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Study of Properties of Sustainable Concrete using Slag and Recycled Concrete Aggregate

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***Abstract*: - Consumption of concrete is increasing every year. Consumption of cement and conventional aggregates has to be reduced for sustainability. Sustainable construction is one way to reduce cement and aggregate consumption. Supplementary cementitious materials can be used as a replacement for cement and recycled aggregates for natural aggregates. This paper studies the feasibility study of using 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 M30 mix, mixes by replacing with 40 percent, 50 percent and 60 percent of cement with ground granulated blast furnace slag (GGBS). Mix with 50 percent of cement when replaced with GGBS gave better performance compared to M30 conventional mix when tested for fresh and mechanical properties. For further study mix was made with 50 percent replacement of cement with slag and 50 percent replacement of coarse aggregate with recycled coarse aggregate. Its fresh and mechanical properties were then compared with M30 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 M30 conventional mix.**

Keywords:-Ground granulated blast furnace slag, Fly ash, Recycled aggregates, Compressive strength, Flexural strength, Splitting tensile strength, Slump test.

1.INTRODUCTION

Concrete is the most popular construction material across the world. Aggregates are the major component of concrete. For last few years the cost of aggregates are increasing tremendously. Quality aggregates are also depleting year by year. Popularity of concrete also causes big damage to environment as billion tons of natural aggregates are being quarried from rock each year. Large scale production of cement requires huge amounts of energy and large amount of natural materials like limestone, clay etc. Also large quantities of CO_2 are released into the atmosphere in the process. There is a need to economize the use of cement and aggregates. This study points to some efforts to economize the use of aggregate.

Large quantities of wastes from construction and demolition works are produced every year and production is increasing year by year. Large quantities of waste materials and by-products like fly ash, ground granulated blast furnace slag etc are generated from industrial processes. We are wasting majority of these materials by dumping as landfills which causes shortage of dumping place in large cities. One way to make use of these waste materials is sustainable construction. It can considerably reduce the problem of shortage of dumping place and simultaneously it helps in the preservation of natural aggregate resources. So if construction and demolition wastes are used instead of natural aggregates and ground granulated blast furnace slag is used as partial replacement to cement without affecting the mechanical properties of concrete we can achieve economic and environmental benefits.

Objective of this study is to assess the properties of concrete that combine both supplementary cementitious materials, ground granulated blast furnace slag and recycled coarse aggregate.

[1] 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.

[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]**Vlastimir Radonjanin et al** studied the properties of green recycled aggregate concrete. Workability ranges from 120 to 130 mm. Mean compressive strengths at 2, 7, 28, 60 and 90 days were 18, 35, 46, 52 and 54 MPa, respectively. Splitting tensile strength was 3 MPa.

[4]**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.

[5]**Amnon Katz** studied the Properties of concrete made with recycled aggregate from partially hydrated old concrete. The slump of almost all the mixes was in the range of 135–185 mm (mostly 175 mm). Concrete made with 100% recycled aggregates was weaker than concrete made with natural aggregates at the same water to cement ratio

2. EXPERIMENTAL WORK

Five different mixes were considered in the investigation work. The first of these was a conventional M30 mix which did not contain ground granulated blast furnace slag. Mixes containing 40%, 50% and 60% replacement of cement with slag is then considered. From the test results of these optimum of 50% replacement of slag with cement is selected for replacing of coarse aggregate with recycled aggregate. Its properties were then compared with conventional M30 mix.

3. MATERIALS

3.1 Cement

Ordinary Portland cement 53 grade conforming to Indian Standard is used in the present investigation. Properties of cement used are given in table 1

Table 1, Properties of cement

Name of test	Result
Specific gravity	3.12
Standard consistency	34%
Initial setting time	90 minutes
Final setting time	540minutes

3.2 Ground granulated blast furnace slag

Ground granulated blast furnace slag of specific gravity 2.93 was used for the study.

3.3 Fine Aggregates

The locally available manufactured sand of zone II was used as fine aggregate in the present investigation. Various properties of manufactured sand are given in table 2

Table 2, Material properties of fine aggregates

Name of test	Test Results
Specific gravity	2.74
Water Absorption (%)	0.8
Water content (%)	3.1
Bulk Density (kg/*l*)	1.73
Percentage Voids (%)	38.73

3.4 Coarse Aggregates

Natural and recycled aggregates were used as the coarse aggregates in the concrete mixtures. Locally available crushed granite of size 20mm was used as the natural coarse aggregate.

