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EFFECT OF PROCESSED SPENT BLEACHING EARTH AS PARTIAL CEMENT REPLACEMENT ON THERMAL CONDUCTIVITY AND POROSITY OF FOAMED CONCRETE

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EFFECT OF PROCESSED SPENT BLEACHING EARTH AS PARTIAL CEMENT REPLACEMENT ON THERMAL CONDUCTIVITY AND POROSITY OF FOAMED CONCRETE

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Thesis submitted in fulfillment of the requirements
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In the Name of Allah, the Beneficent, the Merciful

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ABSTRAK

Konkrit berbusa merupakan konkrit ringan yang mempunyai lompang-lompang udara. Ianya berbeza dengan konkrit lain dimana tidak mengandungi batuan kasar di dalam bancuhannya. Konkrit ini dihasilkan dengan mencampurkan buih ke dalam bancuhan simen dan pasir silika semasa konkrit masih dalam keadaan buburan. Secara praktiknya bahagian simen akan digantikan dengan kapur. Processed Spent Bleaching Earth (PSBE) adalah diantara bahan terkini dalam kumpulan minyak sawit mentah. Ia diproses sehingga menjadi butiran halus dan bahan ini diklasifikasikan sebagai bahan pozolana yang bermutu. Penyelidikan ini bertujuan untuk mengenalpasti samada PSBE boleh digunakan sebagai bahan separa gantian simen dalam konkrit berbusa. Pemerhatian dilakukan terhadap sifat keberaliran haba dan peratusan keliangan. 10%, 20% dan 30% PSBE digantikan sebagai kandungan simen. Agen pembuihan digunakan bagi menghasilkan buih dan membentuk lompang udara di dalam konkrit berbusa. Didapati 30% PSBE memberikan hasil yang bagus dan mengurangkan peratusan liang di dalam konkrit berbusa. Ketumpatan konkrit juga bertambah dengan penambahan PSBE. Secara umumnya aspek keberaliran haba dan peratusan liang berkait rapat dengan sifat-sifat pozolana dan kajian ini menekankan dua aspek ini.

ABSTRACT

Foamed concrete is categorized as a lightweight concrete containing air voids. The only difference is that foamed concrete does not contain coarse aggregate in its mixture. Foamed concrete is produced by inducing foam into the slurry of cement mixing with silica sand. In practice, the cement is usually replace with lime. Processed Spent Bleaching Earth (PSBE) is one of the latest Crude Palm Oil (CPO) product. After it has been degummed and bleached, it will come in fine particle and it is classified as a good pozzolanic material. The study investigates the suitability of PSBE as partial cement replacement. The scope of study includes the thermal conductivity and porosity percentage. 10%, 20% and 30% of PSBE will be replacing cement. Foaming agent is used to form air void in foamed concrete. The results turns out that for thermal for 10% PSBE cement replacement at 28 days gets the best reading which is 0.52 W/m.K. For porosity, the result shows that porosity for 30% PSBE foamed concrete achieved the result at 90 days with 17.9% compared to controlled sample. 21.4%. Foamed concrete density also increase when the PSBE percentage increase. Generally thermal conductivity and porosity percentage is one of pozzolanic material characteristic and this study will emphasize this two aspect.

TABLE OF CONTENT

DECLARATION

TITLE PAGE

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

PSBE	Processed spent bleaching earth
FC	Foamed conrete
ASTM	American Society for Testing and Materials
BS EN	British Standard European Norm
FKASA	Fakulti Kejuruteraan Awam dan Sumber Alam
UMP	Universiti Malaysia Pahang
SBE	Spent bleaching earth
C-S-H	Calcium silicate hydrate
OPC	Ordinary Portland Cement
EPP	Eco Process Pozzolanic
PFA	Pulverised Fuel Ash
GGBS	Ground Granulate Blast-furnace Slag
RILEM	The International Union of Laboratories and Experts in Construction Materials, Systems and Structures

CHAPTER 1

INTRODUCTION

1.1 Background Study

Malaysia is a developing nation that aiming to be a fully developed country by the year 2020. In order to achieve the vision , engineer of today need to come up with more and more sophisticated technologies and brilliant idea to create products that will save people time, money as well as sustaining the environment. As a developing country, Malaysia desire to implement National Green Technology Policy which headed by the Prime Minister Najib Tun Abdul Razak himself. Malaysia is set to become the largest green construction sector in the South-east Asian region.

