EFFECT OF PROCESSED SPENT BLEACHING EARTH AND KENAF FIBRE ON COMPRESSIVE STRENGTH AND DRYING SHRINKAGE OF FOAMED CONCRETE

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ABSTRAK

Bahan Pozzolanic dihasilkan oleh pembakaran sisa dari bahan semula jadi atau tiruan. Dalam kajian ini, Processed Spent Bleaching Earth (PSBE) adalah produk dari kelapa sawit dan pelunturan minyak kelapa sawit mentah (CPO) dari minyak kelapa sawit halus yang lazimnya dilupuskan di tapak pelupusan sampingan dengan kos yang tinggi. Dalam kajian ini, PSBE digunakan sebagai pengganti simen separa kepada Semen Portland Biasa (OPC). Ini adalah tiga campuran yang disediakan iaitu konkrit berbuih (FC), konkrit berbuih dengan 30% PSBE (PFC) dan konkrit berbuih dengan 30% PSBE dan 0.5% kenaf fiber (PKC). Semua spesimen bersedia untuk menyiasat kekuatan mampatan, pengecutan, penurunan berat badan dan kedalaman pengkarbonan. Hasilnya untuk kekuatan mampatan, campuran mengandungi 30% PSBE sebagai pengganti simen separa menghasilkan tekanan mampatan tertinggi berbanding FC dan PKC. Selain itu, campuran kehadiran serat kenaf yang PKC menunjukkan pengecutan yang lebih rendah berbanding PFC dan FC. Di samping itu, hasil penguncupan pengecutan bagi hasil peratusan penurunan berat badan yang bermaksud PKC mempunyai peratusan penurunan berat badan yang lebih rendah berbanding PFC dan FC. Sementara itu, FC menghasilkan nilai tertinggi bagi kedalaman karbonasi dalam konkrit berbuih berbanding PFC dan PKC. Kajian ini membayangkan PSBE sebagai pengganti separa adalah baik dan bermanfaat, terutamanya untuk pengeluaran untuk konkrit berbuih.

ABSTRACT

Pozzolanic material produced by combustion of the waste from natural or artificial material. In this study, Processed Spent Bleaching Earth (PSBE) is a by-product from the degumming and bleaching of crude palm oil (CPO) from physically refined palm oil is commonly disposed of at landfills at a high cost. In this present study, PSBE used as partial cement replacement to Ordinary Portland Cement (OPC). These are three mixture has been prepared, namely foamed concrete (FC), foamed concrete with 30% PSBE (PFC) and foamed concrete with 30% PSBE and 0.5% kenaf fiber (PKC). All specimens were prepared to investigate the compressive strength, shrinkage, weight loss and carbonation depth. The result for compressive strength, the mixture contains 30% PSBE as partial cement replacement produced the highest compressive stress compared to FC and PKC. Other than that, the mixture that presence kenaf fiber, which is PKC, shows the lower shrinkage compared to PFC and FC. Besides that, the result for shrinkage influence for the result of the percentage of weight loss, which means the PKC have a lower percentage of weight loss compared to PFC and FC. Meanwhile, FC produced the highest value for the carbonation depth of foamed concrete compared to PFC and PKC. The study implies PSBE as partial replacement is useful and beneficial, especially for the production for foamed concrete.

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LIST OF SYMBOLS

%	Percentage
°C	Celcius
°F	Fahrenheit
µm	Micrometre

LIST OF ABBREVIATIONS

BC	Before Century
Sdn. Bhd.	Sendirian Berhad
SBE	Spent Bleaching Earth
PSBE	Processed Spent Bleaching Earth
OPC	Ordinary Portland Cement
ASTM	American Society for Testing and Materials
BS	British Standard
FC	Foamed Concrete
PFC	Foamed Concrete with PSBE
PKC	Foamed Concrete with PSBE and Kenaf Fibre
w/c	Water per cement
UMP	University Malaysia Pahang
CO_2	Carbon Dioxide
C_3S	Tricalcium Silicate
C_2S	Dicalcium Silicate
C_3A	Tricalcium Aluminate
C_4AH	Calcium Aluminate Hydrate
SiO_2	Silicon Dioxide
$CaCO_3$	Calcium Carbonate
$Ca(OH)_2$	Calcium Hydroxide
C-S-H	Calcium Silicate Hydrate
H_2O	Water
Al_2O_3	Aluminium Oxide
$C_{20}H_{14}O_4$	Phenolphthalein
mm	Millimeter
kg/m^3	Kilogram per meter cube
MPa	Mega Pascal
L	Litre
m^3	Meter cube
kg	Kilogram

CHAPTER 1

INTRODUCTION

1.1 Background of Study

In the construction industry, concrete is essential because commonly used as a structural element. For example, slab, column and wall are produced by concrete because concrete is a durable building material. In Latin, concrete is called "concretus," which means to grow together. Concretus is the first name of concrete. Concrete made by mixing with different material such as fine aggregates and coarse aggregates which are sand and gravel and also mixing with water. Based on Roxanne Pepin, the earliest recordings of concrete structures by Nabataea traders in the regions of Syria and Jordan date back to 6500BC (previous century). They created concrete floors, build ings and underground cisterns. Concrete is excellent in strength and durability, but it is not good in term of weight.

The advance of technology of concrete, foamed concrete has introduced. Foamed concrete, also is known as lightweight concrete, aerated concrete and porous concrete. Foamed concrete made by mixing of cement, water and foam. Foamed concrete can be used for wide range application such as roof insulation, levelling floors, void filling and ground stabilisation. Its properties can be adjusted on demand by varying the amount of water, cement, sand and foam. Foamed concrete created when air voids in mortar entrapped by a suitable foaming agent. Moreover, foamed concrete with densities between 400 kg/m3 and 1600 kg/m3 obtained for structural, partition, insulation, and filling grades (Farzadnia et al., 2015). One of the advantages of foamed concrete is the concrete is lighter than normal concrete. Nowadays, foamed concrete is popular uses because of the low cost and efficiently to move from the factory to the site.

However, this foamed concrete also have disadvantages that effect the strength of the foamed concrete. A few testing were conducted in this research to study the strength of foamed concrete, drying shrinkage and carbonation. In these studies, the materials that used were kenaf fiber and Processed Spent Bleaching Earth (PSBE) as the partial cement replacement.

1.2 Problem Statement

In the 21st century, every country is developing rapidly and more construction is ongoing indirectly. Every time construction will be carried out, a new area or spacious area will be used to carry out construction activities, and forest exploration will take effect. Carbon dioxide gases freely spread in the atmosphere. Besides that, using normal concrete is standard things to the contractor to construct a building. Standard concrete also will produce gas carbon dioxide (CO_2); hence, these will cause the greenhouse effect. These gas is resulting from the chemical impact of the cement that mix with water. The more construction using normal concrete, the more gas CO_2 will be released. Increasing the concentration of atmospheric carbon dioxide, affect the carbonation of concrete structures will become serious (Aini, Sari, Rahim, & Sani, 2017). After that, damaging of the concrete will give a harmful effect to the structure that can make the concrete crack and will affect the strength of the concrete too. The most common factor that occurs concrete to crack is drying shrinkage. Drying shrinkage is defined as a contracting of concrete due to the loss of water while still in the plastic state. Next, the strength of the concrete will be affected and can cause the concrete to fail. Every structure must good in strength to construct a building for a long period. The low strength in concrete, it is easy for structure to collapse. Lastly, a normal concrete is much heavy because of the existing aggregates. Even though the aggregates are essential in the mixture of concrete, but it causes the concrete to be heavier. The high density of the concrete, the increasing of the structural dead loads. These may lead to an increase in the cost of the construction.

