



Cawangan Kedah  
Kampus Sungai Petani

Faculty of Administrative  
Science and Policy Studies

# i-SPIKE 2021

*Leading An Artificial Innovation In Knowledge, Education And Design*

## **i-SPIKE 2021 INTERNATIONAL EXHIBITION & SYMPOSIUM E-PROCEEDINGS**

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## AN ECO-FRIENDLY CONCRETE BLENDS FROM PALM OIL BOILER ASH

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### ABSTRACT

Palm Oil Boiler Ash (POBA) is a subsequent by-product obtained from the combustion of fibers and kernel shells in palm oil mill boiler, abundantly available and often wasted without further usage. Utilising these materials in lightweight concrete blends offers a great opportunity, especially in addressing environmental issues. The replacement of natural sand and cement with 5% POBA by weight contributes to the highest and favourable compressive strength of the concrete. The compressive strength increases as the curing period of a sample increases up to a maximum of 28 days. The thermal conductivity of the sample was found to be decreased as the POBA replacement increases. In conclusion, an eco-friendly concrete blend from palm oil boiler ash provides a potential alternative in converting industrial waste to beneficial building and construction material. The use of ECO-BAC in

the construction sector can lead to a green structure while reducing the material costs and waste materials from industries. This project will drive to the development of POBA-foamed concrete, which possesses a lightweight characteristic and substantially a favourable compressive strength.

**Keywords:** palm oil boiler ash, compressive strength, thermal conductivity, lightweight concrete

## INTRODUCTION

Over the past decade, a few studies had been carried out to resolve the shortage of natural sand and the upsurge in the waste disposal problems (Awang, Al-Mulali, Khalil, & Aljoumaily, 2014; Mohammad Hosseini et al., 2020; Muthusamy, Zamri, Zubir, Kusbiantoro, & Ahmad, 2015; Rashad, 2016) by using waste material as a replacement of cement and sand in concrete. One of the means to reduce the usage of natural sands in cement production is by partially replacing the cement and sand with supplementary cementitious materials (SCMs) sourced from industrial or agricultural wastes (Roslan, Mohamed Yusof, Sharipudin, Michael, & Sharul Azhar, 2020). Palm oil boiler ash, a local by-product produced by the palm oil industry, is one of the industrial wastes that is in abundance. Palm oil boiler ash (POBA) is a subsequent by-product resulted from the combustion of fibers, kernel shells, and empty pal fruit bunches from the palm oil fruit (Bu, Tian, Zheng, & Tang, 2017). Many studies have been conducted on testing the compressive strength of lightweight concrete by fully or partially replacing the cement and the sand with palm oil shell (Mannan & Ganapathy, 2004; Muthusamy et al., 2015; Teo, Mannan, & Kurian, 2006), oil palm kernel shell (Alengaram, Al Muhit, & bin Jumaat, 2013) and palm oil fuel ash (Awang et al., 2014; Liu, Chua, Alengaram, & Jumaat, 2014; Muthusamy et al., 2015), but to date, no study has been found on utilising the palm oil boiler ash (POBA) as natural sand replacement in lightweight concrete. If POBA can be employed as sand and cement replacement in concrete for structural applications, it would be favourable to the environment by turning these profitless materials into a befitting product. Thus, the present study aims at evaluating the strength response of concrete manufactured with the partial substitution of cement and sand with palm oil boiler ash and to identify the optimum level of replacement. Compression test and thermal conductivity were conducted on the concrete sample with the variation on the percentage of palm oil boiler ash replacement. The optimal level refers to the amount of POBA required as a replacement of sand and ordinary Portland cement (OPC) up to which the compressive strength and thermal conductivity of blended concrete are equivalent or more than that of unblended OPC concrete.

## METHODOLOGY

POBA samples were collected from the palm oil processing factory located in Telok Sengat Palm Oil Mill, Ayer Tawar, Johor, Malaysia. The details of the mixed proportions of plain concrete (control specimen, CM) and concrete containing various POBA content as cement and sand replacement is tabulated in Table 1. Ordinary Portland cement (OPC) was used as a binder to bind the sand and the aggregates. The mixing ingredients of two different sizes of POBA that were used in the experiment, 5 mm and 90  $\mu$ m and were partly replaced with 5% (CM5), 10% (CM10) and 15% (CM15) by weight of cement and sand in concrete, respectively. All materials were dried in the oven to remove the moisture at the temperature of  $110^{\circ}\text{C} \pm 5$  for 24 hours and kept in a humidity-controlled room.