The mentioned initiative are as a result of the rising demand for cement in construction industry. Cement is an important construction ingredient around the world, and as a result, cement production is a significant source of global carbon dioxide (CO2) emissions, making up approximately 2.4 percent of global CO2 emissions from industrial and energy sources (Gibbs, Soyka, & Conneely, 2000). Nowadays, construction‘s company seek for cement that are more lighter, durable, practical, economic and environmental sustainable materials to meets their requirement on construction. Foamed concrete also known as less density cement is the combination of cement paste and preformed foams that causes the foamed concrete to be lighter than normal concrete. Recycled materials were becoming more popular as ingredients in concrete due to higher public awareness about ecological sustainability and environmental damage. The new invented of new concrete mixture using the waste materials is now being practiced in order to improve the wastage produced in Malaysia to become wealth and applicable used in the construction buildings. One of the waste materials used in this study is the spent bleaching earth (SBE) in mixture which has potential to become one of the mixtures in concrete due to its high physical strength and gives less effect to the concrete.Four types of mixture of foamed concrete namely FC with 100% of OPC as control sample and 10%, 20% and 30% SPBE. All the specimens have been prepared and tested to determine the compressive strength, porosity and thermal conductivity.

1.2 Problem Statement

Foam concrete is a lightweight material consisting of Portland cement paste or cement filler matrix (mortar) with a homogeneous void or pore structure created by introducing air in the form of small bubbles. High air contents results in lower densities, higher porosities and lower strength (Kearsley and Wainwright, 2001). In view of the importance of saving of energy and conservation of resources, it is essential to find a functional substitute of cement in manufacture of FC (Wu *et al.*, 2017). Cement is one of the very important raw materials in construction industry. However, cement factory emitted Carbon Dioxide (CO2) during the production to the surrounding. The higher rate of the construction had caused the increase rate of demand for production of cement in factory. As a result, cement production is a significant source of global CO2 emissions, making up approximately 2.4% of global CO2 emissions from industrial and energy sources (Gibbs et al., 2000). The amount of CO2 emitted to surrounding is based on the amount tonnage production in factory. The production of one ton of cement production consumes about 1.6MWh energy and discharge about one tonne of carbon dioxide into the atmosphere (Narayanan & Ramamurthy, 2000). Malaysia has produced 19,500 thousands metric tons of cement in 2010 (Indexmundi, 2013). Hence, Malaysia had produced 17.55 million of CO2 to the atmosphere. The emission of CO2 will cause to serious greenhouse effect to the global.

1.3 Objectives

The goal of this study is to investigate the fitness of Processed Spent Bleaching Earth (PSBE) as partial cement replacement in foamed concrete. The specific objectives of this study are:

1. To investigate the effect of PSBE as partial cement replacement on thermal conductivity of foamed concrete
2. To investigate the effect of PSBE as partial cement replacement on porosity of foamed concrete
3. To investigate the effect of PSBE as partial cement replacement on the relationship between thermal conductivity and porosity of foamed concrete

1.4 Scope of Work

The goal of study is to investigate the performance of PSBE in foamed concrete properties as partial cement replacement. It is focused on the influence of PSBE on the thermal conductivity, porosity and their relationship due to water curing at 28, 60, and 90 days. The study is divided into four main phases as follows:

1. Phase 1 is to prepare Portland cement, silica sand, preform foamed and sieve analysis.
2. Phase 2 is to add PSBE for the cement replacement in concrete mixtures. The percentage of PSBE used is based on 4 different proportion.
3. Phase 3 is to test the performance of PSBE according to thermal conductivity test and porosity test

All the material and specimens preparation are conducted based on standard code of practice design requirement of British Standard at FKASA laboratory, Universiti Malaysia Pahang, Gambang Malaysia.

1.5 Significance of Study

This significant of this study is to learn about the performance of PSBE foam concrete in mechanical properties. Besides that, this study was using PSBE as the waste material is becoming useful and makes benefits to the construction industry for better and greener environment

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discussed the previous study of cement replacement in foamed concrete. It is important to understand the foamed concrete in term of its material, production and properties

2.2 Foamed Concrete

2.2.1 Definition and evolution

Foam concrete, also known as foamed concrete, foamcrete, cellular lightweight concrete or reduced density concrete, is defined as a cement based slurry, with a minimum of 20% (per volume) foam entrained into the plastic mortar. As mostly no coarse aggregate is used for production of foam concrete the correct term would be called mortar instead of concrete. Sometimes it may be called as “Foamed Cement” or

“Foam Cement” because of mixture of only Cement & Foam without any fine aggregate. The density of foam concrete usually varies from 400 kg/m³ to 1600 kg/ m³. The density is normally controlled by substituting fully or part of the fine aggregate with foam. Cellular Concrete was first developed in Stockholm, Sweden in the early 1900‘s. The original material was known as “gas concrete” to be used in producing heat-insulated building materials. This led to the development of related lightweight concrete which are now known as cellular concrete, foamed concrete, aerated concrete and autoclaved cellular concrete. (The Contributors, 2015)