Recycled aggregates obtained by demolishing a water tank of having age 17 years were used. Various properties of coarse aggregates are given in table 3.

Table 3, Material properties of coarse aggregates

Name of test	Test Results	
	Natural aggregates	Recycled Aggregates
Specific gravity	2.74	2.26
Water Absorption (%)	1.2	3.1%
Bulk Density (kg/*l*)	1.52	1.38kg/*l*
Percentage Voids (%)	44.53	41.59%
Crushing value (%)	27.78	26.83
Impact value (%)	29.8	31.45
Abrasion Value (%)	40.29	40.38
Flakiness index (%)	5.76	5.55
Elongation index (%)	20.21	9.75

3.5 Water

Potable water which is free from chemicals and organic materials was used for the study.

3.6 Super plasticizer

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 1.08.pH > 6

4. MIX PROPORTIONING

The mix design was done as per IS: 10262 (2009). The grade of concrete adopted for this study is M30. Maximum size of aggregate taken is 20mm and grading of sand is zone II. The water cement ratio adopted for concrete mix was 0.45 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 M30 concrete mix is given below.

Table 4, Quantity of materials

Material	Quantity
Cement (kg/m^3)	400
Fine aggregate(kg/m^3)	819
Coarse aggregate(kg/m^3)	1072
Water(*l*/m^3)	192
Super plastizers (*l*/m^3)	1.6

5 SPECIMEN PREPARATIONS

150x150x150 mm cubes, 100x100x500mm beams and 300 x150 mm diameter cylinder specimens were cast to determine the compressive strength, flexural strength and splitting tensile strength of the concretes. All specimens were cast in steel molds and compacted using hand. After casting, the specimens were cured in air for a period of 24 h, and then removed from mold. The specimens were cured in a water tank at 27 ± 1 C until the test ages (3 days, 7days and 28 days) were reached.

6. TESTS

6.1 Fresh properties

Fresh properties studied included were

(i) Slump test
(ii) Compaction factor test.

Slump test and compaction factor tests were done on fresh concrete to test the consistency of fresh concrete.

6.2 Mechanical properties

The mechanical properties of the concrete investigated included were

(i) Compressive strength,
(ii) Flexural strength
(iii) Splitting tensile strengths.

After curing, the cube and cylinder specimens were tested in the compression testing machine. Third point loading method is used for testing beams. Cubes were tested at 3, 7 and 28 days. Cylinders and beams were tested at 7 and 28days. Three specimens per mix were tested at each age.

7. TEST RESULTS FOR VARIOUS MIXES

7.1 Conventional mix

Using the mix proportions for a conventional mix (CM) of grade M30 mix as given in table 4 a mix is prepared and it was tested for fresh properties and mechanical properties. Results are tabulated below.

7.1.1 Slump test

Conventional Mix showed a slump of 110mm.

7.1.2 Compaction factor test

Compaction factor value Conventional Mix was 0.92.

7.1.3 Compressive strength

Table 5, Average compressive strength of CM

Mix ID	Average compressive strength		
	3-day	7-day	28-day
CM	23.40 N/mm^2	31.67 N/mm^2	41.73N/mm^2

7.1.4 Flexural strength

Table 6, Average flexural strength of CM

Mix ID	Average Flexural strength	
	7 day	28 day
CM	4.67N/mm^2	6.9/mm^2

7.1.5 Splitting tensile strength

Table 7, Average Splitting tensile strength of CM

Mix ID	Average splitting tensile strength	
	7 day	28 day
CM	2.63 N/mm^2	3.5 N/mm^2

From table 5, 6, & 7, compressive, flexural and splitting tensile strength values are more than target compressive strength value (38.25 N/mm^2) and theoretical flexural strength value (3.83 N/mm^2) for a M30 mix. So the mix prepared has the strength required for a M30 mix.

7.2 Mix with replacement of cement with GGBS

Mixes were made by replacing 40%, 50% and 60% of cement with ground granulated blast furnace slag (40GGBS, 50 GGBS and 60 GGBS). Mixes were tested for fresh properties and mechanical properties. Results are tabulated below.

