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Mechanical Properties of Bamboo Fibre Composite Incorporating Pulverized Fuel Ash

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Abstract. This study reports the findings of an experimental investigation for bamboo fibre (BF) reinforced concrete board. In this research, all specimens were prepared at 0.4 water/binder ratio. There were two series of specimens namely A series and B series. The A group utilizes only ordinary portland cement (OPC) as binder. Meanwhile, series B specimens uses binary binders, which were combination of OPC and pulverized fuel ash (PFA) with PFA to OPC ratio of 0.2. The performance of flat board plates with different percentage of bamboo fiber ranging from 0% to 5% and 20% PFA incorporation of cement weight were tested for bending strength (flexural) and compressive strength in accordance to BS 5669: Part 1 for particleboards. Specimens are cured in water curing tank and tested at 3, 7 and 28 days for compression test. Meanwhile for flexural strength test, the specimens are tested at 28 days. It is found that flexural and compressive strength increases with addition of BF. The optimum compressive and flexural strength at 28 days are recorded with 3% incorporation of BF for both PFA and control samples. Therefore, utilizing natural fibre and waste material for partial substitution of cement content in producing internal wall paneling system could contributes to the economic appeal and promoting sustainable construction approach.

Introduction

In current construction activity, most of the existing internal wall partition system for residential building is made of clay bricks and cement sand bricks. This conventional wall system partition is readily available and cheap to construct with recognized disadvantages of heavy loading, low productivity, high wastage and requiring skill labor to install. In order to overcome this issue, panelized wall system has been introduced into the market. This system is widely used in most of advanced countries namely Hong Kong, Singapore, Korea and Japan. In these countries, utilizing of these types of pre-cast housing material is highly recommended by their respective construction authority. The main reasons for the popularity of these dry wall systems are higher productivity, site cleanliness, and improve wall finishes strength. [1].

Bamboo, known as natural vegetation, able to grow in various soils, fast growing, abundance and has desirable properties. The optimum age of bamboo to harvest for structural application used is between 2.5 and 4 years. The strength decreases at later age [2]. Incorporation of bamboo has been investigated by Ghavami (1999). It is recorded that the ultimate load of a concrete beam reinforced with bamboo increased 400% as compared to un-reinforced concrete [3].

Annually, million tons of the by-products produced in order to satisfy the demand for industrial and as domestic energy. Generally, pulverized fuel ash (PFA) is used mainly as additive or filling material in concrete mix. However, the usage of the material only about 20-30% of the total generated fly ash. The remaining of the unused material is disposed via landfilling technique [4]. Without a proper disposal of the by-product, it will lead to environmental pollution. One of the efforts to be more environmental friendly is to reduce the use of OPC by partially replacing the amount of cement in concrete with by-products materials such as fly ash. Hence, introduction of supplementary cemetitious materials (SCM) namely PFA in concrete reduces the problem caused by improper disposal of PFA and contribute towards cement usage reduction in construction industry.

Methodology

Material. The material selection in this research was based on specific requirement. Ordinary Portland Cement (OPC) type 1 with conformance to BS EN 197-1 2000 was obtained from Duracem Coating Industries Sdn. Bhd. Table 1 describes the typical chemical compound in OPC Type 1.

Table 1. Typical chemical composition of OPC Type 1.

Compound	SiO_2	Al_2O_3	Fe_2O_3	MgO	SO_3	CaO	Total Alkalis	Insoluble Residue
Compositions (%)	19.98	5.17	3.27	0.79	2.38	63.17	0.90	0.20

Fine aggregate used in the testing program was bought from the local supplier in Gombak. The fine aggregate is classified in zone 3, passing 5mm sieve size as per BS 812-103.2 1989 [5]. Bamboo fibre used in this research was known as *gigantochloa scortechinii* and supplied by Research Center of University of Putra Malaysia, Serdang. Meanwhile, pulverized fuel ash (PFA) in this research was taken from Kapar Energy Venture, Stesen Janakuasa Sultan Salahuddin Abdul Aziz, Kapar, Selangor. The PFA used is in accordance to ASTM Class F. Chemical compositions are described for OPC Type 1, bamboo fibre and PFA in Table 2 and Table 3 respectively.

Table 2. Pulverized Fuel Ash (PFA) compositions analysis.

Compound	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	Na_2O	K_2O	CaO	LOI[a]
Compositions (%)	55.07	25.03	3.86	1.32	0.41	1.01	5.26	3.80

.a.LOI – Loss of Ignition

Table 3. Bamboo fibre compositions analysis.

