International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 07 Issue: 05 | May - 2023 Impact Factor: 8.176 ISSN: 2582-3930

EXPERIMENTAL STUDY ON ECO-FRIENDLY AND COST EFFECTIVE CONCRETE BY UTILIZING BLAST FURNACE SLAG AND DEMOLITION WASTE WITH OTHER ALTERNATIVE MATERIALS

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ABSTRACT

The construction industry is the one of the contributing factor to the environmental related problem ; this problem will be minimized by the utilization of the waste material or Industrial by product from various industries as an alternative source for conventional concrete material. It can be substitute of conventional concrete materials, the use of material lead to sustainability in construction sector and conserve the natural resources. There are many environmental related problem created by Cement manufacturing. Will be solve in due course. The purpose of this work is to make cost effective eco-friendly concrete. This concrete has been made by conventional material such as Ground granulated blast furnace ***(GGBS***) with small amount cement as binding material.

Keywords: GGBS, Recycled aggregate, Concrete, Compressive strength, flexural strength, Spilt tensile strngth

I. INTRODUCTION

Approximately 500 kg per tonne waste materials are generated from crude steel by steel plants. Out of these wastes, around 400 kg per tonne is only BFS . India's crude steel production for 2018 was 106.5 Mt, up by 4.9% in 2017, meaning India has replaced Japan as the world's second largest steel producing country. On the other hand manufacturing of cement along with its use also tends to increase the amount of CO2. The huge consumption of naturally occurring materials and energy eventually lead to exhaustion of environment. In both developed and developing countries, the problem of wastes management has already become an issue to be addressed immediately. This problem is compounded by the rapidly increasing amounts of industrial wastes of a complex nature and composition.

Here Ground Granulated blast furnace slag (GGBS) is replaced for cement, the replacement level varying from 40%to 60% and crushed stone sand is replaced for fine aggregate crushed old concrete from construction demolition waste is replaced for course aggregate. Industrial by product such as GGBS and construction demolition waste are available in large quantities, are used to make cost effective eco-friendly concrete. Since natural resource are scarce and to bring this new concrete technology into wider use, the government policy support is required, the scope of our research paper to save the natural resource, to utilized waste and by product from other industries,minimize emission CO2 in production of cement and combination of assorted material leading to cost effective concrete.

II. LITERATURE REVIEW

Several works on the effect of GGBS and silica fume on concrete by replacing cement have been carried out and it was reported that when GGBS is used in concrete, it improves workability, increases strength and durability.

We have obtained following information and data from the scholar acknowledged. These are used as foundation for this technical review paper According to

K. Ganesh Babu et al, - GGBS can be used varying proportion resulting in various compressive strength, level of replacement varying from 10% to 80% but optimum use rang is 50% and 65% of replacement of cement to gives the desirable strength compared between conventional concrete for his experimental results, it is proved that GGBS can be used as an alternative material for cement to certain extant, reducing cement consumption and thereby reducing the cost of construction.

Bibhu P. Lenka et al, - the use of 60% GGBS as replacement of Portland cement decreases the porosity of ordinary Portland concrete mixture, since GGBS acts as a filler material

Kamran et al. (2004) - studied the effect of GGBS on four different mix ratio's (1:2:4, 1:5:3, 1:1.25:2.50, 1:1:2). The water cement ratio for the first two mixes was kept as 0.65 and the remaining two mixes as 0.45. Cement was replaced by GGBS in percentages of 0%, 25% and 50%. It was concluded that the price of GGBS was up-to 25% less than that of Ordinary Portland Cement. Tests on workability, compressive strength, tensile strength and modulus of rupture were carried out. Increase in the percentage of slag, increased workability, improved finishing. The compressive strength of GGBS based concrete was less in the early stages, 3 days and 7 days but the 28 days strength was similar to that of plain cement (control) concrete. The split tensile strength was similar to that of plain cement concrete, even up-to replacement levels of 50 % GGBS.

Dubey et al. (2012) studied the effect of blast furnace slag on concrete by replacing cement from 5% to 30%; from the experimental studies it was observed that the optimum replacement of ground granulated blast furnace slag was 15 % without much reduction in the compressive strength. Only a reduction of 5 % in strength was observed .Concrete cubes were cast of size 150 × 150 × 150 mm and cured for 7, 14 and 28 days. It was concluded that increasing the percentage of blast furnace slag resulted in decrease in compressive strength.

