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Experimental Investigation of Sustainable Concrete Using GGBS and Recycled Coarse Aggregate

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Abastrct— Concrete Consumption is increasing every year. For sustainability reduction of cement and aggregates are necessary. For sustainable construction the only way is to reduce the cement and aggregate consumption. Alternative cementations materials like GGBS can be used as a replacement for cement and recycled aggregates for natural aggregates. This study deals with usage of ground granulated blast furnace slag as an alternative for cement and recycled coarse aggregate for natural coarse aggregate. Experimental investigation is carried out with a conventional M25 mix, mixes by replacing with 10 percent, 20 percent, 30 percent, 40 percent and 50 percent of cement with ground granulated blast furnace slag (GGBS). Mix with 60 percent of cement when replaced with 40 percent GGBS gave better performance compared to M25 conventional mix when tested for fresh and mechanical properties. For further study mix was made with 10, 20, 30, 40 and 50 percent replacement of cement with slag and 0, 25, 50, 75 and100 percent replacement of coarse aggregate with 100, 75, 50, 25 and 0 percent recycled coarse aggregate. Its fresh and mechanical properties were then compared with M25 mix. Fresh properties were studied using slump test and compaction factor test. Mechanical properties studied were compressive, flexural and splitting tensile strengths. Mix with GGBS and recycled aggregates gave a satisfactory performance compared to M25 conventional mix.

Index Terms— Compressive strength, Flexural strength, Ground granulated blast furnace slag, Natural aggregates, Recycled coarse aggregates, Slump test, Splitting tensile strength.

1 INTRODUCTION

Concrete is the most common construction material in the world in existing days.The major component of concrete is aggregates.The cost of aggregates are increasing from last few years tremendously. Depletion of natural aggregates, rapid increase in construction and demolition wastes and mass production of cement are the critical issues that create a threat to environment.From construction and demolition works large quantities of wastes are producing every year. Large scale production of cement requires huge amounts of energy and huge amount of natural materials like limestone, clay etc. In this process large quantities of CO_2 are released into the atmosphere. It was assessed that release of carbon dioxide due to production of cement contributes to 7% of the total green house gas emissions. The use of recycled aggregate, preferable to mineral admixtures also became the preferred choice due to the above-mentioned problem, in addition to solving the disposal problem of dumped waste from thermal and steel industries and enhancing the strength and durability criteria. A number of such mineral admixtures like fly ash (FA), micro silica, meta-kaolin and GGBS were tried in the field. One way to make use of these waste materials is sustainable construction.So if we used demolition waste of concrete (recycled concrete aggregate) for the replacement of natural aggregates and ground granulated blast furnace slag as replacement for cement we can achieve without affecting the mechanical properties of concrete for economic and environmental benefits.

Objective of this study is to assess the properties of concrete for various combinations of materials like cement, ground granulated blast furnace slag, natural aggregate and recycled course aggregate.

Many researchers have studied the effect of slag on concrete properties and reported encouraging results for the replacement of cement with slag in concrete.

[1] Mr. Besil Johny carried out the experimental study of M30 mix concrete to get properties of sustainable concrete using slag and recycled concrete aggregates for diifferenr combinations .Concrete mixes containing 50 percent replacement with cement give better performance and then concluded that compressive strength, split tensile strength values of mix with GGBS and recycled coarse aggregate are less compared to conventional mix.

[2] A.H.L.Swaroop et al evaluated changes in compressive strength in different mixes of M30 grade namely conventional aggregate concrete, concrete made by replacing 20% and 40 %of cement by Fly Ash and GGBS. The early strength was less in fly ash and GGBS concretes then conventional aggregate concrete. The results of fly ash and GGBS concretes when replaced with 20% of cement are more than compared to Conventional aggregate concrete at the end of 28 days and 60 days for normal water curing.

[3] Khaldoun Rahal studied the mechanical properties of concrete with recycled coarse aggregate. The cube and cylinder compressive strength and the indirect shear strength of recycled aggregate concrete were about 90% of that of a normal aggregate concrete with similar mix proportions and slump.

[4] M.L. Berndt studied the properties of sustainable concrete containing fly ash, slag and recycled concrete aggregate. Concrete mixes containing 50% replacement of cement slag gave the best results.

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2 Experimental Investigation

In this work five different mixes are considered except conventional M25 mix.Conventional mix(CM) doesnot contain GGBS and recycled aggregate.In these, first mix was 90 percent of cement, 10 percent of GGBS, 0 percent of natural aggregate and 100 percent of recycled aggregate(CM I). Second mix was 80 percent of cement, 20 percent of GGBS, 25 percent of natural aggregate and 75 percent of recycled aggregate(CM II).Third mix was 70 percent of cement, 30 percent of GGBS, 50 percent of natural aggregate and 50 percent of recycled aggregate(CM III).Fourth mix was 60 percent of cement, 40 percent of GGBS, 75 percent of natural aggregate and 25 percent of recycled aggregate(CM IV). Fifth mix was 50 percent of cement, 50 percent of GGBS, 100 percent of natural aggregate and 0 percent of recycled aggregate(CM V). Table 5 shows all the mix combinations. From the test results 40 percent replacement of GGBS with cement, 25 percent replacement of recycled aggregates with natural aggregate (CM IV) shows optimum results. Its properties are compared with the conventional M25 mix for the age of 28 days.

