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Performance assessment of mechanical properties of green normal strength concrete produced with metakaolin-cement coated recycled concrete aggregate for sustainable construction

Oluwarotimi M. Olofinnade *, Osamudiame P. Osoata

Department of Civil Engineering, Covenant University, PMB 1023, Ota, Nigeria

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ABSTRACT

Reusing demolished concrete waste is a promising alternative to natural aggregate for resource conservation and achieving sustainable environment. However, there is a need to improve their quality and performance in new concrete. Therefore, this study aims to examine the mechanical performance of normal strength concrete containing metakaolin-cement coated recycled concrete aggregate (RCA). Three mixture batches were produced at water-cement ratios (w/c) of 0.25 and 0.45. The first batch is control mix, while the second and third batches contained uncoated RCA and metakaolin-cement coated RCA (TRCA) respectively. Materials characterization and workability of fresh concrete mixes were carried out. Compressive and split tensile strengths and water absorption tendency of hardened samples were determined. Morphology of selected concrete samples was analysed with scanning electron microscopy (SEM) with energy dispersive x-ray (EDX). The experimental results were further analysed with central composite design (CCD) response surface method. Results show improvements in the physical properties of RCA aggregates and declining trends in slump values. However, relative to the control mixes, concrete mixes containing TRCA exhibited significant improvement in strength performance and low water absorption tendency compared to RCA concrete mixes. This was corroborated by the response surface models showing that both w/c ratio and TRCA amount significantly influenced the strength and water intake performance of the concrete. The study demonstrated that TRCA can be deployed as an alternative for natural coarse aggregate up to 50% substitution in making normal concrete for structural purposes.

1. Introduction

In recent times, the construction industry continue to expand globally generating employment opportunities and improving the standard of life, economy and socio-cultural environment [28]. However, this continual expansion has gravely impacted the environment and its natural resources owing to high demand and consumption of non-renewable raw aggregates, energy demands and the enormous volumes of construction and demolition (C&D) wastes generated during construction or renovation activities (Olofinnade & Ogara [41]. According to Waiching et al. [66], the rapid growth of the construction industry has resulted in an enormous demand for natural aggregates for construction activities. Meanwhile, it was projected that the worldwide market for natural construction aggregates will grow by an annual growth rate of 5.2% as of 2016 to about 51.7 billion tonnes by 2019[23]. This high demand for natural aggregate has resulted in considerable over-quarrying and mining activities leading to environmental issues such as damage to landscapes, ecological imbalances, contamination of water basins, and pollution of the air and soil [28]. A study by Soutsos et al. [56] projected that the United Kingdom (UK) demand for new aggregates alone is expected to increase by 1% annually from 275 million tonnes as of 2011 which is about 20 million tonnes per year to

Abbreviations: ANOVA, Analysis of variance; CCD, Central composite design; R^2, Coefficient of correlation; CI, Confidence interval; C&D, Construction and demolition; C&DW, Construction and demolition waste; DOF, Degree of freedom; EDX, Energy dispersive x-ray; NSC, Normal strength concrete; ITZ, Interfacial transition zone; TRCA, Metakaolin-cement coated recycled concrete aggregate; MRA, Mixed concrete and masonry recycled aggregate; OPC, Ordinary Portland cement; RA, Recycled aggregate; RAC, Recycled aggregate concrete; RCA, Recycled concrete aggregate; RMA, Recycled masonry aggregate; RSM, Response surface methodology; SEM, Scanning electron microscopy; w/c, Water-cement ratios; XRF, X-ray fluorescence.

* Corresponding author.
E-mail address: rotimi.olofinnade@covenantuniversity.edu.ng (O.M. Olofinnade).

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