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Experimental Evaluation of Bond Behaviour of Concrete and Rebar Using Recycled Coarse Aggregates, Quarry Dust and Foundry Sand

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Abstract

The construction industry has relied far too heavily on traditional building materials that are derived directly from the earth. In this experiment the bond strength of 8 mixes were determined. Out of the many and varied possible combinations of construction materials, this study is focused on one such factor, namely the use of recycled coarse aggregates in concrete and their bond behaviour with the concrete-steel bar interface. It was found that the cubes' compressive strength gradually decreased as the percentage of recycled coarse aggregate increased; similarly, the values for bond strength tended to decline as the percentage of recycled coarse aggregate increased, with the least value at 100% replacement of natural coarse aggregates in both tests.

Keywords-: *Natural Coarse Aggregate (NCA), Recycled Coarse Aggregate (RCA),Waste Foundry Sand (WFS).*

INTRODUCTION

The demand for materials used in infrastructure development, such as cement, sand, and steel, has increased due to the world population's rapid growth and rising urbanization. Due to the scarcity and overuse of the existing natural resources, the reliance on conventional raw materials needs to be reduced. The demand for construction materials will rise exponentially due to the infrastructure's ongoing expansion, and such large-scale requirements might not be

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satisfied by materials of sufficient quality and quantity. The creation of concrete mixtures that at least partially lessen the heavy reliance on traditional ingredients is an urgent necessity.
The bond performance of steel bars in recycled-aggregate concrete have been investigated by a number of studies. Decrease in the bond strength is relatively proportional to the percentage of replacement of recycled aggregate. Clearly, low amount and small size of coarse recycled aggregates increase the concrete compressive strength and the bond properties. In addition, the increase of coarse aggregate size reduces the bond strength. There are few studies that were carried out to investigate the performance of FRP reinforced recycled-aggregate concrete.

In view of the performance of concrete obviously affected by the weakened interface of recycled coarse aggregate to binder paste, a technology of composite aggregate with recycled aggregate and natural aggregate was proposed. The composite aggregate consists of small particles of recycled coarse aggregate and large particles of natural aggregate in proper proportions to meet the continuous particle grading. Satisfactory strength of concrete and reliable loading performance of reinforced concrete beams can be provided by using the composite recycled aggregate . Another attempt was to produce concrete with 100% recycled coarse aggregate and manufactured sand . This method intends to add the benefits of the stone powder of manufactured sand to the microstructure of concrete. The benefits include the micro-aggregate filling effect on density, the activity effect and crystal nuclei effect on cement hydration, and the enhancement effect on the interface of the aggregate to set cement. This gives the concrete satisfactory performances in terms of good workability of fresh mix, reasonable basic mechanical properties with long-term development and acceptable durability for the structural application. As a result, the RAMC presents good basic mechanical properties except for a slightly lower tensile strength than predicted. This encourages the research of RAMC for structural application. Under this condition, solid wastes recycling for the production of new concrete can reach a high level with 100% recycled coarse aggregate and manufactured sand.

This paper will consider the RAC replacement percent age and the steel rebar style as the main experimental parameters. The aim of this work is to investigate the bond behaviour between recycled aggregate concrete and steel rebars and to establish a bond stress versus slip relationship between recycled aggregate concrete and steel rebars. The bond behavior

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between concrete and steel bar is a key factor to ensure the two materials work together. Unlike NCA, RCA has more porous and higher water absorption, which is because the old cement paste on its surface will influence the bond behavior between concrete and steel bar.

EXPERIMENTAL PROGRAM

Materials

The concrete mixes for preparation of test specimen were done using ordinary Portland cement (OPC 53), confirming to IS 8112:1989, Natural coarse aggregates, Recycled coarse aggregates. Fine aggregate serves as filler material avoiding voids which also forms bond with the cement to provide appropriate strength; they generally include River sand, M-sand or quarry dust. The fine aggregate is replaced by foundry sand. The steel rebar for pull out test specimen is of grade Fe550 is used (Figure 1). GGBS is used to eliminate alkali-silica reaction due to the use of WFS.



Figure 1: Materials

Mix proportion

The mix for M20 grade concrete was designed. The control concrete mixture consisting of only NCA was designed using the absolute volume method and the mixture design of RCA concrete was carried out using equivalent mix proportions where in the mixture proportions for the NCA and the RCA concretes were nominally kept the same, except for direct weight to weight replacement of NCA with RCA, depending upon the desired RCA replacement level. The RCA replacement level is defined as the weight ratio of RCA to the total coarse aggregates in the concrete mixture and depending upon the desired replacement level, direct substitution of NCA with an equal weight of RCA particles was carried out. The percentage of RCA in the mix are shown in Table 1. The water cement ratio was maintained as constant across all the mixes.

