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Study of Cement-sand brick Using Bamboo Ash in Term of Strength

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Abstract: The growth of the building business generates a lot of construction trash, which causes social and environmental issues in communities. This can be concluded that the most unwanted waste is concrete and aggregate which it cannot be reusable and difficult to dispose. Therefore, the researcher suggests the used of bamboo ash as cement partial replacement. As a result, in this study, researcher use bamboo as a building material to create eco-friendly building materials. This study focus on using bamboo ash, sand and cement which to make cement-sand brick. A few test conducted as to test the chemistry composition of the sample, X-Ray Fluorescence (XRF), Particle Size Analyzer (PSA), Compressive Strength Test and Ultrasonic Pulse Velocity (UPV). The goals of this study is to determine compressive strength of cement-sand brick, which content of bamboo ash, and to investigate the quality of cement-sand bricks materials. This study contribute the reduction of cement usage able to minimize the concrete waste at landfill that is difficult to dispose and non-reusable. This research also helped to the development of a bamboo ash-based alternative to cement. From the findings, all objective for this research achieved. The compressive strength test results were decreases but according to BS 3921:1985, all samples are suitable for industrial usage. While, The Ultrasonic Pulse Velocity (UPV) test results reveal that the value of pulse velocity categorized as poor concrete, which is less than 3 km/s. This is due to the bricks' high porosity. This study has a lot of space for development for future studies and may be used as a reference for future research.

Keywords: Cement-Sand Bricks, Bamboo Ash, Compressive Strength

1. Introduction

In Malaysia, construction industry was rapidly increase whether building or infrastructure development projects, it is also led to an increase in construction waste material. According to Nasier, 2020, construction waste affecting the earth and landfills are fill up around 45.00 % and 65.00 % of construction waste [2]. The replacement material to reduce some cement intake will become as an

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alternative to this problem. This study focused on using bamboo ash materials and cement which to make cement-sand brick. The bamboo ash is classified as sustainable materials and the usage of bamboo as alternative to reduce the amount of cement used in making cement-sand brick. The aim of this study is to investigate the strength of cement-sand brick, which content bamboo ash. It also to determine compressive strength of cement-sand brick which containing of bamboo ash, to determine the Ultrasonic Pulse Velocity (UPV) of concrete containing bamboo ash and to determine whether bamboo ash may be utilized as a cement replacement in concrete.

1.1 Issues on Construction Waste

The construction industry contributes significantly to a country's growth. Population in the world increase making a construction industry rapid growth which resulting high waste was generate in landfill. According to Rahim M. H., the increase in waste generation is due to a variety of factors, including the economy, demand, living standards, population growth, industrialization, and urbanization [3]. The construction waste can be classify into two category, which is physical and non-physical waste. Physical waste refers to the material waste like timber, concrete, brick and other materials while non-physical is an overrun of time and cost [4]. Construction waste become a serious issue to many countries including Malaysia. However, for the sake of environmental protection, certain building waste can be sort for reuse, recycling, and disposal [5].

There are many factors that waste bricks might cause by for example lack of management when unloading of brick on site and poor handling when in delivery process [5]. It is also might cause by building demolition. Construction waste management is important to prevent environmental degradation, social, and economic consequences. If it is not treated properly, it will become a big problem [6]. In addition, illegal dumping activities occur due to excessive construction waste and financial issues. This study contributes the reduction of cement usage able to minimize the concrete waste at landfill that is difficult to dispose and non-reusable. This research also helped to the development of a bamboo ash-based alternative to cement. It also able to minimize carbon monoxide to transport and dispose by using heavy equipment.

1.2 Bamboo

In Malaysia, bamboo plant usually found in the countryside which it either in village area or forest bamboos. Bamboo belongs to the Gramineae family, which contains over 1,200 species. The bamboo plant is ideal for building material for example bamboo is fast growing; it is take about one or two years once maturity is reached for full harvest [8]. Bamboo also able to utilize as a building material for structure of the house or building or scaffolding, bridges. It also called, as an alternative for timber due to strength-to-weight ratio is similar. This unique plant able to use as trusses or roof structure due to lightweight and sufficient sturdiness to the structure [9].

From the results, the silica content in bamboo leaf ash is more rather than Portland cement and the ash met the Class N Pozzolan specifications. The researcher used of X-Ray Diffraction (XRD) analysis were to obtained chemical properties of the bamboo leaves ash and for the physical properties used specific gravity, strength activity index with cement and fineness [10].

