

PAPER

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Effect of processed spent bleaching earth content on the compressive strength of foamed concrete

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Abstract. Present research studies the effect of Processed Spent Bleaching Earth (PSBE) on the compressive strength of foamed concrete as partial replacement for cement. The mixture and specimen uses of PSBE replace cement in the proportions of 10, 20, 30 and 40 percent by weight of binder were prepared and tested. The effect of PSBE as partial cement replacement on compressive strength, flexural strength, workability, density, water absorption and carbon content of foamed concrete were reported. Results indicate that 30% PSBE significantly improved the compressive strength of foamed concrete and other properties also performed well which behaviours are comparable to normal concrete There are fewer $\text{Ca}(\text{OH})_2$ crystals and more CSH produces in 30% PSBE through SEM analysis is represent for its superior.

1.0 Introduction

In recent years, designing and constructing lightweight concrete as a building material for the construction industry is another approach for reducing greenhouse gases (GHG) emissions definitely carbon dioxide (CO_2). This can be done by incorporating waste or industrial by product as a mixing component. Foamed concrete (FC) is a type of lightweight concrete [1]. FC is green technology material that can be effectively used for sustainable building and construction industry provides great benefit due to global warming problem [2] Incorporating waste or industrial by product such as fly ash, silica fume, ground granulated blast furnace slag, rice husk ash, sewage sludge ash, sludge paper mill, graphite tailing, soil and palm oil fuel ash as cement and sand replacements in FC has been a major focus for researchers [3-13]. In FC, the compressive strength reduces with decreasing in density [14]. Dransfield [15], found that the strength of FC with densities range between 400-1600 kg/m^3 is between 1-10 MPa which adequate for its purpose as void filling, highway reinstatement and other underground works. The FC can be used as a structural application if the compressive strength turns out to be 25 Mpa [7,8]. Hence, more research is needed to explore the potential application for FC as the important building material in structure design because of its significant benefit in lower density. 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 [16]. 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 [17]. 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 [18]. 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 [16,19-21]. Mostly, the residual oil can be extracted to produce biodiesel [16,22] while the deoiled SBE can be reused as an adsorbent in wastewater treatment [23], as a clay substitute in the bricks, blocks or tile manufacturing process [17,24] and as filler in asphalts [25]. Recently, in Malaysia SBE is regenerated and reused for biomaterial for water treatment and bio fertilizer [18,26]. In Japan and Kenya, SBE has been incinerated for cement manufacturing [27,28].

Therefore, this research studied the effect of Processed Spent Bleaching Earth (PSBE) as a partial cement replacement on the compressive strength of foamed concrete. PSBE is the end product derived from processing of de-oiled SBE after oil is being recovered. During the processing of PSBE, the inter alia silica in its raw material is being converted from its original crystalline form to amorphous phases to yield superior pozzolanic property. The incorporation of PSBE into foamed concrete as a partial cement replacement has not yet been investigated. It is a new alternative to incorporate PSBE in foamed concrete to enhance compressive strength of foamed concrete. The new design of foamed concrete content PSBE as partial cement replacement has decreasing the amount of cement used and reduces the CO₂ emission. Meanwhile, energy production will be reduced likewise the greenhouse gas emission.