After the Second World War, this technology quickly spread to different parts of the world, mostly Europe and the Soviet Union. The applications were for economical large-size structural panel units. These were used in site reconstruction and low-rise structures. It wasn‘t till the late 1950‘s when this was introduced to the United State as foamed or cellular concrete. The applications were for floor, roof and wall units. Having low compression strengths, it limited this product to fills and insulation only. Following this research, new admixtures were developed in the late 1970s and early 80s, which led to the commercial use of foamed concrete in construction projects. Initially, it was used in the Netherlands for filling voids and for ground stabilisation. Further research carried out in the Netherlands helped bring about the more widespread use of foam concrete as a building material. (Lcc, 2003)

2.2.2 Application of Foam Concrete in Construction

Foamed concrete is a versatile material. It is possible to produce with pigments, accelerators, retarders, fibres, fast setting cements, pozzolanic cements, recycled fillers and rheology controllers to tailor the workability, strength development rate and other properties to suit a wide range of applications. Its traditional use is for trench reinstatements, as it is self-compacting (eliminating the ‘white finger’ vibration exposure problem of compacting conventional granular fill), does not settle and its load- spreading characteristics prevent direct transmission of axial loads to services. Its ability to flow easily under its self-weight has led to its use in void filling, including old sewerage pipes, wells, cellars and basements of old buildings, storage tanks, tunnels and subways. Because of its good thermal properties, foamed concrete has been used as an insulating material on roofs, in housing foundations and floors. Its inherent fire resistance has also been exploited in a wide range of uses, such as tilt-up firewalls, vaults etc. Foamed concrete has also been used successfully in bridge foundations, instead of other backfill materials or to provide soil stability on embankment slopes and enhance its bearing capacity with cast-in-place foamed concrete piles. Other applications include precast elements, in raft foundations of houses, as a foundation- layer for sports fields and athletic tracks, for annulus grouting of segmental tunnels, backfilling the voids behind tunnel linings, providing base for storage tanks or as blinding material. Sources by (Society, n.d.)

2.3 Constitutional material of Foamed concrete

Foamed concrete is quite simply mortar with lots of air bubbles in. In fact it is not actually concrete at all and contains no aggregates, so does not offer the same characteristics. The air content is generally between 50% and 75% by volume which makes it a very lightweight and easily free flowing material. It has a range of unique features that make it the ideal solutions for a variety of applications.

Foamed concrete is easy to place, pour or pump to the required location, it does not need to be compacted or vibrated/levelled, it is resistant to frost, water and cracking, and provides great sound and heat insulation. Foamed concrete can be made using a range of different mix designs to suit different purposes and so it almost always needs to be mixed on site to suit the job at hand.

2.3.1 Cement

Cement play important role as binder for the sand to form foamed concrete. In concrete, cement bind with water and turn harder by chemical reaction (Brocken & Nijland, 2004). Cement have place in the place which away from water because it very sensitive to water. Cement will turn harden once it near water (Davidson, 1977). According to (Kearsley and Wainwright, 2001) on their research, with used of rapid hardening Portland cement from Pretoria Portland Cement (PPC) the compressive strength of foamed concrete with densities of 1500 kg/m3 increasing at an early stage (7 days) and showing no significant reduction in strength. This is because cement has low solubility and low diffusivity, hence, make the hydration processes more rapidly (C.A. Hendriks *et al.,* 2002)

2.3.2 Sand

(Amran, Farzadnia and Ali, 2015) reported that with density of 1000kg/m^3 to 1800kg/m^3 for 0% to 100% Fly Ash as pulverized river sand replacement cause increase in surface area, thus necessitate higher water demand. When replacing sand with fly ash by mass, the consistency of the mix is reduced due to a higher fines content. So, an increase in the water–solids ratio is required with an increase in the fly ash replacement level in sand

2.3.3 Water

The amount of water to be added to the mix depends upon the moisture content of the sand, but as an average figure, 40-45 liters of water is used for every 100 kilograms of cement. Additional water is added as a content of the foam, thereby bringing the total water cement ratio up to the order to 0.6. In general, when the amount of foam is increased, as for lighter densities, the amount of water can therefore be decreased. (Pacific, n.d.). The w/c ratio should be kept as low as possible in order to avoid unnecessary shrinkage in the moulds, however, it should be remembered that, if the amount of water added to cement and sand in the first instance it too low, the necessary moisture to make a workable mix will be extracted from the foam when it is added, thereby destroying some of the foam which is naturally an expensive way of adding water to the mix. (Pacific, n.d.)

