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Study of Eco-Processed Pozzolan Characterization as Partial Replacement of Cement

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Abstract

Eco-processed pozzolan (EPP) is a sustainable product recycled from spent bleaching earth (SBE). It is recently used as a blended cement. The pretreatment method of palm oil generates SBE as waste material in the refinery plant. Despite sending the SBE to the landfill, which can lead to environmental pollution, it is extracted to produce sustainable products. The physical, chemical, mineralogical, and microstructural characteristics of EPP were analysed. Furthermore, the conventional cement was substituted with 20% of EPP by cement mass in mortar. The compressive strength of mortar containing EPP was determined for the assessment of strength activity index (SAI) of EPP. EPP consists mainly of silica (SiO_2), and the value of SiO_2, aluminium oxide (Al_2O_3), and iron oxide (Fe_2O_3) combination was 68.98% which is more than 50%. According to the ASTM C618 standard, EPP could be categorised in the Class C pozzolan. The major crystalline phase of EPP was α-quartz. Based on the micrograph image, EPP possesses some relatively spherical, irregular shaped, and agglomeration of its particles. At an early curing age, the compressive strength of the mortar was increased with the inclusion of 20% of EPP. A high value of SAI can be reached by mortar specimen with 20% of EPP.

Keywords: Eco-processed pozzolan, Pozzolan, Strength activity index

1 Introduction

Crude palm oil refinery plant generates spent bleaching earth (SBE) for approximately more than 2 million tonnes per year globally [1]. Malaysia is known to produce a huge number of palm oil fruits. In the pretreatment process which is in the degumming and bleaching of crude palm oil stage, bleaching earth is added to produce refined palm oil. SBE is one of the products of crude palm oil refining process. In Malaysia, the SBE from a refinery plant is often sent to the landfills [2]. The SBE disposal at landfills can affect the greenhouse gas (GHG) emission due to the natural anaerobic degradation. Recently, EcoOils' company provides a solution to recycle SBE to produce sustainable products. Eco-processed pozzolan (EPP) is one of the extracted products from SBE. The sustainable products extracted from SBE are shown in Figure 1.

Recently, EPP has been used as blended cement. From the previous studies, research on EPP as a pozzolanic material is limited. Waste products with pozzolanic characteristics are utilised in concrete to substitute cement, thus minimising the use of cement [3]. The use of pozzolanic material to replace cement could minimise the release of carbon dioxide (CO_2) from the cement industry because the production of cement contributes to 5%–7% of global CO_2 emissions [4].

Palm oil fuel ash (POFA) [5], milled waste glass powder [6], clay brick powder [7], sugarcane bagasse ash [8], and fly ash [9] have been investigated to be used to substitute conventional cement in mortar and concrete. Because of its high percentage of silica (SiO_2), POFA has a high potential to substitute cement in concrete [5]. The reaction of SiO_2 in pozzolanic material with the calcium hydroxide produces more CSH gel. The CSH gel will make the hardened paste denser and enhance its strength and durability [10]. In this study, the properties and the strength activity index (SAI) of EPP were investigated. At 7 and 28 days of curing, ordinary Portland cement was substituted with 20% of EPP by cement mass in mortar to assess the SAI of EPP.

2 Materials and methods

In this study, the EPP was collected from EcoOils, Lahad Datu. The EPP is as shown in Figure 2. The particle size of EPP was measured by using laser diffraction particle size analyser. The chemical oxides, mineralogical, and microstructural characteristics of EPP were investigated by using X-ray fluorescence (XRF), X-ray diffraction (XRD), and scanning electron microscope (SEM), respectively. The ordinary Portland cement was substituted with 20% of EPP by cement mass in

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mortar.

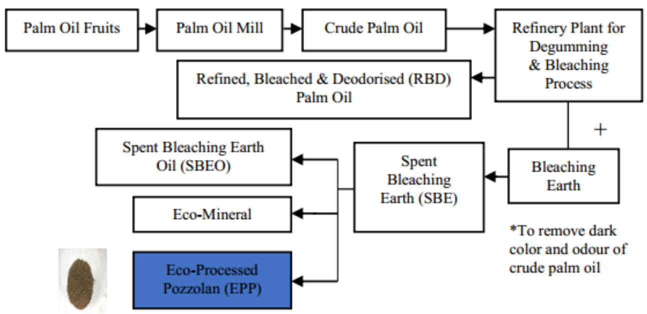


Figure.1: Production of eco-processed pozzolan

The sand was prepared according to the ASTM C778 standard. The mixture with water-to-binder (W/B) ratio of 0.48 was prepared. The mortar specimens with the dimension of 50 × 50 × 50 mm in size were cast. The compressive strength test of the specimens was performed according to the ASTM C109 standard. The pozzolanic activity of EPP was investigated by determining its SAI based on the ASTM C311 standard.

