An Experimental Study on the Behaviour of Concrete by Partial Replacement of Cement with GGBS

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Abstract— Concrete has occupied an important place in construction industry in the past few decades and it is used widely in all types of constructions ranging from small buildings to large infrastructural dams or reservoirs. It is the most widely used man-made construction material in the construction world. Ever since concrete has been accepted as material for construction, civil engineers have been trying to improve its quality, strength etc., against adverse conditions. The OPC is one of the main ingredients used for the production of concrete. However in the context of increased awareness regarding over exploitation of natural resources to manufacture cement, an eco-friendly technology has to be developed for the effective management of resources. The replacement of natural resources in the manufacture of cement is the present issue in the present construction scenario. With increase in demand of concrete, more and more new methods and new materials are being developed for production of concrete. Hence in the current study an attempt has been made to minimize the cost of cement with concrete mix grades M20 and M30 by studying the mechanical behaviour of these concrete mixes by replacing with advanced mineral admixture such as GGBS in concrete mixes as partial replacement of cement. GGBS is a waste industrial by-product from the blast furnaces used to make iron. Use of GGBS does not only reduce the cost of construction but also helps to reduce the impact on environment by consuming the material generally considered as waste product. Therefore an experimental study is conducted to evaluate the workability and strength characteristics of hardened concrete, by partially replacing the cement by various percentages of GGBS for M20 and M30 grades of concrete at different ages. The mixes were designed using IS Code method. In this project, properties of concrete have been assessed by partially replacing cement with GGBS. The cement has been replaced by GGBS accordingly in the range of 0% (without GGBS), 10%, 20%, 30%, 40% and 50% by weight of cement for M20 and M30 mix. Concrete mixtures were produced, tested and compared in terms of compressive, split tensile and flexural strength with the conventional concrete.

Key words: GGBS, Workability, Compressive Strength, Split Tensile Strength, Flexural Strength

I. INTRODUCTION

In the present scenario, as a result of continuous growth in population, rapid industrialization and the accompanying technologies involving waste disposal, the rate of discharge of pollutants into the atmosphere, GGBS is one of the industrial waste which comes out from blast furnace during metal extraction process. In many countries, there is a scarcity of natural aggregate and cement that are suitable for construction, whereas in other countries the consumption of aggregate has increased in recent years, due to increases in the construction Industry. In order to reduce depletion of natural aggregate and cement due to construction, artificially manufactured aggregate and some industrial waste materials can be used as alternatives, GGBS is considered as best options available.

GGBS which is an industrial by-product of Duracem GGBS Company, Auto Nagar, Visakhapatnam. The main objective of this thesis is to determine the concrete strength of M20and M30 Grade by partial replacement of cement from 0% to 50% with GGBS. The other objective is to reduce the cost of construction but also helps to reduce the impact on environment by consuming the material generally considered as waste product.

The mix design of M20 and M30 grade concrete was designed as per the method specified in IS 10262-2009.

Cubes of size 150mm × 150mm × 150mm, Cylinders of size 300mm×150mm and prisms of size 100mm × 100mm × 500mm were casted and tested for compressive strength, split tensile strength and flexural strength after the completion of respective curing periods.

II. EXPERIMENTAL PROGRAM

A. Materials Used:

1) Cement:

Ordinary Portland cement of grade 53 is used for this experimental work.

2) Fine aggregate:

The material which passes through BIS test sieve number 4 (4.75mm) is termed as fine aggregate usually natural sand is used as a fine aggregate at places where natural sand is not available crushed stone is used as fine aggregates. In our region fine aggregate can be found from bed of Krishna River. It conforms to IS 383 1970 comes under zone II.

3) Coarse aggregate:

The material which is retained on BIS test sieve number 4 (4.75mm) is termed as coarse aggregate. The broken stone is generally used as a stone aggregate. Coarse aggregate used is locally available crushed angular aggregate of size 20mm and 10mm are used for this experimental work.

4) Ground Granulated Blast furnace Slag:

GGBS is a waste industrial by-product from the blast furnaces used to make iron. GGBS used in this work was brought from Duracem GGBS company, Auto Nagar, Visakhapatnam.

