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## PERFORMANCE OF CEMENT SAND BRICK CONTAINING BAMBOO ASH AS CEMENT REPLACEMENT MATERIAL

Bamboo Ash is a safer and more sustainable building material. It is possible to use bamboo ash as a partial cement replacement as an alternative to cement application and also to reduce pollution. For this study, the main purpose is to determine the compressive strength and water absorption of cement sand brick containing bamboo ash. Laboratory tests such as compression tests and water absorption tests on cement sand brick with bamboo ash as a partial replacement for cement have been conducted. The mixes with various ratios using bamboo ash are 5%, 7%, and 10%. The specimen size for cement sand brick is 215 mm long, 102.5 mm wide, and 65 mm deep according to BS3921:1985. The results from the specimens containing Bamboo Ash have been compared to the control specimens. The water absorption test results increase as the percentage of Bamboo Ash increases due to particle size and air void, but the compressive strength decreases at 28 days.

*Keywords:* Bamboo Ash; Cement Replacement; Cement sand brick; Compressive Strength; Water Absorption

### 1. Introduction

Due to the rapid growth of the world population, the need of constructing residential and tall buildings also increases. This, in turn, increases the need for construction materials such as brick which utilizes a large amount of cement, sand, and water. The high use of cement in the industry has many negative effects on humans and the environment. Among them is the process of making cement by burning limestone, clay, and other materials in the kiln causing the release of carbon dioxide gas and the greenhouse effect when burning those materials. This study is conducted to reduce the use of cement in the construction industry. Besides, bamboo is one of the materials that have been tested to be a replacement material to cement as we can reduce the contaminant to the environment [1,2]. This is because the use of bamboo in the industry is increasing in construction structures, for example, bamboo is used for foundations, floors, roofs, doors, and windows [3-5]. Further applications of bamboo in construction include its use for bridges, scaffolding, bamboo-reinforced concrete, and bamboo-based panels [6]. Based on these works, bamboo is one of the waste materials that can be recycled and

used as an innovation or research project. The previous study also stated that the yearly production of bamboo across the globe is approximately 20 million tonnes of bamboo (Villar-Cocina et al., 2020) [7].

So, this study is focused on the potential of Bamboo Ash (BA) used as cement replacement in brick mixtures to determine the water absorption and compressive strength of cement sand brick. Also, the Bamboo Ash properties are examined by using X-Ray Fluorescence (XRF), Scanning Electron Microscope (SEM), and Particle size analyzer by CILAS 1180 Liquid. The mixtures of cement sand bricks with BA would give a better quality and efficiency of cement sand bricks.

#### 1.1. Chemical Composition of Bamboo Ash

Bamboo is physically processed and turned into ash. Due to the high potassium content, it is easier to obtain a concrete hardening material. Because high potassium in bamboo ash promotes early ettringite formation and thus early stability, this novel study will be compared to the industry standard beam concrete.

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Ashes made from burning bamboo stems (*Bambusa*) are sieved with a 45  $\mu\text{m}$  sieve to produce grains similar to cement. Building blocks are joined together with mortar, a workable paste. Steel, mortar, cinder blocks, or other materials may be used. Mortar cures form a solid aggregate base [8]. Due to their chemistry, minerals in biomass and coal ash contain a high concentration of oxide forms. Bamboo ash is containing potassium oxide ( $\text{K}_2\text{O}$ ) (34.23%), silicon dioxide ( $\text{SiO}_2$ ) (24.32%), and sulfite ion (14.05%). Calcium oxide ( $\text{CaO}$ ) (3.99%) and magnesium oxide  $\text{MgO}$  were also detected (6.69%) as chemical compositions in this ash. It is a chemical composition present caused by oxidation and ripping of the biomass ash stream [9].

### 1.2. Water Absorption of Cement sand bricks with Mixture Additive

The presence of internal pores in the sand particle was mentioned in connection with the specific gravity or mass of the brick, and indeed the characteristics of these pores are very important in the study of its properties. The porosity of brick can affect permeability and water absorption. Dang et al. [10] claim that moisture transfer in building materials affects the durability and thus the sustainability of structures. Moisture absorption is the main cause of porous construction material deterioration and the start of several moisture-related structural issues. Water absorption also increases the thermal conductivity of building components and heat loss [11].

