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Influence of processed spent bleaching earth on the durability of foamed concrete in acidic environment

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Abstract. The present research investigates the durability performance of foamed concrete with PSBE as partial cement replacement upon exposure to acidic environment. A basic control mix of foamed concrete (FC) cube was designed for density of 1600kg/m^3 and 30% of PSBE by weight of cement namely as PFC were cast. Then all samples were subjected to water curing for 28 days before immersed in the hydrochloric solution with pH 2 for 1800 hour. The mass loss of the specimens was measured at every 100hr until the end of testing period. The findings show that specimens containing PSBE experienced lower percentage of mass loss as compared to control specimen. The use of PSBE assist in generation of larger amount of calcium silicate hydrate gel through pozzolanic reaction that consume calcium hydroxide, a by-product of hydration process which is susceptible to chemical attack. Generally, integration of PSBE as partial cement replacement enhances the resistance of foamed concrete towards acid attack.

1.0 Introduction

Foamed concrete is a lower density of concrete that can be achieved without the aggregate. It can be produced by combination of cement, sand, water and preformed foams that causes foamed concrete to be lighter than normal concrete. In recent years, foamed concrete has shown the potential to fulfil all the requirements as the new alternative material in construction industry through its unique properties of low density, flowing and self-compacting, excellent sound and thermal insulation [1-5]. More useful characteristics of the foamed concrete are presented in others studies [6-10]. Unfortunately, without the present of aggregate, the consumption of cement is higher in producing good quality foamed concrete because the strength of foamed concrete is lower. Density of foamed concrete is within the low range of 240-1900 kg/m^3 and the 28 days compressive strength is between 0.3 to 15 MPa. It has been observed that the compressive strength has a direct relationship with density which a reduction in density the compressive strength is also decrease [11]. However, pozzolanic materials become popular and widely used in the concrete technology for various reasons, especially to reduce the consumption of cement but able to enhance the compressive strength. Recent studies show that fly ash [12-14],sewerage sludge ash [15], sludge from paper mill [16], granulated blast furnace slag[17] and graphite tailing[18] were used as partial replacement for cement in foamed concrete prove to be effective to meet both strength and durability requirements due to its high pozzolanic activity.

Bleaching Earth is very fine powder clay and its main component is silicon dioxide used for refining process of palm oil and it by product is known as Spent Bleaching Earth (SBE) is commonly disposed to landfill at high cost [19]. Globally, it is estimated that about 2 million or more of SBE are utilized worldwide in the refining process based on worldwide production of more than 200 million tons of oils with equivalent to 1% mass of SBE is produced relative to the amount oil produced yearly [20]. Malaysia is one of the largest producers for palm oil product in the world. Currently, there are 423 palm oil mills in Malaysia and it is estimated that 240,000 tons per annum or more of SBE are utilized in the refining process of crude palm oil [21]. So, the SBE will be generated are large in quantity and it becoming increasingly difficult to ignore the disposal of SBE when production of palm oil increased. Principally, the main task of bleaching earth is used to remove colourings, soap, gums, metals and oxidizing compounds during the oils refining process, and the waste is usually dumped in landfill without any treatment. It should be noted that SBE can present a potential fire and pollution hazards, because it contains 20 to 40% residual oil by weight, metallic impurities and organic compound upon its disposal. Then, dumping of SBE in landfill or public disposal sites should be restricted to protect environmental. In response to this serious issues, SBE disposal has been resolved by removing the oil and colouring materials [19-24]. Mostly, the residual oil can be extracted to produce biodesel [19,25] while the deoiled SBE can be reused as an adsorbent in wastewater treatment [26], as a clay substitute in the bricks, blocks or tile manufacturing process [27,20] and as filler in asphalts [28]. Recently, in Malaysia SBE is regenerated and reused for biomaterial for water treatment and bio fertilizer [29,21]. In Japan and Kenya, SBE has been incinerated for cement manufacturing [30,31]. The current research reports the durability performance of foamed concrete containing processed spent bleaching earth as partial cement replacement. Durability is the most important property of foamed concrete which define its ability to resist any external interference that may cause deterioration and lead to reduce the serviceability of its lifespan. In this study, the durability of foamed concrete is focused on the resistance against aggressive environment. Acid is one of the aggressive agents that may affect foamed concrete durability. Based on previous research, the water absorption of foamed concrete is almost twice the normal concrete at similar water to binder ratio, but independent of volume of air entrained, ash type and content [12].

2.0 Materials

2.1 Cement
The cement used as binder is localize Orang Kuat Ordinary Portland Cement (CEM I 42.5 N) manufactured by YTL Cement conforming to BS EN Specification for Portland cement (BS12/BS EN 197-1:2000) and ASTM C 150-95 Type I. The chemical composition and physical properties of the OPC was given in Table 1. The SEM micrograph of cement was shown in Figure 1.

