Economic Comparison: Bamboocrete Multi-Purpose Panel and Typical Reinforced Concrete Panel

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Economic Comparison: Bamboocrete Multi-Purpose Panel and Typical Reinforced Concrete Panel

(Perbandingan Ekonomi: Panel Serba Guna Bamboocrete dan Panel Konkrit Bertetulang)

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ABSTRACT

This study investigated the economic comparison between bamboo reinforced concrete called Bamboocrete with the conventional reinforced concrete panel. Materials contribute significantly to the construction cost. Bamboo can be an alternative to replace steel bars in typical reinforced concrete as it is low in cost and sustainable material. To optimize the benefit, this study used whole solid bamboo as the reinforcement as well as to reduce amount of concrete in the panel, thus reducing the panel weight. Furthermore, the concrete used is lightweight concrete by partially replaced coarse aggregate with Palm Kernel Shell (PKS). The Bamboocrete panel at 1 500 mm height, 300 mm width, and 125 mm thick can sustain axial load of more than 100 KN (10 ton), and flexural bending load between 32.51 to 35.20 kN. Bamboocrete panel contribute towards economical building structures when it is 14% cheaper than steel reinforced concrete. Furthermore, bamboocrete panel is 23% lighter.

Keywords: Affordable panel; bamboo structure; concrete panel; bamboocrete

ABSTRAK

Kajian ini menyelidik tentang perbandingan ekonomi antara konkrit bertulang buluh yang disebut sebagai Bamboocrete dengan panel konkrit bertetulang konvensional. Sumbangan terbesar kepada kos pembinaan adalah bahan pembinaan. Buluh boleh menjadi alternatif untuk menggantikan besi di dalam konkrit bertetulang kerana kosnya murah dan berkelestarian. Untuk mengoptimumkan manfaatnya, kajian ini menggunakan keseluruhan buluh sebagai pengukuhan dan juga untuk mengurangkan jumlah konkrit pada sesebuah panel, sekaligus mengurangkan berat panel. Selanjutnya, konkrit yang digunakan adalah konkrit ringan dengan menggantikan sebahagian agregat kasar kepada tempurung kelapa sawit atau dikenali sebagai Palm Kernel Shell (PKS). Panel Bamboocrete pada ketinggian 1500 mm, lebar 300 mm, dan tebal 125 mm dapat menahan beban aksial lebih dari 100kN (10 ton), dan beban lenturan lenturan antara 32.51 hingga 35.20 kN. Panel Bamboocrete menyumbang kepada struktur bangunan yang ekonomik apabila ia 14% lebih murah daripada konkrit bertetulang keluli. Selanjutnya, panel bamboocrete lebih ringan sebanyak 23%.

Kata kunci: Panel mampu milik; struktur buluh; panel konkrit; bamboocrete

INTRODUCTION

The needs for low cost construction materials is rising for more dwelling to be constructed to fulfill high demand for low-cost houses. Inadequate supply of low-cost houses is due to the rapid rise in construction materials and construction cost. Materials contribute to the critical elements in building construction cost. 50% or up to 60% from the total construction cost is required for materials in a typical construction project. Construction materials are considered as the main cost factor in housing construction (Sardroud 2012).

For concrete structure, it is often reinforced with steel bars. These steel bars provide tensile strength to the concrete structure due to concrete weakness in tension carrying capacity. But, using steel as the reinforcing materials have various disadvantages such as high in cost, non-renewability, and may contribute to greenhouse gas emission in steel production and fabrication. Therefore, there are needs for other reinforcement alternative such as using vegetable fibers materials, i.e., bamboo as the reinforcing material in concrete (Agarwal et al. 2014). Bamboo can contribute towards the sustainable construction as it reduces the usage of steel and concrete (Daud 2018).

Bamboo is superior to timber and steel in construction structures in terms of bamboo's weight to strength ratio. With the characteristics of bamboo that is rapid growing, affordable and easily available natural resources, bamboo gained attention to replace the usage of steel as the reinforcing material (Javadian et al. 2016; Pawar 2014). Bamboos have good earthquake-resistant characteristics and may reduce the total construction cost about 40% (Parikh et al. 2016).