7.2.1 Slump test

All three mixes with replacement of cement with GGBS showed a workability of 100mm

7.2.2 Compaction factor test

40 GGBS and 50 GGBS gave compaction factor value of 0.89. 60 GGBS showed a compaction factor value of 0.92.

7.2.3 Compressive strength

Table 8, Average compressive strength of GGBS mixes

Mix ID	Average compressive strength		
	3-day	7-day	28-day
40 GGBS	13.28 N/mm^2	23.50 N/mm^2	41.10 N/mm^2
50 GGBS	13.46 N/mm^2	22.46 N/mm^2	44.00 N/mm^2
60 GGBS	17.77 N/mm^2	22.55 N/mm^2	34.24 N/mm^2

7.2.4 Flexural strength

Table 9, Average flexural strength for GGBS mixes

Mix ID	Average Flexural strength	
	7 day	28 day
40 GGBS	4N/mm^2	5.75 N/mm^2
50 GGBS	4N/mm^2	7.75 N/mm^2
60 GGBS	4N/mm^2	6.50 N/mm^2

7.2.5 Splitting tensile strength

Table10, Average splitting tensile strength for GGBS mixes

Mix ID	Average splitting tensile strength	
	7 day	28 day
40 GGBS	2.86 N/mm^2	3.14N/mm^2
50 GGBS	2.73 N/mm^2	3.07N/mm^2
60 GGBS	2.2N/mm^2	2.79N/mm^2

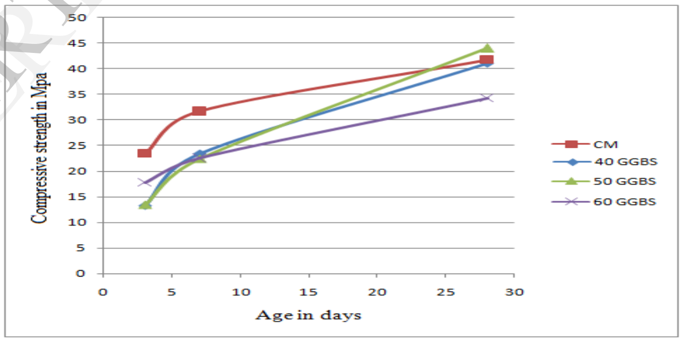

Fig 1, Variation of compressive strength with age for GGBS mixes

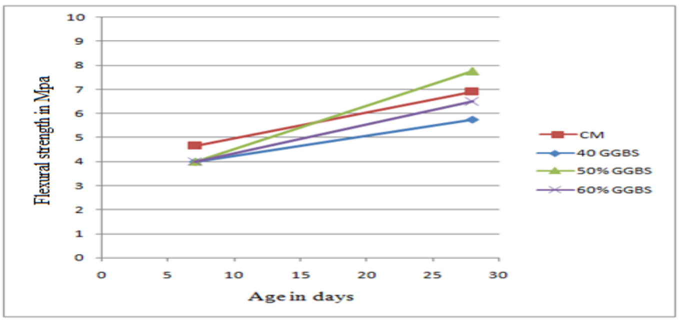

Fig 2, Variation of flexural strength with age for GGBS mixes

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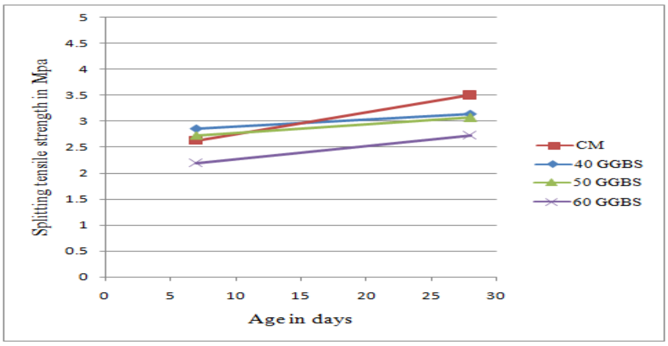

Fig 3, Variation of splitting tensile strength with age for GGBS mixes

From table 8, 9 &10 and fig 1, 2 &3, though splitting tensile strength values at 28days were less, compressive and flexural strength values at 28 days are more for 50 GGBS compared with CM. So for further test 50% of cement can be replaced with cement along with 50 % replacement of coarse aggregate with recycled coarse aggregates.

7.3. Mix with replacement 50% of cement with GGBS and 50% coarse aggregate with recycled coarse aggregate

Mix was made by replacing 50 % cement with ground granulated blast furnace slag and 50% fine aggregate with recycled coarse aggregate (50GGBS +50RCA) and tested for fresh properties and mechanical properties. Results are tabulated below.