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Table 1: Percentage of RCA

Mix	Percentage of RCA
1	0%
2	10%
3	20%
4	30%
5	50%
6	100%

Specimen

The specimen for compressive strength test as well as pullout test were casted as per IS 516:1959 and IS 2770:1967 part 1 respectively , 3 cubes per set of mix were casted for each test and the dimensions of the cubes were 15 cm . The pull out test specimen was casted with the steel rebar at the centre of the cube which was perpendicular to the surface of the cube and protruded 600mm out of the cube. Standard moulds of cubes with dimensions 15 cm3 were used and the specimen were casted and demoulded after 24 hours and then cured for 28 days.



Figure 2: Compressive test and Pullout test specimen

Test setup

The compressive strength test was carried out in compressive strength testing machine , the no casting surface was loaded as per IS code regulations. The pull out test was carried out in Universal testing machine (UTM), the cube consisting rebar was inverted and inserted from the top of the UTM and gripped in the lower jaw which pulled the rod out of the cube when load was applied.

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Figure 3: CTM and UTM

EXPERIMENT AND RESULTS

Workability

Each of the eight sets of mixes undergoes a slump test to make sure the batch of concrete is usable and has slump values that fall within the acceptable range for casting cubes. Fresh concrete has an important quality that makes it simple to implement on the job site while adhering to the established limits. It is vital to ascertain the slump value of each mix since in this experiment, the percentage of aggregates, both fine and coarse, varies for each mix.

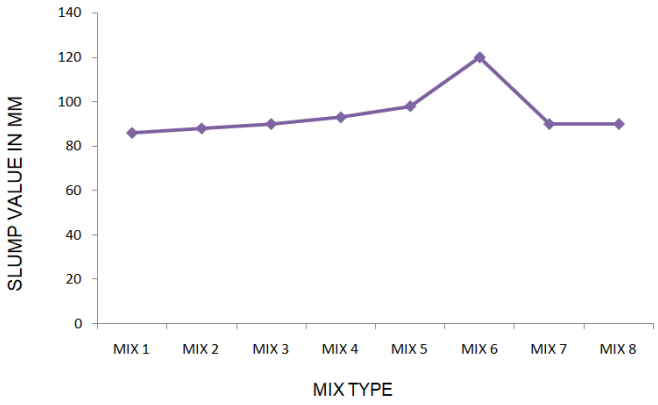


Figure 4: Slump test

Compressive strength

The compressive strength of all the mix batches is determined . The compressive strength is determined by using the formula :

Compressive strength = Load/Area

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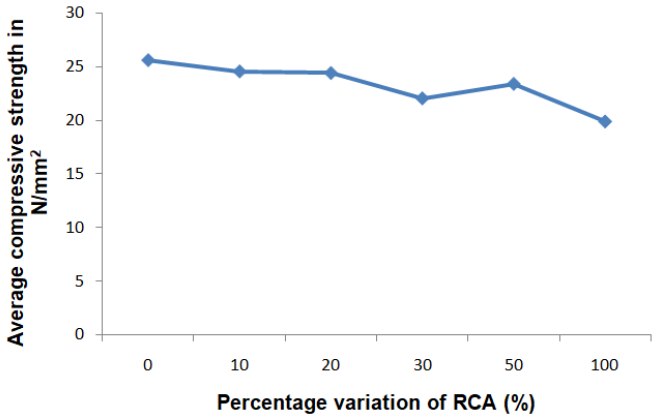


Figure 5: Compressive strength

Bond Strength

Bond strength is defined as the adhesive force that is important to form the bond between concrete and steel bar which is essential for structure to be safe and serviceable . The bond strength is calculated using the formula :

$T=P/\pi DL$

Where, T is the Bond strength , P is the failure load , D is the diameter of the rebar and L is the embedment length.

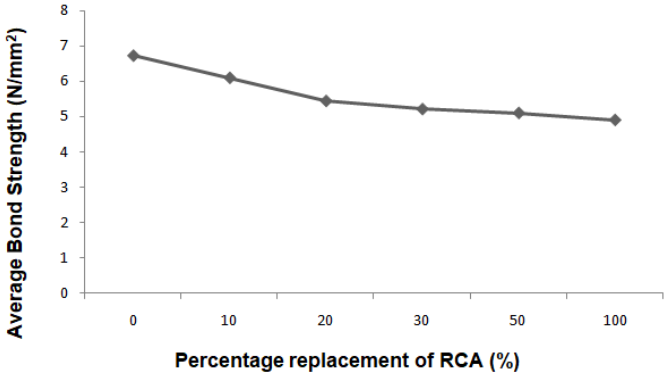


Figure 6: bond strength

CONCLUSIONS

In this experiment the following conclusions can be observed :

- The workability of the mix increases from Mix 1 to Mix 6. Satisfactory workability could be obtained for the recycled coarse aggregate concrete. However, relative to the control concrete made with natural coarse aggregates, the compressive strengths of the equivalent

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mix proportions designed recycled aggregate concrete mixtures decreased with increase in the recycled coarse aggregate replacement percentage.

- The compressive strength decreases as the recycled coarse increases in the mix.
- The bond strength decreases as percentage of recycled coarse aggregates increases.

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