**Table 1.** Concrete sample mixtures by weight percentage

Sample Name	OPC (g)	Water (g)	Sand (g)	Aggregates (g)	POBA (90 $\mu$ m ground)	POBA (5 mm ground)
CM	14.56	7.82	27.94	49.68	0.00	0.00
CM5	13.38	7.82	26.54	49.68	0.73	1.40
CM10	13.11	7.82	25.14	49.68	1.46	2.79
CM15	12.38	7.82	23.75	49.68	2.18	4.19

### Compressive Strength Test

All samples (CM, CM5, CM10 and CM15) were tested for compressive strength at 7, 14, and 28 curing days. The compression test follows accordingly to the ASTM E4 standard (ASTM Standard E4-07, 2007). In this test, the compressive strength limits for all samples were assessed using the compression strength machine. Three replicates of each age were used to determine the average and experimental bounds of the data.

### Thermal Conductivity Test

The measurement of thermal conductivity is conducted using KD2 Pro Thermal Properties Analyser at ambient temperature and pressure. The device uses the transient heated needle to measure the thermal properties of the concrete sample by evaluating the time and temperature response of the sudden electric signal. The thermal conductivity of all samples were measured at the age of 28 days. The corresponding thermal conductivity of three replicates were measured and their average were calculated.

## RESULTS AND DISCUSSION

### Compressive Strength of CM, CM5, CM10 and CM15

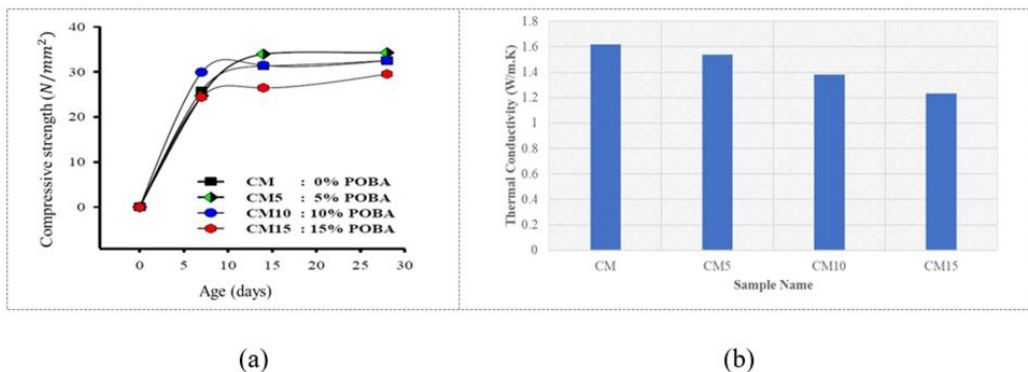
The results obtained show that the variation of compressive strength of four samples with different percentages of POBA mixture at the age of 7 to 28 days. The compressive strength for all samples show an increasing pattern as the amount of POBA increases. The amount of cement in the concrete mixtures plays an important role in the variation of concrete compressive strength. At a high amount of cement, it promotes higher hydration reaction to the concrete mixture, thus increasing the compressive strength of concrete mixtures. CM5 contains higher ratio of cement to POBA, when compared with other samples CM10 and CM15, and this promotes higher hydration reaction that results in higher compressive strength than others [Figure 1(a)] after 28 days.

It can be observed that CM5 and CM10 reached compressive strength above 30 N/mm<sup>2</sup> of M30 concrete mixture and above control sample (CM) compressive strength. The increase in the percentage amount of POBA was observed to linearly reduce the strength of concrete mixture and reach an allowable limit of compressive strength at 28 days. Among three different

replacement levels, the use of POBA at the replacement level of 5% performed the best, contributes to the highest and favourable compressive strength of concrete.

### Thermal Conductivity of Concrete Samples

From Figure 1(b) it is apparent that for the concrete mixture without presence of POBA (CM) results in thermal conductivity of 1.62 W/m.K, whereas for CM5, CM10 and CM15 are 1.54 W/m.k, 1.38 W/m.K, and 1.23 W/m.K, respectively. The reduction in the thermal conductivity ranged from 4% to 14% of the controlled sample. The decrease in the thermal conductivity as POBA replacement level increases could be attributed to the presence of porosity in the concrete samples (Sulaiman & Pahang, 2014) and interfacial distance between hydration products and aggregates. The density of concrete decreases as the voids in the concrete mixtures increases. This voids initially filled up with water and during the hydration process, this water will be consumed to proceed with the reactions. Drying of the concrete will remove its water content, creating voids and entrap air. The presence of entrapped air will therefore promote additional resistance to the thermal activity, thus decreasing the thermal conductivity of the concrete mixture.



**Figure 1.** (a) Compressive strength development of CM, CM5, CM10 and CM15 at 7, 14 and 28 of curing days. (b) Thermal conductivity test results of concrete samples.

### CONCLUSION

From the present study on the feasibility of POBA as cement and sand replacement, it is shown that the percentage replacement of the POBA contributes a significant effect to the properties of concrete. The compressive strength of concrete samples decreases as the replacement of POBA level increases. The thermal conductivity also decreases as the POBA replacement increases. Nevertheless, for future research it is recommended to study the effect of different POBA particle sizes on the concrete mixture's compressive strength and the stability of the concrete to the temperature treatment.

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