Fig. 1: Ground Granulated Blast furnace Slag

Physical Properties	GGBS	Cement
Colour	White	White & Grey
Water Absorption%	0.75	4.35
Specific Gravity	2.77	3.13
Fineness	3%	2%

Table 1: Physical Properties of GGBS and Cement

B. Mix Design:

The mix proportion chosen for this study is M20 and M30 grades with water-cement ratios of 0.5 and 0.45. In this test total 54 Cubes of standard size 150x150x150mm and 54 Cylinders of standard diameter 150mm and height 300mm and 54 Prisms of size 500x100x100mm were casted for each design mix and cured for 3,7 and 28 days and tested as per code IS: 516-1959. The mix proportion chosen for this study is given in Table 2 and 3.

Water	Cement	Fine Aggregate	Coarse Aggregate (60% + 40%)
165	330	717.77	1270.58 (762.3 + 508.3)
0.5	1	2.17	3.85

Table 2: Mix proportion (Kg/m^3) and mix ratio for M20

Water	Cement	Fine Aggregate	Coarse Aggregate (60% + 40%)
180	402	660.7	1220.63 (732.4 + 488.3)
0.45	1	1.60	3.03

Table 3: Mix proportion (Kg/m^3) and mix ratio for M30

III. TESTS AND RESULTS

The different tests were conducted in the laboratories as shown in below. It consists of mixing of concrete in the laboratory by partial replacing Cement with proportions (by weight) of GGBS added to concrete mixtures were as follows: 0% (for the control mix), 10%, 20%, 30%,40% &50% Concrete samples were prepared and cured in the laboratory, and are tested, to evaluate the concrete fresh and harden properties like compressive strength, Split tensile strength and flexural strength requirements.

A. Workability of Concrete:

The workability of concrete with increase in percentages of GGBS is determined by Slump Cone test, Compaction Factor test and Vee Bee time test as these tests are suitable for mixes of low workability.

1) Slump Cone Test:

Slump cone test was conducted to determine the workability of concrete.

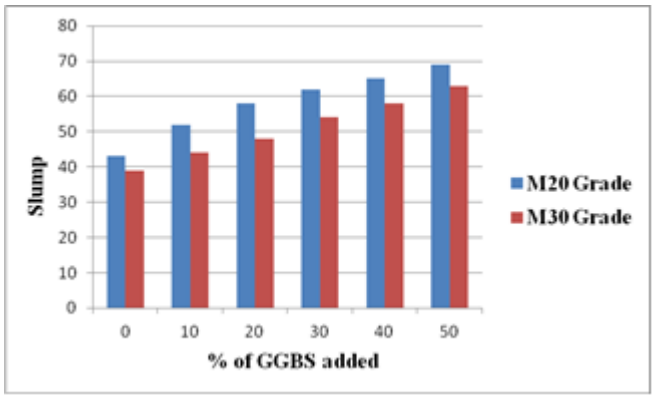

Fig. 2: Variation of slump

2) Compaction factor test:

Compaction factor test was conducted to determine the workability of concrete.

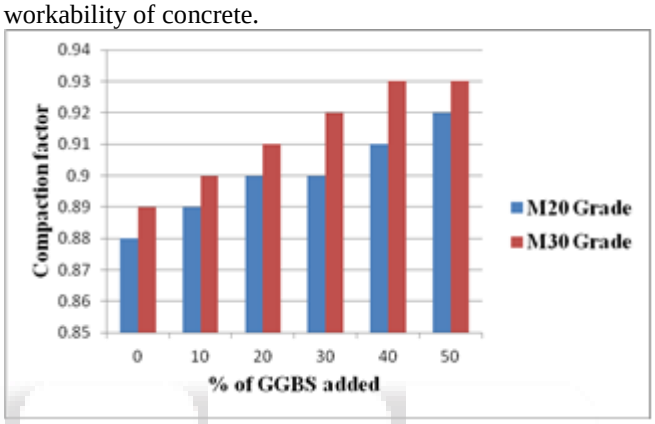

Fig. 3: Variation of Compaction factor

3) Vee Bee time test:

Vee Bee time test was conducted to determine the workability of concrete.

