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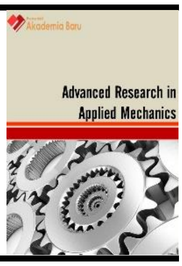

Enhanced Properties of Palm Oil Boiler Clinker Concrete with Sang Yod Rice Husk Ash

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ABSTRACT

Laboratory experiments of this investigation are to reclaim palm oil boiler clinker (POBC) as coarse aggregate for concrete and partially replaced Portland cement type 1 with Sang Yod rice husk ash (SYRHA) in proportion of 10%, 20% and 30wt.%. Characterization of POBC aggregate was carried out on grain size distribution and shape analysis, specific gravity, loose and compacted bulk density, water absorption, organic impurity, aggregate impact value and Los Angeles abrasion. Each mixing specimen was kept water to binder ratio at 0.42 throughout this study and varied duration of curing in water for 7, 28 and 56 days. The properties of paste and harden cube concrete in size 10×10×10 cm including setting time, bulk density, water absorption and compressive strength and were determined. According to aggregate testing results indicated that POBC was met the specification of normal-weight aggregate. Addition of SYRHA decreased both setting time and hydration temperature of paste. Furthermore, concrete contained 20% SYRHA provided highest 56-day compressive strength of 53.12 MPa and increased water absorption of 5.27%.

1. Introduction

Palm Oil Boiler Clinker (POBC) was a by-product from palm oil mill and it is defined as kind of non-hazardous waste material [3]. In the southern part of Thailand, The disposal of POBC has been unidentified and only used for landfill. The origin of POBC was made during the combustion and cooling down process with various condition depended on the mill. For a few decade, POBC were often used as a coarse and fine aggregate replacement in lightweight concrete produced [22, 2,4,20]. The mix design of concrete containing POBC was different from others normal aggregate according to their porous and rough surface texture characteristics. Thus, Mannan and Neglo [22] were investigated the suitable mix design for POBC concrete. They were found that using POBC as coarse aggregate replacement with maximum size at 20 mm including Ordinary Portland cement (OPC),

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sand, and superplasticizer at w/c ratio 0.48-0.60 and cure in tap water for 28 days. Which can provide the compressive strength in range of 27-35 MPa. Perversely, Abutaha *et al.*, [2] was produced concrete containing POBC as partial coarse aggregate replacement at 10%, 20%, 40%, 60 and 100%. The compressive strength and hardened density of POBC concrete were obtained in the range of 33–49 MPa and 2074–2358 kg/m^3 at 28 days, respectively. Moreover, it provided the compressive strength to 33 MPa with 100% coarse aggregate replacement by POBC. Thus, POBC has a good potential to replace natural aggregates, making it suitable to be used in concrete [22,2,4,20]. According to several researches have been investigated, There are some weak points of using POBC as aggregates that were reported from Abutaha *et al.*, [1], Ibrahim *et al.*, [19], Shafigh *et al.*, [23]. The increasing of POBC in concrete as both coarse and fine aggregate reduces the slump and workability in fresh concrete. But only POBC coarse aggregate reduces strength value. Therefore, this research aims to enhance the POBC concrete properties with Song Yod rice husk ash (SYRHA) which was waste of rice husk derived from the rice products from Phattalung, Thailand. It also has a slim grain, dark red pericarp, soft and aromatic of cooked rice as well as nutritional enrich [15]. As wildly usage of rice husk ash (RHA), which is beneficial in many way to concrete i.e. increase the compressive strength and reduce the corrosion deterioration (Gastaldini et al, 2010). In addition, SYRHA was characterized in chemical composition and strength activity index (SAI) of gravel gap-graded aggregate concrete by Tonnayopas and Jitnukul [24] and met the specification of ASTM C618-12a and D5370-14. Thus, in this experimental investigation to evaluate into suitability of POBC coarse aggregate and SYRHA as a complement for green concrete.

2. Materials and experimental procedures

To carry out this experiment the concrete mix design are following material were used OPC type I according to ASTM C 150, palm oil boiler clinker coarse aggregate (POBCCA) regarded with sieving size between 4.75-12.5 mm, fine aggregate used river sand with fineness modulus of 3.15. The SYRHA powder particles was used as OPC partial replacement at mean particle size 16.7 microns according to Fritsch-Analysette 22 Nanotec laser particle analyser. The particle size distribution of all materials used are illustrated in Figure 1.