1.3 Brick

One of the most significant materials in the construction industry is brick especially in Malaysia, which is cheapest rather than other country. This is due to Malaysia have raw materials for construction brick such as clay, shale, and sand, but it’s affecting environment such as resource depletion, environmental degradation, and energy consumption. Mining operations cause environmental degradation by polluting the air and leaving marks on the landscape [12].

This study focusing on cement-sand bricks to mix with bamboo ash. The component of cement-sand brick consists of Portland cement, bamboo ash, sand and aggregate with some water. Table 2.5 shows common brick specification as per British Standard BS 3921:1985.

Table 1: Dimensions & Tolerances

Specified Dimensions	Overall Measurement of 24 Bricks
Height: 65 + 1.875 mm	1560 + 45 mm
Width: 102.5 + 1.875 mm	2460 + 45 mm
Length: 215 + 3 mm	5160 + 75 mm

2. Materials and Methods

The procedure is gathered and prepared the raw materials, mixing and curing. The testing will conduct at the laboratory and workshop, which is compressive strength test and Ultrasonic Pulse Velocity (UPV) test. Before that, this process is required to collect bamboo waste materials, which is the type of bamboo is Bambusa Vulgaris burned at Tandom hill resort, Selangor. Figure 1 shows the flowchart of the procedure and testing will be conduct. It is significant to ensure systematic work according to the planning and guideline for the whole project regarding to the sampling and testing the sample.

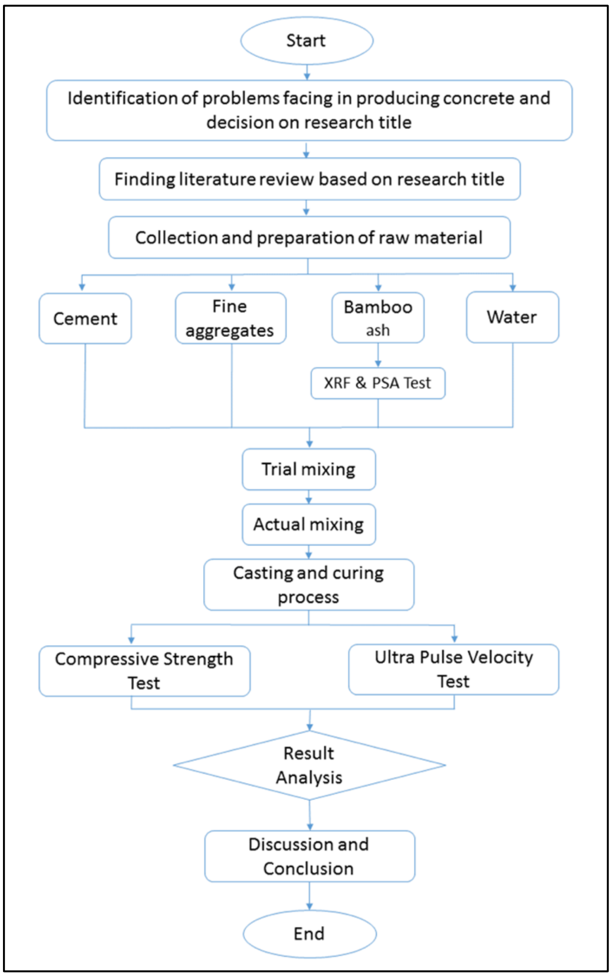

Figure 1: Research flow

2.1 Bamboo Ash (BA)

This process is required to collect bamboo waste materials, which is bamboo oil (Bambusa vulgaris) at Tandom hill resort, Selangor. The procedure of preparing the sample are list as follow:

i. The bamboo waste cut into smaller pieces and burnt for 6 hours in a furnace at 600-700 °C.
ii. Afterward, the bamboo ash packed and weight 2-kilogram into plastic bags to bring to the laboratory.
iii. The drying process was carried out which the bamboo ash were placed into a tray and place in oven for at least 1 hour at temperature 150-300 °C.
iv. In order to achieve criteria like cement, the bamboo ash required to grind by using Ball Mill Machine at speed of 350 rpm for 10 minutes every 100-gram.. This process able to make bamboo ash with a size of <45 µm.

2.2 Mixing Design

This project will be conduct the mixing process between Bamboo Ash (BA) and cement to produce cement-sand bricks. For this project, the mixing ratio are between Ordinary Portland Cement (OPC) and Bamboo Ash (BA), in the concrete brick are design such as 95OPC:5BA, 93OPC:7BA then increase to 80OPC:10BA. To determine desire strength according to British Standard BS 3921:1985. The specimens will be 36 specimens for compressive strength test according to the list in the Table 2.