2.3.4 Foaming Agent

According to (Johnson Alengaram *et al.*, 2013) from the research that has been conducted, foamed concrete is produced by using mortar or cement paste in which large volume of air are entrapped by using a foaming agent. There are various type of foaming agent that can be used to produce foamed concrete, including detergent, saponin, and hydrolysed proteins, such as keratin and similar materials. The prominent advantage of foamed concrete is its lightweight, which economies the design of supporting structures including the foundation and wall of lower floor. It also been reported by (Narayanan and Ramamurthy, 2000) that aluminum powder as foaming agent provides a high degree of thermal insulation and considerable savings in material due to the porous structure.

2.4 Production of Foamed Concrete

Foamed concrete is a cementious paste of neat cement or cement and fine sand with a multitude of micro/macroscopic discrete air cells uniformly distributed throughout the mixture to create a lightweight concrete. It is commonly manufactured by two different method. Method A, consists of mixing a pre-formed foam [surfactant] or mix-foaming agents mixture into the cement and water slurry. As the concrete hardens, the bubbles disintegrate leaving air voids of similar sizes.

Method B, known as Autoclaved Aerated Concrete [AAC] consists of a mix of lime, sand, cement, water and an expansion agent. The bubble is made by adding expansion agents [aluminum powder or hydrogen peroxide] to the mix during the mixing process. This creates a chemical reaction that generates gas, either as hydrogen or as oxygen to form a gas-bubble structure within the concrete. High carbon ash, recycled aluminums waste and zeolite powders are additional mechanical structures suitable in the production of cellular lightweight concrete. (Lcc, 2003)

2.5 Processed Spent Bleaching Earth

Spent Bleaching Earth is a solid waste material generated as a part of the refining process in the edible oil industry, worldwide. Spent Bleaching Earth is usually disposed of in landfills or waste dumps. Due to increasing cost of disposal and being an environmental hazard, it is desirable to recover oil using a Solvent Extraction process in an efficient and economical manner, before disposing off Spent Bleaching Earth as per environmental regulations.

It usually contains 20-40 wt.% oil by weight (Eliche-Quesada and Corpas-Iglesias, 2014) and these oils retained and not removed by filter pressing may possess the pyrogenic nature due to the instauration The output de-oiled Spent Bleaching Earth is safe for disposal in land fill. The disposal of SBE to landfill may be limited by strict environment regulations in the near future (Loh *et al.*, 2017). It can also be used as a fuel in the boilers. The anhydrous clay can be used in cement manufacturing. It can also be used in manufacturing fertilizers containing silica/silicates or can be used as a soil amendment, as it poses no harm to the soil and acts as a soil conditioner

When the oil is being extracted away, it turns into Processed Spent Bleaching earth, pozzolanic material with the same characteristic as cement

2.6 Properties of Foamed Concrete

2.6.1 Thermal Conductivity

Thermal conductivity refers to the amount/speed of heat transmitted through a material. Heat transfer occurs at a higher rate across materials of high thermal conductivity than those of low thermal conductivity. Materials of high thermal conductivity are widely used in heat sink applications and materials of low thermal conductivity are used as thermal insulation. Foam concrete are widely known for its thermal insulator properties(Noraini M Zahari A Mujahid A Zaidi, 2009). Also, concrete density plays significant role in thermal conductivity, whether cured using autoclave or conventional method (air and water), it will gives the same result. Number of pores and its distributions can affect thermal conductivity. Insulator is more effective when the pore produce is much smaller. As stated by, moisture content can also affect thermal conductivity (with an addition of every 1% moisture content, there will be an increase of 42% of thermal conductivity rate). The main factor that contribute to thermal conductivity is the density.

2.6.2 Porosity

In this study, the porosity test of foamed concrete was carried out by following BS EN 1881:122 (BS EN 1881:122, 2013). The porosity test was used to identify the durability of the foamed concrete specimen. The percentages of air void which consists in the specimen can be determined by porosity test. Besides identifying the durability of the specimen, porosity test also can identify the rate penetration of water into the specimen. For the specimen which have high porosity rate resulted in low durability. Hence, reduce porosity of the specimen will increase the durability of the specimen. This happened because the air void consisted in the specimen is higher. The reduction of porosity was due to finer and lighter particles of EPP as compared to OPC (Jiang *et al.*, 2016). Therefore, the liquid will easily penetrate into the specimen.

Previous study on porosity (Miled and Limam, 2016) reported that, with density of 1400 kg/m3 Alkali Activation (AA) cementless mortar pastes using GGBS with a higher fineness had a lower porosity, fewer unhydrated particles, and denser surface. It has been observed that the porosity of

AA containing GGBS decrease as the increased percentage of GGBS in the mix. Also stated by (Lim *et al.*, 2013) by using vacuum saturation method to determine porosity for both cement - sand and cement-sand-fly ash mixes, even with a reduction in density of foamed concrete, the porosity increase. This is because a relatively higher water-solids ratio produce a weaker and pervious matrix, leading to higher capillary porosity which is in turn responsible for the increase in water absorption of mixed with fly ash.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter discussed the steps to perform the testing, preparation of materials, mixing and testing. All the preparation work and testing are carried out in the Concrete Laboratory of civil Engineering and Earth resources at University Malaysia Pahang (UMP).