Latha et al. (2012) conducted an experimental program on GGBS and high volume flyash for M20, M40 and M60 at different ages of 28, 90 and 120 days with GGBS replacements from 0 to 70% in increments of 10%. It was found that in case of GGBS concrete with 40% being the optimum percentage of replacement and 50% in case of higher grade concrete (M60). They concluded that the partial replacement of cement with GGBS and high volume flyash (HVFA) in concrete has shown enhanced strength and durability properties which offer good compatibility.

III. METHODOLOGY

3.1. Materials

In this work, Ordinary Portland cement (OPC) of 43 Grade was utilized as the main binder. GGBFS were used to replace OPC. The physical and chemical properties of the binders and Properties of OPC conforms with IS: 8112 (1989). GGBFS and lime are much finer than OPC. The higher percentage of SiO2 and Al2O3 in GGBFS ensures its pozzolanic nature. The XRD analysis of OPC presented shows the major crystalline phases such as Alite and Belite within OPC.

GGBFS manufactured by Jindal Steel and Power Ltd., Jharsuguda, Odisha, India was used as high-volume replacement of OPC.

Fig.1 Cement

Fig.2 GGBFS

TABLE NO:1

PROPERTIES	OPC	GGBFS
Specific Gravity	3.14	2.82
Consistency	28%	-
Initial setting time	40 min	-
Final setting time	8 hr	-

TABLE NO:2

Oxides	OPC	GGBFS
SiO2	20.31	37.8
Al2O3	4.7	18
Fe2O3	2.83	3.2
MgO	1.64	5
So3	1.9	-
Na2O	0.18	-
K2O	0.44	-

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3.1.2. Aggregates:

In this research work, locally sourced river sand and 20 mm crushed granite pieces were used as NFA and NCA, respectively. Similarly, GBFS collected from Jindal Steel and Power Ltd., Jharsuguda and 20 mm crushed RCA sourced from 10-years old precast sleepers at NALCO, Angul were used as replacements of NFA and NCA, respectively. The particle size distribution of both fine aggregates and coarse aggregates were carried out as per IS: 2386 (1963a) and are shown in Figure 3. The particle size distribution was car ried out for the sieves of 40 mm, 20 mm, 16 mm, 12.5 mm, 10 mm and 4.75 mm size, but the maximum and minimum limits have shown only for 40 mm, 20 mm, 10 mm and 4.75 mm size sieves as per IS: 2386 (1963a). From this figure, the aggregates are found to fully satisfy the specified range of IS: 383 (1970) corresponding to sieves of 40 mm, 20 mm, 10 mm and 4.75 mm size. However, with respect to the 16 mm and 12.5 mm size sieves, the particle size distribution is slightly below the minimum range provided by IS: 383 (1970). The other properties of aggregates were evaluated as per IS: 2386 (1963b,1963c) and pre sented in Table 4, which reveals that the properties of GBFS and RCA are inferior to those of NFA and NCA, respectively. The mortar content of RCA was evaluated by acid presoaking method following the procedures reported in the literature (Akbarnezhad et al., 2013).

Fig.3. Recycled Coarse Aggregate

Fig.4. Crushed Sand

3.2.Mix Design:

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 0.5

Calculation of mix design for M20 Grade

1. Target Strength

F'ck = Fck+1.65 S OR F'ck = Fck+x

S = 4 for M20…….(IS 10262 Table no 2)

X = 5.5 For M20….(IS 10262 Table no 2)

F'ck = 20+1.65(4) & F'ck = 20+5.5

=26.6 > =25.5

:. Targrt Strength = 26.6 mpa @ 28 days

2. Water Cement ratio

From (IS 10262:2009) Table no 3

Water cement ratio = 0.55

:. (W/C = 0.5)

3. Selection of water content

For 20mm aggregate water content

20mm aggregate - 186 kg (For 50 mm slump)

…(IS 10262:2009, Table No 4)

& For 100 mm slump

Using IS 10262:2009 cl.5.3 required to add 6%

:. 186+((6*1860)/100) = 197 kg

(Water Content = 197 kg)

4. Calculation of Cement content

W/C Ratio = Water content/Cement

:. Cement Content = 394 kg/m^3

Here 394kg/m^3 > 300kg/m^3(min c.c from IS 456)

