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Enunciation of size effect of sustainable palm oil clinker sand on the characteristics of cement and geopolymer mortars

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ABSTRACT

Palm oil clinker (POC), a by-product from palm oil industry, has gained attention as a potential sand replacement in concrete. This study focuses on the grading of palm oil clinker sand (POCS) as a whole replacement of conventional sand in cement and geopolymer mortars. Fly ash (FA) and ground-granulated blast-furnace slag (GGBS) were used as binders and activated with a Na_2SiO_3/NaOH ratio of 1.5 in geopolymer mixes. Four different gradings of POCS with a maximum size of 4.75, 2.36, 1.18, and 0.60 mm, along with a control mix with the utilization of Mining sand (MS), were used to cast a total of 10 mixes for cement and geopolymer mortars. The microstructure of the POCS was analysed, and engineering properties of mortars were investigated through flow table test, compressive and flexural strengths, density, drying shrinkage, water absorption and sorptivity tests, and SEM images. The results revealed that mixes with the incorporation of finer POCS particles produced better compressive, flexural, and water absorption values, while the opposite was experienced in terms of drying shrinkage. Overall, the density of the mixes incorporating POCS was reduced by up to 20% and POCS geopolymer mortars produced higher strengths than those of cement. A 28-day compressive strength of 55–65 MPa was produced with the utilization of POCS in geopolymer mortar under the ambient temperature of 26–28 °C.

1. Introduction

Over the past decades, the consumption of natural resources has rocketed due to the increasing demand for housing and construction. One of the most vital natural resources that have been overlooked is sand. The formation of sand takes thousands of years of eroding and breaking down of the rocks while it is consumed in a reasonably short period. The yearly consumption of aggregates was estimated at 25.9–29.6 billion tones worldwide in 2012 [1], with the demand rising to 50 billion in 2019 [2]. The excessive exploitation of natural sand has caused severe harm to the ecosystem and environment, affecting the species [3,4]. As the second most used natural resource on the earth [1], the scarcity of this raw material could significantly affect the lives of humans, primarily in Southeast Asia, where the thirst for high-rise buildings and other constructions has escalated.

The utilization of waste and recycled materials is much considered as a potential approach in tackling the shortage of natural resources as it contributes to the sustainability and preservation of virgin materials. Thus, many researchers have focused on replacing sand with coal bottom ash (BA) [5], POCS [6], spend garnets [7], recycled plastics [8], and copper slag [9] in the concrete and mortar. Considering the disposal issue that is caused by large amounts of industrial wastes generated by factories, utilization of the by-products could mitigate environmental pollution.

Malaysia, along with Indonesia, possesses nearly 85% of the total palm oil production worldwide, in which large amounts of waste are being generated. Among the waste materials from palm oil industries, palm oil fuel ash (POFA), POC, palm oil clinker powder (POCP), and oil palm shell (OPS) have been used in the previous studies. A study [10] revealed that POFA has the potential to partially replace cement in self-compacting concrete with an almost comparable outcome in terms of mechanical and durability of the concrete. Furthermore, POFA is reported to be a suitable binder in geopolymers as an aluminosilicate source [11]. POFA and POCP have been used as partial replacements of cement [12] in recent years since the replacement of cement has been introduced as an important step toward tackling the global warming and

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