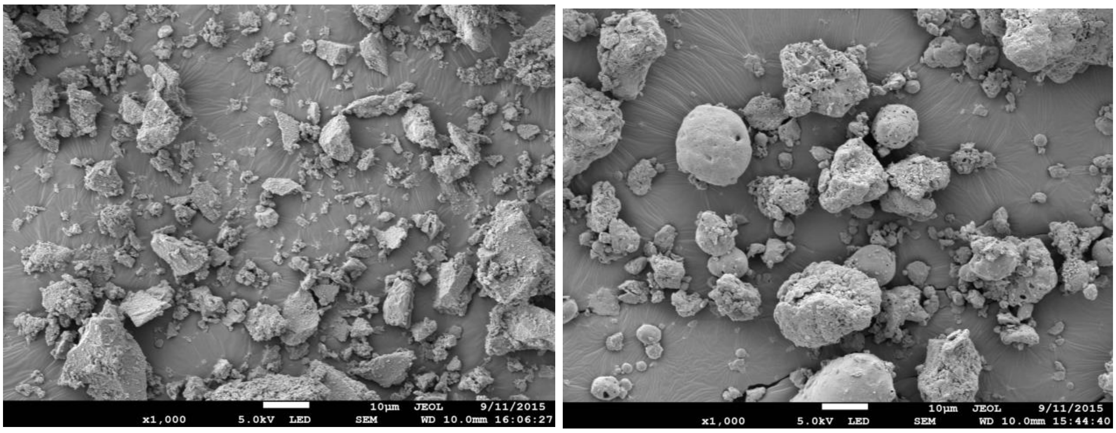
2.2 Sand
Fine sand used is silica sand manufactured by Johor Silica Industries Sdn Bhd with a 425um sieve (No. 425 ASTM) conforming to BS Specification for Aggregates for Concrete (BS EN 12620).

2.3 Foaming Agent
Hydrolyzed protein foaming agent and foam machine are locally manufactured by LCM Technology Sdn. Bhd Kuantan, Pahang which conforming to ASTM C796 and tap water is used for combining the ingredients and diluting the foaming agent.

2.4 Processed Spent Bleaching Earth
Processed Spent Bleaching Earth (PSBE) used in this study was provided by Eco Innovation Sdn. Bhd. The PSBE was dried in oven for 24 hours at a temperature of 105±5ºC then sieved through a No.300 ASTM. PSBE was classified as Class N Pozzolan in accordance with ASTM C618-12 and conforming to BS Specification for Pulverised-Fuel as for use with Portland cement (BS 3892-1/BS EN 450). Table 1 shows the chemical composition and physical properties of Processed Spent Bleaching Earth. The SEM micrograph of PSBE was shown in Figure 1.

Table 1. The chemical composition of the OPC and PSBE

Oxides %	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Loss on Ignition	Surface Area(BET) m^2/g
OPC	16.05	3.67	3.41	62.28	0.56	4.1	1.2	1.29
PSBE	55.82	13.48	8.24	6.6	5.94	1.05	0.18	0.143



(a) Odinary Portland Cement (OPC) (b) Processed Spent Bleaching Earth (PSBE**)**

Figure 1. SEM micrograph of OPC and PSBE

3.0 Methodology

3.1 Mix Design

In this study, a basic control mix of foamed concrete (FC) cube was designed for density of 1600kg/m^3 and 30% of PSBE by weight of cement namely as PFC. The cement content, water cement ratio and sand cement ratio in this study were kept constant throughout at 500 kg/m^3, 0.5 and 1.5 respectively. The cube specimens of 100 x 100 x 100 mm size were prepared and tested to determine the durability performance in acidic environment for both mixture FC and PFC.

3.2 Sample Preparation

Foamed concrete is the combination of cement, fine sand, water and preformed foams. In this study, preformed foam has been prepared by diluting 1 liter of foaming agent with 25 liters of water into the foam machine where the density of foam should be in the range of 50 kg/m^3. Then foam is added into the cement paste and mixed continuously until there was no sign of foam during the mixing and the slurry become homogenously mixed as shown in Figure 2. Filled the fresh mix into the cube specimens size 100x100x100 mm and then the specimens were removed from the mould after 24 hours. The specimens were subjected to water curing with temperature in the range 25-28 ºC until testing age at 28 days. All the equipment, materials and procedures in producing foamed concrete have been implemented according to ASTM C796 [32].

Prepare cement paste by mixing dry material with water	Added prefoamed foam into cement paste	Continuosly mixerd

Figure 2. Production of Foamed Concrete

3.3 Resistance to acid test

The acid attack test on cube was conducted by immersing the cubes in the acid hydrochloric solution with pH 2 for 1800 hour after 28 days of water curing. The cube specimens were removed from the curing tank and allowed to dry for one day. The mass of the specimens was taken. The mass loss of the specimens was measured at every 100hr until the end of testing period. The pH 2 was maintained throughout the period of 1800 hours. The resistance of foamed concrete to acid attack was found by the % loss of mass of specimen and the physical deterioration in acidic environment. The acid attack test of foamed concrete was performed according to ASTM C267, [33] and [34].

