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An Experimental Study of Concrete with Soaked Recycled Aggregate as Coarse Aggregate

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Abstract — *Concrete is the most widely used construction material because of its high structural strength and stability. Its main constituents are cement, sand, fine, coarse aggregates, and water. Most of the aggregates and raw materials for cement used in the manufacture of concrete come from quarries or alluvial rivers. Recycled construction wastage is the promising way towards sustainable construction. Recycled coarse aggregate (RCA) is the most common idea, Recycled aggregate (RA) obtained from crushed concrete rubble, instead of being stored, can be reused in building industry. An attempt has been made to study the possibility of reusing the recycled concrete aggregate from demolished structures in the place of normal aggregate. The main problem of using recycled aggregate is the adhered mortar poses which deleterious effects on the concrete. To overcome this problem, in this study recycled aggregate is soaked in GGBS solution for 24 hours and then used in concrete (GRAC mix). Experimental investigation is carried out with a conventional M40 mix. The GRAC mix gives better performance in terms of compressive strength, splitting tensile strength and flexural strength comparing with M40 conventional mix.*

Keywords—*Ground granular blast furnace slag, Recycled aggregate concrete.*

I. INTRODUCTION

A. General

Concrete is one of the most widely used construction materials; it is usually associated with Portland cement as the main component for making concrete. The demand for concrete as a construction material is on the increase. It is estimated that the present consumption of concrete in the world is of the order of 10 billion tonnes every year.

Most of the aggregates used in the manufacture of concrete come from quarries or alluvial rivers. Nowadays, these sources of natural aggregates are in the process of depletion and their extraction also has harmful consequences for the environment. For these reasons, it is important to optimize the consumption of natural aggregates as well as to enhance their replacement by other alternative sources. This research will examine the potential use of recycled coarse aggregates resulting from crushing or demolishing the waste concrete as substitutes for natural aggregates for the manufacture of concrete.

B. Objectives of the Study

- To prepare and asses the properties of M40 conventional mix and self-compacting concrete mix
- To replace coarse aggregate with recycled aggregate that soaked in solution of GGBS

II. PROPERTIES OF MATERIAL

A. Cement

Cement used for the study is Ordinary Portland Cement (OPC) of grade 53. The manufacturer of the cement is Dalmia. The different labarotary test were conducted on cement to determine standard consistency, initial and final setting time as per IS 4031 and IS 269-1967. The results were tabulated in table I and it confirms to the IS recommendations.

TABLE I. Properties of cement.

Sl. No	Test conducted	Result
1	Specific gravity	3.14
2	Standard consistency	34%
3	Initial setting time	120 min
4	fineness	5%

B. Fine Aggregate

M sand passing through 4.75 mm sieve was used for this study. Physical properties of fine aggregates determined as per IS 2386-1968 and result of tests are shown on table II.

TABLE II. Properties of fine aggregate.

Sl. No	Test conducted	Result
1	Zone	II
2	Fineness modulus	3.04
3	Specific gravity	2.67
4	Water absorption	1.5%
5	Bulk density	1.86 kg/l
6	Percentage of air voids	3.7%

C. Coarse Aggregate

Coarse aggregate collected from approved quarry and the aggregates having size ranging from 10mm to 20 mm were used. The tests were carried out on coarse aggregate as per IS 2386-1968 and results are given in table III.

TABLE III. Properties of coarse aggregate.

Sl. No	Test conducted	result
1	Specific gravity	2.67
2	Water absorption	0.85%
3	Flakiness index	17.7%
4	Elongation index	25.4%
5	Bulk density	1.63kg/l
6	Percentage of air voids	44.56%
7	Crushing value	22.5

D. Recycled Coarse Aggregate

Recycled aggregate collected from a 25 year old residential building and crushed manually. The properties

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were tested as per IS 2386-1968 and the results are shown in table IV.

TABLE IV. Properties of recycled Aggregate.