Compound	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	Na_2O	K_2O	CaO	LOI[a]
Compositions (%)	-	0.106	0.001	0.0027	0.0017	0.777	0.032	98.4

.a.LOI – Loss of Ignition

Mixture Proportion. The specimens were prepared as per BS 5669: Part 1 for particleboards [6]. The size of specimen prepared for bending test was 500 mm x 100 mm x 20 mm. Meanwhile, for compression test, the specimens' size done was 180 mm x 45 mm x 45 mm. Specimens are cured in water curing tank and tested at 3, 7 and 28 days.

The target density of bamboo fibre reinforced concrete board was 1250kg/m^3 which in accordance to the findings of Sudin and Swamy (2006) [7]. In preparing bamboo fibre reinforced cement board samples, 0%, 1%, 3% and 5% bamboo fibre incorporations were adopted. Water to binder ratio adopted in this study was 0.4, in which 40% water and 60% binders (OPC and PFA). Replacement of PFA to OPC content is 0.2 by weight (20% PFA and 80% cement). Table 4 summarizes the mixture proportions of bamboo fibre reinforced cement board.

Table 4. Mixture proportion of bamboo fibre reinforced cement board.

Sample Code	Bamboo Fibre		Water to binder ratio: 0.4	PFA to OPC ratio: 0.2		Sand (kg/m^3)	Target Density (kg/m^3)
	%	*kg/m^3*	*Water Content (kg/m^3)*	*PFA (kg/m^3)*	*OPC (kg/m^3)*		
A0	0	0	200	-	500	550	1250
A1	1	5	200	-	500	545	1250
A3	3	15	200	-	500	535	1250
A5	5	25	200	-	500	525	1250
B0	0	0	200	100	400	550	1250
B1	1	5	200	100	400	545	1250
B3	3	15	200	100	400	535	1250
B5	5	25	200	100	400	525	1250

Experimental Procedures. Concrete mixing procedure for bamboo fibre reinforced cement board need to be done carefully to ensure the fibres to distribute uniformly in the mix. The procedures flow of mixing, casting and curing done are illustrated in Figure 1.

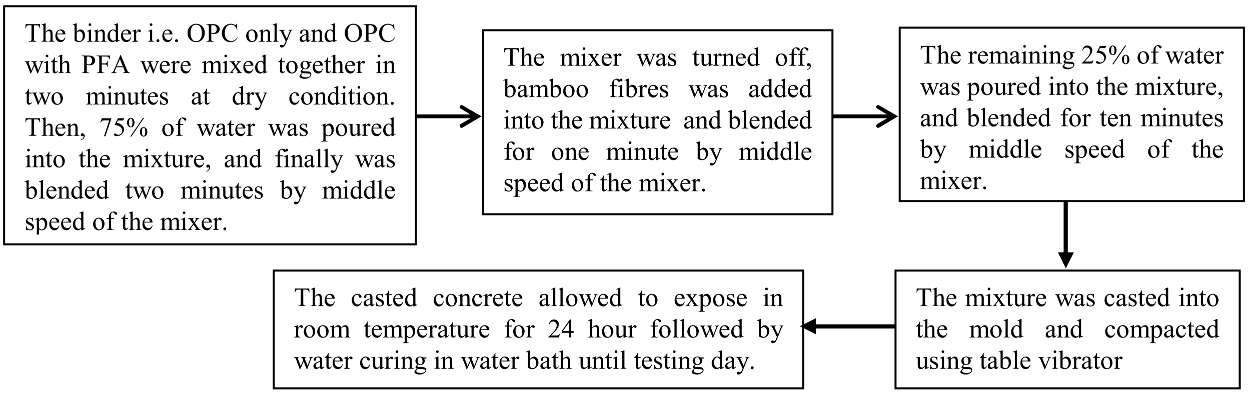

Fig. 1. Process flow chart of samples preparation.

Results and Discussion

Compression Test. The results of the compressive strength, performed in accordance to the procedure specified in BS 1881: Part 119: 1983 are presented in Fig. 2(a) and Fig. 2(b). According to the results, the same trend of strength development was recorded, where the strength increases as curing period extended. The highest compressive strength values at 28 days were recorded as 42.17 MPa and 31.19 MPa respectively with incorporation of 3% bamboo fibre. It was noted that the compression value dropped at 5% fibre content for both specimens prepared using OPC only and OPC with substitution of 20% PFA. This condition occurred due to the excessive volume of fibre in the concrete matrix. The compressive strength of the bamboo cement composite increased up to 3% fiber content due to the reduction of porosity in the mortar. The strength however, started to decrease abruptly at 5% fiber content. This happened because of attribution of void introduction in the mortar due to overload fiber content that may lead to reduce bonding and disintegration [8].