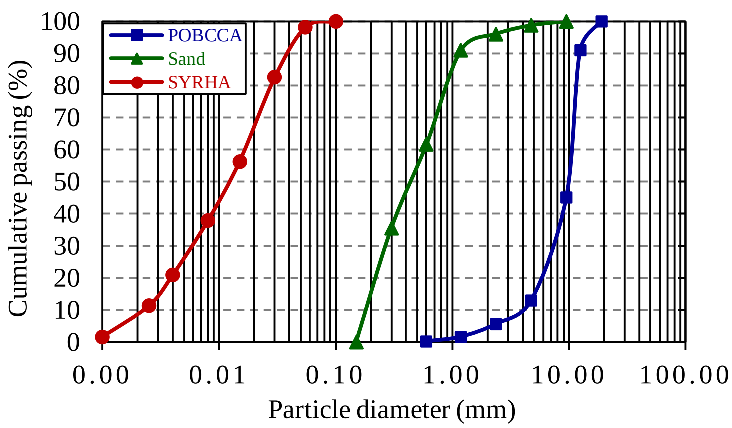

Fig. 1. Particle size distribution of materials used in this study

2.1 Palm Oil Boiler Clinker Coarse Aggregate

POBC samples in this study were collected from a palm oil factory in Surat Thani, Thailand. It was obtained from the combustion of fibres, seeds and shells of palms after oil extraction process as a fuel for boiler. This combustion process will be taken time for 6-12 h at the range of temperature from 700 to 1200°C after cooling down. The POBC is 90% greenish grey, 5-10% black and 3-1% pinkish brown color, sintered, vesicular texture with unidirectional and unconnected porous (bubble-shaped localities) because of rapid cooling down, irregular shape, brittle edges and exposed in large lumps within 95-70 cm as shown in Figure 2(a). The POBC was washed and air-dried for one week then crushed within size less than 12.5 mm as shown in Figure 2(b).

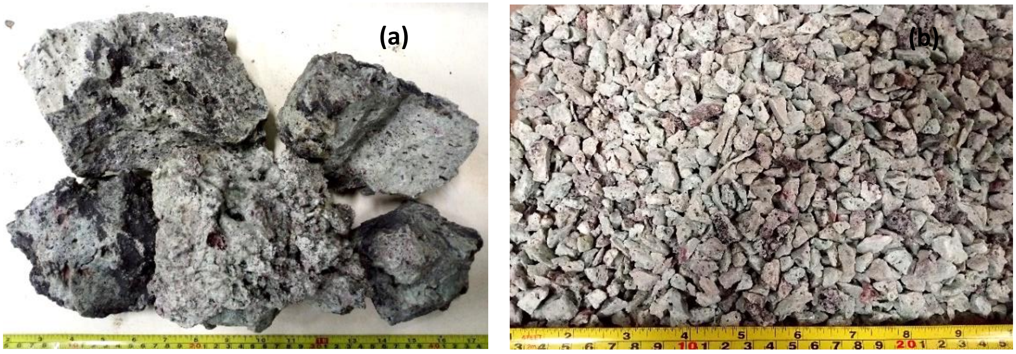

Fig. 2. POBC sample (a) lumps and (b) aggregate used

The chemical composition of POBC was also analysed via X-ray fluorescence (XRF) and tabulated on Table 1. It composed of dominant SiO_2, and moderate of CaO, K_2O, P_2O_5 and MgO contents, respectively. Particularly, loss on ignition (LOI) is very low or negligible. According to microstructure analysis, found that the evidence of POBC occurrence is similarly to "aa" lava or metal slag. The morphology of POBC- under scanning electron microscope (SEM) revealed slightly smooth concave surface with brittle fracture and thermal crack and depicted frame in Figure 3(a). It also observed clearly spherical particles cluster of silica component "Si" (Figure 3(b)).