## 2. Materials and methods

The mixtures were produced according to British Standard specifications (BS-5628-3). In general, the cement-to-sand ratio in cement sand brick is 1:4. According to Malaysian Standard (MS 76: 1972), the compressive force of the sand and cement brick should exceed 7  $\text{N}/\text{mm}^2$ .

The mixture composition of BA as partial cement replacement materials on cement sand brick was used to manage the manufacturing of brick specimens. Before casting the brick, all materials were weighed according to the mix design. The bricks were moulded to British Standard dimensions of 215 mm in length, 102.5 mm in breadth, and 65 mm in depth.

All materials were weighed based on each mix design before casting the brick. The mix proportion of single bricks containing BA which is 0%, 5%, 7%, and 10% as shown in TABLE 1.

TABLE 1

Mix proportion of brick

Mix Design	Sand ( $\text{kg}/\text{m}^3$ )	Cement ( $\text{kg}/\text{m}^3$ )	Bamboo Ash ( $\text{kg}/\text{m}^3$ )	Water ( $\text{kg}/\text{m}^3$ )	w/c
Control	2084	521	0	259	0.5
95OPC + 5BA	2084	494	25.9	259	0.5
93OPC + 7BA	2084	484	36.4	259	0.5
90OPC + 10BA	2084	469	52.4	259	0.5

### 2.1. Materials

Cement sand brick is made of raw materials mixture of cement, fine aggregate (sand), and water. As the purpose of this study is to use other raw materials as a replacement, the preparation of bamboo ash is also explained in this section. To achieve the objective, the material is prepared following the ratio of replacement.

The process of making bamboo ash starts from the collection of bamboo waste material of bamboo oil (*Bambusa vulgaris*) which is sourced in this study from Tandom hill resort in Selangor. The remaining used parts of the bamboo will then be burned in a furnace with a temperature of 600-700°C for 6 hours. The material is still in the pre-treatment phase where it has not yet been used as a substitute for cement for the manufacture of concrete.

The processed raw material will be brought to the laboratory, before undergoing the next process, the material will be placed in a tray that fits the size of the oven because it is required for the process of drying raw material at 150-300°C for at least more than 1 hour. The machine can grind raw materials from bamboo to produce ash with a size of <45  $\mu\text{m}$ . The material was processed using a Ball Mill machine at a speed of 350 rpm for 10 minutes for every 100 g of bamboo ash preparation as shown in Fig. 1.

After that, it has been isolated into airtight plastic to ensure that it is always dry and not mixed with foreign matter.



Fig. 1. Bamboo ash after the grind

The study is focusing on cement replacement since then the specimen of bamboo need to go through X-Ray Fluorescence (XRF) and Scanning Electron Microscope (SEM) testing to fulfilled the requirement for cement replacement. The mixture of cement sand brick also involves other materials such as cement, fine aggregate (sand), and water.

## 2.2. Methods

After determining the proper mix design of Bamboo Ash cement sand brick, preparation to make a concrete cube sample has been conducted. The preparation of mixing material that needs to be prepared before starting the mixing is cement and BA. BA has been grind by using Planetary Ball Mill Apparatus until it reaches the size of  $<45\ \mu\text{m}$ . This size is required to ensure it is fine like cement. Fine aggregate has been sieved to produce a size  $<5\ \text{mm}$ . The water/cement ratio used for this mix is 0.5. Fig. 2 shows some material preparation before the mixing process is conducted.



Fig. 2. Material preparation before mixing

## 2.3. Testing of sample

In this study, several tests have been conducted to recognize the properties of BA. This is to ensure that BA can be used as a partial replacement cement material. For this study, the tests and analysis used are, X-Ray Fluorescence (XRF) which is to analyze chemical substances in BA, Scanning Electron Microscope (SEM) to determine the content elements and Par-

ticle Size Analysis by using CILAS to determine the particle size suitable to replace cement in a cement sand brick. On the other hand, for testing the hardened properties, the compressive strength test and water absorption test have been conducted. The compressive strength is conducted after the cement sand brick is cured for 7, 14, and 28 days. This test is conducted according to BS EN12390-3:2002 (British Standard Institution, 2002). Then for water absorption, the test is conducted according to BS 1881-122:2011.

## 3. Results and discussion

The results and discussion for tests that have been conducted in this study are as follows sub-topic.