Figure.2: Eco-processed pozzolan

3 Results and discussions

3.2 Physical Properties

Table 1 reveals the physical properties of EPP and OPC. The mean particle size, d_{50} of EPP and OPC was 29.3 and 27.4 µm, respectively. The particle size, d_{90} of EPP and OPC was 80.42 and 94.36 µm, respectively. Based on the results, the specific gravity of EPP and OPC was 1.93 and 3.27, respectively. The EPP has a lower specific gravity than the OPC.

3.3 Chemical properties

Table 2 reveals the chemical oxides of EPP and OPC. The XRF result reveals that the EPP composed of SiO_2 at 47.6% and the combination value of SiO_2, aluminium oxide (Al_2O_3), and iron oxide (Fe_2O_3) was 68.98%. The value is less than 70% as according to the ASTM C618 standard. However, it is more than 50% which the EPP can be classified in the Class C pozzolan. The EPP contains high percentage of SiO_2. The loss on ignition of EPP was 3.3% which is less than 6% as specified in the ASTM C618 standard. From the chemical compositions result, the EPP can be categorised as a Class C pozzolan according to the ASTM C168 standard.

Table 1: Physical properties of EPP

Physical Properties	Particle size, d_{10} (µm)	Mean particle size, d_{50} (µm)	Particle size, d_{90} (µm)	Specific gravity
OPC	3.37	27.4	94.36	3.27
EPP	7.04	29.3	80.42	1.93

Table 2: Chemical oxides properties of EPP

Chemical Properties (%)	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	LOI
OPC	14.4	3.6	3.2	72.3	1.7	5.78
EPP	47.6	11.6	9.8	12.5	6.2	3.3

3.4 Mineralogical and microstructural properties

The XRD analysis of EPP and OPC are shown in Figure 3. The existences of a broad peak at 20° to 30° indicate the presence of amorphous phase in the EPP. The peak at 20° to 30° also shows the existence of SiO_2, which is comparable to the information from the previous study [11]. The major crystalline phase of EPP, which is α-quartz was detected at 2θ angles of 26.63°, 20.86°, and 50.20°. Meanwhile, the minor crystalline phases: cristobalite, hematite, calcite, and α-Al_2O_3 were also identified in the diffractograms of EPP. Cristobalite peak was detected at 2θ angle of 28.03°. Meanwhile, the 2θ angles of 33.21° and 29.44° were assigned to hematite and calcite, respectively. The peaks at 31.31° correspond to the presence of mullite, while the peaks at 35.68° and 39.44° were assigned for α-Al_2O_3.

The mineralogical analysis shows that the EPP consists of different minerals as it possesses SiO_2 either in the crystalline phase or the amorphous phase. The pozzolanic reactivity of material can be relied more on the occurence of its amorphous phase than other properties of the material [12]. The results are in agreement with the chemical composition findings from previous studies which show that EPP contains high SiO_2 content. Meanwhile, the presence of mullite and α-Al_2O_3 corresponds to the presence of Al_2O_3 as stated in Table 2. In addition, the detection of hematite and calcite conform the presence of Fe_2O_3 and calcium carbonate ($CaCO_3$) as discussed in the chemical composition findings.

The micrograph images of EPP and OPC are shown in Figure 4. The SEM image shows that the EPP particles was irregularly shaped, relatively spherical, and agglomerated, while OPC was irregular in shape. EPP has a porous texture on its particles.

3.5 Strength activity index

The SAI of control mortar (reference mortar) is supposed to be 100% at the curing ages of 7 and 28 days. The SAI of EPP and control specimens are shown in Figure 5.