Table 2: List of Specimens According to Tests

Mix Designation	**Sample**			
	Compressive Test			**UPV Test**
	3 days	**7 days**	**28 days**	
Control	3	3	3	3
5 BA	3	3	3	3
7 BA	3	3	3	3
10 BA	3	3	3	3
Total	**12**	**12**	**12**	**12**
			48	

2.3 Compressive strength test

This test is conduct after 7, 14 and 28 days of concrete cast to let the concrete hardened completely. The objective of this test is to determine the resistance of a sample to withstand load. This test will be conduct according to BS EN12390-3:2002 [13]. Table 2 shows that the compressive strength and water absorption of the various type of brick based on British Standard [13]. Figure 2 shows the sample of bricks being applied load by compression testing machine. The procedure of compressive strength test;

i. Sample were taken out from water tank and wipe out before placing in compressive strength machine.
ii. Specific load was apply until failure.
iii. The load at failure will determine as maximum load.

The formula of compressive strength is:

$$f_c = \frac{F}{A_c} \qquad Eq.1$$

Where;
f_c is the compressive strength (MPa)
F is maximum load at failure

A_c is the initial cross-sectional surface area

Table 3: Strength & Water Absorption

Designation	Class	Ave. Compressive Strength, N/m^2	Ave. Water Absorption, % (max)
Engineering Brick	A	69.0	4.5
	B	48.5	7.0
Load Bearing Brick	15	103.5	No Specific Requirement
	10	69.0	
	7	48.5	
	5	34.5	
	4	27.5	
	3	20.5	
	2	14.0	
	1	7.0	
Brick for Damp-proof Courses	DPC	As required	4.5

2.4 Ultrasonic Pulse Velocity (UPV) Test

Ultrasonic Pulse Velocity is a concrete testing to determine the integrity whether the concrete have void, crack or any defect. It requires two-sided access for direct testing. Thus, it able to assessed using the guideline. The transducers can be place in one of three ways. Direct Method (opposite faces), Semi-direct Method (adjacent faces) and Indirect Method (same faces). In this study, Direct Method used to determine the quality of the sample. Figure 2 shows the position of the transducers, which placed at three-difference place to measure. In this testing, the total of the sample is 12 samples according to Table 4.

Figure 2: Ultrasonic Pulse Velocity (UPV) test

3. Results and Discussion

The testing is chemistry test, which is X-Ray Fluorescence and the fineness test, Particle Size Analyzer (PSA). These tests were conduct toward Bamboo Ash (BA) and Ordinary Portland Cement (OPC) to find the composition and to determine the size of the samples. There are 48 sample of cement-sand bricks, which is according to the Chapter 3. Each mix design created nine specimens; the compressive strength test were conduct at day 7, 14 and 28 days after casting. The ratio for cement-sand bricks will be 1:4 for control and for cement partial replacement variable be 75OPC:5BA, 73OPC:7BA and 70:10BA. Each mix design have three samples and the data was record.

Ultrasonic Pulse Velocity (UPV) test also conducted at Concrete Technology laboratory with compressive strength test. For UPV test, total specimen are 12 samples. It required 28 days maturity to conduct the test and let the sample dried after take out after from curing tank. After test completed, the data was collect, record, analyze and discuss in this chapter with help by the graph and table.

3.1 X-Ray Fluorescence (XRF) Test

Figure 3 shows the typical wavelength dispersive XRF spectrum. The result shows that the content of the silica is high. According to Figure 3 and 4, the silicon dioxide (SiO2) concentration of bamboo ash is 37.4 percent greater than that of ordinary Portland cement (OPC), which is 34.4 percent. The chemical compositions measured by X-ray fluorescence (XRF), loss on ignition, free lime content, and insoluble residue were determined in accordance with BS ISO 29,581-2. According to the findings, Bamboo Ash (BA) has a higher silica concentration than Ordinary Portland Cement (OPC). A sufficient amount of silica helps in the development of di-calcium and tri-calcium silicates, which provide the cement strength.