Figure 3.1 showed the flowchart of the study. In this case, the laboratory works were carried out step by step to achieve the objectives. The flowchart was start with preparation of materials, casting of specimen and testing sample.

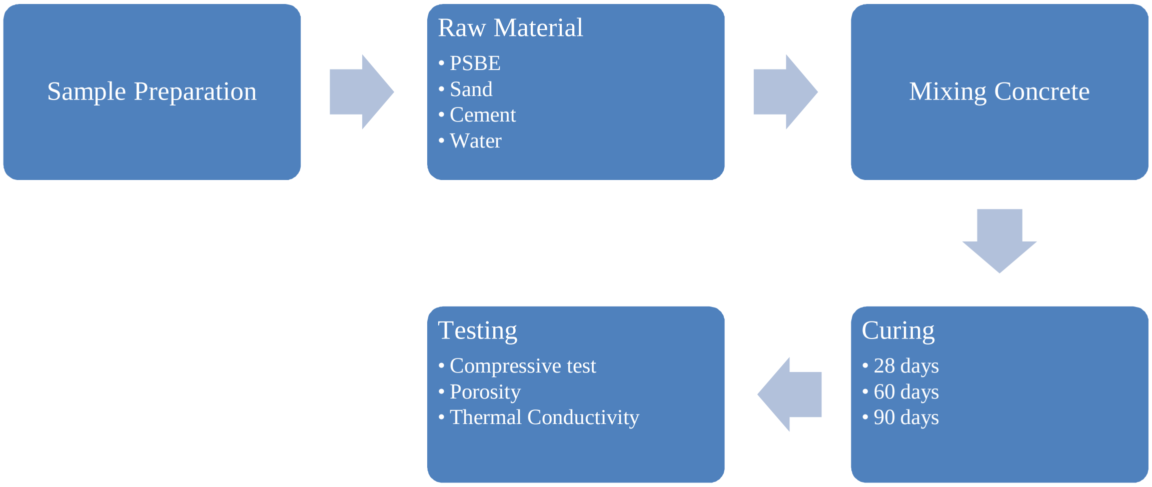

Figure 3.1 Flow chart of sample preparation

3.2 Preparation of Material

In this study, the material used has been prepared and discussed as follow.

3.2.1 Processed Spent Bleaching Earth

Processed Spent Bleaching Earth (PSBE) used in this study was supplied by Eco Innovation Sdn. Bhd. The grain size for this PSBE is 300 µm. PSBE was classified as Class N Natural Pozzolan in accordance with ASTM C618-12 (2012)

Figure 3.2 Processed Spent Bleaching Earth

3.2.2 Cement

The type of cement used is 32.5 MPa Ordinary Portland cement Type I (OPC) also known as ‘Orang Kuat’ produced by YTL Cement Sdn. Bhd. Table 3.1 shows the chemical composition of OPC used in this study

Table 3.1 Chemical composition of OPC

CaO %	55.49
SiO_2 %	26.49
Al_2O_3 %	9.81
Fe_2O_3 %	3.9
MgO %	0.8
SO_3 %	4.72
Loss on Ignition %	0.88
BET Surface Area %	1.29

Figure 3.3 Ordinary Portland Cement

3.2.3 Sand

Sand that are used in this Samsung Starex silica sand. It was sieved same as PSBE passing sieve size BS 300 µm

Figure 3.4 Silica sand

3.2.4 Water

Water played the major roles in the concrete production. The presence of water in concrete mixing is to promote hydration. Water also facilitates mixing placing and compacting of the fresh concrete and also for curing process of concrete. Water must be clean from impurities. Tap water is used in this research because impure water can have adverse effect to the strength of the concrete. Figure 3.5 show the tap water utilized throughout the study.

Figure 3.5 Tap water

3.2.5 Foaming Agent

Figure 3.6 Foaming agent

3.3 Preparation process

First step is preparation of mortar paste or slurry preparation. Fill the mixer drum with cement, silica sand and PSBE and mix dry the constituents for a few minutes and add water and mixing it until the slurry becomes homogenous. The density and the workability of the slurry are measure before and after the pre foamed foam added. In this study, density is obtained by measuring 1 liter of slurry by beaker and weights it. Second step is preparation of pre formed foam by mixing 1 liter of foaming agent with 25 liters of water into the foam machine. Start the machine and control the air compression until it reach the density of foamed in range 50 to 60 kg per meter cube. Next stage is combining the foam into the cement slurry after flow table test is tested.