5. Aggregate proportion between coarse aggregate and fine aggregate

By volume of coarse aggregate per unit total volume of aggregate for w/c ratio 0.5…(IS 10262:2019 table no.5) Zone 2 - 0.62 for w/c = 0.5

6. Mix calculations

a) for volume of concrete - 1m^3

b) volume of cement = (mass / s.g) * (1/1000)

= (400/3.16)*(1/1000)

= 0.126m^3

c) volume of water = (mass / s.g) * (1/1000)

= (197/1)*(1/1000)

= 0.197m^3

d) volume of total aggregate

= 1-(0.126+0.197)

= 0.677m^3

e) mass of coarse aggregate=

volume of total aggregate *volume of C.A * S.G*1000

=0.677*0.62*2.73*1000

=1145 kg

f) mass of fine aggregate=

volume of total aggregate *volume of F.A * S.G*1000

= 0.677*0.38*2.46*1000

=632.86 kg

SUMMARY

1. Cement - 400kg/m^3
2. Water - 197 kg/m^3
3. Fine aggregate - 632.86 kg
4. Coarse aggregate -1145 kg

7. Mix proportion

1:1.6:2.9

8. Specimen Preparations

150x150x150mm cubes, 150x150x750mm 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.

9. TESTS

a) Slump Cone Test
b) Compressive Strength
c) Flexural Strength
d) Splitting Tensile Strength

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 28 days. Three specimens per mix were tested at each age.

IV. RESULTS AND DISCUSSION

a) Conventional Mix:

Using the mix proportions for a conventional mix (CM) of grade M20 mix as given in following table a mix is prepared and it was tested for fresh properties and mechanical properties.Results are tabulated below.

Table No : 03

Material	Quantity
Cement	400 kg/m^3
Water	197 kg
Fine Aggregate	632.86 kg
Coarse Aggregate	1145 kg

b) Slump Test

Conventional Mix a Slump of 110mm

c) Compressive Strength

Table 04, Average Compression Strength of CM

MIX ID	Average Compression Strength		
	3-day	7-day	28-day
CM	16.44 N/mm^2	21.95 N/mm^2	29.54N/mm^2

e) Flexural Strength

Table 05, Average Flexural Strength of CM

Mix ID	Average Flexural Strength of CM	
	7 day	28 day
CM	3.35N/mm^2	4.53$/mm^2$

f) Splitting Tensile Strength

Table 06, Average Splitting Tensile Strength of CM

Mix ID	Average splitting tensile strength	
	7 day	28 day
CM	2.50 N/mm^2	3.07 N/mm^2

From table 4,5 and 6 Compressive strength, Flexural Strength and Splitting tensile strength Values are more than target compressive strength strength value (26.6N/mm2) and theoretical flexural strength value (3.13 N/mm2) for a M20 mix. So the mix prepared has the strength required for a M20 mix.

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.

a) Slump Test

All three mixes with replacement of cement with GGBS showed a workability of 110mm.

b) Compressive Strength

Table 07, Average Compression Strength of CM

Mix ID	Average compressive strength		
	3-day	7-day	28-day
40 GGBS	14.10N/mm^2	19.19N/mm^2	25.22N/mm^2
50 GGBS	13.07N/mm^2	17.90N/mm^2	33.47N/mm^2
60 GGBS	10.23N/mm^2	15.30N/mm^2	20.03N/mm^2

c) Flexural Strength

Table 08, Average Flexural Strength of CM

Mix ID	Average Flexural strength	
	7 day	28 day
40 GGBS	3.07N/mm^2	5.3 N/mm^2
50 GGBS	3.04N/mm^2	6.83 N/mm^2
60 GGBS	3.02N/mm^2	4.35N/mm^2

d) Splitting Tensile Strength

Table 08, Average Splitting Tensile Strength of CM

Mix ID	Average splitting tensile	
	7 day	28 day
40 GGBS	2.63 N/mm^2	2.97N/mm^2
50 GGBS	2.51N/mm^2	2.85N/mm^2
60 GGBS	2.1N/mm^2	2.69N/mm^2