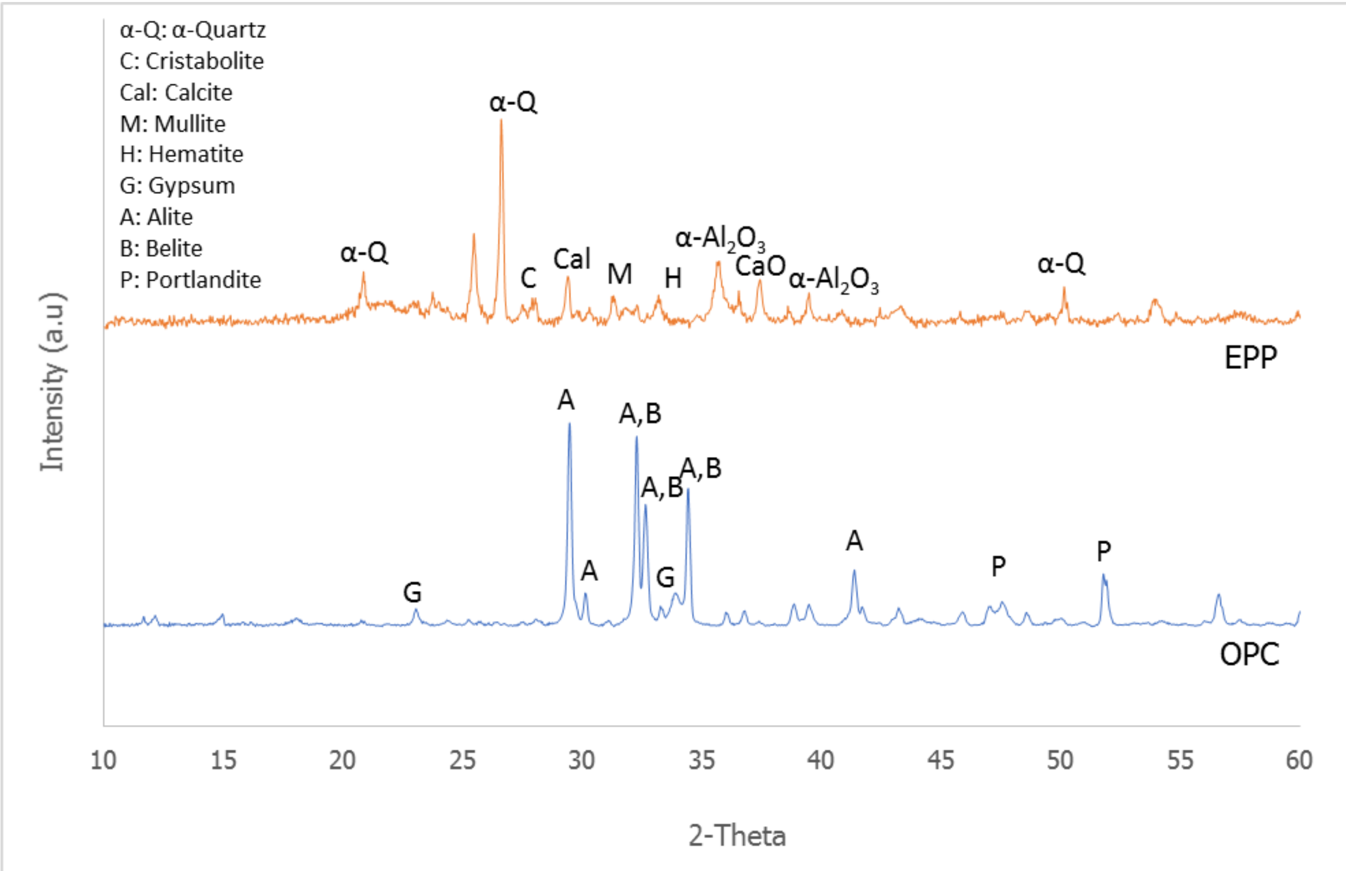
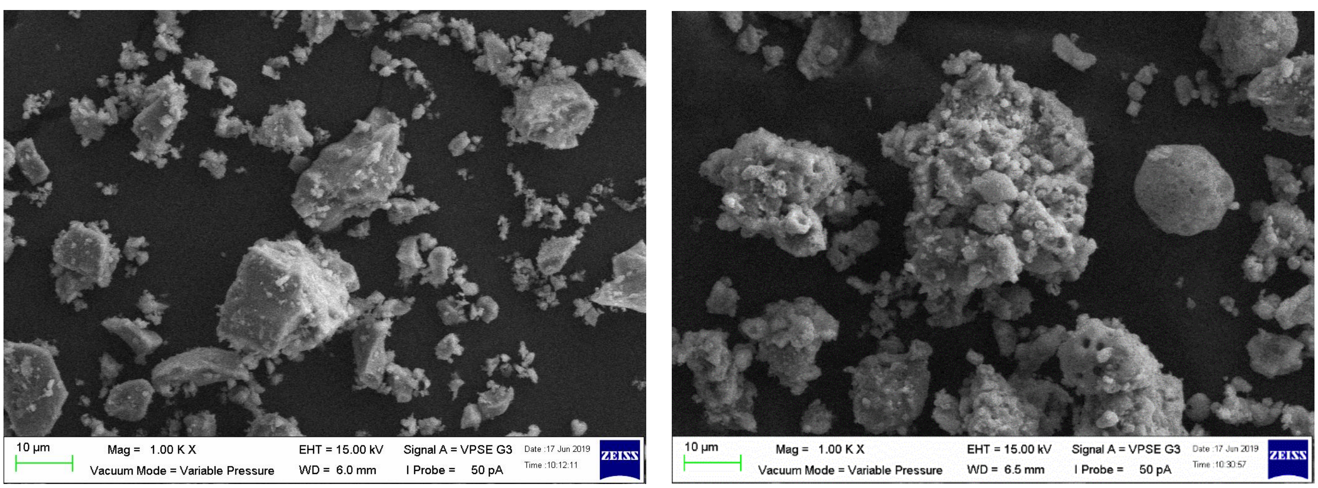