Foam is added into the cement slurry and mixing it continuously until the foam is smooth and homogenously mixed with the slurry during the mixing. After that, take reading of fresh foamed concrete density by measuring 1 liter of mix and weight it.

Figure 3.7 Measuring weight of 1 liter of foam

Cube of 100mm x 100mm x 100mm were cast and put in water curing for 28, 60 and 90 days. There were four types of mixtures; normal 1600kg/m^3 foamed concrete cube, 10%, 20% and 30% with partial cement replacement and they were labelled as PFC, PFC1, PFC2 and PFC3 respectively. It were put in oven for 24 hours and left to room temperature for 2 hours before testing.

Figure 3.8 Curing process

3.4 Testing Method

3.4.1 Thermal Conductivity

The thermal conductivity test was performed at the age of 28 days, 60 days and 90 days in accordance with BS EN 12664. The samples were oven dried for 24 h at a temperature of 105 ± 5C to remove any moisture present. The samples were placed between hot and cold plates with a temperature of 40C and 18 C, respectively, to stimulate the exterior and interior temperature. The temperatures on the hot and the cold plates were recorded at every 60 min for 8 h and the data recorded. The mean values of the recorded temperatures were used in the calculation of the thermal conductivity.

The thermal conductivity of the foamed concrete specimen was calculated using Fourier’s law as given below in Eq. 3.1:

$$k = \frac{\varphi \times t}{A \times \Delta T} \qquad \textit{Eqn 3.1}$$

where:

k = thermal conductivity (W/mK),

φ = heat flow (J/s),

t = thickness of specimen (m),

A = area of specimen (m) and

ΔT = temperature difference between hot and cold plates

3.4.2 Porosity Measurement

The porosity of foamed concrete was determined through the Vacuum Saturation method. The measurements of foamed concrete porosity were conducted on slices of 68 mm diameter cores cut out from the centre of 100 mm cubes. The specimens were heated to predetermined temperature (ambient, 200 C, 400 C and 600 C) until constant weight had been attained and were then placed in a desiccator under vacuum for at least 3 h, after which the desiccator was filled with de-aired, distilled water. The porosity are calculated using Eq 3.2:

$$P = \frac{W_s - W_d}{W_s - W_w} \times 100\% \qquad \textit{Eqn 3.2}$$

Where,

P= porosity percentage

W_{sat} = weight in air of saturated sample

W_{dry} =weight in water of saturated sample

W_{wat} =weight of oven dried sample

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Thermal Conductivity

Thermal conductivity were done with data logger with interval of 15-minutes. From Table 4.1, the thermal conductivity increase as the increase of percentage of PSBE. And within each sample type, the thermal conductivity increase as the increase of days. This happened due to formation and size of pore that consist inside FC. The increase of PSBE makes it denser. Air is a good thermal insulator. The thermal conductivity gives a better result as the density decrease. Also this was due to different formations and size of pores on the microstructure formation of FC (Liu *et al.*, 2014)

Table 4.1 Thermal conductivity, k (W/m.K)

Sample	**28-day**	**60-day**	**90-day**
PFC	0.5	0.53	0.55
PFC1	0.52	0.55	0.56
PCF2	0.52	0.56	0.56
PFC3	0.55	0.57	0.57

For control sample, PFC shows 0.5 W/m.K at 28 days, increase gradually to 0.53 W/m.K at 60 days and increase 0.53 W/m.K at 90 days. For PFC1, at 28 days it decrease 0.003%, with 0.52 W/m.K. At 60 day 0.55 W/m.K and increase at 90 days with 0.56 W/m.K. For PFC2 the reading shows the same with PFC1 at 28 days, 0.52 W/m.K, increase and remain constant at 60 and 90 days, with 0.56 W/m.K. Lastly for PFC3 the first 28 days shows 0.55 W/m.K .increase in 60 and 90 days with 0.57 W/m.K and 0.57 W/m.K, respectively.

Based on Figure 4.1, for PFC and PFC3, it is clearly that PFC have better thermal conductivity with 0.5 W/m.K. This is because of PFC3 has higher density compared to PFC, as higher density gives higher thermal conductivity. Compared to Johnson Alengaram (Johnson Alengaram *et al.*, 2013), for density 1600 kg/m^3, he obtained the thermal conductivity is 0.57 W/m.K when added Fly Ash as partial cement replacement. This proved that higher density gives higher thermal conductivity