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

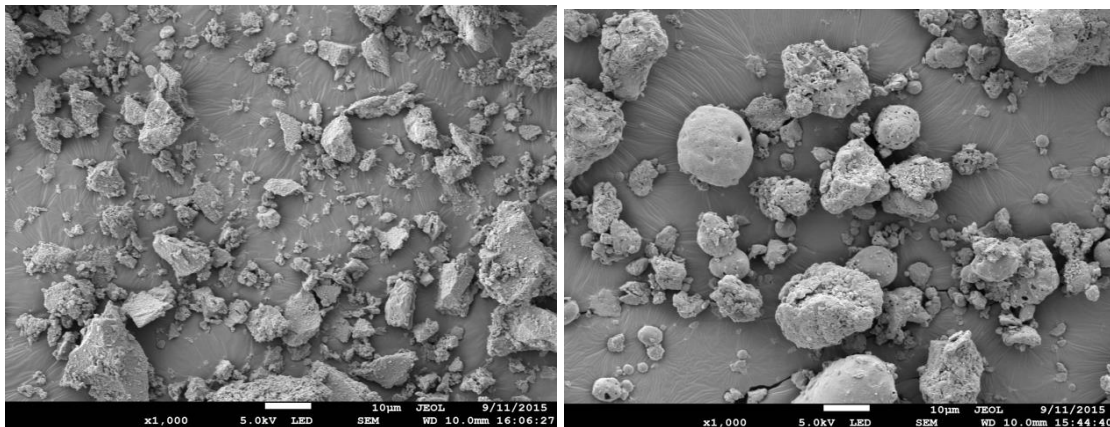
The foaming agent used is Hydrolyzed protein and foam machine are locally manufactured by LCM Technology Sdn. Bhd Kuantan, Pahang which conforming to ASTM C796 and tap water is used for combining the ingredients and diluting the foaming agent.

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±5°C 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 ₂ O ₃	Fe ₂ O 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) Ordinary Portland Cement (OPC)

(b) Processed Spent Bleaching Earth (PSBE)

Figure 1. SEM of OPC and PSBE

3.0 Methodology

3.1 Mix Design

In total, five mixes proportion were prepared for this study included control mix (0% of PSBE) and 4 more mixes containing PSBE replacing cement at levels of 10, 20, 30 and 40 % by weight of cement. The water/cement ratio, sand/cement ratio, dilution ratio and percentage of foam dosage in this study were kept constant throughout at 0.5, 1.5, 1:25 and 25% respectively. The compressive strength of foamed concrete containing different percentages of PSBE (10%PSBE to 40%PSBE) were compared to control mixture M (100% OPC without foam) and FC (100% OPC with foam).

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/m³. 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 prism beam size 100 mm height x 100 mm width x 500 mm length. Then the specimens were removed from the mould after 24 hours. All the equipment, materials and procedures in producing foamed concrete have been implemented according to ASTM C796 [29].

Prepare cement paste by mixing dry material with water	Added prefoamed foam into cement paste	Continuously mixerd
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Figure 2. Production of Foamed Concrete

3.2 Flow table test

The flow table test used to measure workability of foamed concrete has been followed by the procedure of ASTM C1437 [30].

3.3 Density test

The fresh density and oven dry density of foamed concrete were determined as per ASTM C796-12 and C513-11[31]. The cube specimens 100 mm x 100 mm x 100 mm were used for this testing.

3.4 Water absorption test

The water absorption of foamed concrete was performed according to ASTM C642-13 [32]. The cube specimens 100 mm x 100 mm x 100 mm were used for this testing.

3.5 Compressive strength test

The compressive strength of foamed concrete was carried out following the ASTM C513-11. The cube specimens 100 mm x 100 mm x 100 mm were used for this testing.

3.6 Flexural strength test

The Flexural strength of foamed concrete was determined by following the procedure of ASTM C78 (third-point loading) and the carbonation depth test was conducted after flexural strength test. Carbonation depth test of foamed concrete is determined by following standard BS EN 14630 which is determination of carbonation depth in hardened concrete by the phenolphthalein method. The prism specimens (100 mm height x 100 mm width x 500 mm length) were used for this testing.

3.7 SEM test

The scanning electron microscopy (SEM) were performed based on ASTM C1723. The 28 days specimens of FC and 30PSBE were tested to identify the formation images of specific chemical composition of the specimen such as calcium silicate hydrate, calcium hydroxide and ettringite.

