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Short communication

Acid resistance of quaternary blended recycled aggregate concrete

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ABSTRACT

The possibility of reusing the aggregate from demolished structures in fresh concrete, in order to reduce the CO_2 impact on the environment [23] and to preserve natural resources, was explored worldwide and it is established that recycled aggregates can be used as a partial replacement of natural aggregates. Due to its potential to be used in eco-friendly structures and shortage of supply of natural aggregates in some parts of the world, there is an increasing interest in using the recycled aggregate. The durability aspects are also of equal concern along with the strength and economy of any material to be used in the construction. Studies reveal that the behaviour of ternary and quaternary blended concretes is superior from durability point of view compared to conventional concrete. Therefore a study is conducted to assess the acid resistance of recycled aggregate based Quaternary Blended Cement Concrete (QBCC) of two grades M40 and M60. Fly ash and silica fume are fixed at 20% and 10% respectively from the previous studies while two percentages of Nano silica (2 and 3%) were used along with the cement to obtain QBCC. Three percentages of recycled aggregates as partial replacement of conventional aggregate (0%, 50% and 75%) were used in this study. Two different acids (HCL and H_2SO_4) with different concentrations (3 and 5%) were used in this study. Acid resistance of QBCC with Recycled Concrete Aggregate (RCA) is assessed in terms of visual appearance, weight loss, and compressive strength loss by destructive and non-destructive tests at regular intervals for a period of 56 days. The test results showed marginal weight loss and strength loss in both M40 and M60 grades of concretes. The Ultrasonic Pulse Velocity (UPV) results show that the quality of QBCC is good even after being subjected to acid exposure.

1. Introduction

The widespread use of concrete for making architectural structures, foundations, brick/block walls, pavements, bridges/overpasses, highways, runways, parking structures, dams, pools/reservoirs, pipes, footings for gates, fences and poles and even boats, has increased the demand for cement concrete as a construction material. Due to increase in infrastructure developments, the demand for concrete would increase in future. With the continuing expansion of infrastructure and housing construction, especially in the developing countries of Asia, Africa and South America, the rate of consumption of cement and concrete is bound to grow further. It is estimated that the world cement production will increase to around 4.8 billion tons per annum by the year 2030 [1], resulting in proportionate growth in the production of concrete. This consumes the natural resources on one side and increases the demolition waste on the other. Aggregate recycled from demolished concrete is considered to be waste product which can be utilized effectively to overcome the harmful effect of producing natural aggregate like depletion of natural resources, effect on the surrounding

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environment, etc. Quaternary blended cement concrete has high workability and improved properties apart from usage of industrial wastes like fly ash, silica fume, etc. For any material to be used for construction, the durability properties are also important along with the desired strength and mechanical properties. Hence, a study is undertaken to investigate the acid resistance of Quaternary blended cement concrete made with varying proportion of recycled concrete aggregate subjected to hydrochloric acid and sulfuric acid attack. In this study M40 and M60 grades of concrete with different RCA proportions were used.

Alexander and Fourie [2] measured acid resistance of six different sets of concrete materials using hydrochloric acid in a test method developed at the University of Cape Town. They found that Silica fume concrete showed better acid resistance compared to the standard concrete and the meta-kaolin concrete. Tang et al. [3] carried out study on compressive strength and durability of concrete and covered the effect of alkali aggregate reaction, sulphate attack, steel corrosion and freeze-thaw. Medina et al. [4] conducted studies on the chloride penetration and electrical resistivity, as well as the relationship among the durability indicators that predict concrete performance during its service life. The study showed that chloride penetration was slightly deeper in recycled concretes, while no alterations were observed in the relationship among the durability indicators. Faiz and Supit [5] carried out experimental investigations on the compressive strength and durability properties of high volume flyash concretes containing ultrafine class F fly ash (UFFA). They concluded from their investigation that the introduction of ultra fine fly ash improved early age compressive strength and also durability properties. Chousidis et al. [6] investigated the effect of greek flyash as a partial replacement of cement on the durability and mechanical resistance of concrete immersed in sodium chloride solution (NaCl) and concluded that with increase in flyash content chloride concentration increased which in turn increases corrosion of steel.