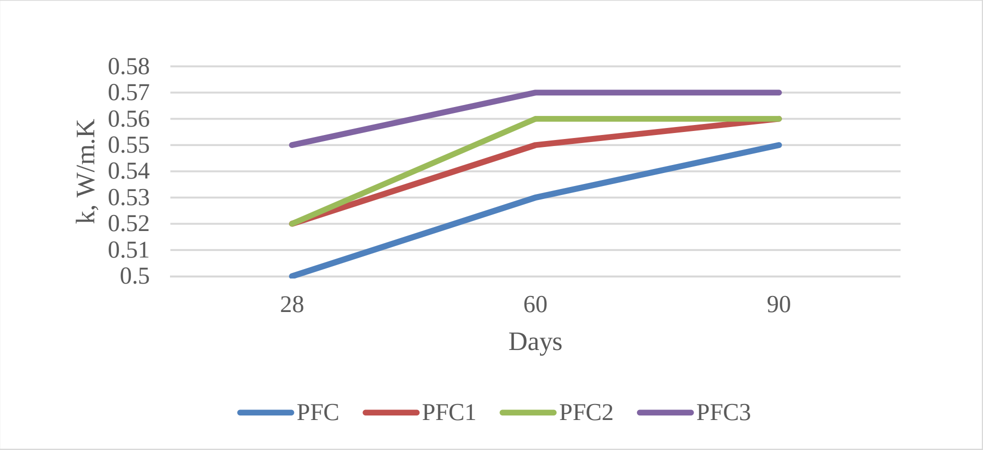

Figure 4.1 Thermal conductivity of foamed concrete

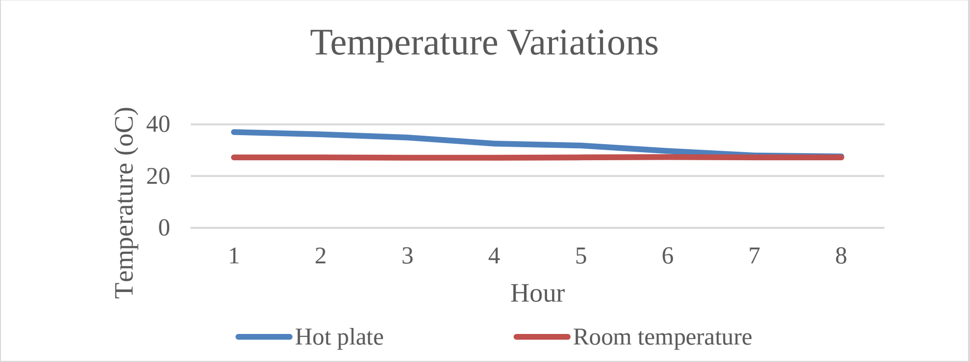

Figure 4.2 Variations of temperature through 8 hour run

4.2 Porosity

As for porosity, in Table 4.2, the overall results shows that an increase of percentage of PSBE cement replacement will decrease the porosity percentage. This is due to PSBE has smaller particle size than cement, thus it incorporated in the concrete with the foam, lowering amount of air pores are formed inside, as the result makes it more denser (Mydin and Wang, 2012)

Table 4.2 Porosity (%)

Sample	**28-day**	**60-day**	**90-day**
PFC	22.3	20.8	21.4
PFC1	21.1	19.7	19.5
PCF2	20.6	19	18.6
PFC3	18	18.8	17.9

Figure 4.3 shows that for PFC, control sample get 22.3% at 28 days, slight decrease at 60 days, 20.8% and increase 21.4% at 90 days. For PFC1 it gets 21.1% at 28 days, 19.7% at 60 days and 19.5% at 90 days. With increase of 20% of PSBE as partial cement replacement, PFC2 gets 20.6% for 28 days and decrease at 60 and 90 days, with 19% and 18.6% respectively. Lastly for PFC3 the reading shows 18% at 28 day, but it gradually increase fir the next 60 with 18.8% and at 90 days, the reading get the lowest with 17.9% only

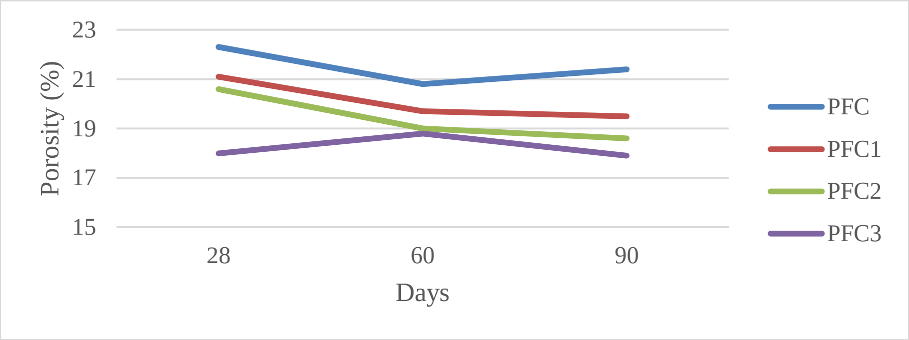

Figure 4.3 Porosity of foamed concrete

4.3 Relationship between thermal conductivity and porosity

Figure 4.4 shows the relationship between thermal conductivity and porosity of foam concrete when PSBE acts as partial cement replacement. As the porosity gets higher, the thermal conductivity get lower. As stated by Md Azree Othman (Mydin and Wang, 2012) this happened due to formation and size of pore that consist inside FC. Air is a good thermal insulator. The thermal conductivity gives a better result as the density decrease. Also this was due to different formations and size of pores on the microstructure formation of FC. PSBE have much smaller particle size than ordinary cement, thus makes it blend well with other binder and lessen the air pore produced in the foamed concrete, this is why when more PSBE replaced, the foamed concrete became denser