4 Materials

4.1 Cement

53 grade ordinary Portland cement are used according to Indian Standards.Following are the properties of cement given in Table 1

Table 1: Properties of Cement

Name of the test	Result
Specific gravity	3.16
Standard consistency	28%
Intial setting time	45 min
Final setting time	260 min

4.2 Ground granulated blast furnace slag (GGBS)

Specific gravity of GGBS of 2.84 is used for this work.

4.3 Fine Aggragarte

Locally available manufactured sand of zone II was used for this investigation. Some of properties of M-Sand are given in Table 2

Table 2: Mechanical properties of M-Sand

Name of the test	Result
Specific gravity	2.58
Water Content %	7.47
BulkDensity(loose)(kg/m^3)	1763.47
BulkDensity(compacted)(kg/m^3)	1847.85
Percentage of voids%	52

4.4 Coarse Aggregate

Combination of both Natural aggregate (NA) and Recycled coarse aggregates (RCA) was used for the present work. Locally available crushed granite of size 20mm was used as the natural coarse aggregate.

Recycled aggregates obtained by demolishing of building by 1 year old were used. Various properties of coarse aggregates are given in Table 3.

Table 3: Mechanical properties of Coarse aggregates

Name of the test	Test Results	
	NA	RCA
Specific Gravity	2.88	2.27
Water absorption%	1.4	7.47
Bulk density kg/m^3	1.52	1.38
Crushing value %	49.43	42.69
Impact value%	29.78	27.63
Flakiness index%	30.2	33.55
Elongation index%	40.84	40.63

4.5 Water

Potable water was used for the this study which is free from chemical and organic matters.

4.6 Superplasticizer

High performance super plasticizer named masterglenium sky 8233 based on polycarboxylate ether was used for the study.
It confirms to IS 9103:1999 and IS 2645 -2003. Specific gravity is 1.06.

5 Mix Proportioning

The grade of concrete used for this study is M25. The mix design was done as per IS: 10262(2009). Size of coarse aggregate was taken as 20mm and fine aggregate was under zone II. Water cement ratio adopted for this study is 0.4 and mix proportion was carried out for a slump of 100 ± 20 mm with superplasticizer addition. The quantity of materials required for 1m^3 of conventional M25 concrete mix is given in Table 4

Table 4: Quantity of the material

Material	Quantity
Cement(kg/m^3)	394
Fine aggregate(kg/m^3)	864.89
Coarse aggregate(kg/m^3)	1100.78
Water(l/m^3)	222
Superplasticerzer%	0.15

5 Preparations of Specimen

To determine the Compressive strength, Split tensile strength and Flexural strength, casted the cubes of size 150mmX150mmX150mm, Cylinders of size 300mm length and 150 mm diameter, Beams of size 100mmX100mmX500mm. Steel molds are used to cast all specimens. Compaction has done by hand.The specimens were cured for 24 hrs in air before remold.After remold specimens were water cured for the the days of 3, 7 and 28 days.

6 NUMBER OF TESTS CONDUCTED

6.1 Fresh properties

To test the consistency of concrete basically two fresh properties were tested.

(i) Slump test
(ii) Compaction factor test

6.2 Mechanical properties

The cubes and cylinders were tested in Compression testing machine after curing. From this compression strength and spilt tensile strength results were obtained. Two point load method were used for the Flexural strength. Cubes were tested at 3, 7 and 28days. Cylinders and beams were tested at 7 and 28days. Three specimens per mix were tested at each age.

7 VARIOUS MIX TEST RESULTS

Various mixes were prepared as per mix proportion for M25 and it was tested for fresh and mechanical properties and are listed below.

Table 5: Fresh properties for various mix combinations.

Mix Idn.	Cement(%)	GGBS (%)	NA (%)	RCA (%)	FA (%)	Slump (mm)	Compaction factor
CM	100	0	100	0	100	110	0.94
CM I	90	10	0	100	100	105	0.76
CM II	80	20	25	75	100	104	0.82
CM III	70	30	50	50	100	111	0.79
CM IV	60	40	75	25	100	100	0.92
CM V	50	50	100	0	100	115	0.89

Mechanical properties for various mixes are given below

Table 6: Compression strength for various mixes

Mix Idn	Average Compressive strength in N/mm²		
	3 days	7 days	28 days
CM	30.81	31.10	32.60
CM I	20.78	21.88	27.66
CM II	15.89	18.26	31.11
CM III	14.36	16.22	26.00
CM IV	5.92	10.11	32.11
CM V	18.96	19.77	24.00