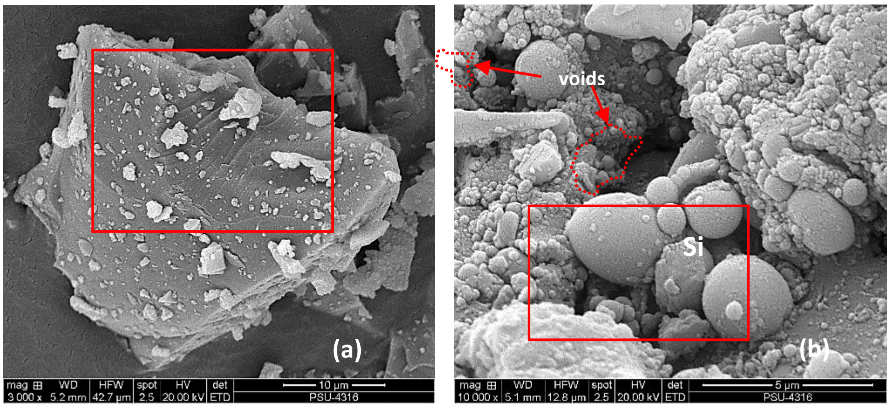

Fig. 3. SEM photomicrograph of POBC (a) slightly smooth concave surface with crack trace and (b) enlargement of silica particles and small void spaces

The aggregate properties of POBC used as coarse aggregate were preliminary tests performed including grain size distribution, specific gravity and water absorption, (ASTM C127-15), loose and compacted bulk density (ASTM C29/C29M-17a), organic impurity (C40/C40M-16), aggregate impact value and Los Angeles abrasion (ASTM C535-16).

2.2 Sang Yod Rice Husk Ash

The Sang Yod rice husk was collected from a local rice mill in Phattalung, Thailand. Then, it was burned into open-air condition by using recycled oil tank for 3-4 days (Figure 4a). Then later it was incinerated in an electrical furnace again at 700°C for 1 h in order to reduce some organic matter (Figure 4b). Then, grinding with jar mill for 12 h and sieved through 325 sieve mesh to obtain the final binder sample and kept in a container to prevent it from moisture. Its chemical composition result was analysed by XRF technique shown in Table 1.

Table 1
Chemical composition of POBC and SYRHA used for this study

Oxides (wt.%)	SiO_2	Al_2O_3	Fe_2O_3	MgO	P_2O_5	SO_3	K_2O	CaO	MnO	Others	LOI*
POBC	65.23	1.66	1.78	5.37	5.50	0.04	9.56	10.00	0.17	0.59	0.04
SYRHA	93.83	0.66	0.36	0.36	1.04	0.21	1.77	0.76	0.11	0.23	0.67

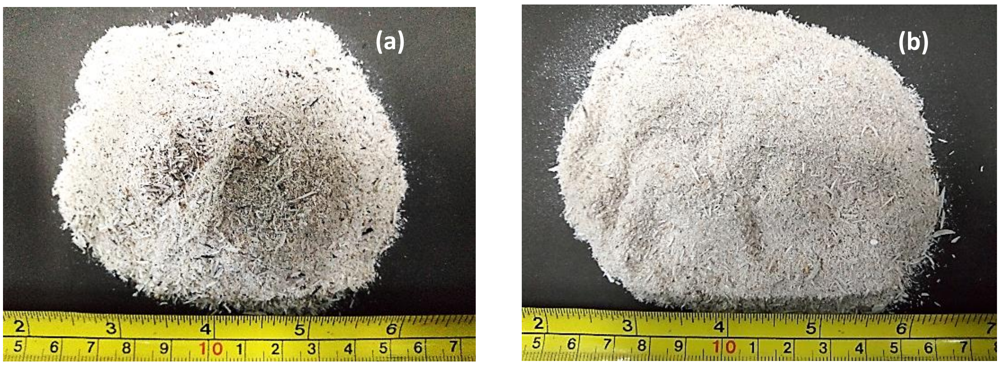

Fig. 4. SYRHA after treatment processing of (a) open-air burned and (b) incinerated at 700 °C for 1 h

According to XRF analysis, the amount of SiO_2+Al_2O_3+Fe_2O_3 is greater beyond 70% and LOI is also less than 6%. In consequence, the SiO_2 contents of SYRHA is higher than Tonnayopas and Jitnukul [24] due to the incinerated treatment process reduced unburned carbon. The XRF analysis also confirmed that SYRHA was met the threshold of artificial pozzolans in burnt materials type but cannot identify in any classes although its chemical composition was same as pozzolan definition but its evidence of occurrence was not according to ASTM C 618 and ASTM D 5370. Therefore, SYRHA was conformed to specified requirements of blended pozzolan for use in concrete and should be added to brand new type “RHA” of organic pozzolan in opportunity. The microstructure of SYRHA powder was analysed via SEM and can be noticed that the physical characteristic of SYRHA was a spherical shape and almost round (Figure 5(a)). Most particles size were in the range of 2.3-38 microns as shown in Figure 5(b), it effected on more surface area as observed on SEM image.