To act as a construction material, bamboo has a very strong fibre. The compressive strength of bamboo is two times higher than concrete. Furthermore, its tensile strength is comparable to steel and the shear stress was higher than wood. Bamboo can be curved and bend easily without breaking the structure, which these characteristics are suitable for organic shaped building structures (Nurdiah 2016). Bamboos can turn into its original form after the removal of load when it is tested for flexural bending test (Daud et al. 2018).

The tensile properties of bamboo is suitable to be used for steel substitution as the reinforcing material in concrete structure. They found that the average tensile strength of bamboo is 250 N/mm². Bamboo is the fastest growing plant which is able to grow 60 cm or more in a day. Matured bamboo is required for the construction purpose and bamboo can be matured after three years of its plantation (Dev & Chetia 2018).

To further enhance green technology in the construction industries, use of agricultural waste should be considered. High demand for aggregate to produce concrete will lead to environmental issues due to vigorous demolition of natural stone deposits. As a solution, Oil Palm Shell (OPS) or Palm Kernel Shell (PKS), is used as aggregates to produce structural lightweight concrete (Huda et al. 2016). The usage of Palm Kernel Shell (PKS) in concrete reduced the density of concrete and maintain reasonable strength (Aslam et al. 2017).

Bamboocrete multi-purpose panel looked as the alternative in producing the affordable and sustainable construction material using bamboo reinforced PKS lightweight concrete. This paper aims to do economic comparison of bamboocrete multi-purpose panel and the steel reinforced concrete panel.

MATERIALS

The most abundant bamboo in Peninsular Malaysia and globally is named as Gigantochloa Scortechinii, locals call them as Semantan Bamboo were used in this study (Hamdan et al. 2009). Matured bamboo with the age of 3 to 4 years with the diameter size of 53 mm ± 10 mm were collected and treated by soaking in borax and boric acid for two weeks before it was dried under shed for four weeks. For concrete mix, the aggregates were partially replaced by PKS to obtain lightweight and affordable panel. 1500 mm × 300 mm × 125 mm size of PKS lightweight concrete panel was casted in the wooden formwork mould. Whole solid bamboos act as the reinforcement in the PKS lightweight concrete as shown in Figure 1.

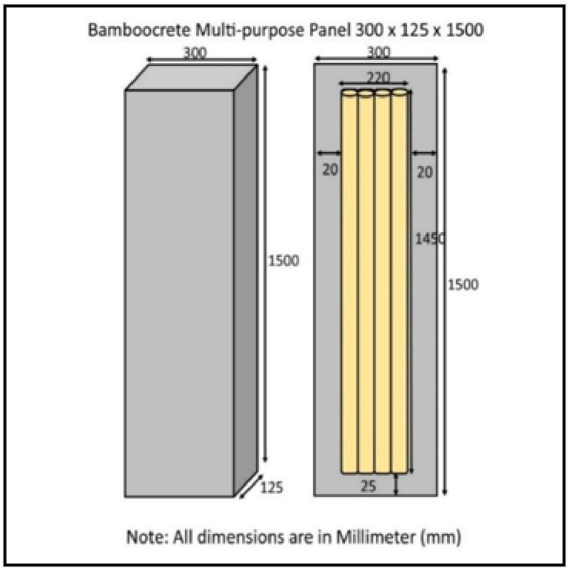

FIGURE 1. Bamboo reinforcement in PKS lightweight concrete

PREPARATION OF SAMPLE

Four pieces of bamboos were tied and wrapped with the wire mesh to ensure the proper bonding with concrete. The group of tied whole solid bamboos was casted inside the 16 MPa compressive strength of PKS lightweight concrete. The mix proportion for the PKS lightweight concrete are shown in Table 1. The bamboocrete multi-purpose panel was cured for 28 days. The bamboocrete multi-purpose panel casting process is shown in Figure 2. Then, the bamboocrete underwent the axial load test and flexural bending test referring to the standard of ASTM E72-05.