4.0 Results and discussions

4.1 Effect of PSBE on Compressive strength of Foamed Concrete

Figure 3 shows the compressive strength of foamed concrete. For all mixes, the compressive strength increased as the curing period increased from 3 to 28 days for both curing method. The compressive strength of control mixture M produced of 100% cement was higher than FC and PSBE mixture. However, the compressive strength of foamed concrete containing PSBE was higher than control FC. It can be observed that at all the ages of testing, the compressive strength increased with the increase in the percentage of PSBE as cement replacement. Among different percentage of replacement, 30% and 40% PSBE mixture performed the best where the value resulted in 20% lesser than control sample M. The reduction in the compressive strength of mix when PSBE was added is probably due to the strength gain for pozzolan materials is slow at early ages. Similar trend of compressive strength development of foamed concrete due to pozzolanic effect broadly followed the patterns of concrete or

mortar made with pozzolan materials as reported by others [33,34] that the strength gain for pozzolanic reaction takes place at slower rate than the hydration of cement.

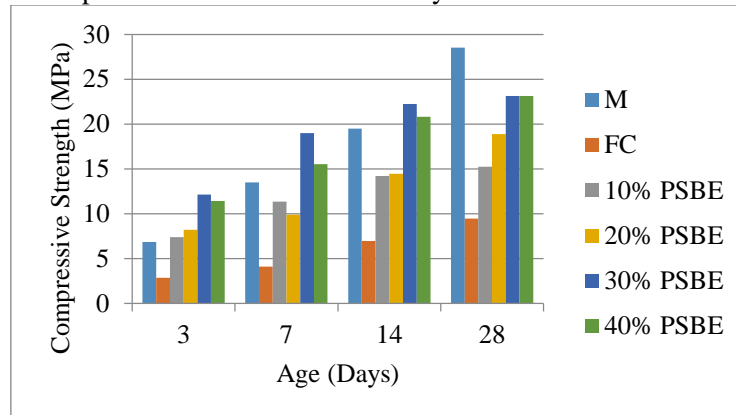


Figure 3. Compressive strength of foamed concrete

4.2 Effect of PSBE on Flexural strength of Foamed Concrete

Figure 4 presents the development of flexural strength for all foamed concrete mixture. It demonstrates that for all mixes, the flexural strength increased as the curing period increased from 3 to 28 days for both curing method. As compared to control FC, the flexural strength of foamed concrete containing PSBE as cement replacement was higher than control mixture FC. Furthermore, the flexural strength of foamed concrete containing PSBE mixtures increased with the increase in the percentage of PSBE for all curing age. In most mixtures, the production of foamed concrete with 30% and 40% PSBE performed the highest value of flexural strength at 28 days with 6 Mpa which shows significant improvement compared to control FC with 2 Mpa. Through the data observation, the increasing of PSBE as cement replacement in foamed concrete has pointers to increase in the flexural strength. The PSBE acts as a pozzolanic material, hence the flexural strength of foamed concrete increases as the percentage of PSBE increases due to the pozzolanic reaction. PSBE as pozzolanic materials which contains high amount of silicon dioxide has increased the rate of pozzolanic reaction which produced high amount of C-S-H gel. This C-S-H gel filled the voids in the foamed concrete causing the foamed concrete denser and durable leads to improve the strength. According to [11], it has been reported that flexural strength development possesses linear relationship with the compressive strength development of the foamed concrete. It can be seen that the ratio of flexural strength to compressive strength of foamed concrete is 25% or 0.25. The ratio of flexural strength to compressive strength of lightweight foamed concrete is in the range of 0.25-0.35 [11].