1.3 Objective

The goal of this study is to investigate the effect of kenaf as fiber and processed spent bleaching earth (PSBE) as cement partial replacement in foamed concrete. The objectives of this study are:

i. To determine the compressive strength of foamed concrete
ii. To determine the drying shrinkage of foamed concrete
iii. To determine the weight loss of foamed concrete
iv. To determine the carbonation of foamed concrete

1.4 Scope of Research

This study was done to determine the effect of kenaf as fiber and processed spent bleaching earth (PSBE) as partial replacement of cement in foamed concrete. The materials mixed according to ratio 30% of PSBE and 0.5% of kenaf fiber. All materials and specimen preparation based on ASTM and BS standard code practice requirement. For this research, there are four testings conducted using three types of the mixture with namely foamed concrete (FC), foamed concrete with 30% of PSBE (PFC), and foamed concrete with 0.5 % kenaf fiber and 30% of PSBE (KFC). In this study, the shrinkage, compressive strength, weight loss and carbonation were tested and evaluated. The prism beam with dimension 40mm x 40mm x 60mm used for shrinkage and weight loss as followed ASTM C157 / C157M – 17 Standard Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete. The cube with dimension 150mm x 150mm x 150mm used for compressive strength and carbonation referred to ASTM C109 Standards Standard Test Method for Compressive Strength of Hydraulic Cement Mortars.

1.5 Significant of Study

The significance of this study is to determine the effect of kenaf as fiber and processed spent bleaching earth (PSBE) as partial replacement of cement in foamed concrete that can increase the strength of foamed concrete and prevent from cracking. Other than that, the inclusion of kenaf as fiber and PSBE as partial replacement of cement in the foamed concrete produce a low density of foamed concrete. Hence, the greenhouse effect can be reduced due to PSBE act as partial cement that can minimize the amount of cement used in concrete.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The purpose of the Literature Review chapter is to provide information on the application and properties of foamed concrete. Other studies conducted by different research were reviewed and discussed based on the presented resources material obtained, for an example research paper, books, journals and articles. For example, silica sand, kenaf as fiber, processed spent bleaching earth (PSBE) and Ordinary Portland Cement (OPC). The study related to the effect of foamed concrete with Pozzolan materials as partial cement replacement. Other than that, this chapter also surveys the impact of different materials utilized as a substitution of cement on foamed concrete.

2.2 Foamed Concrete

The definition of foamed concrete is a light cellular concrete, also known as a lightweight concrete with random air voids resulting from the mixture of foaming agents in mortar. The density of the lightweight concrete is about 400-1850 kg/m^3 (Amran et al., 2015). Firstly, lightweight concrete is quite different from normal concrete. A lightweight concrete product is considered a form of concrete with the existing air bubbles replacing aggregates. According to (Jagdeesh et al., 2017), the creation of uniform distribution air bubbles of foam concrete is throughout the mass of concrete. For the fresh concrete to remain stable, the foam cells must have walls when mixing, transporting, pumpinig and placing. The size of the cells or the bubble is in the range of 0.1mm and 1mm. Lightweight concrete also is an alternative to the normal concrete, which is lightweight concrete lighter than normal concrete in term of weight. Other than that, it has some major setbacks like low strength and increased shrinking at a later age (Harith, 2018). For example, in Indonesia, there is a lot of damaging building caused by an earthquake due to the significant disadvantage of concrete (Tanveer et al., 2017). Other than that, lightweight concrete is excellent because it can reduce the reinforcement steels in the foundation. These happened when there is a reduction occur in dead weight. (Wendling et al., 2018)(Ahmed et al., 2017). The present research investigates the performance of durability of foamed concrete with PSBE as partial cement replacement of cement when exposed to acidic environment. PSBE integrastion as partial replacement of cement enhances the resistance of foamed concrete towards acid attack (Rokiah, 2019).

2.3 Application of Foamed Concrete

Foamed concrete become popular because of its advantages in low thermal conductivity, density reduction, high flowability and self-compacting concrete, ease to produce and it is relatively cost effective. These led the applications to many civil and structure areas (Farzadnia et al., 2015). Use of foamed concrete in civil and structure such as concrete for void filling, foamed concrete roofing isolation, lightweight foamed concrete bridge, foamed concrete for trench and wall contruction. However, the uses of foamed concrete were increasing in the past few years as there is developing interest in using foamed concrete in the building and structure constructions.

2.4 Constituent Materials of Foamed Concrete

2.4.1 Cement

Cement is a substance used for construction that sets, harden and adhere to other materials to bind them together. Cement is the most widely used material in existence. Many types of cement can be used on its usage and condition. The most type of cement that usually used is Ordinary Portland Cement (OPC). In foamed concrete, the amount of cement used is less than normal concrete in the same volume, but the strength of the concrete decreased. The reason why cement used is less because there will be adding another material, agent foamed. The particle bonding in the foam concrete is weak compared to normal concrete, so it is hard to retain as a mono structure in the foamed concrete. The cement paste is the primary material in mortar and concrete and is a complex porous structure with pores ranging from nanometers to micrometers (Stepišnik & Ardelean, 2016). Portland cement contains four main compounds namely Tricalcium Silicate (C_3S), Dicalcium Silicate (C_2S), Tricalcium Aluminate (C_3A) and Tetracalcium Alumino Ferrite (C_4AH), and Portland cement is not a simple chemical compound. They have their unique functions, respectively. For Tricalcium Silicate, it is rapidly hydrated and contributes towards early strength development. Then, Dicalcium Silicate slightly slower hydrates due to its less reactive property and it contribute towards belated strength development. Meanwhile, Tricalcium Aluminate is an essential content in cement and contribute slightly towards early strength development. Due to the reaction is superior fast and releasing high heat, it may lead to "Flash Set," and thus Gypsum is needed to slow down the reaction.

2.4.2 Sand

Sand is essential in making concrete. A mix concrete contains 60 to 80 percent sand and gravel, also known as aggregate. This aggregate is an essential part of this concrete composition. Aggregate is defined into two types, fine aggregate and coarse aggregate. The mixture's strength and texture of the concrete can be determined by the amount of sand. If sand removed from the concrete mixture, it will become a completely different product. Sand defined as particles with a diameter of between 0.074 and 4.75 millimeters. The composition of sand depending on the local sources of rock and the conditions. The most common type of sand is silica (SiO_2) and calcium carbonate

($CaCO_3$). Different type of sand may give a different strength of concrete (Hasdemir, Tuƚrul, & Yilmaz, 2016).

2.4.3 Water

Water is an essential material in concrete. The amount of water needed in concrete mixing depends on the amount of cement and admixture used. In hydration process, it reacts chemically with cement to produce the desired properties of concrete. Water is responsible for hardening the concrete into a different form. Other than that, the water content will affect the workability, stability, uniformly and consistency of the concrete mix. The optimum water-cement ratio is 0.45 to 0.60 used. If the ratio is small, then the strength of the concrete will be high. When the water content is low, the density ratio is higher than unity and will cause the mix to be stiff and the bubble will break during mixing resulting in increased density (Nambiar & Ramamurthy, 2006a). Besides that, water quality is also important for fresh concrete properties, such as setting time and workability. It also gives an effect on the strength and durability of concrete. The water used in concrete should be clean and can drink. Quality of protein-based foamed agent might be affected by organic content (Amran et al., 2015).