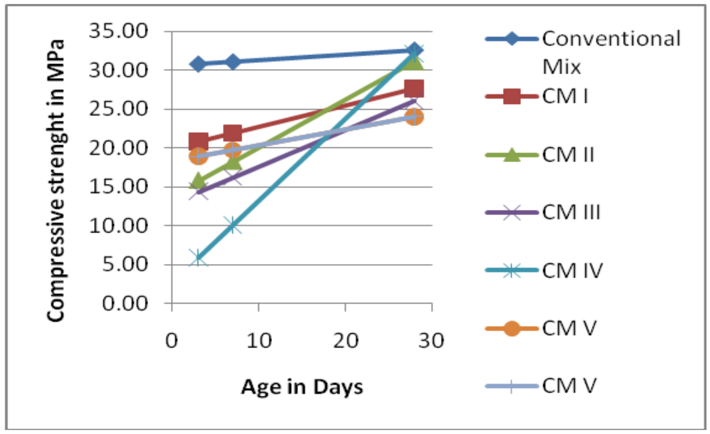

Fig 1: Variations of Compressive strength for all mixes

The compressive strength for different percentage replacements of NA with RA and cement with GGBFS at the age of 3, 7 and 28 days concrete is shown in Table 6. Irrespective of all replacements the result shows that the strength increases when age increases. From the 28 days experimental results it was observed that, the compressive strength of concrete reduces for all replacements (25% to 100%) of coarse aggregate (NA) with RA.
For the mix of replacement of 25% of RCA with 75% NA, 40% GGBS with 60% Cement, the concrete mix obtained the strength of 90% of the conventional mix. The variation in the compressive strength improvement at the age of 3, 7and 28 days for all mixes of CM, CM I,CM II,CM III, CM IV, CM V are shown in Fig. 1. The rate of strength may increases after 28 days for replacements of NA with RA. The compressive strength of concrete at the age of 28 days obtained for the mix of 40% GGBS and 25% RCA replacement is better. Therefore, 40% replacement of cement by GGBFS seems to be the better replacement.The strength may increase for the age of 56 and 90 days as compared to 28 days.The rate of strength gain of concrete with 40% cement replacement has been found to be higher than the concrete with 10%, 20%, 30%and 50%.

Table 7: Tensile strength for various mixes

Mix Idn	Average tensile strength in N/mm²	
	7 days	28 days
CM	2.89	3.43
CM I	2.24	3.12
CM II	2.31	2.98
CM III	2.45	2.84
CM IV	2.86	3.34
CM V	2.37	3.25

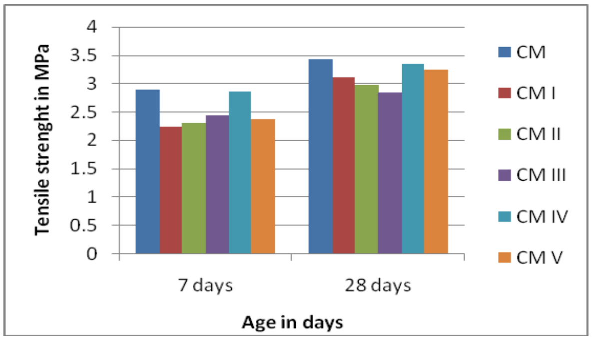

Fig 2: Variationsof spilt tensile strength for all mixes

From the results it is observed that the tensile strength of concrete improves when age increases irrespective of the replacement percentage of cement with GGBS. It is also observed that the strength improvement was reduced when GGBFS increased above 40% as replacement for cement in concrete. The same trend was observed for the NA with RA replaced concrete.

Table 8: Flexural strength for various mixes

Mix Idn	Average Flexural strength in N/mm2	
	7 days	28 days
CM	4.89	6.51
CM I	3.52	4.98
CM II	3.87	5.13
CM III	4.25	5.54
CM IV	4.46	6.23
CM V	4.36	5.98

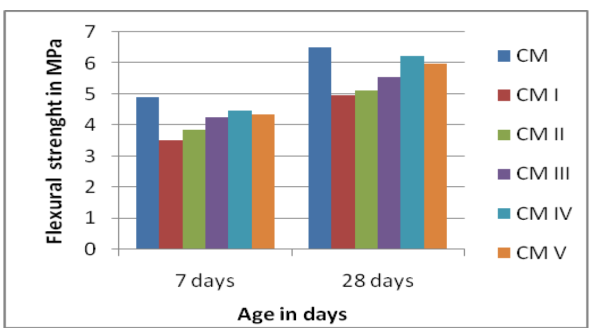

Fig 2: Variationsof flexural strength for all mixes

From the result it is observed that the flexural strength of concrete improves when age increases irrespective of the replacement percentage of cement with GGBS. It is also observed that the strength improvement was reduced when GGBFS increased above 40% as replacement for cement in concrete. The same trend was observed for the NA with RA replaced concrete.

8 CONCLUSION

This experimental investigation conducted on recycled aggregate concrete with GGBS. Based on results the following conclusions are drawn:

1. The compressive, tensile and flexural strength of RAC has been found to be lower than the strength of NAC at all ages of concrete and for all percentage of NA and cement replacements. But the mix satisfies the requirements of a M25 mix. So it is satisfactory.

2. Mix shows the adequate workability when workability of mix with GGBS, RCA and NA was tested using slump test and compaction factor test

3. From the detailed study it was inferred that concrete with 40% GGBS and 25% RCA yielded better results compared to other combinations and was found to be optimum.

9 ACKNOWLEDGMENT

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