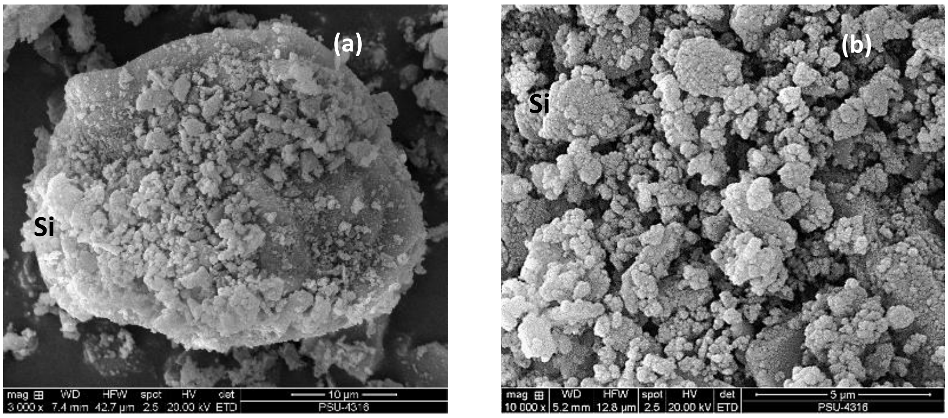

Fig. 5. SEM photomicrograph of SYRHA (a) clusters and (b) spherical and rounded particle of silica

2.3 Specimen Preparation and Mix Proportions

Whole investigated specimens were cast in cube with dimension of 100×100×100 mm. Then, the concrete mix designs were inspection on ACI 211.1-91 method to approach slump value between 35-50 mm and compressive strength at 35 MPa in 28 days as tabulated in Table 2. Mix proportions of specimens were designed by replacing OPC with SYRHA at 10, 20, 30wt.% and kept water to binder ratio at 0.42 throughout this study. The test specimens were stored in moist air for 24 h and after this period each specimens are marked and removed from the moulds then kept submerged in tap water until 7, 28, and 56 days and taken out to prior test. The various tests were carried out on paste and harden concrete specimens with standard procedures in ASTM specifications containing setting time ASTM C403/C403M-16), heat of hydration (ASTM C186-17), bulk density and water absorption according to ASTM C642-13, and compressive strength modified on ASTM C39/C39M-18.

Table 2
Mix batches of specimens

No.	Mix designation	w/b ratio	Mix containing (kg/m^3)			
			OPC	Sand	POBCA	SYRHA
1	Control	0.42	500	1315	700	0
2	SYRHA10	0.42	450	1315	700	50
3	SYRHA20	0.42	400	1315	700	100
4	SYRHA30	0.42	350	1315	700	150

3. Results and Discussions

The result of POBC coarse aggregate testing were tabulated in Table 3. It has coincided with several previous researches results even its physical appearances was not similarly i.e. color, texture but it has the highest specific gravity and lowest 24 h water absorption when compared to previous researches which are in the range of 1.67-1.8 and 2.7-5.4% respectively [1-4].

Table 3
Summary of Aggregate Properties of POBC raw material used

Aggregate properties	Value
Specific gravity	2.16
Loose bulk density (kg/m³)	1013.69
Void (%)	39.66
Compacted bulk density (kg/m³)	1080.61
Void (%)	35.68
Water absorption (%)	
1 day	1.42
7 days	3.00
Organic impurity	None
Aggregate impact value (%)	37.30
Los Angeles abrasion (%)	28.30
Fineness modulus	5.42

3.1 Setting Time and Hydration Temperature of Paste

The initial and final setting times of OPC partial replacement by SYRHA at 10, 20 and 30% were tested gather with heat monitoring. The increasing SYRHA replacement effected directly on water demand due to ultrafine particles. The paste which contains high content of SYRHA signify less consistent than without SYRHA or control mix since after mixing with the same amount of water as shown in Figure 6(a). The Vicat penetration depth indicated that the increasing replacement level of SYRHA played the key role to decrease both initial and final setting time of paste due to pozzolanic reaction, high water demand and specific surface area. At 30% SYRHA replacement reduced initial and final setting time of paste down to 32% and 16% respectively when compared the result of control mix as depicted in Figure 6(b).