Sl. No	Test conducted	Results
1	Specific gravity	2.72
2	Water absorption	3.4
3	Flakiness index	17.2
4	Elongation index	18.4
5	Bulk density	1.38g/l
6	Percentage of air voids	41.59%
7	Crushing value	19.6

E. *Super Plasticizer*

Master Glenium SKY 8233 was used as super plasticizer for the study. It is an admixture based on modified polycarboxyllic ether. The product has been primarily developed for applications in high performance concrete where the highest durability and performance is required. It is free of chloride and low alkali. It is compatible with all types of cements. Physical properties of super plasticizer as shown in table V.

TABLE V. Properties of super plasticizer.

Test conducted	Results
Aspect	Light brown liquid
Relative density	1.08 at 25^0C
ph	>6
Chloride ion content	0.2%

III. MIX DESIGN

The main objective of experimental work is to investigate compressive strength, split tensile strength and flexural strength of concrete. M40 grade of concrete is used to examine the mechanical properties of concrete. The mix design of concrete carried out as per IS 10262:2009. The Constituents of control concrete mix and concrete with Recycled aggregate as coarse aggregate are as shown in table VI.

The different mixes were labeled as CM, RAC and GRAC. Table VI shows designation of different mixes.

TABLE VI. Mix designation.

Mix	Designation
CM	Control mix(M-sand)
RAC	Mix with normal recycled aggregate
GRAC	Mix with recycled aggregate soaked in GGBS solution

TABLE VII. Details of mix.

Details of mix	Grade – M40
Cement	415 kg/m3
Fine aggregate	803 kg/m3
Coarse aggregate	1090 kg/m3
Water cement ratio	0.38
Amount of water	172.6 liters
Superplasticizer	0.3%

IV. RESULTS AND DESCUSSIONS

The test result of various parameters like compressive strength using cube, split tensile strength using cylinder, flexural strength using prism and flexural behaviour using beam specimens.

A. *Compressive Strength*

This is one of the most important properties of concrete, as it will affect many other properties of hardened concrete. Because, concrete is strong in compression but relatively weak in tension and bending. The testing was done in the compression testing machine and the failure load was noted and compressive strength was calculated. The test results for cube compressive strength are shown in the table VIII. Test was conducted as per IS 516: 1959.

TABLE VIII. Compressive strength.

Mix designation	Compressive strength (N/mm^2)		
	3 Days	7 Days	28 Days
CM	27.85	43.40	53.63
RAC	29.85	35.55	44.15
GRAC	36.18	43.24	55.26

Figure I shows the graphical variation of compressive strength of different concrete mixes with curing periods.

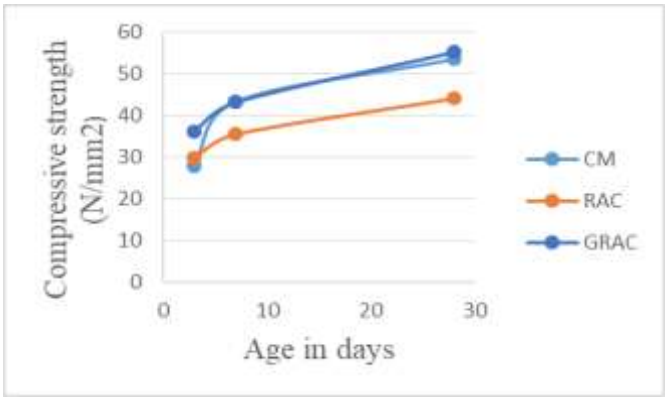

Fig. I. Compressive strength.

Figure I shows the variation of compressive strength of different mixes with varying curing periods such as 3, 7 and 28 days. According to the test results there is an increase in the compressive strength of concrete mixes with recycled aggregate soaked in GGBS solution as coarse aggregate. There was an increase of 3.03% compressive strength than control mix. In case of mixes with recycled coarse aggregate there was a decrement of 17.67% in compressive strength and also it is less than target mean strength of M40 concrete.

B. *Flexural Strength*

Flexural strength, also known as modulus of rupture, bend strength, or fracture strength, a mechanical parameter for brittle material, is defined as a material's ability to resist deformation under load. Beams of size 500mm×100mm×100mm were tested after 7 days and 28 days from day of curing. Table IX shows the flexural strength values obtained for the ceramic waste concrete mix. The test was conducted as per IS-516: 1959.

TABLE IX. Flexural strength.

