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Engineering performance of sustainable geopolymer foamed and non-foamed concretes

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ABSTRACT

This study investigates the effect of using palm oil fuel ash (POFA) as a partial replacement for fly ash (FA) in lightweight geopolymer foamed concrete and geopolymer mortar. Three different proportions of POFA contents of 10%, 20%, and 30% with a target fresh density of about 1300 ± 50 kg/m^3, were used. The development of compressive strength and splitting tensile strength were investigated over a 28-day curing period. Transport properties, in terms of water absorption, porosity, and sorptivity, were also investigated. Microstructural characteristics through XRD, SEM and EDX were also investigated and reported. The results found that the compressive strength of geopolymer foamed concrete, with up to 30% POFA, was higher than the control; however, for the POFA-based geopolymer mortar, the compressive strength reduced with increasing POFA content. The highest compressive strength of 6.1 MPa was recorded in the geopolymer foamed concrete with 20% POFA, whereas the control mix of geopolymer mortar produced 36.6 MPa. The geopolymer foamed concrete achieved 70% of its 28-day compressive strength within 3 days. The oven-dry density of the geopolymer foamed concrete ranged from 1193-1344 kg/m^3. The ultrasonic pulse velocity (UPV) value was 1.5 km/s for the geopolymer foamed concrete while the geopolymer mortar had the range of 2.2–2.4 km/s. In general, the transport properties were mostly dependent on the oven-dry density of the geopolymer foamed concrete. The POFA content of 20% was found to provide the required silica and alumina to produce geopolymerization gel. Further, the SEM images showed unreacted FA particles that led to an increase in the voids. Furthermore, the XRD patterns showed the addition of foam affected the intensity of the peaks.

1. Introduction

Concrete is one of the oldest manufactured construction materials and it has widely been used in the construction of various structures since the ancient days. The advancement in research of concrete has resulted in the development of concrete for diverse purposes. Each of the concrete acquires their own unique characteristic in order to meet the demand of the industry. One of the latest advancements in such development is cement-free concrete or geopolymer concrete in which the conventional ordinary Portland cement (OPC) is wholly eliminated. This type of concrete is produced using industrial by-products and waste materials; the prominent among these are fly ash (FA), ground granulated blast furnace slag (GGBS), silica fume (SF), bottom ash (BA), palm oil clinker powder (POCP), palm oil fuel ash (POFA), metakaolin (MK) and rice husk ash (RHA). In the current construction practices, however, OPC remains the main binder used to produce concrete [1]. However, the negative environmental impact of concrete production has become well known, with one ton of cement resulting in the emission of around 0.9 tons of CO_2 [2], and cement production accounting for 5–7% of the total worldwide CO_2 emissions [3]. The construction industry is responsible for one-third of the global greenhouses gas emissions [4].

Consequently, the modern construction industry is developing green concrete, where at least one component is a waste material [5]. Waste materials from agriculture are especially useful due to their high silica content. About 37% of the worldwide POFA production is in Malaysia [6]. Replacing OPC with POFA enhances certain concrete properties as reported from studies comparing the mechanical behavior of cement-based concrete [7,8]. Besides, the utilization of POFA could lead to

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