2.4.4 Foaming Agent

The foaming agent is defined as a material that helps to form foam when added to fluids such as a surfactant or a blowing agent. Foaming agent will reduce the surface tension of a liquid which can easily form bubbles. The function of the agent foamed is to control density in the cement paste mixture through a rate of air bubble created (Amran et al., 2015). There are several types of foaming agent that used, which are rosin, synthetic surfactant, protein and compound type. Rosin is the first generation of the foaming agent. It includes rosin soap and hot rosin polymers. Then, the second generation of the foaming agent is a synthetic surfactant. The advantages of this foaming agent are easy to foaming and high foaming times, but there is a weakness which thin foaming wall, poor foam stability and significant influence on concrete strength. After that, the third generation of foaming agent is a protein, which are can be divided into two, plant protein and animal protein. Tea saponin type and saponin type that is include in the plant protein foaming agent. For the protein animal foaming agent, hydrolysed animal hoof horn, hydrolysed animal hair and hydrolysed blood glue included. Compound types are the fourth generation of a foaming agent, which is composed of multiple functional components. Generally, the foaming agent that widely used in the industry is the protein foaming agent. This is because protein foaming agent can produce stronger and more closed-cell bubble structure which can entrap a large amount of air and enable more stable air void network (Tikalsky, Pospisil, & Macdonald, 2004). The range of air void approximately from 6% to 35% of the total volume of the desired mix (Panesar, 2013). The air void spacing will give effect to the strength of concrete. It confirmed that the higher strength values could be achieved, the smaller the air void size distribution needed, but the larger air void will decrease the strength (Tikalsky et al., 2004). The quality of foam is essential because it is the main factor that can affect the strength and stiffness of foamed concrete (Nambiar & Ramamurthy, 2006b). The strength of foamed concrete depends on the type and content of the foam.

2.4.5 Processed Spent Bleaching Earth (PSBE)

Processed spent bleaching earth (PSBE) is a product from Spent Bleaching Earth (SBE) which is a waste created the material from edible palm oil. Processed Spent Bleaching Erath (PSBE) is very suitable to use in concrete mixing as a partial cement replacement. The percentage content of silica (SiO_2) in the PSBE compared to SBE after the bleaching process is less 5%, which is approximately 56.9%. When the silica in PSBE mix with Calcium Hydroxide ($Ca(OH)_2$) in the presence of water, the pozzolanic reaction will occur. The result from the reaction will produce additional C-S-H gels, which can help the durability of concrete to increase. Thus, decreasing the content of the calcium hydroxide will happen.

Hydration Process

$$\text{Cement} + H_2O = \text{C-S-H Gel} + Ca\,(OH)_2$$

Pozzolanic Reaction

$$SiO_2 + Ca\,(OH)_2 + H_2O = \text{C-S-H Gel}$$

Table 2.1: Chemical Composition of PSBE and SBE

Characteristic	SBE	PSBE
Free moisture (%)	10.5	0-1.8
pH (20% suspension)	4.6	4.5-5.3
Chemical composition (%)		
SiO_2	60.4	56.9
Al_2O_3	11.55	9.24
Fe_2O_3	9.3	8.27
MgO	5.2	4.32
CaO	1.7	3.90
Na_2O	0.4	0.08
K_2O	1.2	0.96
MnO_2	N/A	0.10
TiO_2	N/A	0.90
P_2O_5	N/A	4.87

Source: (Kheang et al., 2013)

2.5 Properties of Foamed Concrete

2.5.1 Compressive Strength

Compressive strength is a material's capacity to withstands loads that tend to decrease size. Concrete compressive strength between 93 and 871 ° C (200 and 1600° F) for 23-45 MPa (3300-6500 psi) solid concrete containing carbonate, silica and lightweight aggregate (D.A. Abrams, 1918). Other than that, parameter such as rate the rate of the foaming agent, the type of sand particles, the curing method, the water-cement ratio and the characteristics of additional ingredients and their distribution will affect the compressive strength (Amran et al., 2015). The most mechanical properties of concrete are compressive strength. Sandor confirmed that compressive strength was the most convenient to measure a concrete (Sandor Popovic, 1998). Compressive strength also can be a useful index of the number to determine the strength of concrete technically.

2.5.2 Drying Shrinkage

Drying shrinkage can be defined as contracting the hardened concrete mixture due to capillary water loss in concrete. This shrinkage can cause tensile stress to increase, which is cracking, internal warping and external deflection before the concrete is exposed to any loading. When the drying shrinkage is restrained, cracks may occur in concrete depending on the internal stress (Arbili, 2015). In slabs, beams, columns, bearing walls, prestressed members, tanks and foundations, the drying shrinkage usually occurs. There are several factors that depend on drying shrinkage, which are the properties of the components, the proportions of the ingredients, the manner of mixing, amount of moisture during curing, dry environment and member size. It was proven by Neville that, there was no coarse aggregate in the concrete leads to less shrinkage than mortar (Neville, 1995). Other than that, it is very complicated for foam concrete in the drying process. Charming Pang has stated it, shrinkage significantly increasing in the range of low moisture content (Wan, Li, Wang, & Pang, 2017).

2.5.3 Weight Loss

The loss of the weight of the concrete was related to the producing of the concrete. The concrete produced and cracking occurred can lead to the weight loss of the concrete.

Other than that, fire or temperature change factor in concrete causes differential ingredient volume changes, resulting in cracking and reduced durability (Sancak, Sari, & Simsek, 2008)(Xiang-ong, 2009). The concrete will lose strength and also the weight of the concrete also decreased or loss. The higher the temperature applied to the concrete, the higher the weight loss of the concrete(Chandramouli, P, T, & Sravana, 2011).

2.5.4 Carbonation

Carbonated concrete acts as a kind of "store" that permanently absorbs significant quantities of atmospheric CO2. Carbonation of the cover, however, threatens the durability of a structure by reducing the concrete's protective ability to reinforcement (Czarnecki & Woyciechowski, 2012). Carbonation also connected with the corrosion of steel reinforcement and shrinkage. In a high carbon dioxide environment, carbon-indueced corrosion in concrete can often occur (Ann et al., 2010). The carbonation will happen when the reaction between atmosphere Carbon Dioxide (CO_2) and Calcium Hydroxide ($Ca(OH)_2$) generated in cement hydration. Besides, the carbonation process indicates the diffusivity of CO_2 and the reactivity of the concrete with CO_2 are the factors controlling carbonation (Wang & Lee, 2009)(Collins, 2010). Carbonation will occur in concrete, but it can be reduced by using cement replacement such as fly ash. The higher resistance to carbonation was contributed by used fly ash as cement replacement in the mix (Amran et al., 2015).

Chemical Reaction: $Ca(OH)_2 + CO_2 = CaCO_3 + H_2O$

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter, all laboratory set up the preparation of materials and specimens discussed. All the preparation and laboratory test conducted at Concrete Laboratory, Universit Malaysia Pahang. Figure 3.1 shows the flowchart of this research.