3.4 SEM test

The scanning electron microscopy (SEM) were performed based on ASTM C1723 (Ag,2013). The specimens of FC and PFC were tested to identify the formation images of specific chemical composition of the specimen such as calcium silicate hydrate, calcium hydroxide and entringite.

4.0 Results and discussions

4.1 Influence of PSBE on Mass loss of Foamed Concrete

The investigation on resistance to acid attack of foamed concrete cube specimens were conducted by measuring the loss of mass of the specimens continuously immersed in a 5% hydrochloric acid solution. Figure 3 presents the percentage loss in mass of control foamed concrete (FC) and foamed concrete mixture containing 30% PSBE (PFC) as partial cement replacement upon acidic environment. It demonstrates that the mass gradually decreased as the curing age increased from 100hr to 1800 hr for both specimens. The percentage loss in mass of foamed concrete start to decrease after 300hr for FC and 500hr for PFC. As compared to control FC, the percentage loss in mass of PFC was always lower than control FC. From the graph, it is showed that at the end of the immersion period, percentage loss in mass for cube specimen of FC and PFC was 1.6% and 0.25% respectively. It is interesting to note that PFC with 30% PSBE exhibit the higher durability exposed to acid attack. It can have been seen from it physical deterioration which both specimens begin to lose its surface and corner edges as the period of immersion increased as shown in Figure 4 and 5. Although both specimens lose its mass, the surface of PFC cube showed better surface condition compared to FC that have faces loss of small particles on both surface and corner edges. This condition has been published by previous study [33-34] which revealed that loss of mass is one of the signs of acidic attack, and faces and corner edges loss is one of the physical deterioration signs. Overall, both observations of mass loss and physical deterioration support that PFC has higher resistance towards acid attack compared to control FC. Therefore, it has confirmed that PSBE acts as a good pozzolanic reaction between silicon dioxide (SiO_2) from PSBE with calcium hydroxide (CaOH) from hydration process of cement and water that leads to increase the production of calcium silicate hydrate (C-S-H gel) and make PFC denser thus improve its durability towards acid attack. Principally, this good pozzolanic established due to different percentage of chemical composition especially low content of CaO in PSBE which is 6.6% in comparison to the high content 62.28% in OPC. Higher percentage of CaO would produce higher calcium hydroxide which lowers resistance to acid attack that leads to deterioration of foamed concrete. This has been approved by another researcher [33,35-37] concludes that higher content of CaO , the hydration products of OPC contain about 25% calcium hydroxide was responsible for the resistance of OPC exposed to acid environment. Since PSBE contains a small percentage of CaO, consequently the lower percentage of CaOH produces during hydrations that make better resistance of PSBE cube.