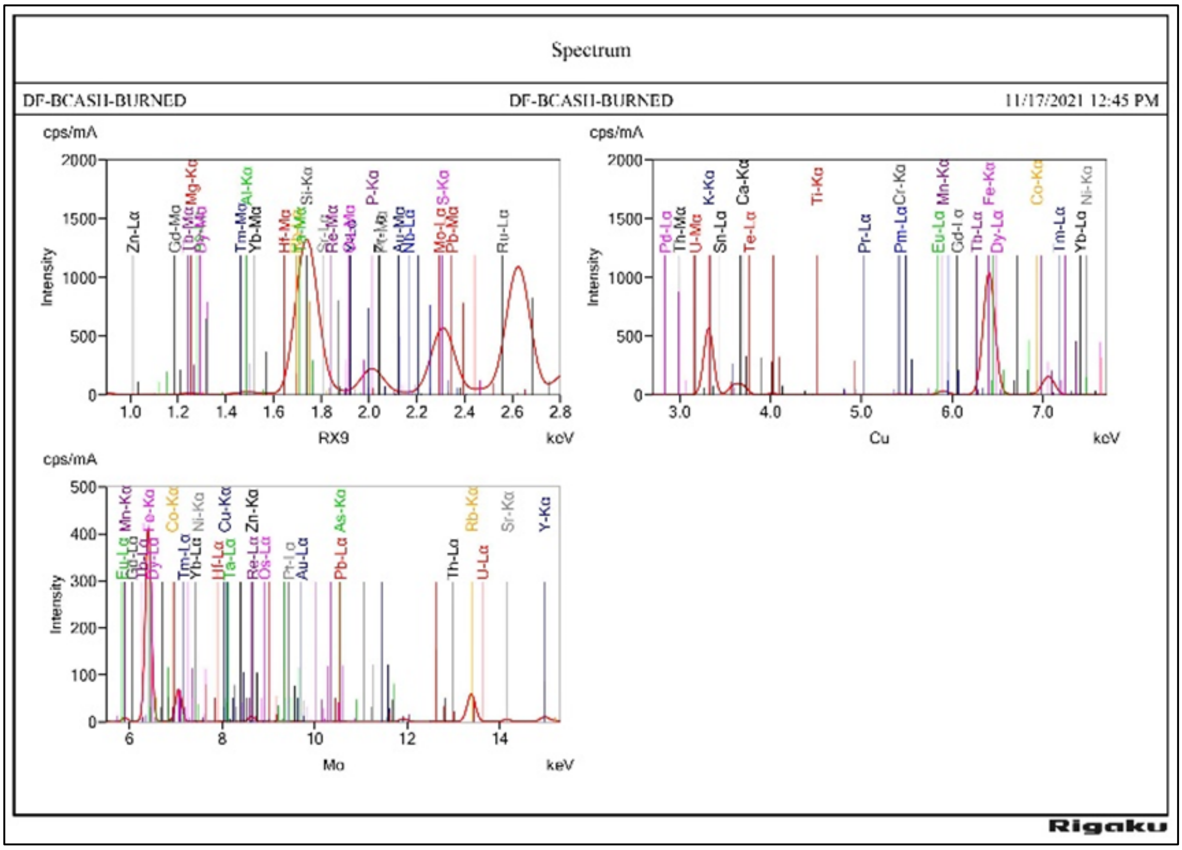

Figure 3: XRF spectrum for Bamboo Ash

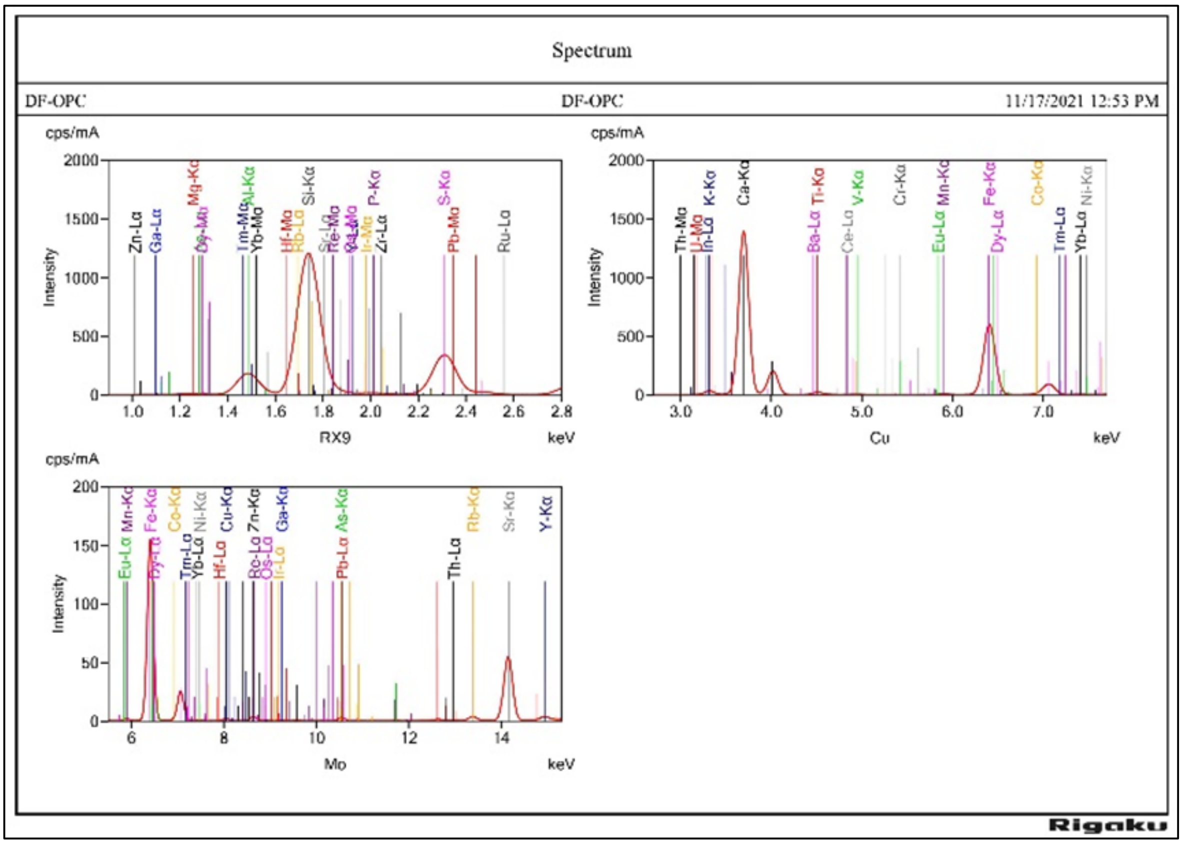

Figure 4: XRF spectrum of OPC

3.2 Particle Size Analyzer (PSA)

The test was conduct by using Particle Size Distribution CILAS 1180 Liquid. The Particle Size Analyzer is a commonly used technology for characterizing sediment particles based on the diffraction of a laser light source by the samples under examination. The test is to determine the size distribution of a bamboo ash based on light diffraction. Figure 5 shows the result of the testing conducted. The particle size distribution of the specimen is lower below 100 µm. According to Appendix D, 94 percent of the bamboo ash particle is less than 45 µm and the remaining 6 percent is greater than 45 µm but less than 100 µm.

3.3 Tables.

The fineness of the sample is significant due to physical properties of the BA, which be must identical to OPC. The results shows that the sample is similar size as OPC. Characterization, such as fineness, assessed in accordance with BS EN 196–6 criteria. In general, any material must meet the requirements specified in the standards under consideration in order to qualify as a pozzolan. As a result, BA's fulfilment of the physical and chemical standards proves their feasibility as a prospective cement alternative for the cement industry.

