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Evaluation of Industrial By-Products as Sustainable Pozzolanic Materials in Recycled Aggregate Concrete

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Abstract: The utilization of traditional supplementary cementitious materials (SCMs) has become more intense in the concrete industry due to their better long-term properties. This research evaluates the fresh and hardened properties of concrete that was developed using a high amount of recycled aggregate (RA) incorporated with sustainable SCMs. Rice husk ash (RHA), palm oil fuel ash (POFA) and palm oil clinker powder (POCP) were used as SCMs at 10%, 20% and 30% cement replacement levels to investigate their positive role in the performance of RA concrete. The results showed that the 10% replacement level of cement by RHA produced the highest strength at all ages tested. Although POFA and POCP were found to negatively affect the strengths at an early age, the hardened properties showed improvement after a relatively long curing time of 90 days. In addition, the targeted compressive strength of 30 MPa was achieved by using SCMs at levels up to 30%. Overall, the sustainable SCMs can reduce the quantity of cement required for concrete production, as well as reduce the conventional cement with the industrial by-products, which are considered as waste materials; thus, the concrete produced using up to 30% of SCMs as a replacement for cement could be considered as more environmentally-friendly concrete.

Keywords: sustainability; supplementary cementitious materials; pozzolans; recycled aggregate concrete; engineering properties

1. Introduction

In today's fast growing urbanization, environmental sustainability is a significant factor that cannot be ignored by architects, engineers, researchers and, above all, by the construction industry; one of the means to achieve the balance in sustainable development is through the utilization of locally available waste or recyclable materials. The alarming rate of concrete production that consumes a vast amount of natural resources around the world signifies the need for sustainability through the use of alternate materials. It is estimated that the production of concrete consumes about 27 billion tonnes of raw materials or four tonnes of concrete per person per year [1]. The quarrying and manufacturing process of massive quantities of aggregates, in addition to about 2.8 billion tonnes of cement products manufactured every year [2], cause around 5–7% of the planet's total CO_2 emissions [3]. Consequently, the problem is likely to get worse, as it is foreseen that by 2025, about 3.5 billion tonnes of CO_2 will be emitted from the manufacturing of cement [4]. Further, it is predicted that by 2050, concrete production will reach four-times the level as that of 1990 [5]. It is to be borne in mind that the main

Based on the findings of this study, it can be demonstrated that the utilization of industrial by-products as supplements to conventional cement is feasible in 100% RA-based concrete. Further, the benefits of sustainable SCMs are not only constrained to the technical effects on the concrete, but also through their vital impact on the economic and environmental aspects. The incorporation of such products serves as an avenue to reduce the volume of waste dumped in the vicinity of factories and at the same time would reduce the exploitation of natural resources. Therefore, minimizing the deleterious impact of the construction industry on the environment and keeping the movement towards more environmentally-conscientious building materials would pave the way for achieving sustainability in the concrete industry. The cost-benefits of incorporating sustainable materials into concrete differ for each application and depend on the availability of these materials. The widespread acceptance of waste materials and industrial by-products by the concrete industry can be facilitated by filling the knowledge gaps that currently exist with respect to the myriad of potential alternatives. However, further research is recommended to study the contribution of non-traditional SCMs to the economic aspect and their effect on the greenhouse gas emission. In addition, research on the durability and performance of concrete incorporating non-traditional materials is vital.

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