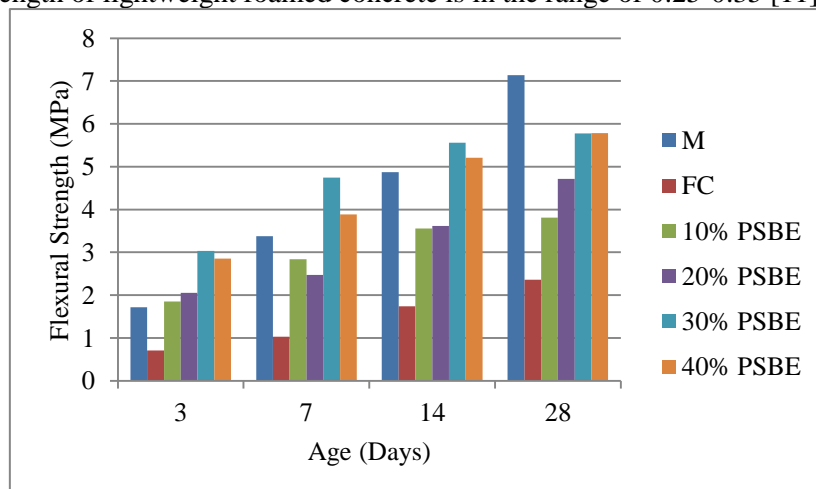


Figure 4. Flexural strength of foamed concrete

4.3 Effect of PSBE on Workability of Foamed Concrete

Figure 5 illustrated the workability of mixture M, FC and four different percentages of PSBE. The flow diameter values, a measure of workability decreased as the increased percentage of PSBE in the foamed concrete. The results show 10%, 20%, 30% and 40% PSBE mixture have 215mm, 205mm, 200mm and 150 mm flow diameter respectively. The reduction in the workability of mix when PSBE is added is probably due to increased particle surface of fine PSBE compare to cement. This fact has been highlighted by a researcher [27] who stated that due to the small particle size and relatively higher surface area of pozzolan particles. Similarly previous researchers [33,34] reported that concrete made with pozzolan materials has less workability than control specimen produced of 100% cement.

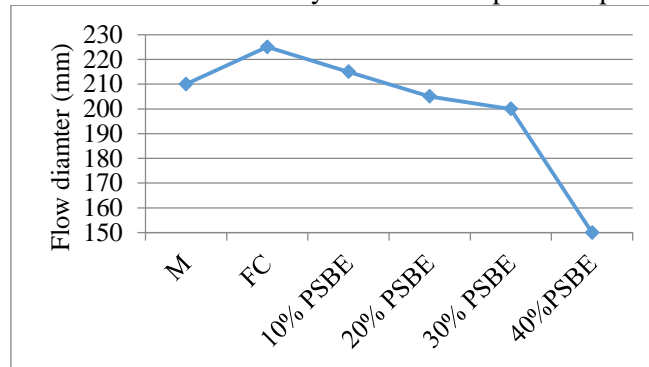


Figure 5. Workability of foamed concrete

4.4 Effect of PSBE on Density of Foamed Concrete

Figure 6 shows the oven dry density of foamed concrete mixture. It can be observed that density of control mixture M and FC were higher than density of PSBE content for both curing method. The higher the PSBE content in the mixture the lower is the density due to specific gravity of the cement which is more than PSBE. It can be concluded that for the concrete or mortar made with pozzolan materials which has lower density than the control specimen produced of 100% of cement has similar agreement with available study on pozzolan materials[33,34].

