TS).

Bamboo : Cement ratio	BS (MPa)	IB MPa)	WA (%)	TS (%)
1 : 2.50	2.44c	0.07c	28.99a	2.15a
1 : 2.75	3.87b	0.12b	26.10b	1.17a
1 : 3.00	5.04a	0.23a	20.40c	1.26a
MS 934	9.00	0.50	-	< 2.00

Means are averages of 18 replicates

of the water absorption and thickness swelling of all the boards were found to be higher than those manufactured by the mill. Ahmad Shakri and Rahim (1989) reported that the water absorption and thickness swelling in the bamboo-cement particleboard is probably due to the loose binding between cement and bamboo particles and thus caused a series of gap within the board.

Effect of chemical additives

All board properties showed a remarkable improvement when 2% chemical additives were added into the bamboo-cement ratio (1 : 2.75) as shown in Table 5. In BCB manufacture, chemical additives (so called mineralizing fluid) is normally added in small quantities to counter the poisoning effect on cement; and also to boost the hydration process of cement (Chittenden *et al.* 1975). From the analysis it appears that the addition of chemical ($Al_2(SO_4)_3$), magnesium chloride ($MgCl_2$) and additives during board making shows some differences. Among aluminum sulphate calcium chloride ($CaCl_2$); aluminum sulphate is the best mineralizing agent and make the board such to meet the minimum requirements of the Malaysian Standard MS 934. Addition of 2% aluminum sulphate and sodium silicate (Na_2SiO_3), a formulation practiced in the mills for BCB manufacture showed better results. The bending strength, internal bond and thickness swelling the board are 9.41 MPa, 0.77 MPa and 0.82% respectively, surpassing the minimum requirements of MS 934.

Table 5 : Duncans Multiple Range T-test on the effect of chemical additive on bending strength (BS), internal bond (IB), water absorption (WA) and thickness selling (TS).

Chemical additive	BS (MPa)	IB (MPa)	WA (%)	TS (%)
$Al_2(SO_4)_3 + Na_2SiO_3$	9.405a	0.766a	12.57d	0.82c
$Al_2(SO_4)_3$	9.254a	0.625b	13.43d	0.76c
$MgCl_2$	6.990b	0.433c	15.95c	1.11b
$CaCl_2$	5.477c	0.194d	23.69b	2.26a
No chemical	3.910d	0.120e	25.44e	1.05bc
MS 934	9.00	0.50		<2.00

- Means having the same letter down the column differ insignificantly at $p < 0.05$.
- Means are average of 16 replicates

Conclusion

From this study the following conclusion could be made:

a. *Bambusa vulgaris* culm possessed a high amount of sugars (4.92%), which showed a retarding effect on cement setting,

b. Higher cement ratio gives better board properties,

c. Bamboo-cement ratio of 1 : 2. 75 with an addition of 2% $Al_2(SO_4)_3$ alone or in combination with Na_2SiO_3 produced an acceptable board which meets the requirement of the Malaysian Standard MS 934.

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