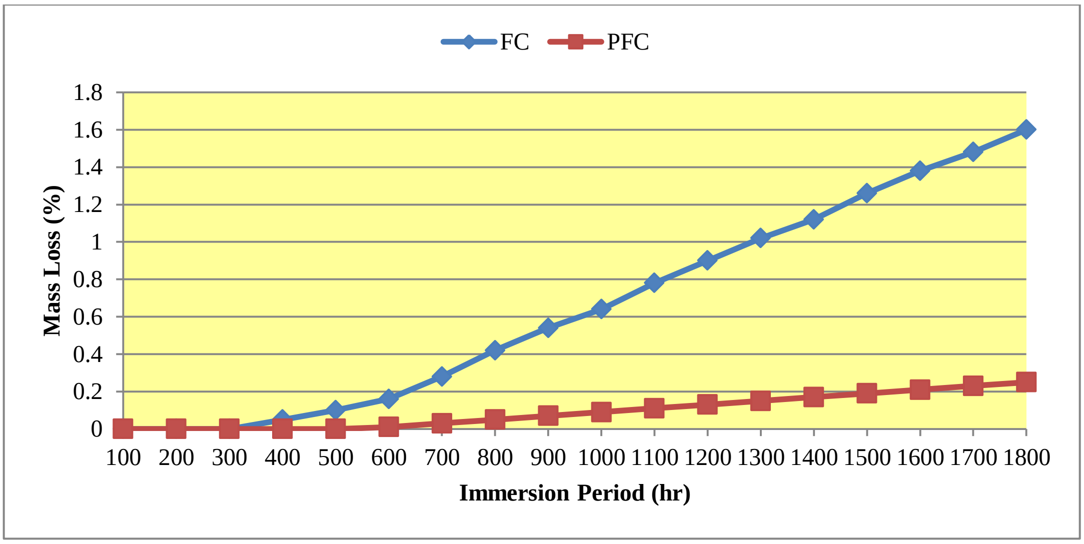


Figure 3. Workability of foamed concrete

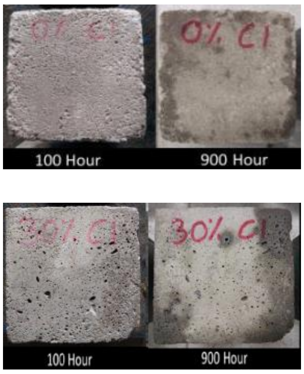
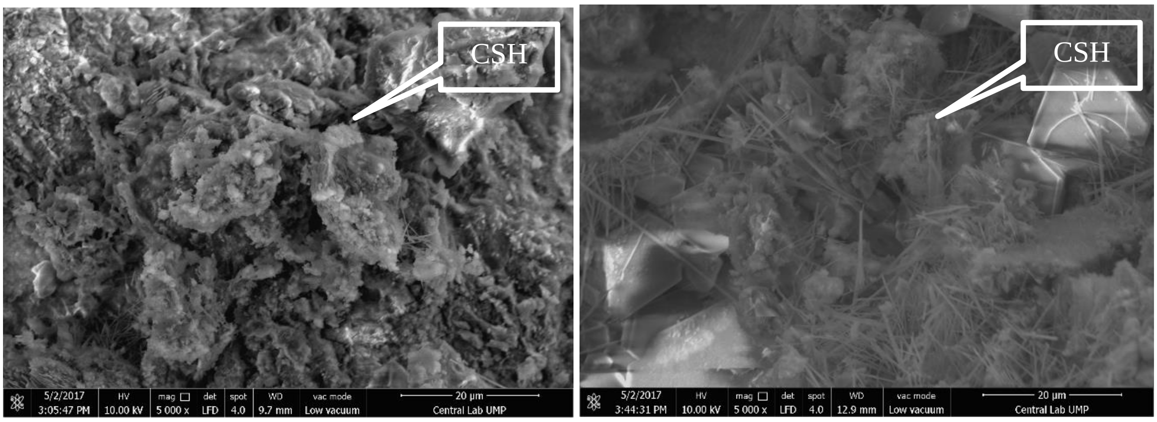


Figure 4. Physical Deterioration of Foamed Concrete at 100hr to 900hr

Figure 5. Physical Deterioration of Foamed Concrete at 1800hr

4.2 Influence of PSBE on Pozzolanic reaction of Foamed Concrete

From observation, the inclusion of PSBE has increased the rate of pozzolanic reaction that produced extra amount of CSH gel which filled the voids in the FC causing the FC denser and durable leads to improve the strength. The microstructure study has confirmed that by inclusion of PSBE also improves the internal structure of PFC (30%PSBE) to be denser than control FC specimen. The result is shown in Figure 6, where it may be seen that the formation of the crowded tiny of cotton shaped symbolizes the additional CSH in the specimen of containing PSBE is more than control FC for 1800 hour. There are fewer $Ca(OH)_2$ or CH crystals and more CSH produces in PFC specimen through SEM analysis is represent for its superior. The reaction of PSBE continues to consume CH to form additional CSH as long as CH is present in the cement paste. As a consequence of this, the main attribute of PSBE contributes to the densification of the microstructure of PFC and enable to exhibit greater strength compare to control FC specimen. Meanwhile, the lower amount of CSH and more CH crystals produces in FC specimen through the hydration process cement was due to high amount of CaO in FC causing excessive production of CH and without pozzolanic reaction the CH cannot be consumed. This behaviour was confirms with others reaction of pozzolan materials which results in CSH that improve the strength of concrete [38].It has been reported across the world that pozzolan materials contain little or no cementitious properties of their own but they react with calcium hydroxide produced during the hydration process of cement [39,40].



(a) PFC specimen (b) FC specimen

Fig. 6. SEM micrograph of PFC and FC specimens for 1800 hour

5.0 Conclusion

Based on the experimental results, it can be concluded that PSBE has a significant impact on the durability performance of foamed concrete in acidic environment. It was found that 30% PSBE partial replacement for cement more durable and performed better result in acidic compared to control FC mixture. In principle, the partial replacement of cements by PSBE which has low percentage of CaO is responsible to produce lower percentage of calcium hydroxide during hydrations that make better resistance in acid environment. It should be noted that the integration of PSBE in foamed concrete established two advantages, primary to reduce calcium hydroxide and the most greatest is when the SiO_2 react with calcium hydroxide $(Ca(OH))_2$ would create additional Calcium Silicate Hydrates (C-S-H) .These conclusions point out that the use of PSBE as a replacement for cement is highly useful in developing the durable of foamed concrete in acid environment as compared to control foamed concrete

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