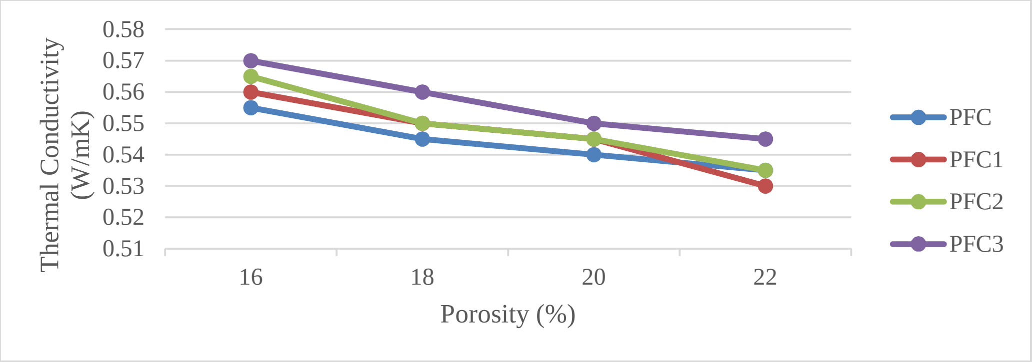

Figure 4.4 Relationship between thermal conductivity and porosity

CHAPTER 5

CONCLUSION

5.1 Introduction

From the test result, it can be concluded that using PSBE as partial cement replacement in foamed concrete give the expected result. But there are some result that not well but is acceptable as discussed. Based on thermal conductivity, PSBE foamed concrete gives higher result than control foamed concrete. As for porosity, control foamed concrete has higher percentage than PSBE foamed concrete

5.2 Conclusion

This research focused on the thermal conductivity and porosity of foamed concrete with PSBE as partial cement replacement. From the investigations, the following conclusions can be deducted:

i. The thermal conductivity of concrete increases with increase in the cement replacement. The highest thermal conductivity of 0.57 W/m.K was found for PFC3 in 90 days

ii. All of the sample show thermal conductivities within 0.5-0.6 W/m.K, the range that is specified by the RILEM for foamed concrete with density of 1600 kg/m^3 Thus, they can be considered as structural and insulating concrete as per the RILEM classification. The tiny air pores created due to foam act as an insulator.

iii. Porosity results shows that the increase of cement replacement will decrease the porosity percentage. And the porosity will gradually decrease as they matured. The highest reading is PFC with 22.3%.

iv. This research exhibits that thermal conductivity increases with decreasing porosity percentage, as expected. With gradually increase in percentage of cement replacement, more foam is incorporated in the concrete, and, as a result, a lower amount of air pores are formed inside. As air is a good insulator, the thermal conductivity of PFC1, PFC2 and PFC3 was found to be higher than that of PFC. Thermal conductivity of all the sample show that these could be considered as structural and insulating concrete.

5.3 Recommendation

PSBE is a good pozzolanic material, suitable with it characteristic, economic and ecological. From the test result it can be concluded that the usage of PSBE as partial cement replacement in foamed concrete is good. But there are few aspect that can improved for future studies, which is:

a. This study is focused for foamed concrete that has 1600 kg/m^3, variations of density may give better results.

b. Adding more percentage of PSBE as partial cement replacement. Finding the optimum PSBE content as partial cement replacement as higher PSBE percentage may not produce better result

c. This study only covers two test, which is thermal conductivity and porosity. Adding more test and study their relationship will give more understanding about PSBE full potential

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APPENDICES

LABORATORY TESTING RESULT

	THERMAL CONDUCTIVITY (W/m.K)			
DAYS	**FOAMED CONCRETE**	**10% PSBE**	**20% PSBE**	**30% PSBE**
28	0.5	0.52	0.52	0.55
60	0.53	0.55	0.56	0.57
90	0.55	0.56	0.56	0.57

	POROSITY PERCENTAGE (%)			
DAYS	**FOAMED CONCRETE**	**10% PSBE**	**20% PSBE**	**30% PSBE**
28	22.3	21.1	20.6	18
60	20.8	19.7	19	18.8
90	21.4	19.5	18.6	17.9