Figure.3: XRD patterns of OPC and EPP



(a) OPC (b) EPP

Figure.4: Micrograph images of OPC and EPP

The figure shows that the compressive strength of specimens increased with the inclusion of 20% of EPP compared to that of the control specimens. The SAI of EPP at both curing ages of 7 and 28 days was 114.4% and 104.2%, respectively, and the values are more than the minimum requirement value of 75% according to the ASTM C618 standard. It shows that the SAI of specimens at 7 days of curing was higher than that of the specimens at 28 days of curing. The increase in SAI value of mortar containing EPP shows that EPP possesses pozzolanic properties. The high percentage of SiO_2 and Al_2O_3 in chemical compositions with some amorphous phase in EPP might contribute to the pozzolanic properties of EPP to be used as cement replacement. The similar behaviour of material was reported in previous study [11]. The pozzolanic reaction of SiO_2 with calcium hydroxide produces more CSH gel resulting in high compressive strength [13]. Therefore, the SAI of EPP reached to a high value at an early curing age. As the CSH gel production increases, the compressive strength increases.

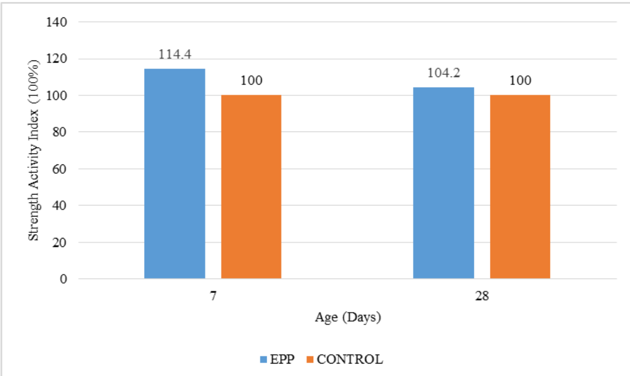


Figure 5: Strength activity index (SAI) at 7 and 28 days

4 Conclusions

This paper concludes that EPP possesses pozzolanic properties as it consists high SiO_2 amount and has the potential to substitute cement in mortar and concrete. The value of SAI of EPP satisfied the requirements of pozzolanic materials as according to the ASTM C618 standard and can be categorised as a Class C pozzolan. High value of SAI can be achieved by EPP at an early curing age. To a better sustainable mortar and concrete production, 20% of EPP can be used as cement replacement. Therefore, further reliable information of EPP is required to increase its usage in industries.

Aknowledgment

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Ethical issue

Authors are aware of, and comply with, best practice in publication ethics specifically with regard to authorship (avoidance of guest authorship), dual submission, manipulation of figures, competing interests and compliance with policies on research ethics. Authors adhere to publication requirements that submitted work is original and has not been published elsewhere in any language.

Competing interests

The authors declare that there is no conflict of interest that would prejudice the impartiality of this scientific work.

Authors' contribution

All authors of this study have a complete contribution for data collection, data analyses and manuscript writing.

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