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Properties of recycled concrete aggregate under different curing conditions

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Abstract Construction and demolition wastes are produced every day around the world. Thus the idea of using recycled concrete aggregate in new concrete production appears to be an effective utilization of concrete waste. This paper presents the results of an experimental study to evaluate the effects of recycled concrete aggregate (RCA) percentages under different curing conditions. The percentages of recycled coarse aggregate to dolomite were (0:100%, 25:75%, 50:50%, 100:0%) respectively. The concrete properties which were studied were the mechanical properties (compressive and splitting strength) and mass transport properties (ISAT and sorptivity). The concrete specimens were exposed to three different curing conditions, moist (standard), open-air, and painted specimens using the substance (Curassol 1). The coarse recycled concrete aggregates were obtained by crushing a laboratory produced primary concrete at age of 28 days. The results showed that curing using paint material was the most efficient method of curing at all ages and percentages of recycling except at 100% recycling, where the maximum value of both compressive and tensile strengths was obtained using water curing. Also, in moist curing, full replacement of coarse aggregates gave the highest compressive strength at age of 28 days. In all cases of recycled aggregate ratios, curing using water caused a decrease in the concrete permeability.

Introduction

Crushing concrete to produce coarse aggregates for the production of new concrete is one of the common methods to achieve an environmentally-friendly concrete. This reduces the consumption of natural resources as well as the disposal of waste concrete in landfills [1]. Thus the idea of using recycled concrete aggregate in new concrete production appears to be an effective utilization of concrete waste. However, the strength of new concrete produced using recycled concrete aggregate needs to be evaluated before their use in structures.

Many researchers studied the mechanical behavior of recycled concrete coarse aggregates [1–9]. Also, many authors have pointed to the possibility of using recycled aggregates to produce structural concrete [10–13]. On the other hand, few of

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them studied the effects of curing conditions on the mechanical properties of concrete made of recycled aggregates.

Curing is a treatment that avoids excessive drying and provides enough water content to the concrete mass in order for cement to reach the desired degree of cement hydration. The curing process of concrete tries to oppose the undesired effects of some environmental actions (sun radiation, air moisture and wind), so the effect of curing conditions on the compressive strength of recycled concrete is an interesting issue to be studied.

Two different qualities of recycled aggregates were used by Fernando et al. [14] to make concrete with 0.65 water/cement ratio. The recycled aggregates were added with their natural moisture and replaced different percentages of the coarse aggregates (0%, 20%, 50% and 100%). The concrete specimens were exposed to two different environments (standard curing and open air curing). The results showed that the 7-day strength increases with the percentage of replacement, this behavior was more evident for the standard curing environment. The 28-day compressive strengths of concretes with recycled aggregates were found similar to the ones obtained with natural aggregates regarding the standard curing condition. Fonseca, et al. [15] studied the influence of different curing conditions on the mechanical properties of recycled concrete coarse aggregate concrete. Four concrete mixes were produced using different replacement ratios, along with four different curing methods. It was concluded that compressive strength did not seem to be affected by recycled concrete coarse aggregate incorporation for a given curing condition when compared to conventional concrete. In other words, compressive strength seems to be reasonably insensitive to curing condition.

However, there is a lack of information regarding the effect of recycled aggregate concrete on mass transport of concrete such as initial surface absorption test (Isat) and sorptivity. Moreover, there is still a need to signify the impact of various curing conditions on properties of concrete made with different percentages of recycled aggregate.

In the present study the effects of different curing conditions (moist–standard curing, open air and painted) on the mass transport (ISAT sorptivity) and mechanical properties (compressive strength and splitting strength) of recycled concrete were investigated.

Experimental program

Four concrete mixes were produced using different replacement ratios of recycled coarse aggregate to dolomite (0:100%, 25:75%, 50:50%, 100:0%) respectively. The four mixes were then exposed to three different curing methods (open Air, Saturated, and Painted). After the curing period, hardened concrete tests were performed to determine the concrete properties such as mechanical properties (compressive and splitting strength) and mass transport properties (ISAT and sorptivity).

Materials and mix design

Four different concrete mixes were produced: a control concrete mix and three recycled aggregate concretes with replacement ratios of 25%, 50% and 100%. One type of cement was used in this study, Portland cement (OPC). Natural siliceous sand with medium grade of fineness modulus of 2.73 and dolomite natural coarse aggregate with maximum nominal size of 25 mm were used in all mixes. Tap water was used for mixing and curing (saturated). Table 1 shows the mix design and slump of the concrete used in the experimental program.

The coarse recycled concrete aggregate was obtained by crushing a laboratory produced primary concrete at age of 28 days. About 250 cubes of dimension 15 * 15 * 15 cm were crushed to produce the recycled coarse aggregates using mix design No.1 (Table 1). After crushing of these cubes, the maximum nominal size of recycled coarse aggregate used in mixes 2, 3 and 4 was 25 mm. From the results of slump shown in Table 1, it is noticed that all mixes were very dry especially mix numbers 3 and 4. This means that the used mixes needed an admixture to improve the concrete workability. ADDICRETE BVF was used as an admixture with dosage 1.0% of cement weight and the resulting slump shown in Table 1.

Curing condition

After 24 h from mixing, the specimens were cured in three conditions, open-air curing in laboratory atmosphere, standard curing and painted curing for 3, 7 and 28 days respectively. Five specimens were cured in each condition. The concrete cubes were painted using Curassol 1. The paint was sprayed on the surface of concrete after casting directly, thus closing the pores and maintaining adequate moisture to interact with cement. Curassol 1 is a material that satisfies ASTM C309-81 class B type 1 with a density of 0.8 kg/liter for type 1.

Testing procedures

Compressive strength of hardened concrete was measured at the age of 3, 7 and 28 days on 150 mm cubic specimens (5 specimens in each case). 28-day splitting tensile strength was measured on five 100×200 mm cylindrical specimens. Sorptivity test was carried out on 100 mm concrete cubes according to the test details described in Ref. [16]. Fig. 1 shows the sorptivity test. The test was performed on three specimens at the age of 28 days, and then the average was calculated using the following equation [16]:

$$I = A + ST^{1/2}$$

where
A, is constant,
I is increase in mass in g/mm^2,
T is the time, measured in minutes, at which the weight is determined, and
S is the sorptivity in mm/min$^{1/2}$.

Initial surface absorption test (ISAT) was carried out on 100 mm concrete cubes. The apparatus is shown in Fig. 2 and test details are described in Ref. [17]. The test was performed on three specimens at the age of 28 days and the flow rates in ml/m^2/sec were calculated using the following equation:

$$F = (60 \times D \times 0.01/t)$$

where
F: flow rate (ml/m^2.sec),
D: number of divisions read on tube, and
t: time (sec).