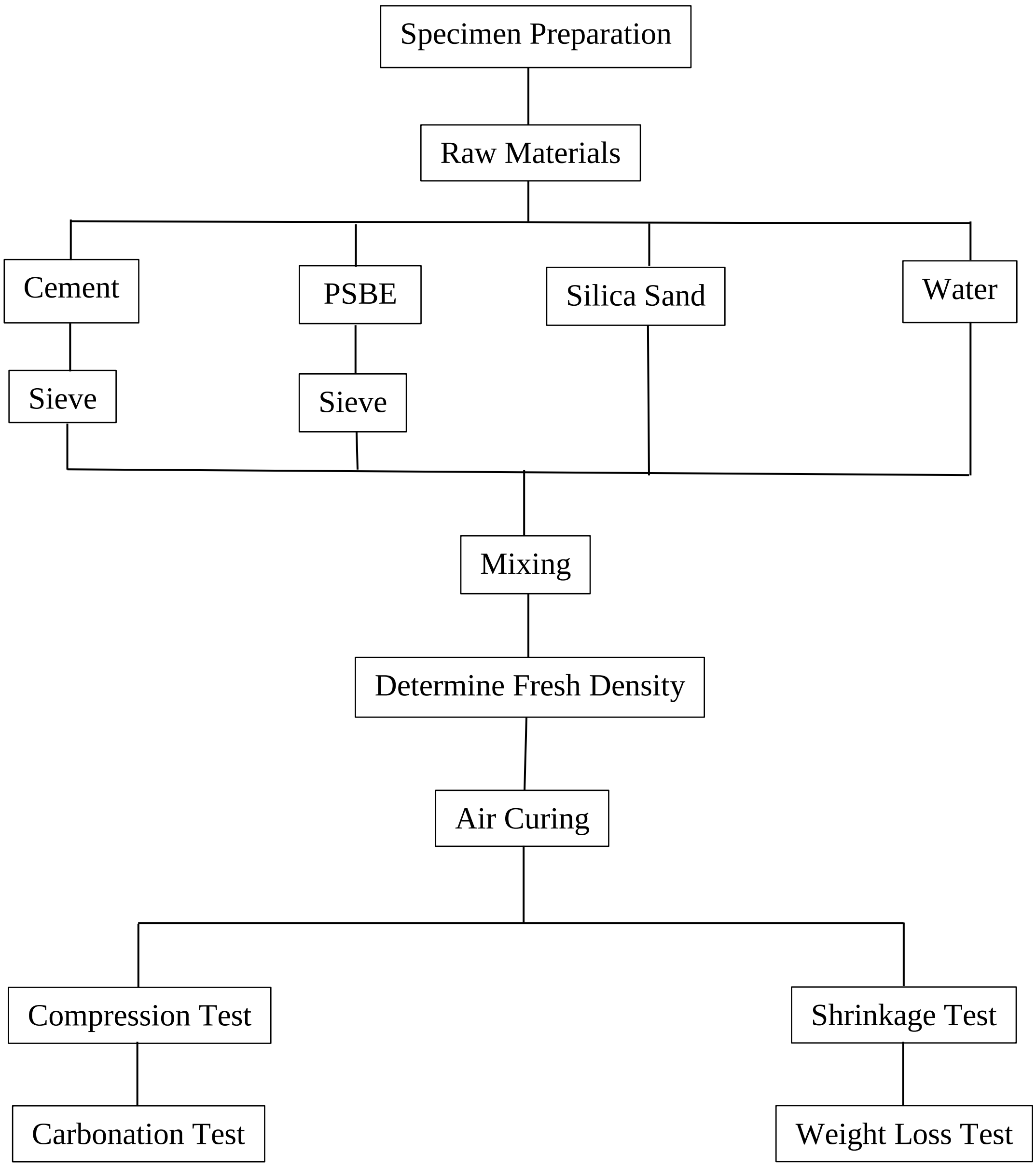

Figure 3.1: Flowchart of study

3.2 Constituent Material

The foamed concrete produced by using cement, sand, water, foaming agent, kenaf fiber and processed spent bleaching earth.

3.2.1 Cement

100% Ordinary Portland Cement (OPC) used throughout this study. The Portland cement was produced in Malaysia and widely used. The mixture of the cement prepared in Concrete Laboratory of Faculty of Civil Engineering and Earth Resources, Universiti Malaysia Pahang. Figure 3.2 shows the cement used for the concrete mixture.

Figure 3.2: Ordinary Portland Cement

3.2.2 Sand

Sand type used is Silica sand with size 425µm produced by Johor Silica Industries Technology Sdn. Bhd. for the concrete mixture. Figure 3.3 shows the sand used for this study.

Figure 3.3: Silica Sand

3.2.3 Water

In the case of concrete, the water demand needs to be carefully attended to. The w/c ratio (mass ratio of water to cement) was the key factor that determined the strength of concrete. Higher water to cement ratio produces a greater strength while lower water to cement ratio produces a lower strength of foamed concrete.

3.2.4 Foaming Agent

For this study, the protein synthetic foaming agent used. The density of the foam produced is in the range from 50kg/m^3 to 60kg/m^3. The preformed foamed in 25 liters of water by diluting 1 liter of the foaming agent. Figure 3.4 shows the foaming agent and Figure 3.4 shows the preformed foam.

Figure 3.4: Prefoamed foam

3.2.5 Processed Spent Bleaching Earth (PSBE)

In this study, Eco-Innovation Sdn. Bhd. has manufactured Processed Spent Bleaching Earth (PSBE) to be use and classified as Class N Natural Pozzolan by ASTM C618-12 (2012). Before mixing, the PSBE was dry under the sun for two days and sieved passing 300µm to get the fineness particle of the PSBE.

Figure 3.5: Processed Spent Bleaching Earth

3.2.6 Fiber

In this study, kenaf fiber used in producing foamed concrete. Before the kenaf fiber can be used, the kenaf fiber was cut into 5cm long and treated in Sodium Hydroxide for one day.

Figure 3.6: Kenaf fibre

3.3 Mix Proportion of Foamed Concrete

For this study, three types of the mixture were prepared namely foamed concrete (FC) as the controlled mixture, foamed concrete mixed with 30% PSBE (PFC) and combination foamed concrete with 30% PSBE and 0.5% kenaf fiber (PKC). Table 3.1 shows the mix proportion of the foamed concrete.

Table 3.1: Mix Proportion of Foamed Concrete

Mixture	Density (kg/m^3)	Cement (kg)	PSBE (kg)	Kenaf (kg)	Sand (kg)	Water (L)	Volume (m^3)
FC	1600	69.7	-	-	104.5	34.8	0.13
PFC	1600	48.8	20.9	-	104.5	28.3	0.13
PKC	1600	48.8	20.9	0.24	104.5	28.3	0.13

3.4 Production of Foamed Concrete

3.4.1 Mixing Process

In this study, silica sand, cement, water, PSBE, kenaf fiber and preformed foamed was mixing to form foamed concrete according to ASTM C796. Firstly, 25 liters of water was used to dilute 1 liter of foaming agent for preformed foamed into a foam machine. It was to ensure that the density of foamed must in range of 50 to 60 kg/m^3. After that, mixed the preformed foam with the cement paste continuously until the mix was homogeneously mixed. Then, weighted 1 liter of the fresh foamed concrete to determine the fresh density of 1600 kg/m^3. The workability of the fresh foamed concrete was determined by conducted flow table test according to ASTM C1437. The fresh foamed concrete was filled into the cubes and cured in air curing.