7.3.1 Slump test

Slump value for 50 GGBS + 50 RCA was 110mm

7.3.2 Compaction factor

Compaction factor value for 50 GGBS + 50 RCA was 0.89

7.3.3 Compressive strength

Table 11, Average compressive strength of 50GGBS+50 RCA mix

Mix ID	Average compressive strength		
	3-day	7-day	28-day
50GGBS+ 50 RCA	22.47N/mm^2	32.44N/mm^2	40.11N/mm^2

7.3.4 Flexural strength

Table12, Average flexural strength for 50 GGBS+50 RCA

Mix ID	Flexural strength	
	7 day	28 day
50GGBS+50RCA	3.25N/mm^2	5.5N/mm^2

7.3.5 Splitting tensile strength

Table 13, Average splitting tensile strength of 50GGBS+50 RCA mix

Mix ID	Average splitting tensile strength	
	7 day	28 day
50 GGBS+50 RCA	1.7N/mm^2	2.97 N/mm^2

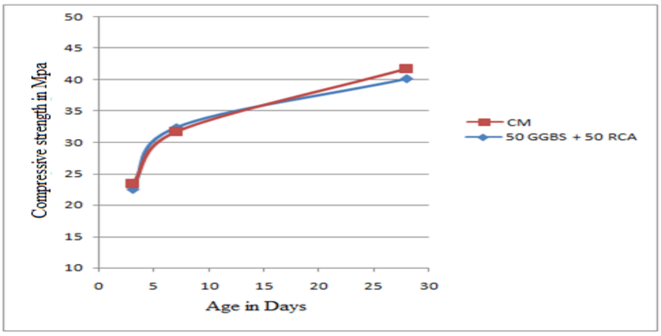

Fig 4, Variation of compressive strength with age for 50 GGBS + 50RCA

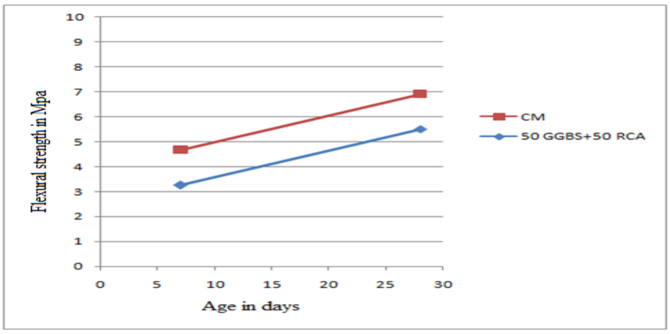

Fig 5, Variation of flexural strength with age for 50 GGBS + 50RCA

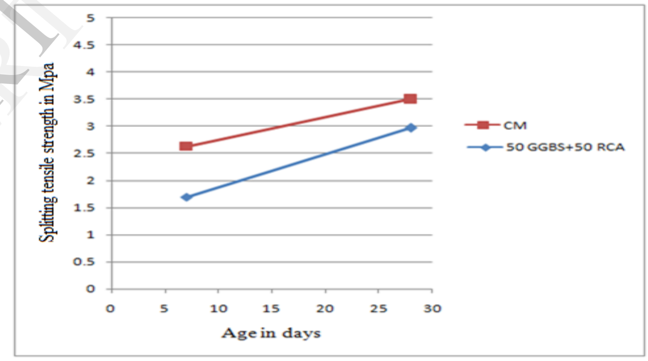

Fig 6, Variation of splitting tensile strength with age for 50 GGBS + 50RCA

When mixes are made by replacing 50 % cement with slag and 50% coarse aggregate with recycled coarse aggregate, 3 day and 28 day compressive strength are little low compared with CM while 7 day compressive strength are little more for compared with CM. 7day, 28 day flexural strength and splitting tensile strength values are low compared with CM.

8. CONCLUSION

Based on this experimental study, the following conclusions are drawn

(1) When workability of Mix with GGBS and recycled coarse aggregates was tested using slump test and compaction factor test, the mix shows adequate workability.
(2) Compressive strength, flexural strength and splitting tensile strength values of Mix with GGBS and recycled aggregates were less compared with conventional mix.

But the mix satisfies the requirements of a M30 mix. So it is satisfactory.

The study shows that replacement of GGBS for cement and recycled coarse aggregates for natural aggregate gives satisfactory strength. So the partial replacement is of much benefit and shall be encouraged.

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