### 3.1. Properties of bamboo ash

Bamboo ash, in general, has a similar proportion of atomic weight elements to typical Portland cement, according to SEM. The morphology of bamboo ash by SEM while detecting particle size at a size of  $25\ \mu\text{m}$  could be seen in Fig. 3, which is the element's description.

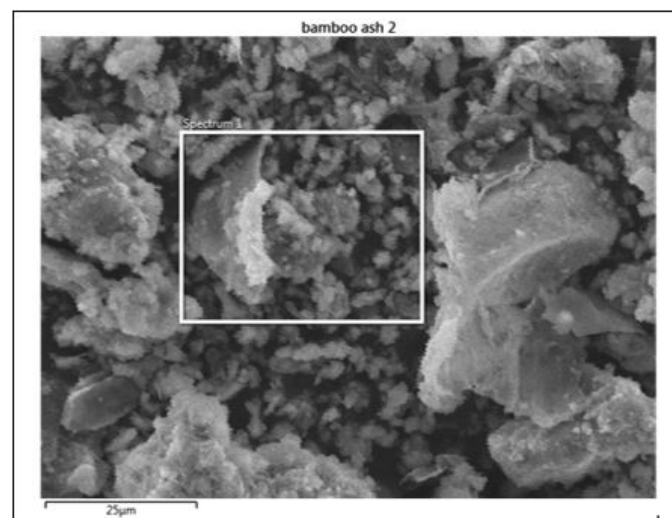


Fig. 3. Morphology of bamboo ash by SEM

TABLE 2 shows the chemical composition of BA and Ordinary Portland Cement (OPC). According to this table, the chemical composition of  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{Fe}_2\text{O}_3$ ,  $\text{MgO}$ ,  $\text{CaO}$ ,  $\text{Na}_2\text{O}$ ,  $\text{K}_2\text{O}$ ,  $\text{SO}_3$ ,  $\text{P}_2\text{O}_5$ ,  $\text{MnO}$ ,  $\text{ZnO}$ , and  $\text{Al}_2\text{O}_3$  are among the compounds that can be detected. This XRF test revealed that bamboo ash

TABLE 2

Chemical Composition of BA and OPC by XRF

	$\text{SiO}_2$	$\text{Al}_2\text{O}_3$	$\text{Fe}_2\text{O}_3$	$\text{MgO}$	$\text{CaO}$	$\text{Na}_2\text{O}$	$\text{K}_2\text{O}$	$\text{SO}_3$	$\text{P}_2\text{O}_5$	$\text{MnO}$	$\text{ZnO}$	$\text{Al}_2\text{O}_3$
BA (%)	37.4	1.43	9.91	2.5	4.35	ND	27	4.83	2.53	0.197	0.0758	1.43
OPC	34.4	9.96	3.78	1.63	44.5	ND	0.977	3.12	0.0687	0.0513	0.0224	9.96

has a high silica content of 37.4%, which is higher than OPC, which has a lower silica level of 34.4%. Because of the high silica value, it has demonstrated the qualities observed in bamboo ash pozzolanic material. Furthermore, the iron oxide (iii) content of bamboo ash is exceptionally high, at 9.91%, while OPC is 3.73%. Bamboo ash also contains aluminium oxide, on the other hand, is lower at 1.43% compared to OPC, which contains aluminium oxide at 9.96%. Calcium oxide was low in both samples. Furthermore, bamboo ash includes high levels of potassium oxide and phosphorus oxide (27 and 4.83%, respectively). As a result of this XRF test, it is demonstrated that bamboo ash has pozzolanic qualities and can be used as a substitute for cement in concrete design referring to the standard of the chemical requirement for pozzolanic material [12].

Fig. 4 shows the particle size distribution graph of BA. It is shown that the maximum particle size of 45 microns represented 94.33% of the cumulative percentage of Q3, with a cumulative percentage of 2.98% for the differential distribution of Q3. This signifies that the majority of the BA samples have been ground down to the appropriate particle size of 45 microns or smaller. However, in most cases, the particle size of bamboo ash is less than 100 microns.

### 3.2. Compressive strength test

Cement sand brick compressive strength is the ultimate load performance of cement sand brick. The test is conducted for bricks aged 7, 14, and 28 days, with each point in the graph representing the average of three readings from three different bricks. The tests compared the strength of a standard cement sand brick (control) and a cement sand brick with various percentages of BA. TABLE 3 shows the results of the compressive strength of control and modified brick.