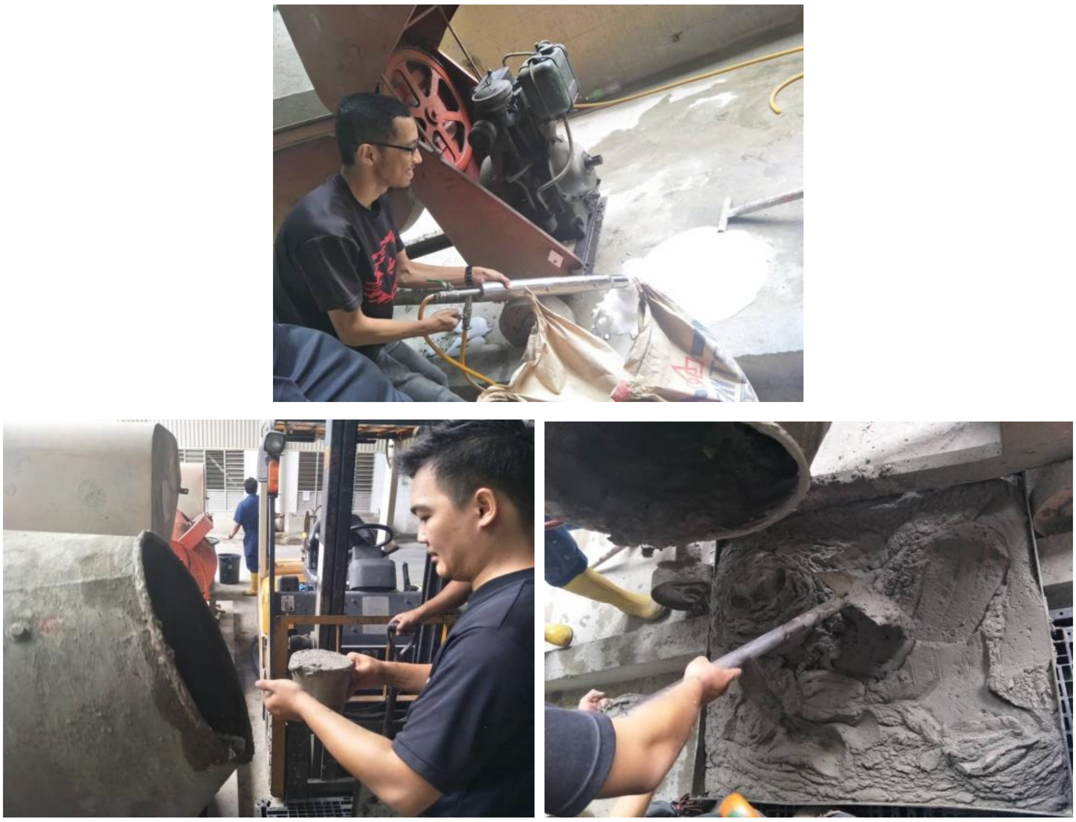

Figure 3.7: Mixing the materials

3.4.2 Preparation of Specimens

For this study, nine cubes specimens with the size of 150mm x 150mm x 150mm, nine mortar bar with size 40mm x 40mm x 160mm prepared for each mixing type according to ASTM C796.

Table 3.2: Number of Specimen Preparation

SPECIMENS	TESTINGS	FC			PFC			PKC		
		7d	28d	60d	7d	28d	60d	7d	28d	60d
150 x 150 x 150 mm	Compression Test	3	3	3	3	3	3	3	3	3
	Carbonation Test									
40 x 40 x 160 mm	Shrinkage & Weight Loss Test	Every day (28 days)								

Figure 3.8: Specimen after casting

3.5 Experimental Testing

3.5.1 Compression Test

In this study, the compression test has been done to determine the compressive strength on the cube specimens. The size of the specimens is 150mm x 150mm x 150mm and cured in air curing. There were three specimens have been a test for each of the curing day to obtain the compressive strength. The test conducted for the age of 7 days, 28 days and 60 days. In this test, the Universal Testing Machine (UTM) was used to test the compression of the specimens. The specimens have been prepared and placed at the center of the bearing plate between the upper and lower plain surface. Then, the upper and lower plain surface was positioned accordance properly with ASTM C109 Standards. After that, the specimen observed and record the maximum load that the specimen can accept.

Figure 3.9: Compression test set

3.5.2 Drying Shrinkage Test

To obtained shrinkage result, the reading is taken for each specimen until 28 days of curing. The size of the specimen is 40mm x 40mm x 160mm and cured in air curing. First, two shrinkage bullets glued on the mortar bar surface. The glue prepared by mixed the resin and adhesive then applied on the shrinkage bullets. The bullets glued on the surface of mortar in distance 100mm. The dial gauge was used to take the reading. This test followed by ASTM C157 – 14.

Figure 3.10: Equipment for shrinkage

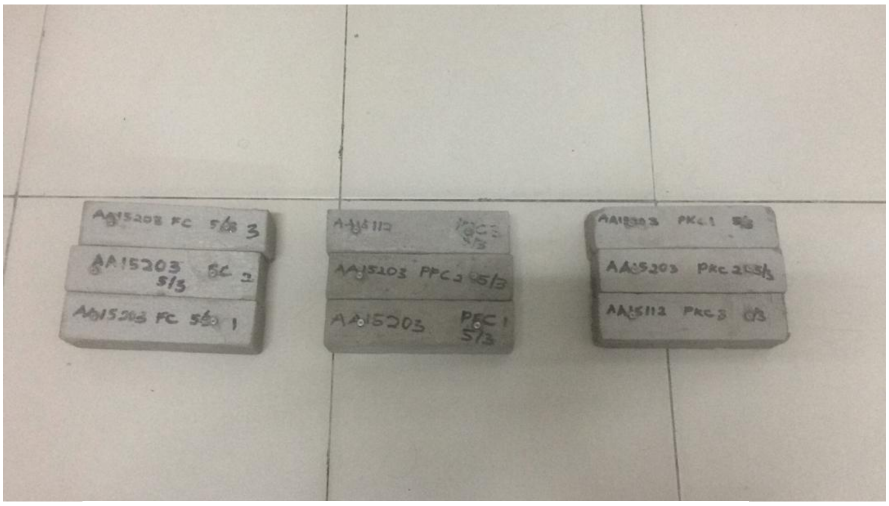

Figure 3.11: Specimen for shrinkage

3.5.3 Weight Loss Test

In this study, the weight recorded for each specimen for 28 days of curing to obtain the results of weight loss. The specimen was a weight on the analytical balance and the reading recorded. This reading is taken from the same three specimens and an average reading calculated. This test, followed by a previous research paper by (Kucharczyková et al., 2017).

Figure 3.12: The specimen was weight

3.5.4 Carbonation Test

In this study, the carbonation test conducted after the compression test. This test was conducted to determine the durability of foamed concrete against carbonation. Dilution of phenolphthalein used in this test as the indicator of carbonation and it sprayed on the splitting surface of the specimen. This test has been determined based on the British Standard BS 1181: Part 201: 1986.

Figure 3.13: Carbonation depth

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This research studied the effect of Processed Spent Bleaching Earth (PSBE) as cement replacement on the strength and durability of foamed concrete. Compression test has been conducted to investigate the effect of PSBE as partial cement replacement on the strength of the foamed concrete. Furthermore, it also included a discussion on the test result of drying shrinkage. Details results of the investigation on this studied presented as follow.

4.2 Compressive Strength

The result of the compression test necessary for determining the compressive strength of the concrete. Compressive strength was the strength of a material to withstand axial load. When the limit of compressive strength reached, the materials crushed or cracked. In this compression test, 18 specimens of the concrete mixture cast on cube mould. This mixture determined at age 7, 14 and 60 days in air curing and the average of two samples was taken for every testing age. The compression test results were given in Table 4.1 and Figure 4.1. In general, the higher concrete strength is mostly durable than the lower concrete compressive strength.

Table 4.1: Compressive Strength (MPa)

Mixture	Age (Days)		
	7	28	60
FC	2.437	4.414	5.326
PFC	3.584	6.042	9.018
PKC	3.247	5.424	6.785

