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Assessment on engineering properties and CO_2 emissions of recycled aggregate concrete incorporating waste products as supplements to Portland cement

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ABSTRACT

This paper presents an experimental investigation on the durability properties and carbon dioxide (CO_2) emissions of concrete developed using waste products. The concrete comprised of recycled concrete aggregate (RA) as a complete coarse aggregate replacement. In addition, rice husk ash (RHA), palm oil fuel ash (POFA) and palm oil clinker powder (POCP) were used as replacement materials for cement at levels up to 30%. The supplementary cementitious materials (SCMs) were used in RA concrete with the aim of reducing the dependency on cement as a stand-alone binder. The compressive strength, water absorption, chloride-ion penetration and electrical resistivity were investigated for RA concrete containing SCMs. Moreover, the residual compressive strength was also examined along with the weight loss to check the elevated temperature resistance of RA concrete with SCMs. The results revealed that the use of 30% RHA as SCM produced the highest compressive strength efficiency of 0.143 MPa/kg cement among all mixes at the age of 90 days. In addition, a significant enhancement was observed for the durability-related properties at later ages, although the engineering properties of RA concrete containing SCMs was low at the age of 28 days. The thermogravimetric (TG) analysis indicated that the RHA is more effective as a pozzolanic additive than POFA and POCP. The CO_2 emissions from RA concrete were reduced by approximately 29% when it was incorporated with 30% SCM, where the eco-strength efficiency showed the highest values at 20% cement replacement level of 20%.

1. Introduction

Cleaner production of concrete is characterized by embracing sustainable binders which is less aggressive to the environment. Modern concrete incorporating sustainable materials is evolving in light of the remarkable growth in the construction industry. Consequently, the use of supplementary cementitious materials (SCMs) from industrial by-products as a partial replacement for conventional cement is considered as a viable alternative to reducing CO_2 emission. Furthermore, the use of recycled materials, in particular, recycled concrete as a replacement to conventional crushed granite aggregate in the concrete industry would enable us to preserve the virgin materials. The annual requirement for 2016 was approximately 3.81 billion tonnes of cement (USGS, 2017) and 22 billion tonnes of aggregates for concrete manufacturing (Celik et al., 2015). The latter adds more woes on ecological imbalance and sustainable development. To put these figures in perspective, a wall of about 4 m width × 70 m height could be built along the equator using the 11.25 billion cubic meter of concrete produced annually. Although the concrete industry has a detrimental impact on the environment and sustainability, it is an indispensable component in the development of infrastructure, industry and housing.

From another perspective, concrete industry accounts for 5% of all man-made carbon dioxide (CO_2) emissions (Cai et al., 2016). This progressive emission of CO_2 reached an alarming level and is expected to rise faster in the near future. According to Celik et al. (2015), approximately 866 kg of CO_2 is being emitted for every

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caused by the disposal of these materials as well as reducing the CO_2 emission during the production of cement.

6. Further research can be done on the treatment of POFA since it yielded a high LOI value. Hence, heat treatment is recommended to remove the high carbon content that exists in POFA. Future work could include testing the RA based concrete incorporating high-volume SCMs in a full-scale structural application as the current study only concentrated on the durability and sustainability performance of RA based concrete.

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