TABLE 1. Mix proportion of PKS

Concrete Mix Material	Mixture (kg/m³)
Cement	526.00
Palm Kernel Shell (PKS)	263.00
Fine Aggregate	263.00
Course Aggregate	526.00
Water	526.00
Superplasticizer	5.26

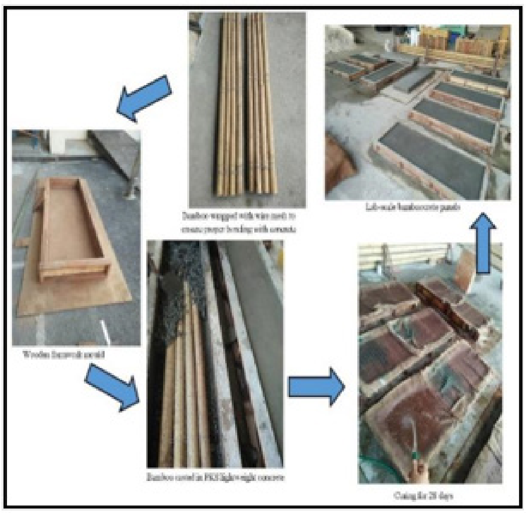

FIGURE 2. Bamboocrete multi-purpose panel sample preparation process

Two design alternatives using bamboo as the reinforcing material and steel as the conventional reinforced concrete are considered for cost comparison in this study as shown in Table 2. The structural analysis for the characteristic strength of concrete, fck = 16 MPa and 20 kN flexural load applied to the panel were analysed to determine the equivalent number of steel bars required when the same size of panels for bamboo reinforcement is used.

TABLE 2. Design alternatives for cost comparison

Design Alternative	Aggregate Used	Reinforcement
PKS – Bamboocrete Multi-PurposePanel	Palm Kernel Shell (PKS)	Bamboo
PKS – Steel Bar Reinforced Concrete Panel	Palm Kernel Shell (PKS)	Steel Bar

AXIAL LOAD AND FLEXURAL BENDING TEST

Bamboocrete multi-purpose panel achieved more than 100 kN (10 ton) axial load. Figure 3 shows the axial load test on the bamboocrete multi-purpose panel. The flexural load achieved of between 32.51 to 35.20 kN as shown in Figure 4. The advantage for this bamboocrete multi-purpose panel is in term of its flexibility. The bamboocrete multi-purpose panel returned into its straight form after the load removal. It is suitable for the structural components in hurricane and earthquake prone areas.

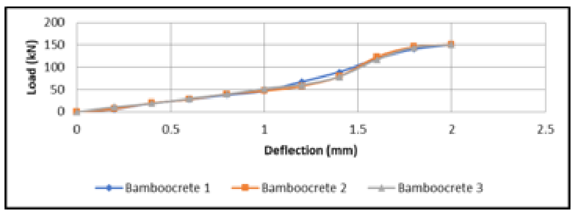

FIGURE 3. Axial load test on bamboocrete multi-purpose panel

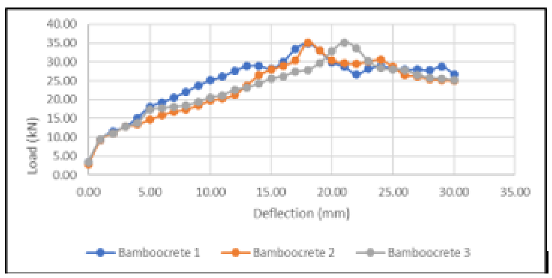

FIGURE 4. Flexural bending test on bamboocrete multi-purpose panel

STRUCTURAL ANALYSIS RESULT

From the analysis conducted by using the fck, 16 N/mm² with 20 kN load applied to the panel, 8.5 meters of 6 mm diameter bar is needed in the same size of panels that uses bamboo as the reinforcing material in PKS lightweight concrete. The analysis is done by using formulation adopted from RC design book (Mosley & Bungey 1990) to determine the number of bars required to resist the applied load. TABLE 3 summaries the reinforced concrete design for 20 kN load applied on the panel.