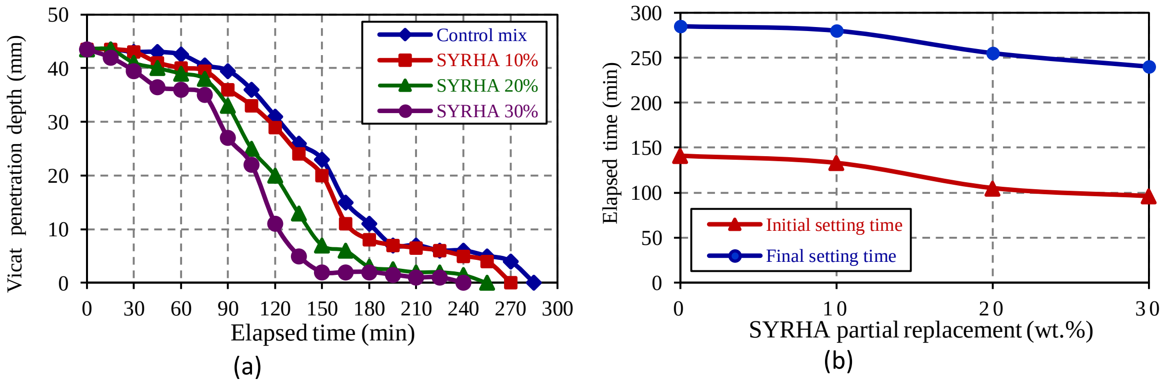

Fig. 6. Effects of SYRHA partial replacement on (a) development of setting time behaviour and (b) interval duration of setting time

The hydration temperature of paste also decreased when increased replacement level of SYRHA due to reduce cement contents or tricalcium silicate (C_3S) and aluminate hydrated (C_3A) by SYRHA as shown in Figure 8. Concordantly, there are 3 factors controlled the heat of hydration including pozzolanic reaction, tricalcium silicate hydrated (C_3S) content and tricalcium aluminate hydrated content [18].

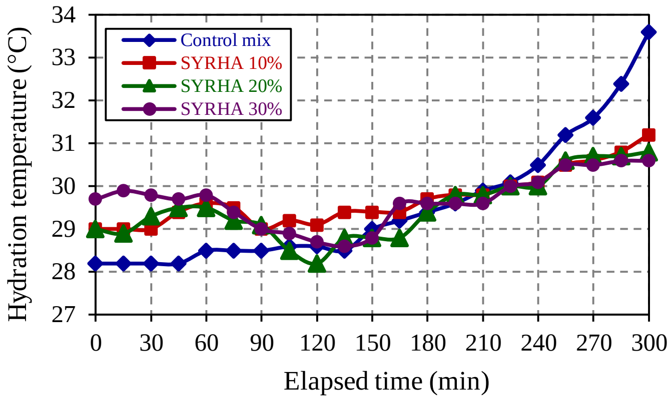

Fig. 8. Effects of SYRHA on hydration temperature of paste

3.2 Bulk Density

The POBC concrete at the ages of 56-day without SYRHA as a cement replacement can be achieved bulk density at 2205.81 kg/m^3 (Figure 9) which is not significantly different from normal weight concrete densities owing to higher specific gravity of POBC coarse aggregate than previous researches [22,2,4]. The entire results have shown that increasing replacement level of SYRHA decreased the bulk density at all curing periods. As the result of OPC was replaced by SYRHA, bulk density of concrete also reduced. Conversely, the long term curing ages effected on increasing POBC concrete density by given more hydration process and condensation of concrete structure [21].