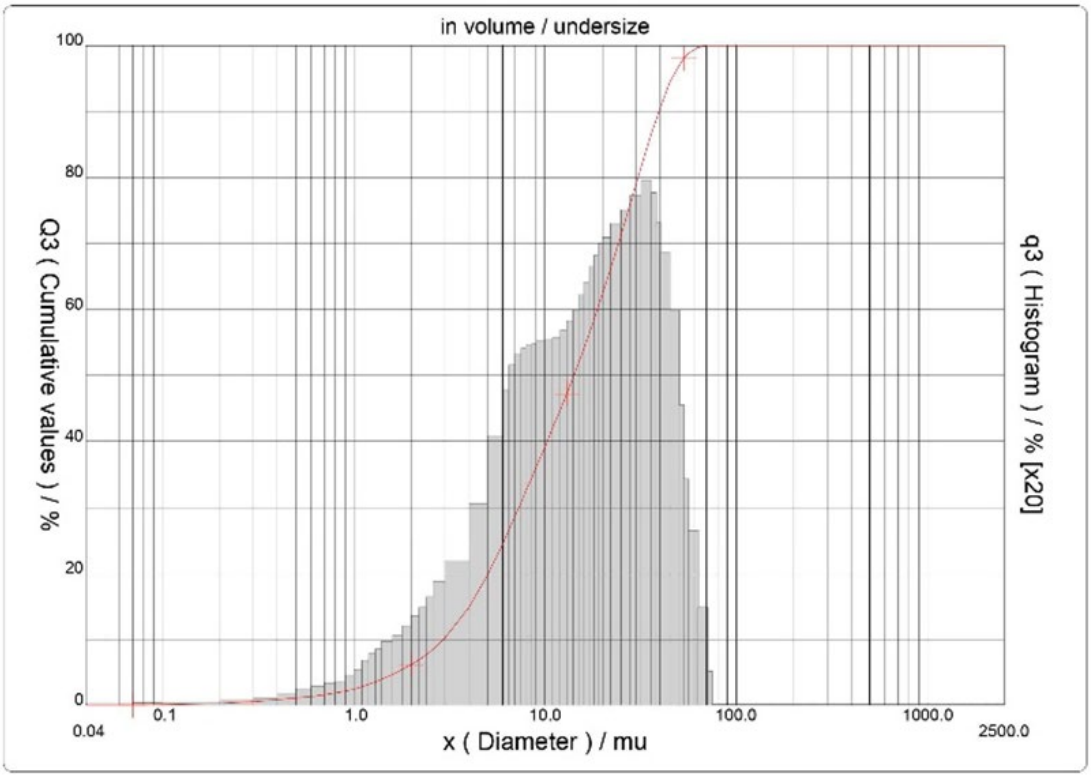

Figure 5: Particle Size Distribution

3.3 Compressive Strength Test

The compressive strength of cement-sand brick can be assessed the performance of cement-sand brick subjected to an ultimate load. The test was conduct toward the sample at age 7, 14 and 28 days with difference mixing design, which is control, 5.00 %, 7.00 % and 10.00 % of Bamboo Ash (BA). The mixing design is Bamboo Ash (BA) is partially replaced Ordinary Portland Cement (OPC). The test was carry out to measure the average compressive strength of control and BA-modified bricks. Then, control and modified bricks compared based on these findings. Table 4 shows the result for the compressive strength test and the different strength between control brick and modified brick, which according to the various age of sample and mix design.

Figure 6 shows the pattern of compressive strength values for every 5.00 %, 7.00 %, and 10.00 % of the sample, as well as the maturity of the sample (7, 14, and 28 days). According to the British Standard, minimum strength for the cement brick is 7 N/mm^2. Any brick design strength must be above 7 N/mm^2. The results shows that the value of the all sample decrease compared to control sample. The value of the compressive strength for control mix design at 28 days where dropped that because of the improper mixing process. The compressive strength toward the sample influenced by the improper mixing process, which occurs during the mixing of the components, sand and cement, and the compacting process. According to Table 4 , sample 5.00 % BA at 14 and 28 days slightly decreased.

Table 4: Average compressive strength result and the different strength between control brick & modified brick

Mix Design	Average 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 + 5 BA	17.12	22.8	13.05	-6.55	-0.33	-1.71