TABLE 3. Steel bar for reinforced concrete panel

	20kN Load Applied, fck = 16 N/mm²
Main Bar No. of Bar (Panel b = 500mm)	H6-200 2
Secondary Bar No. of Bar (Panel L = 1500mm)	H6-300 5
Total Bar needed	8.5 meters

COST COMPARISON

The unit price for the materials to construct the normal concrete and bamboocrete multi-purpose panel is shown in Table 4.

TABLE 4. Material's unit price

Item	Quantity	Price (RM)	Price per uni (RM)
Cement (kg)	Bag (50 kg)	27.80	0.56
PKS Aggregate (kg)	Ton	270.00	0.27
Fine Aggregate (kg)	Ton	338.00	0.34
Course Aggregate (kg)	Ton	345.00	0.35
Wire mesh (m)	Roll (50 metres)	45.00	0.90
Treated Bamboo	Pcs (3 metres)	6.00	2.00 (per meter)
Steel Bar (d=6mm)	Pcs (6 metres)	14.50	2.42 (per meter)

By using bamboo as the design alternatives, it contributes to the sufficient cost and weight difference. It has the negligible impact on the cost reduction of the construction materials. Table 5 tabulates the volume and mix proportion for the bamboocrete and steel bar reinforced concrete panel and Table 6 shows the cost analysis for one panel for each design.

TABLE 5. Volume and mix proportion for 1 panel

	Panel	
Alternative Design (1500 x 500 x 125 mm) panel	Bamboocrete Multi-Purpose Panel	Steel Bar RC Panel
Design Flexural Load (kN)	20	20
Panels Volume	0.094	0.094
Bamboo Volume	0.024	-
Concrete Volume	0.070	0.094
Cement (kg)	36.69	49.31
Coarse Aggregate (kg)	36.69	49.31
Fine Aggregate (kg)	18.34	24.66
PKS (kg)	18.34	24.66
Wiremesh (m)	1 m	-
Treated Bamboo		
d = 2 inches		
L = 1.5 m	8 pcs	-
Steel Bar (d = 6 mm)	-	8.5 m

TABLE 6. Cost for 1 panel

Alternative Design (1500 x 500 x 125 mm) panel	PKS – Treated Bamboo	PKS (16 MPa) – Steel Bar
Cement	20.55	27.62
Coarse Aggregate	12.48	17.26
Fine Aggregate	6.24	8.38
PKS	4.95	6.66
Wiremesh	0.90	-
Treated Bamboo		
d = 2 inches		
L = 1.5 m	24.00	-
Steel Bar (d = 6 mm)	-	20.57
Total (RM)	69.12	80.48
Panel weight (kg)	142.23	185.89

From the cost analysis, by replacing bamboo as the reinforcing materials in partially replaced aggregate by palm kernel shell (PKS) lightweight concrete, it can reduce cost by 14% compared to using steel bar. The usage of whole solid bamboo to reinforce concrete contributes to less usage of concrete. Moreover, using bamboo reduced the total weight for one panel from 185.89 kg using steel bar to 142.23 kg, which about 23% weight reduced. Table 7 tabulates the percentage of cost for one panel and weight reduced when replaces bamboo to reinforced concrete.

TABLE 7. Percentage of price and weight reduced

	PKS – Bamboo	PKS – Steel Bar	% Reduced
Price for 1 panel	RM 69.12	RM 80.48	14
Weight for 1 panel	142.23 kg	185.89 kg	23

CONCLUSION

The abundance of readily available raw material should be used at its optimum. From the analysis conducted, the usage of bamboo and PKS as the construction materials has significant impact on the reducing cost of concrete panel. Cost reduction was influenced by the selection of suitable and low-cost materials. At the best option from this study, bamboocrete multi-purpose panel is the economic structural components which is 14% cheaper and 23% lighter than the concrete panel that are reinforced using steel bar. Bamboocrete multi-purpose panel does not need the steel reinforcement since it has the properties of high tensile strength and can be used as load carrying members. The bamboocrete multi-purpose panel samples tested can sustain of more than 100 kN (10 ton) axial load and between 32.51 to 35.20 kN flexural load.

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DECLARATION OF COMPETING INTEREST

None

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