The target strength of cement sand bricks according to British standards must exceed 7 N/mm<sup>2</sup>. The results of compressive strength on cement sand bricks show a decreasing condition as the percentage of BA added to the cement sand bricks increases.

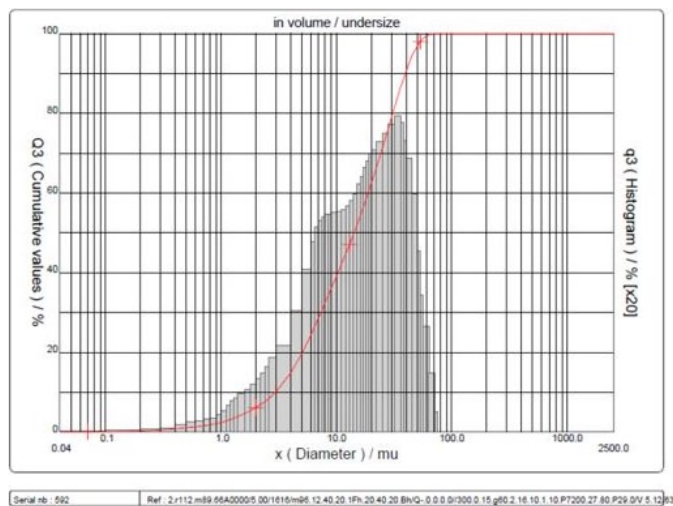


Fig. 4. Particle size distribution graph of BA

TABLE 3

Compressive strength result and different strength between modified brick and control brick

Mix Design	Compressive Strength (MPa)			The different Strength Between Control Brick & Modified Brick		
	7 days	14 days	28 days	7 days	14 days	28 days
Control	23.67	23.13	14.76	0	0	0
95OPC + 5BA	17.12	22.8	13.05	-6.55	-0.33	-1.71
93OPC + 7BA	11.67	16.88	12.19	-12.00	-6.25	-2.57
90OPC + 10BA	8.72	14.15	10.18	-14.95	-8.98	-4.58

The compressive strength of the cement sand bricks on the control shows the strength of each specimen for 7, 14, and 28 days. As can be seen in Fig. 3 the optimum percentage for a partial replacement for cement sand brick is 5% of BA. The result for the 28<sup>th</sup> day decreases because due to improper process which lack of compacting and the lack of adhesion or compounds between the bamboo ash and the cement particles. Ismail & Yaacob also proved that the value of compressive strength depends on the

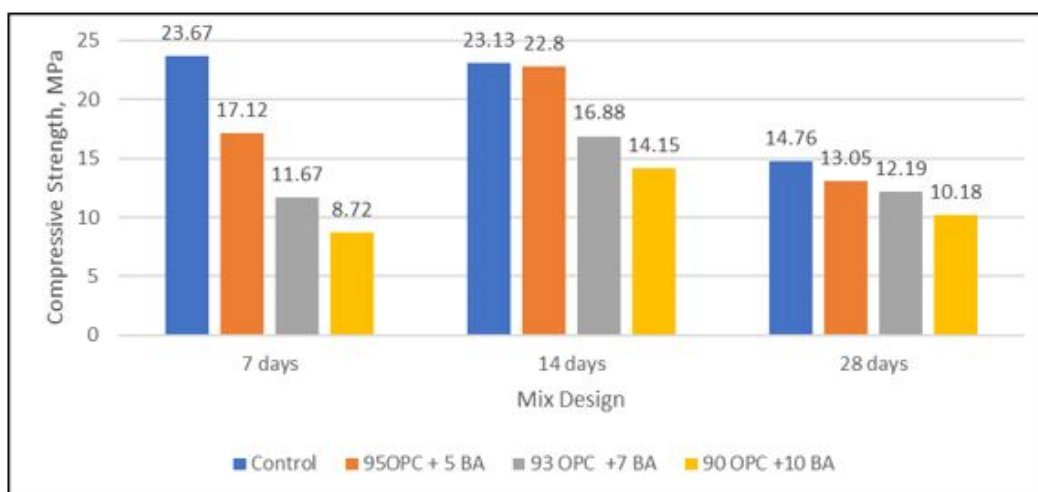


Fig. 5. The average value of compressive strength

material used as a partial replacement [13]. From the findings of Y.B. Jiao et al. [14], it is obvious that when the amount of bamboo ash in concrete mix increases, the percentage of voids in the concrete mix increases as well.