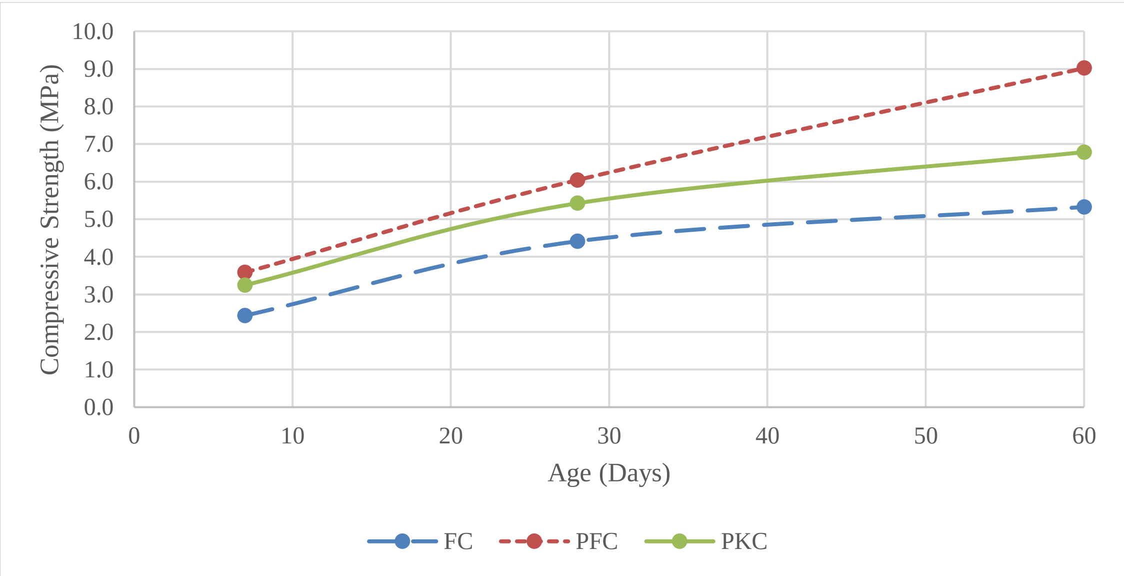

Figure 4.1: Compressive Strength (MPa) of Foamed Concrete

Figure 4.1 shows for all mixtures, increasing air curing period from 7 to 60 day will increase the compressive strength subjected to air curing. As compared to control FC, the compressive strength of foamed concrete containing PSBE as cement replacement was higher than the control mixture FC. Meanwhile, the mixture containing kenaf fiber, PKC was not contributed to the compressive strength of foamed concrete. This result shows that PFC was the higher compressive strength followed by PKC and FC for all aging days. It shown that the compressive strength of foamed concrete increased from 2.44, 3.25, and 3.58 MPa at day 7 to 4.14, 5.42 and 6.04 MPa at day 28 for FC, PKC and PFC respectively. At day 60, the increasing trend also the same, which is 5.33, 6.78 and 9.02 MPa for FC, PKC and PFC respectively. Overall, the highest value of compressive strength at day 28 is 6.04 MPa produced by foamed concrete with presence of PSBE. This shows substantial improvement compared to FC control which is 4.14 MPa only.

It observed that, the compressive strength has increases due to the presence of PSBE in foamed concrete as a cement replacement. The pozzolanic material that reacts from PSBE that makes the compressive strength of foamed concrete increased. The increasing trend was proved by (Aref, Aliyan, & Adarnaly, 2016) in agreement with their observation that the chemical reaction of pozzolanic materials with calcium hydroxide, in equation 1, have produced more calcium hydroxide gel in strength development thus improved the concrete strength. According to (Jitchaiyaphum, Sinsiri, Jaturapitakkul, & Chindaprasirt, 2013), it reported that a high percentage of silicon dioxide from pozzolanic materials produced more C-S-H gel and the amount of calcium hydroxide reduced to make the concrete stronger, denser and more durable.

4.3 Drying Shrinkage

The replacement of cement with PSBE influences the drying shrinkage of the foamed concrete. In this study, the drying shrinkage test conducted for each prism specimen with different mixtures. Furthermore,to determine the shrinkage strain of foamed concrete presence of PSBE as partial cement replacement, drying shrinkage was tested. The drying shrinkage test was carried out by measuring the length change of the prism specimen every day for 28 days.

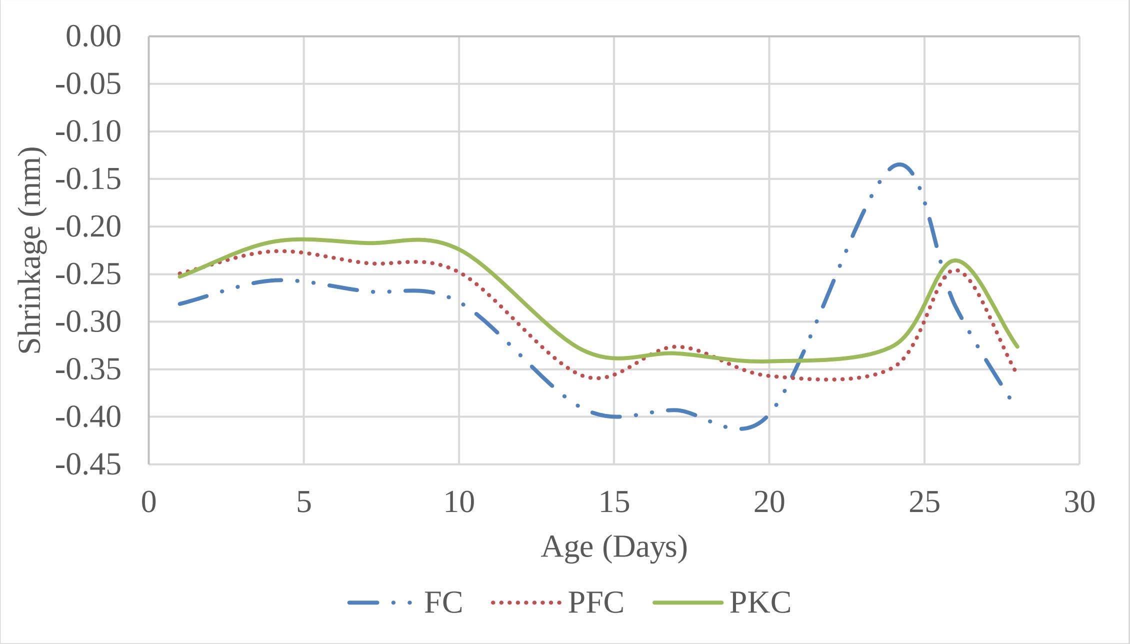

Figure 4.2: Drying Shrinkage of Foamed Concrete

From Figure 4.2, there was a big difference between readings of drying shrinkage of FC compared to PFC and PKC. However, the drying shrinkage on-air curing gradually increased and decreased. The different of the reading between the FC with PKC and PFC was quite big compared to the reading of PKC and PFC. Under the 28 days test period, all three specimens show a constant value of increase and decrease except for day 24th for FC and day 26th for PKC and PFC. For PKC and PFC, both data trend are the same because both PKC and PFC contain PSBE in the mixture compared to control FC. PKC has the lowest value of shrinkage due to the presence of kenaf fiber that played a role as reinforce used to reduce the formation of shrinkage. On the 28th days of curing, PKC obtained -0.3263 mm, PFC obtained -0.3557 mm and FC obtained -0.3937 mm for the shrinkage. It shows that PKC had the lowest shrinkage occurred, followed by PFC and FC.

4.4 Percentage Weight Loss Test

The replacement of cement with PSBE influences the weight loss of the foamed concrete. In this study, the weight loss test conducted for each prism specimen with different mixtures. Furthermore, the purpose of the weight loss test is to determine the percentage of weight loss of foamed concrete containing PSBE as partial cement replacement due to the drying shrinkage. The weight loss test was carried out by measuring the weight of the prism specimen every day for 28 days.