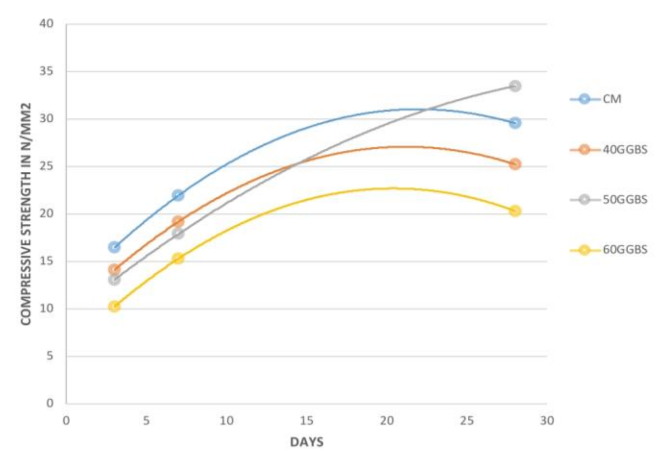
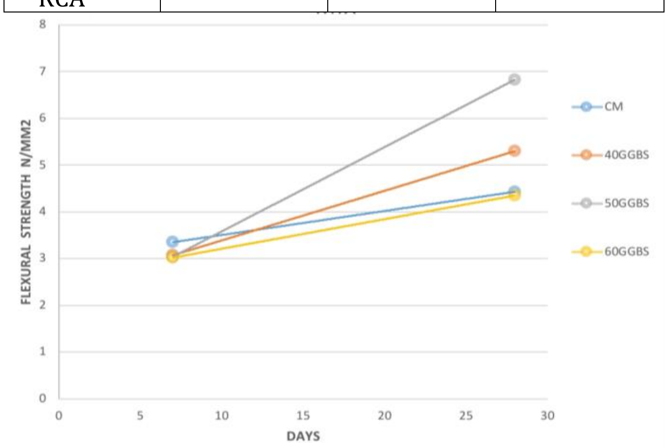


Fig.4.Variation of Compressive strength with Age for GGBS mix

Mix ID	Average Compression Strengthh		
	3-day	7-day	28-day
50GGBS+ RCA	16.16N/mm^2	23.42N/mm^2	29.31N/mm^2



Mix ID	Flexural Strength	
	7-day	28-day
50GGBS+50RCA	2.34N/mm^2	3.53N/mm^2

Fig.5.Variation Flexural strength with Age for GGBS mix

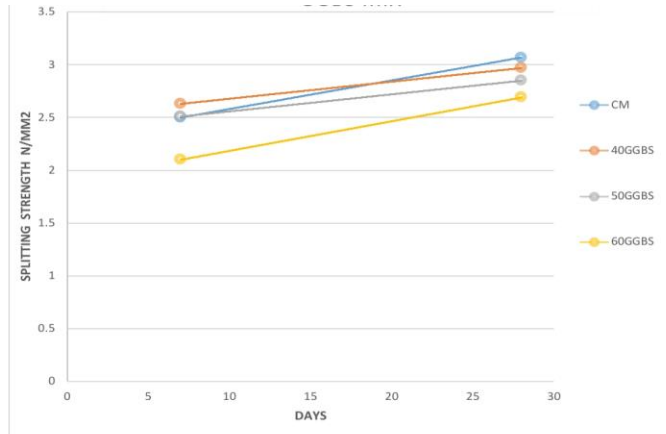


Fig.6..Varition of Splitting Tensile Strength with ages in day for GGBS Mix

From table 7, 8 &9 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.

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.

a) Slump Test

Slump value for 50 GGBS + 50 RCA was 110mm

b) Compressive Strength

Table 07, Average Compression Strength of CM 50GGBS+ RCA Mix

d) Flexural Strength

Table 05, Average Flexural Strength of CM
50 GGBS+50 RCA

d) Splitting Tensile Strength

Table 05, Average Splitting Tensile Strength of CM

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 07 Issue: 05 | May - 2023 Impact Factor: 8.176 ISSN: 2582-3930

50 GGBS+50 RCA

Mix ID	Average splitting tensile	
	7 day	28 day
50 GGBS+50 RCA	1.59N/mm^2	2.60 N/mm^2