### 3.3. Water absorption test

The performance of cement sand brick in permeability can be represented by the water absorption test of sand cement brick. The purpose of the testing was to determine the permeability of a standard cement sand brick (control) and a cement sand brick with various replacement percentages of BA content. The water absorption of brick (control) and modified brick was evaluated based on these findings. TABLE 4 shows the results for several brick specimens in terms of water absorption.

TABLE 4

Water absorption result and percentage of different strength between modified brick and control brick

Mix Design	Percentage of Water Absorption, (%)	Percentage of Different Absorption Between Modified Brick & Control Brick (%)
Control	7.77	0
95OPC + BA5	12.53	4.76
93OPC + BA7	12.94	5.17
90OPC + BA10	14.08	6.31

The water absorption results in the cement sand bricks show an increasing condition as the percentage of BA added into the cement sand bricks increases shown in Fig. 6. The water absorption of cement sand bricks on the partial replacement of cement has increased the average rate of water absorption of cement sand bricks. Meanwhile, water absorption findings for sand bricks based on the standard MS 76: 1972 reveal no specified water absorption rate for sand bricks, and no specific water absorption rate classification for bricks with load characteristics is shown in the standard BS 3921: 1976. The

Singapore Standard SS103: 197, on the other hand, specifies that a brick must have a water absorption rate of no more than 25.0% [15]. In this case of water absorption, the average value for the cement sand brick determines the durability of a brick to withstand the environment.

### 4. Conclusion

The use of scanning electron microscopy (SEM) has revealed that BA contains elements that are extremely similar to OPC. In accordance with the results of the XRF test, the chemical composition of bamboo ash containing a similar amount of silica as obtained in OPC. A subsequent particle size study performed by CILAS revealed that the BA that had been ground in the ball mill machine had been ground to a similar size as the OPC, which had been ground to a size of 45 microns. Concrete compressive strength decreases as the percentage of BA in the cement sand brick increases. Although all BA percentages tested showed no significant differences from ordinary cement sand bricks. Compressive strength test results showed that each setting of cement sand brick mix mixture exceeded the sand cement brick's normal strength target of 7 N/mm<sup>2</sup>. Finally, the durability of cement sand brick using bamboo ash can be determined by comparing the data of water absorption and compressive strength which can be achieved using a mix design 95OPC + 5BA. Then, the cement sand brick absorbed significantly more water than the control cement sand brick. This study achieved its goal of determining the water absorption referring to Singapore standard SS103: 197 is not more than 25%. It means all samples had a lower porosity after water curing at 28 days and show that the water absorption rate on BA brick is still valid.

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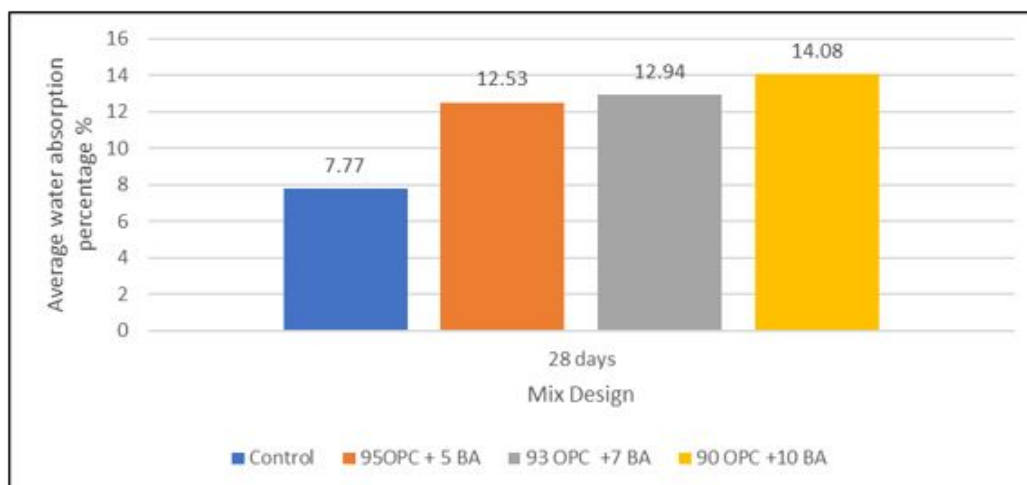


Fig. 6. The percentage value of water absorption

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