Mix designation	Flexural strength (N/mm^2)	
	7 Days	28 Days
CM	4.61	6.08
RAC	2.9	3.8
GRAC	4.4	6.06

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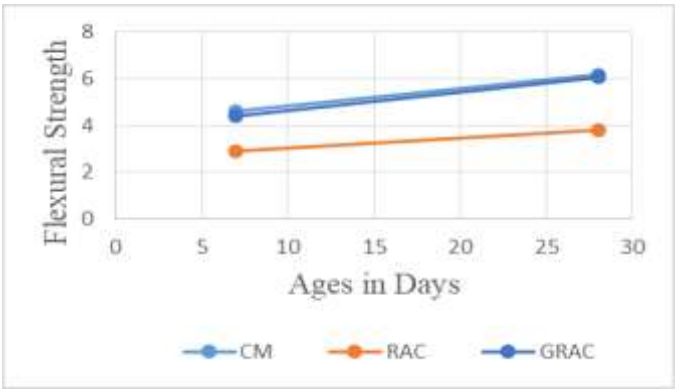

Fig. II. Flexural strength.

From the results obtained from the flexural strength of concrete, it shows there is a decrease in flexural strength of RAC mixes compared to controle mix. GRAC mix shows similar value compared to control mix.

C. Splitting Tensile Strength

Tensile strength is one of the basic and important properties of the concrete. The concrete is not usually expected to resist the direct tension because of its low tensile strength and brittle nature. However, the determination of tensile strength of concrete is necessary to determine the load at which the concrete members may crack. The cracking is a form of tension failure. The splitting tensile strength of concrete cylinder was determined based on IS: 5816-1999. The load shall be applied in the nominal rate within the range of 1.2 N/mm2/min to 2.4 N/mm2/min. Load is applied until the specimen fails, along the vertical diameter. Tensile strength of the concrete design mix was check by casting and testing of 150mm diameter & 300mm depth size after curing period of 7 days and 28 days. Table X shows the splitting tensile strength values for different mixes.

TABLE X. Splitting tensile strength.

Mix designation	Splitting tensile strength (N/mm^2)	
	7 Days	28 Days
CM	2.32	3.37
RAC	2.24	2.74
GRAC	2.25	3.18

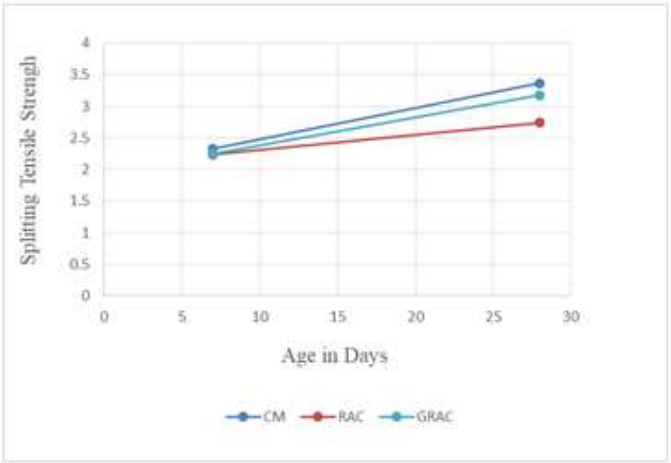

Fig. III. Splitting tensile strength.

From the results obtained RAC mixes shows decrement in splitting tensile strength and GRAC mixes shows similar results compared to control mixes.

V. CONCLUSION

The conclusions obtained from this studies are:

- Compressive strength for 28 days obtained for control mix was 53.63 N/mm^2 which is more than theoretical value (48.25 N/mm^2).
- Flexural strength for 28 days obtained for control mix was 6.08 N/mm^2 which is more than theoretical value (4.43 N/mm^2).
- Splitting tensile strength for 28 days obtained for control mix was 3.37 N/mm^2 which is more than theoretical value (2.95 N/mm^2). So the mix prepared has the strength required for a M40 mix.
- Compressive strength of GRAC mix has 3.03% higher value than control mix.
- The flexural and splitting tensile strength of GRAC mix is similar to control mix and also higher than the target mean strength.
- The RAC mix shows lesser value for compressive strength, flexural strength and splitting tensile strength compared to control mixes and also lesser than the target mean strength.

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