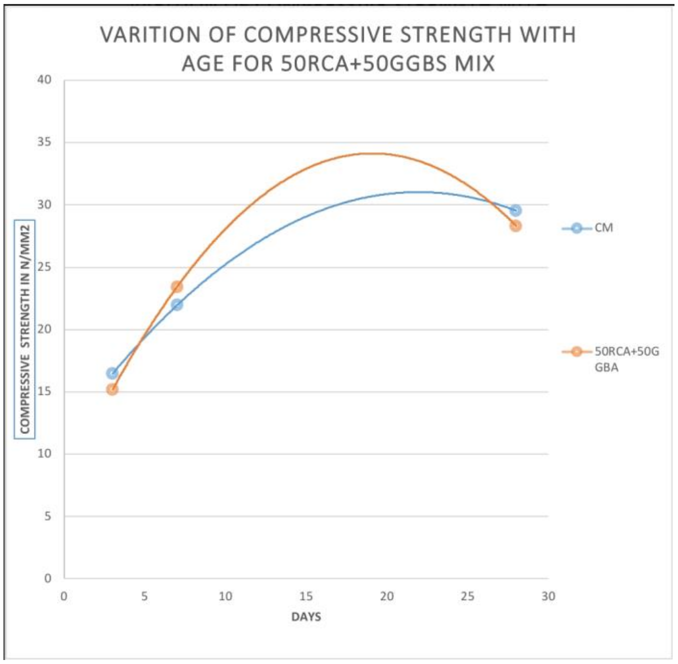


Fig.7.Variation of Compressive strength with Age for 50GGBS mix+50RCA

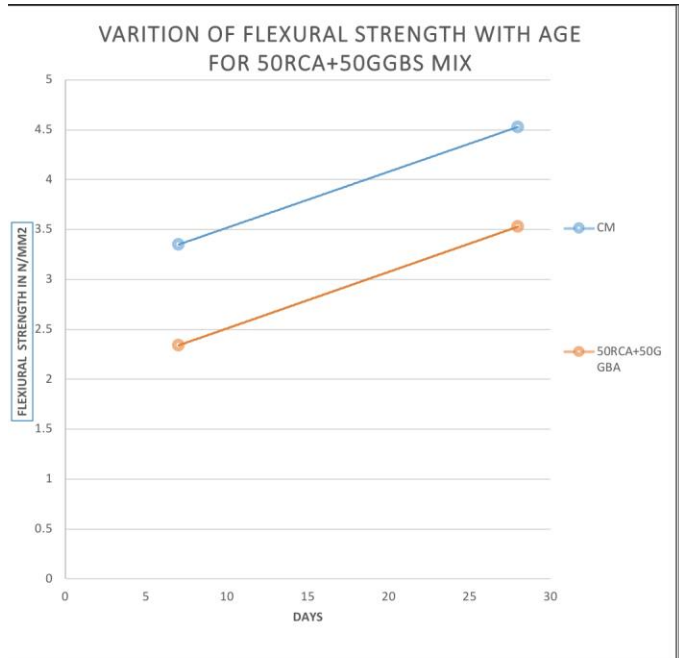


Fig.8.Variation of Flexural strength with Age for 50GGBS+50RCA mix

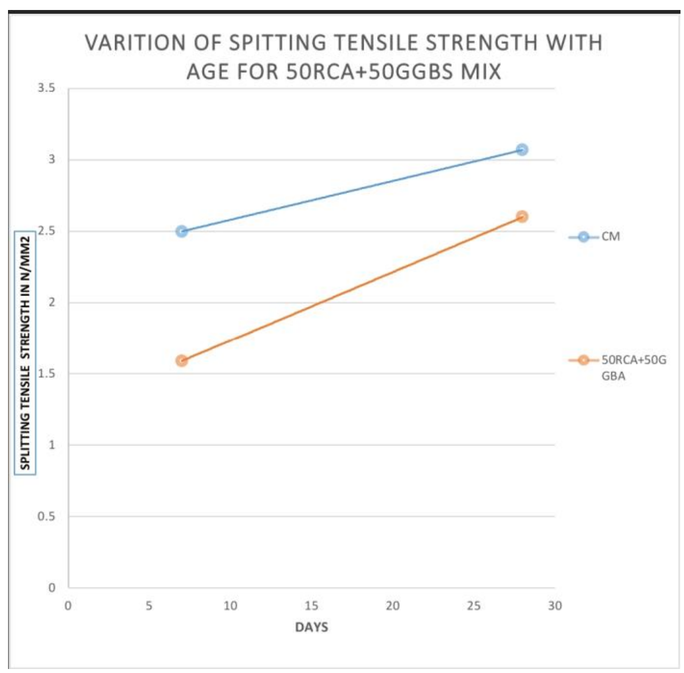


Fig.9.Varition of Splitting Tensile Strength with ages in day for 50GGBS+50RCA Mix

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

IV. 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 M20 mix so it is satisfactory.

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

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