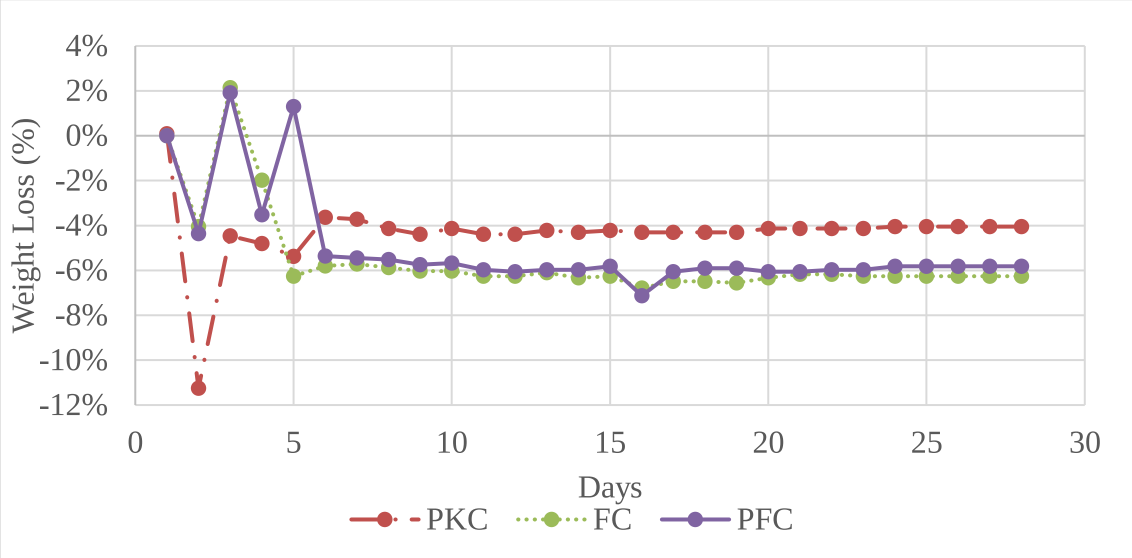

Figure 4.3: Percentage Weight Loss of Foamed Concrete

Figure 4.3 shows the percentage of weight loss of foamed concrete due to shrinkage behaviour. It indicates that the PKC had the smallest value of percentage weight loss of foamed concrete compared to PFC and followed by FC. This result was matching to the shrinkage which the lower amount of shrinkage, the lower amount of percentage of weight loss. It proved that the shrinkage influence to the weight loss of foamed concrete. On day 28th days of curing, the percentage weight loss for PKC is 4%, for PFC is 6% and for FC is 6%.

4.5 Carbonation Test

The replacement of cement with PSBE influences the durability of foamed concrete. In this study, the carbonation depth test conducted from a cube specimen after the compression test with different mixtures. Furthermore, the purpose of carbonation depth test is to identify the carbonation resistance of foamed concrete containing PSBE as partial cement replacement. The result of carbonation depth test of foamed concrete subjected to air curing as follow.

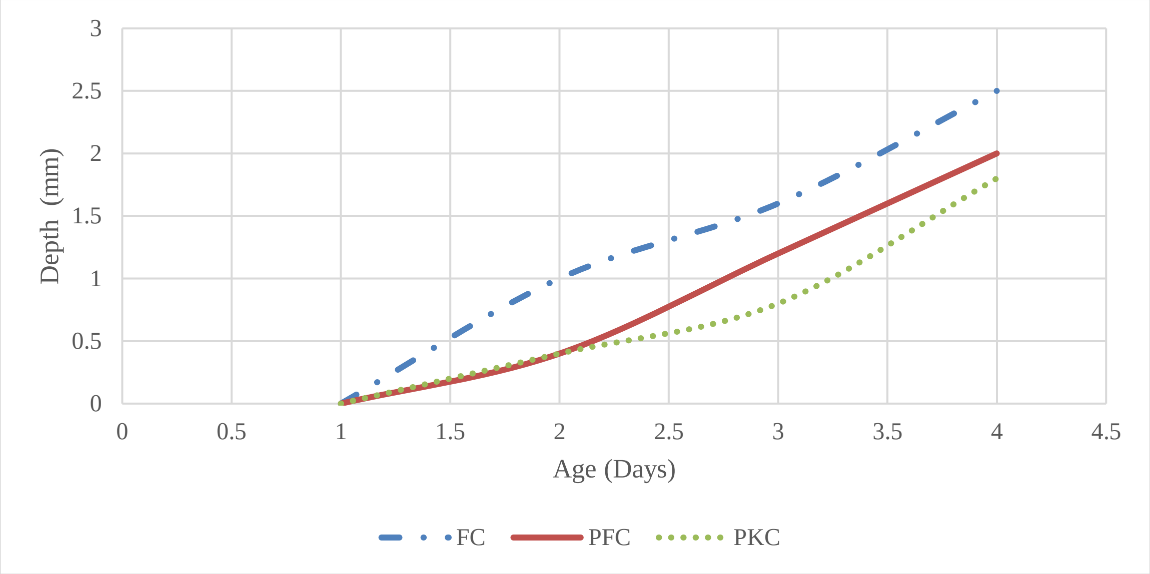

Figure 4.4: Carbonation depth of foamed concrete

Figure 4.4 shows the trend of carbonation depth from the all type of mixtures of foamed concrete. The depth of carbonation, an indicator of durability, decreased as the PSBE percentage increases. Control FC has the higher carbonation depth of foamed concrete compared to mixture with presence of PSBE as partial cement replacement. In addition, the carbonation depth of PSBE-containing concrete mixtures decreased with presence of PSBE in the mixture. It shows that the depth of carbonation for FC, PFC and PKC was 1.6 mm, 1.2 mm and 0.8 mm respectively at day 28. Hence, against the carbonation resistance, the durability of foamed concrete with presence of PSBE as partial cement replacement increased. In most mixtures, the FC shows the highest depth of carbonation. It shows that at the age 7 to 60 days, the carbonation depth of FC reached 2.5 mm.

Principally, foamed concrete has lower density than normal concrete, resulting in lower carbonation resistance of foamed concrete lower than normal concrete. Foamed concrete is not dense and very porous. Therefore, to forms calcium carbonate which results in carbonation, a hydration product called calcium hydroxide react with carbon dioxide in the surrounding that penetrate into the foamed concrete easily (Chun, Naik, & Kraus, 2007). It also was support by (Rostami, Shao, & Boyd, 2012) and (Younsi, Turcry, Rozière, Aït-mokhtar, & Loukili, 2011), concrete carbonation was made possible by the initial curing in a controlled environment, which allowed capillary spaces to penetrate

CO_2. Overall, a lower depth of carbonation resistance has been achieved by production of foamed concrete with presence of PSBE. Similar behaviour occurred for PKC at 28 days and 60 days of curing. By adding 30% PSBE as partial cement replacement as more hydrated calcium silicate and pozzolanic reaction, the foamed concrete become denser. Pozzolanic reaction produced by the hydration process consumed calcium hydroxide. Concrete carbonation resistance increasing due to the lower calcium hydroxide contains in the concrete because of carbon dioxide react with less calcium hydroxide to cause concrete carbonation. Similar agreement has been found that carbon dioxide diffuses in the cement matrix abd reacts to form calcium carbonate with calcium hydroxide (Suhaizad, 2011.)

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Introduction

In this chapter, it concludes the whole study at the previous section. The entire test that has been carried out essential to find out the engineering properties of Processed Spent Bleaching Earth (PSBE) as a replacement material for Ordinary Portland Cement in foamed concrete application. Some conclusions have been drawn out according to the analysis of results obtained from laboratory experiments in this study. There were still needs a lot of further studies, many of improvements for future works that can be made for this study to obtained and achieve a better and excellent result.

5.2 Conclusion

From the experimental data, it can be concluded that the Processed Spent Bleaching Earth (PSBE) as partial cement replacement in foamed concrete was improve the compressive strength, reduced the drying shrinkage and reduced the percentage weight loss of foamed concrete, and also durability against resistance carbonation. These studies have leads to prove that PSBE acts as pozzolanic material. Hence the foamed concrete containing PSBE performed a higher compressive strength, reduced drying shrinkage and percentage weight loss and carbonation resistance of foamed concrete. These is because silica provide in pozzolan material react with calcium hydroxide from the hydration process to form calcium silicate hydrate which contributes to the strength development on concrete. This process called a pozzolanic reaction. Increasing PSBE replacement resulted in low workability and denser concrete. In practical, the partial replacement of cement by pozzolan is known to improve the mechanical strength because chemical reactions of pozzolanic occurred when the Al_2O_3 and SiO_2 react with calcium hydroxide ($Ca(OH)_2$) to create additional Calcium silicate Hydrates (C-S-H) and Calcium Aluminate. The result proved that the use of PSBE as a partial cement replacement is highly useful in developing the strength and reduced rate of carbonation of foamed concrete as it increases the compressive strength, reduced the drying shrinkage and percentage weight loss, and carbonation resistance of foamed concrete. Meanwhile, the use of kenaf fiber in these studies did not contribute to the strength and carbonation resistance. It is only suitable for drying shrinkage, which helps to reduce the shrinkage occurred because kenaf fiber acts as reinforce used to reduce the formation of shrinkage.