Dilbas et al. [7] studied the properties of the specimens made of recycled concrete aggregate with silica fume and without silica fume. The study resulted that the compressive strength of the recycled concrete aggregate was low when compared to the specimens with silica fume mixed in the concrete. Prasad Rao and Kumar [8] concluded that with the increase in the percentage of nano silica the various strength characteristics of the concrete were increased upto 1.5% and with further increase in nano silica the strength decreased. The split tensile strength also indicated the similar trend. Based on the study the strength properties of concrete can be improved by addition of 1.5% of nano silica and 10% of micro silica by weight of concrete. Prasad Rao and Kumar [9] found the optimum values of nano-silica and flyash as 3% and 20% respectively from strength point of view. Abdul Wahab et al. [10] concluded from their study that in triple blended mixes, there is a gradual increase in strength upto 2% of nano silica with 10% condensed silica fume (CSF) in the mix and above there is gradual decrease in the strengths. Finally the study concluded that adequate plasticizers are to be added when nano silica and CSF are used along with the cement in high strength concrete mixes. Seshasayi et al. [11] Carried out an experimental investigation to assess the performance of three types of concrete: the study concluded that Concrete with high volume fly ash showed better resistance when exposed to acidic environment, though strength decreased marginally. Concrete with blended cement is found to be more impermeable than concrete with fly ash mixed at site. Mukesh et al. [12] investigated the mechanical properties and durability performance of concrete produced with Portland silica fume (PSF) and RCA. In this study a gradual reduction in strength with an increase in RCA content was observed. Reducing the w/c of concrete treated with the RCA has led to an enhanced compressive strength, higher resistance to carbonation, and chloride ion ingress. Torben and Erik [13] concluded from their experimental investigations that Recycled aggregate concretes have 15–30% lower modulus of elasticity and 40–60% higher shrinkage than corresponding conventional concretes.

Buttler and Machado [14] carried out an experimental study to evaluate the physical properties of the recycled concrete coarse aggregates and the physical and mechanical properties of the concretes produced with these aggregates. Results indicate that the residues of concrete that were recycled right after generation exhibit higher compressive and tensile strengths when compared to those concretes with natural aggregates because of the presence of a large amount of non-hydrated cement particles. Meinhold et al. [15] demonstrated through their experimental work that the industrial production of a high-grade, durable concrete is possible. Yamato et al. [16] concluded that decrease in strength can be suppressed low by partial use of recycled coarse aggregate. The drying shrinkage of recycled aggregate concrete showed larger value than conventional crushed aggregate concrete whereas shrinkage reducing agent can reduce the drying shrinkage of recycled aggregate concrete. Torben and Soren [24] reported experimental results that show that addition of a plasticizing, an air entraining, a retarding, and an accelerating admixture to original concretes had little or no effect on the properties of new concretes produced from recycled aggregates obtained by the crushing of original concretes. Adam et al. [17] investigated the workability, compressive strength, and elastic modulus of normal-strength concrete with recycled concrete aggregate (RCA) as replacement for coarse natural aggregate (for example, crushed stone, gravel). The results suggest that the RCA water absorption and deleterious material content can be used to prequalify the material for selected concrete strength and stiffness performance objectives. Corinaldesi and Moriconi [18] carried out an investigation by completely replacing natural aggregates with recycled aggregates from a crushing plant in which rubble from building demolition was ground. The results obtained show that because of mineral addition and W/C reduction, recycled aggregates can be used instead of natural aggregates since concretes with similar compressive strength can be obtained. The use of the recycled aggregates with fly ash replacements also has significant cost and environmental advantages over ordinary concrete.

Therefore, in this study, acid resistance of quaternary blended recycled aggregate concrete is studied for two different grades of concrete M40 and M60. The weight loss and strength loss are the main parameters of study. Two acids HCL and H_2SO_4 are used with two different percentages selected, based on the literature available, corresponding to exposure conditions. The loss of strength increased with increased recycled aggregate concrete. However, the value of strength loss is observed to be less compared to earlier researchers' findings [19] due to the addition of powders (Quaternary blending). The results of the investigation are useful for application of QBCC in sewage pipes.