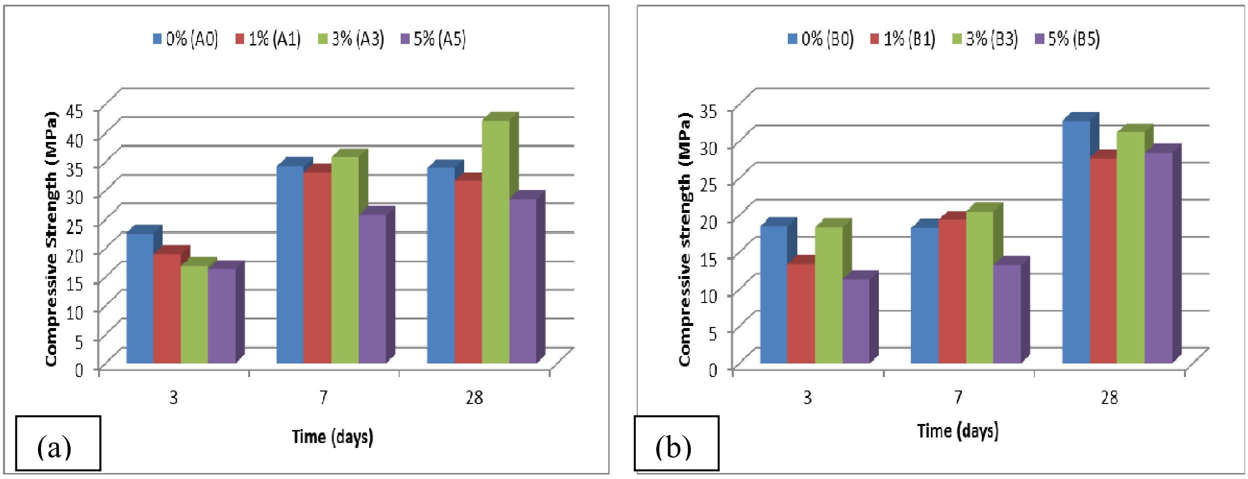

Fig. 2. Compressive strength versus curing period for specimens contain (a) OPC only and (b) OPC with incorporation of 20% PFA as SCM.

Flexural Strength Test. The flexural strength test was done in line with BS 1881: Part 118: 1983. All the specimens were tested at 28 days. The results are illustrated in Fig.3. In any fibre reinforced structure, it is expected that, introduction of fibre into the concrete matrix is able to sustain load and bridge crack effectively. Based on Fig.3, it can be seen that the flexural strength of bamboo fibre reinforced concrete increased with the increased of fibre content at 3% and dropped drastically at 5% of bamboo fibre incorporation. The trend of flexural strength was equal to the compressive strength analysis. This phenomenon occurred due to its higher volume fraction of fibre in the matrix [9]. Therefore, it caused congestion of fibre and eventually the binder paste was unable to penetrate through the bamboo fibre matrix evenly.

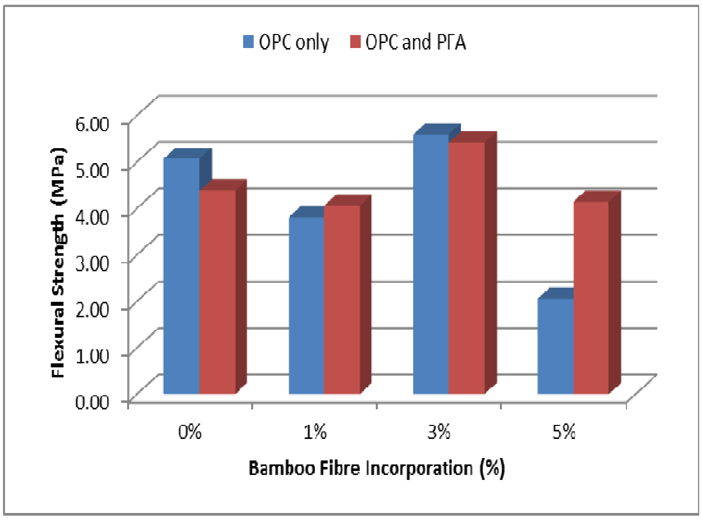

Fig. 3. Flexural strength of bamboo fibre reinforced cement based at various bamboo fibre percentage content.

Conclusion

A method for producing bamboo fibre reinforced cement board composite was optimized. The mechanical tests namely compression test and flexural strength test has been reported in this paper. It is found that the optimum percentage of bamboo fibre incorporated with respect to binder density is found to be 3%.

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