5.3 Recommendations

Based on the study and laboratory works conducted, it is recommended to use PSBE as a construction material because it can reduce the carbon dioxide emission as it can replace cement content. Concrete with PSBE as partial cement replacement produced better strength and durability concrete. PSBE increased the durability and strength of concrete. This study shows that PSBE as cement replacement in foamed concrete will gives out a better result on the performance of PSBE as construction materials. However, further study should be conducted to improve its properties; it is recommended to:

- Conduct a series of investigation on higher and different content of PSBE as partial cement replacement in foamed concrete.
- Conduct a series of investigating on the effect of different curing condition methods of foamed concrete containing PSBE as partial cement replacement.
- Conduct a study on resistant of foamed concrete containing PSBE as partial cement replacement toward acid and sulphate attack.
- Conduct a series of investigation on fire resistance of foamed concrete containing PSBE as partial cement replacement.

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APPENDIX A
DRYING SHRINKAGE RESULT

Day	Bil	FC Shrinkage (mm)	PFC Shrinkage (mm)	PKC Shrinkage (mm)
1	1	-0.285	-0.244	-0.275
	2	-0.269	-0.238	-0.251
	3	-0.29	-0.266	-0.232
2	1	-0.303	-0.027	-0.296
	2	-0.265	-0.29	-0.269
	3	-0.324	-0.271	-0.278
3	1	-0.232	-0.196	-0.209
	2	-0.254	-0.228	-0.193
	3	-0.225	-0.215	-0.2
4	1	-0.25	-0.209	-0.229
	2	-0.245	-0.238	-0.207
	3	-0.275	-0.231	-0.212
5	1	-0.255	-0.213	-0.231
	2	-0.247	-0.253	-0.195
	3	-0.276	-0.234	-0.215
6	1	-0.254	-0.212	-0.23
	2	-0.242	-0.255	-0.202
	3	-0.273	-0.234	-0.211
7	1	-0.263	-0.214	-0.23
	2	-0.255	-0.261	-0.207
	3	-0.286	-0.24	-0.215
8	1	-0.274	-0.222	-0.243
	2	-0.268	-0.232	-0.245
	3	-0.3	-0.246	-0.226
9	1	-0.284	-0.299	-0.25
	2	-0.279	-0.266	-0.222
	3	-0.309	-0.256	-0.23
10	1	-0.275	-0.229	-0.241
	2	-0.265	-0.267	-0.211
	3	-0.298	-0.248	-0.22
11	1	-0.28	-0.233	-0.25
	2	-0.275	-0.275	-0.22
	3	-0.306	-0.254	-0.239
12	1	-0.281	-0.236	-0.253
	2	-0.281	-0.276	-0.221
	3	-0.311	-0.255	-0.241

13	1	-0.277	-0.226	-0.243
	2	-0.271	-0.27	-0.216
	3	-0.301	-0.248	-0.233
14	1	-0.387	-0.337	-0.351
	2	-0.377	-0.377	-0.315
	3	-0.41	-0.357	-0.324
15	1	-0.374	-0.324	-0.34
	2	-0.366	-0.37	-0.311
	3	-0.389	-0.348	-0.321
16	1	-0.369	-0.322	-0.42
	2	-0.362	-0.366	-0.31
	3	-0.378	-0.344	-0.326
17	1	-0.389	-0.26	-0.348
	2	-0.379	-0.37	-0.318
	3	-0.411	-0.349	-0.334
18	1	-0.387	-0.334	-0.351
	2	-0.376	-0.375	-0.322
	3	-0.389	-0.355	-0.335
19	1	-0.382	-0.328	-0.348
	2	-0.373	-0.375	-0.317
	3	-0.402	-0.352	-0.334
20	1	-0.395	-0.333	-0.358
	2	-0.382	-0.376	-0.328
	3	-0.415	-0.362	-0.339
21	1	-0.386	-0.329	-0.346
	2	-0.377	-0.375	-0.318
	3	-0.406	-0.348	-0.308
22	1	-0.282	-0.228	-0.248
	2	-0.276	-0.276	-0.218
	3	-0.31	-0.25	-0.229
23	1	-0.383	-0.322	-0.345
	2	-0.37	-0.373	-0.315
	3	-0.401	-0.35	-0.324
24	1	-0.38	-0.325	-0.342
	2	0.368	-0.37	-0.31
	3	-0.398	-0.349	-0.324
25	1	-0.387	-0.228	-0.236
	2	-0.374	-0.274	-0.21
	3	-0.31	-0.253	-0.225
26	1	-0.282	-0.225	-0.242
	2	-0.27	-0.266	-0.24
	3	-0.299	-0.246	-0.225

27	1	-0.283	-0.225	-0.245
	2	-0.271	-0.266	-0.21
	3	-0.3	-0.246	-0.266
28	1	-0.394	-0.332	-0.344
	2	-0.382	-0.378	-0.312
	3	-0.405	-0.357	-0.323

APPENDIX B
WEIGHT LOSS RESULT

Day	Bil	PKC weight loss (g)	FC weight loss (g)	PFC weight loss (g)
1	1	400	433	432
	2	414	449	434
	3	396	429	439
2	1	341	416	413
	2	347	432	415
	3	385	410	420
3	1	387	443	441
	2	388	448	443
	3	380	448	446
4	1	383	420	411
	2	386	436	420
	3	382	429	428
5	1	382	400	440
	2	382	423	440
	3	380	406	442
6	1	385	408	409
	2	399	423	411
	3	381	404	415
7	1	385	409	408
	2	399	423	411
	3	380	404	415
8	1	384	408	408
	2	395	422	410
	3	380	404	415
9	1	381	407	407
	2	397	422	409
	3	378	403	414
10	1	383	408	407
	2	397	422	410
	3	379	402	414
11	1	382	406	406
	2	396	421	408
	3	378	402	413
12	1	382	406	405
	2	396	421	408
	3	378	402	413

13	1	383	406	405
	2	396	421	409
	3	379	404	413
14	1	383	405	406
	2	396	421	408
	3	378	402	413
15	1	383	406	406
	2	397	421	409
	3	378	402	414
16	1	383	405	401
	2	396	419	402
	3	378	398	409
17	1	383	405	405
	2	396	420	408
	3	378	401	413
18	1	383	404	406
	2	396	420	408
	3	378	402	414
19	1	383	404	406
	2	396	420	408
	3	378	401	414
20	1	383	406	404
	2	397	420	408
	3	379	402	414
21	1	383	408	405
	2	397	420	408
	3	379	402	413
22	1	383	407	406
	2	397	420	408
	3	379	403	413
23	1	383	406	406
	2	397	420	408
	3	379	403	413
24	1	384	406	406
	2	397	420	409
	3	379	403	414
25	1	384	406	406
	2	397	420	409
	3	379	403	414
26	1	384	406	406
	2	397	420	409
	3	379	403	414

	1	384	406	406
	2	397	420	409
27	3	379	403	414
	1	384	406	406
	2	397	420	409
28	3	379	403	414

APPENDIX C
CARBONATION DEPTH RESULT

CARBONATION			
	DEPTH (mm)		
Age (Days)	FC	PFC	PKC
7	1	0.4	0.4
28	1.6	1.2	0.8
60	2.5	2	1.8