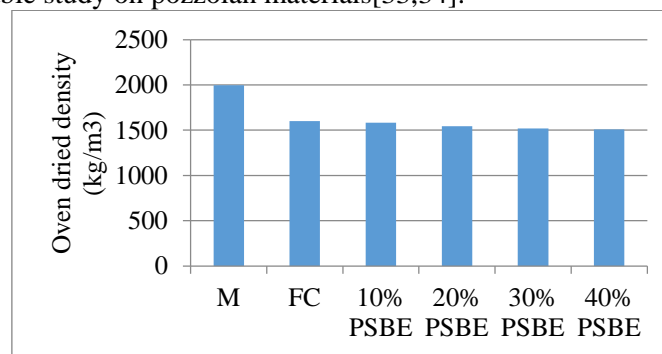


Figure 6. Oven dried density of foamed concrete

4.5 Effect of PSBE on Water absorption of Foamed Concrete

Figure 7 shows the water absorption of foamed concrete mixture. For all mixes, the water absorption decreased as the curing period increased from 3 to 28 days for both curing method. It is also can be observed that water absorption decreased with the increase in the percentage of PSBE as cement replacement. Among all the different percentage of replacement, 30% PSBE mixture performed the best result when compared to control sample M. The reduction in the water absorption of mix when PSBE was added is probably due to the particle size of PSBE which is less than that of cement therefore it can pack the binder phase. Secondly, the decrease was due to the fact that chemical reaction between natural pozzolan and calcium hydroxide of hydrated cement paste was lime

consuming instead of lime producing as similarly observed by others [33]. The water absorption decreased with the pozzolan materials substitution up to 30% thus testifying the results[34].

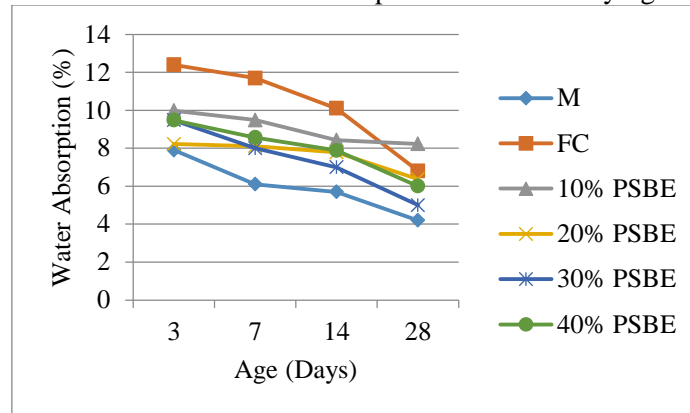
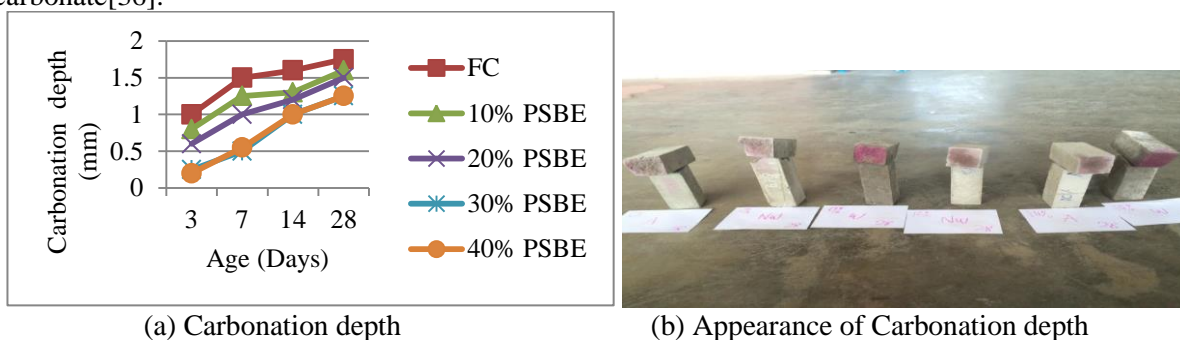