93 OPC + 7 BA	11.67	16.88	12.19	-12	-6.25	-2.57
90 OPC + 10 BA	8.72	14.15	10.18	-14.95	-8.98	-4.58

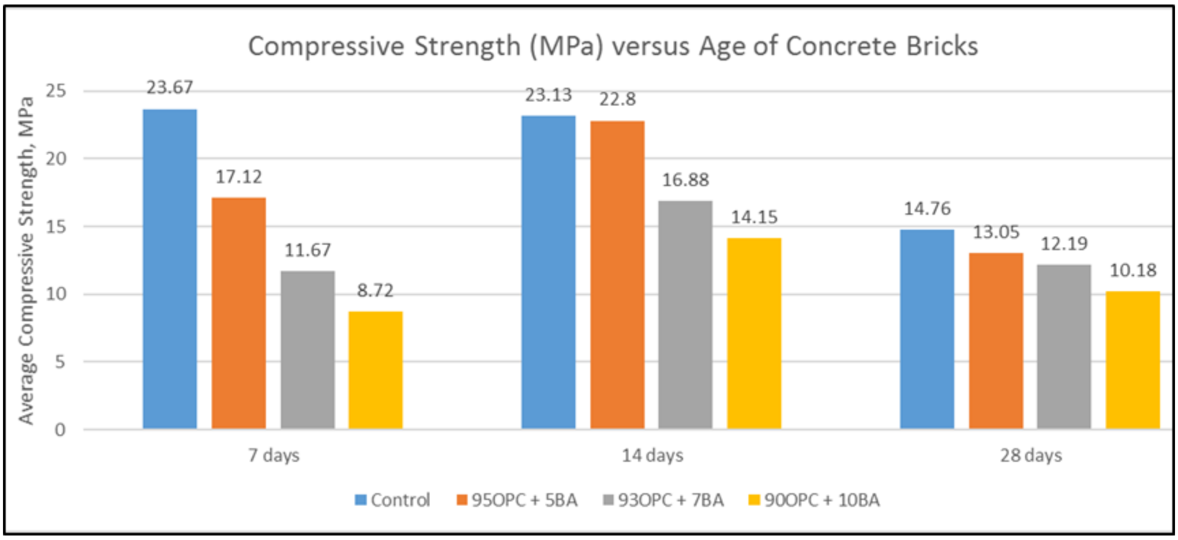

Figure 6: The average value of compressive strength

3.4 Ultrasonic Pulse Velocity (UPV) Test

Table 5 shows that the result of the UPV test according to the difference mix design between Bamboo Ash (BA) and Ordinary Portland Cement (OPC), which is control, 95 OPC + 5 BA, 93 OPC +7 BA and 90 OPC + 10 BA. The tests were repeat three times to obtain an average of the travel time. From the result, the Pulse Velocity at 5.00 % BA and 10.00 % BA were same, which 2.56 km/s. The highest value is 7.00 % BA, 2.83 km/s. Figure 6 shows that the relation between average time travel and mix design, which the 10.00 % BA the highest value at 4.01E-5 s and the lowest is 7.00 % BA, 3.63E-5. This due to the pulse velocity at 7.00 % BA is high, 2.83 km/s, and at 10% BA is lowest, 2.56 km/s as shown in Figure 8.

Table 5: The result of UPV test

Mix design	Distance (km)	Average Travel time (s)	Pulse Velocity (km/s)
Control	10.25E-5	3.77E-05	2.72
95OPC + 5 BA	10.25E-5	4.00E-05	2.56
93 OPC + 7 BA	10.25E-5	3.62E-05	2.83
90 OPC + 10 BA	10.25E-5	4.01E-05	2.56

