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Assessment of sustainable eco-processed pozzolan (EPP) from palm oil industry as a fly ash replacement in geopolymer concrete

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ABSTRACT

This research focusses on the feasibility of using eco-processed pozzolan (EPP), a palm oil industrial by-product, as partial replacement for fly ash (FA) in the geopolymer concrete (GPC); in addition, the effect of another palm oil industrial by-product, palm oil clinker (POC) as the lightweight coarse aggregate in the EPP-based GPC was also investigated. The ratios of alkaline activator to binder and sodium silicate to sodium hydroxide were kept constant, and the specimens were cured at 60 °C for 24 h. The mechanical properties, namely compressive, splitting tensile and flexural strengths, and modulus of elasticity (MOE) were investigated; further, microstructural analyses such as SEM, XRD and EDX were conducted. The test results show that the utilisation of 10–30% of EPP as FA replacement produced the compressive strengths in the range of 28–39 MPa. The splitting tensile strength of both the lightweight (LW) and normal weight (NW) GPC, except for M6 containing 30% of EPP substitution, fulfilled the minimum requirement of 2.0 MPa. In addition, the flexural strength of GPC produced about 12% of the respective compressive strength. The lower MOE of LW GPC compared to the NW GPC is attributed to the lower stiffness and specific gravity of POC aggregates. The XRD analysis shows the evidence of geopolymerization products of quartz, sillimanite, magnetite, and almandine.

1. Introduction

Ordinary Portland cement (OPC) is a common building material that emits substantial amounts of carbon dioxide (CO_2). It is well documented that the manufacture of about 907 kg of cement produces 499 kg of CO_2 in addition to another 363 kg of CO_2 responsible for the burning of carbon fuel for clinkers [1,2]. Thus, the global manufacturing of about 1 billion metric tons of cement produces almost an equal amount of CO_2 [1,2]. It is also crucial to note that about, 6–7% of worldwide anthropogenic greenhouse gas emission is from the manufacture of cement [2]. There are other serious consequences of over-exploitation of natural materials that include flooding, lack of sand and coarse aggregates etc. The ecological imbalance caused due to the overuse of virgin materials has had a serious impact and many governments and non-governmental organizations have taken a series of measures to address these issues [3–5]. Furthermore, Eco process pozzolan (EPP) material is currently used in producing blended cement. It is a solid waste substance derived from the waste product of refined crude palm oil [6]. Globally, around 2 million tonnes of spent bleaching earth (SBE) are produced annually by crude palm oil refinery plants [7]. Most of the SBE from the refinery plants is frequently disposed of in landfills [8]. To a certain extent, the spontaneous anaerobic decomposition of SBE dumped in landfills can affect the GHG emissions.

One of the damage control mechanisms is the usage of supplementary cementitious materials (SCMs) and other alternative industrial by-products to replace the conventional cement, sand, granite aggregates etc. The use of EPP, palm oil fuel ash (POFA), rice husk ash (RHA), fly ash (FA), ground granulated blast furnace (GGBS) etc. had some impact in on reducing the dependence on OPC as the sole binder [9–12]. There is a vast potential in encompassing such materials for future use based

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