Figure 7. Water absorption of foamed concrete

4.6 Effect of PSBE on Carbonation Depth of Foamed Concrete

Figure 8 presents the durability against resistance carbonation for all foamed concrete mixtures. The carbonation depth, which is an indication of durability, decreases as the percentage of PSBE increases. As compared to control FC, the carbonation depth of foamed concrete containing PSBE as cement replacement was lower than control mixture FC. Besides, the rate of carbonation of foamed concrete containing PSBE mixtures decreased with the increases of PSBE in the mixture. Hence, it indicates that, durability of foamed concrete containing PSBE as partial cement replacement increased against the carbonation resistance. In most mixtures, the FC shows the highest depth of carbonation. It shows that at the age of 3 to 28 days the carbonation depth of FC reached 1.75mm. Principally, foamed concrete has lower density compared to normal concrete thus making the carbonation resistance of foamed concrete lower than normal concrete. Foamed concrete are not dense and very porous. Thus, carbon dioxide at surrounding can easily penetrate into the concrete and react with hydration product which is calcium hydroxide to forms calcium carbonate that leads to carbonation [35]. Overall, the production of foamed concrete with 30% and 40% PSBE achieved the lower depth of carbonation resistance. Foamed concrete became denser by adding 40% of PSBE as partial cement replacement as more calcium silicate hydrate produced from hydration and pozzolanic reaction. Pozzolanic reaction consumed calcium hydroxide produced from hydration process. Lower calcium hydroxide contains in the concrete increased the carbonation resistance of the concrete because less calcium hydroxide can react with carbon dioxide to cause carbonation in concrete. It was similar agreement reported that carbon dioxide diffuse in the cement matrix and react with calcium hydroxide to form calcium carbonate[36].



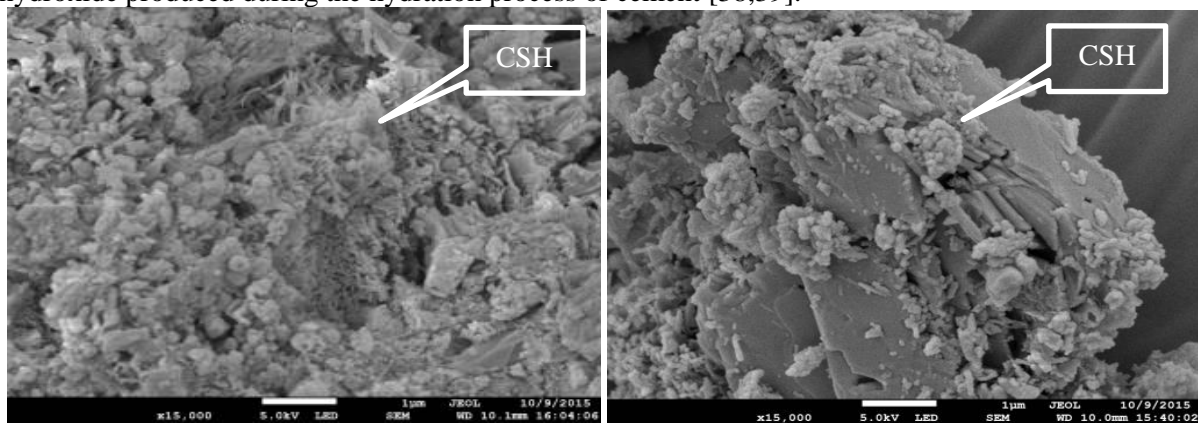
(a) Carbonation depth

(b) Appearance of Carbonation depth

Figure 8. Carbonation depth of foamed concrete

4.7 Effect 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 30%PSBE to be denser than control FC specimen. The result is shown in Figure 9, 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 28 days. There are fewer $\text{Ca}(\text{OH})_2$ or CH crystals and more CSH produces in 30%PSBE 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 30%PSBE 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 [37]. 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 [38,39].



(a) 30% PSBE specimen

(b) FC specimen

Figure 9. SEM micrograph of 30% PSBE and FC specimens for 28 days

5.0 Conclusion

Based on the experimental results, it can be concluded that PSBE has a significant impact on the compressive strength of foamed concrete. It was found that 30% PSBE partial replacement for cement provided greater compressive strength and performed better result in other properties of foamed concrete compared to control FC mixture. Increasing PSBE replacement decreases the density of the specimen and water absorption. In addition, the partial replacement of cements by PSBE is known to improve the compressive strength of foamed concrete due to fewer $\text{Ca}(\text{OH})_2$ or CH crystals and more CSH produces in 30%PSBE specimen through SEM analysis is represent for its superior. These conclusions point out that the use of PSBE as a replacement for cement is highly useful in developing the compressive strength of foamed concrete.

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