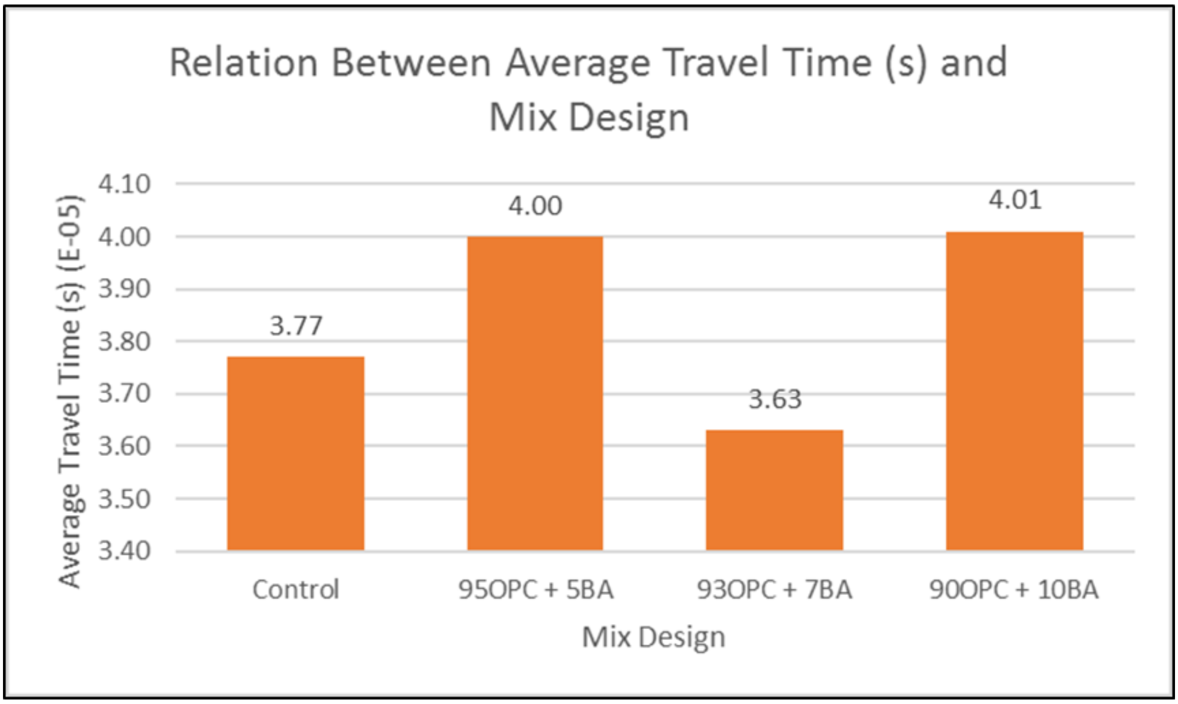

Figure 7: Relation between average travel time (s) and mix design

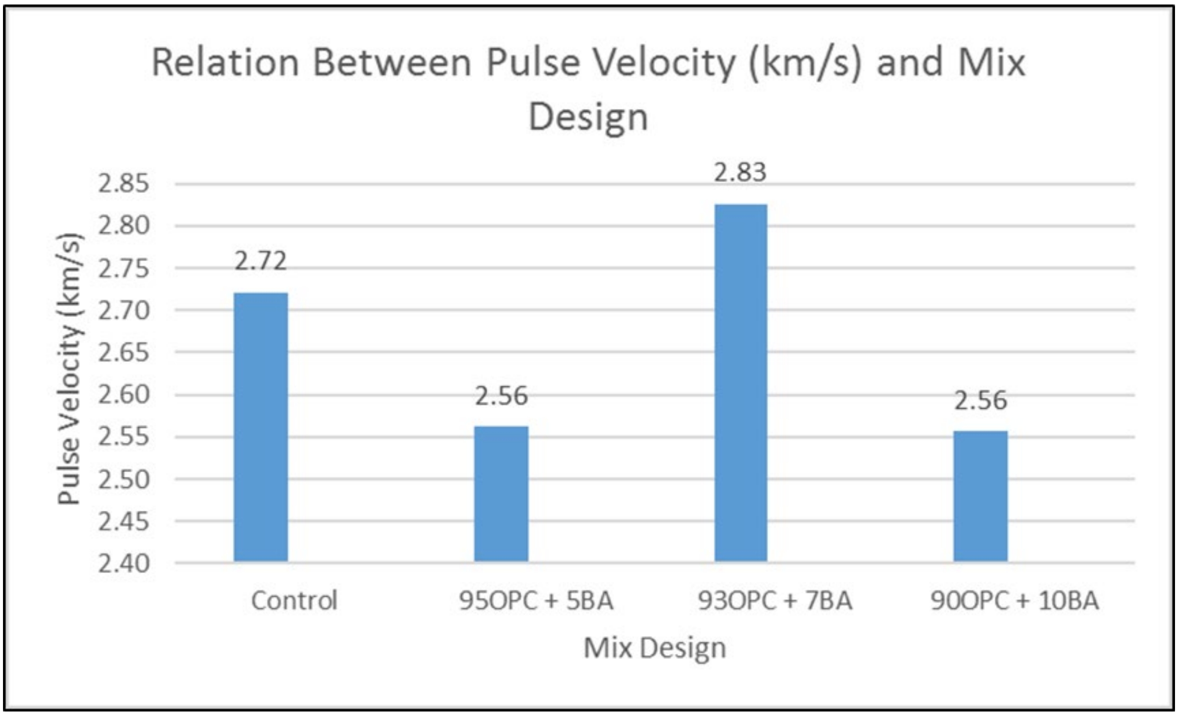

Figure 8: Relation between pulse velocity and mix design

4. Conclusion

The following conclusions can be taken based on the findings of the XRF test, PSA test, Compressive Strength test, and UPV test: The chemical compositions measured by X-ray fluorescence (XRF), loss on ignition, free lime content, and insoluble residue were determined in accordance with BS ISO 29,581-2. The results of the X-Ray Fluorescence test showed that the sample of Bamboo Ash (BA) content high silica and able to replace cement or substitute cement. The fineness test, which is

Particle Size Analyzer, showed that the 94 percent of the sample size is below 45 µm and another 6 percent were greater than 45 µm but still below 100 µm.

The compressive strength value decreases according to the difference type of mix design especially at 7 days samples and the sample at 14 and 28 days were slightly decrease. The compressive strength test results demonstrate that the strength of the bricks decreases rapidly, with the exception of 14 and 28 days, which show a slight decrease between control and 95OPC + 5BA, which, 1.43 % and 11.59 % reduction. All compressive strength value were achieved since the minimum of the compressive strength for ordinary bricks is 7 N/mm^2. UPV's results test were poor concrete, the sample is high of porosity and the surface is not completely flat which the transducers and the gel did not fully placed. The sample also might be content moisture that disturbed the testing.

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