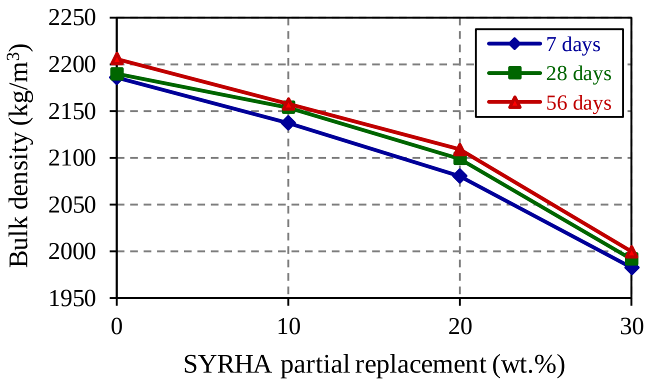

Fig. 9. Effects of SYRHA on bulk density of POBC concrete at different ages

3.3 Water Absorption

According to Figure 10, it can be represented that at 10% SYRHA replacement of OPC decreased water absorption of POBC concrete compared to control mix. It is represented the optimum usage for reduce porosity of POBC concrete as water absorption value calculated from the saturated water was taken place on void in concrete. Thence, further water absorption was gone beyond 10% SYRHA replacement of cement and depended on curing time in this study. In general, adding some pozzolans i.e. rice husk ask, fly ash and silica fume can be decreased pore size of concrete. In conversely on this study, due to SYRHA is particle usually absorption water, thus it may not be optimum for pozzolanic reaction and should not over grinding if using SYRHA to produce concrete for durability usage.

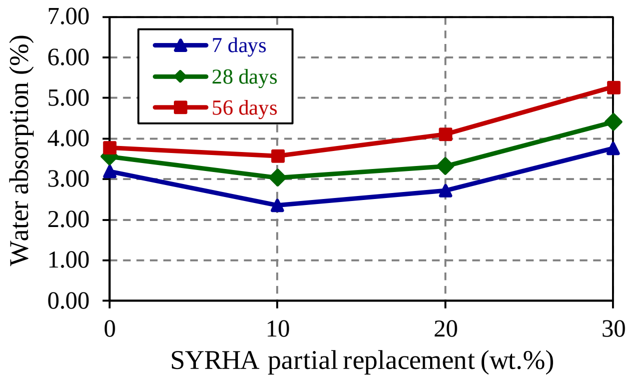

Fig. 10. Effects of SYRHA on water absorption of POBC concrete at different ages

3.4 Compressive Strength

Effect of OPC replacement by SYRHA on compressive strength was depicted Figure 11. All level of replacement performed higher strength at prolonger curing ages. At 20% SYRHA, the compressive strength of 56-day concrete was the highest of 53.12 MPa. The maximum strength activity index (SAI) of 7, 28 and 56-day concrete were 116%, 113%, 109% at 10% and 20% SYRHA replacement, respectively. It can be implied that at 10% SYRHA was suitable for early strength development and at 20%SYRHA for late strength development since 28 days of curing ages. It can be noticed physical and mechanical properties of POBC concrete blended SYRHA had closely relationships.

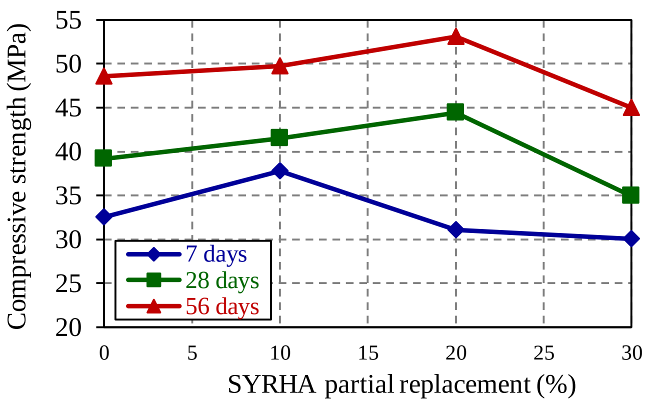

Fig. 11. Effects of OPC replacement by SYRHA on compressive strength of POBC concrete at different ages

4. Conclusions

According to experimental results on this study can be delineated the POBC is classified into normal-weight aggregate and was available as coarse aggregate on concrete produced for other construction applications except heavy duty and pavement wearing surfaces. Chemical composition of SYRHA was met the specification of artificial pozzolans in burnt materials type. It is also reduced setting time, heat of hydration of paste and bulk density of POBC concrete. Considering as enhanced POBC concrete, 10% SYRHA replacement of OPC was significant developed the early strength and reduced water absorption of POBC concrete, benefit of 20% SYRHA replacement of OPC was provided satisfactory strength for long term of the curing ages of 28-day concrete.

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