ABSTRACT

The use of fine recycled aggregate (FRA) produced from construction and demolition waste (CDW) in new concrete applications offers a sustainable solution to the environmental and social issues associated with the extraction of natural sand resources as well as the challenges of CDW management. However, the use of FRA in structural concrete is restricted due to the adhered cement paste (ACP) and multiple interfacial transition zones (ITZ) in the FRA matrix that increase the porosity of concrete. Therefore, this research aims to investigate and develop practical ways of optimising and enhancing the properties of FRA where the inherent properties such as ACP, porosity and multiple ITZ have limited consequences on concrete properties.

This study utilised a multi-technique enhancement approach such as the use of fly ash and ground granulated blast-furnace slag (GGBS) to optimise the physical (pore structure) and chemical (hydrated and unhydrated cement) properties of ACP through pore densification and pozzolanic reactions respectively. Also investigated, was the effect of screening the fine fraction of FRA < 1.18 mm that is often reported in literature to contain significant amounts of ACP. To understand the influence of FRA on concrete properties, the physical, chemical, and mineralogical properties of FRA were investigated using XRD, XRF, TGA, water absorption, density, and particle size distribution tests. To investigate the concrete performance, a total of 30 concrete mixes were produced using two water/binder (w/b) ratios of 0.55 and 0.45; three types of binder namely Portland cement, fly ash and GGBS; and two types of FRA namely FRA 1 (1.18 – 4.75 mm) and FRA 2 (< 4.75 mm) to replace fine natural aggregates at 25% and 50%. The tests carried out on concrete include slump, compressive strength, elastic modulus, durability indexes (OPI, CCI and WSI), bulk diffusion, electrical resistivity, and carbonation.

The results show that all concrete mixes achieved the design slump of 75 ± 25 mm with minimal or no superplasticizer dosage, especially mixes containing fly ash and GGBS. The compressive strength results indicate that the use of up to 50% FRA can produce concrete of equivalent or superior compressive strength properties to the control natural aggregate concrete (NAC) at 28 and 180 days. Also, for up to 180 days of curing, the rate of strength gain for FRA concrete was higher than NAC. The permeability coefficient (k) as measured by the OPI test indicate that permeability increases with an increase in FRA content, however, the OPI values of all mixes exceeded 10 indicating excellent concrete according to the test standard. Overall, for any given w/b ratio and binder type in the OPI, CCI, WSI and electrical resistivity tests, all FRA concrete mixes irrespective of FRA type or content, were categorised according to the respective test standards, to be within the same good to excellent quality

as the control NAC. Results also show that the The cementitious phases detected in the ACP of FRA will also contribute to the naturechemistry of the pore solution, allowing further reactions and thereby enhancing the durability properties of FRA concrete. It can be inferred that Tthe Ca(OH)2 and C-S-H in the ACP react with C02 during carbonation thereby producing a buffering effect, while the C-S-H and AFm phases are involved in chloride binding thereby making the resistance to chloride diffusion of FRA concrete comparable to NAC. Furthermore, the use of fly ash and GGBS led to improvements in strength and durability properties particularly over long curing periods. Compared to GGBS, fly ash showed better improvement in FRA concrete properties owing to more phases in the ACP such as Ca(OH)2 and calcite that react with fly ash to form C-A-S-H and other hydrated aluminate phases. Overall, the study showed that using the appropriate enhancement techniques, the properties of FRA concrete can be optimised and enhanced for structural concrete applications.