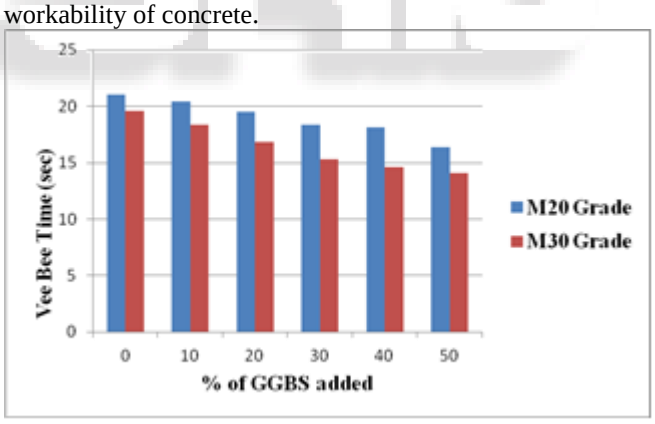

Fig. 4: Variation of Vee Bee time

B. Description:

From Fig 2,3&4, The Slump, Compaction factor is increased and Vee Bee time is decreased as the percentage of GGBS replacement is increased for both M20 and M30 grades.

1) Compressive Strength Test:

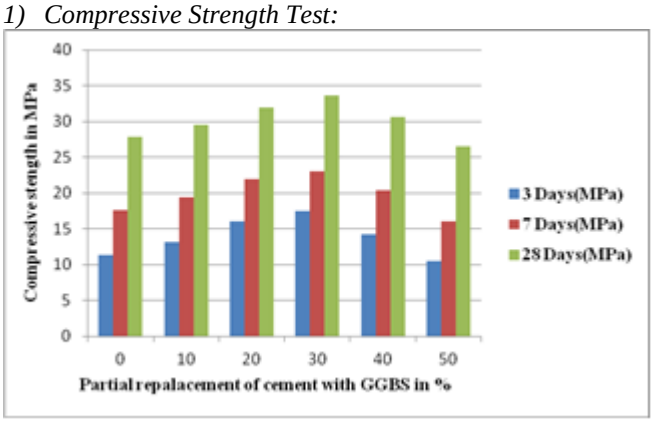

Fig. 5: Variation of Compressive strength of M20 Grade Concrete

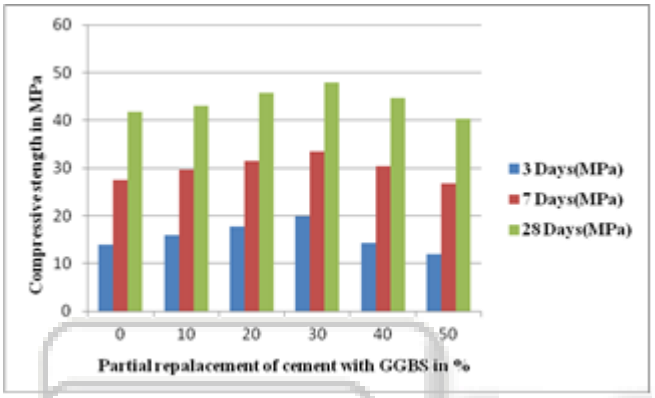

Fig. 6: Variation of Compressive strength of M30 Grade Concrete

2) Description:

1) From Fig 5&6, It is observed that the 30% replacement of cement with GGBS gave more strength than any other replacement for both M20 and M30 grades.
2) For M20 grade concrete the increase in compressive strength is in the order 0%, 6.24%, 14.76%, 20.72% for 0%, 10%, 20% and 30% and decreased by 9.98%, 4.70% for 40% and 50% replacements respectively compared with control specimen.
3) For M30 grade concrete the increase in compressive strength is in the order of 0%, 3.19%, 9.50%, 14.7% for 0%, 10%, 20% and 30% and decrease by 7.00%, 3.43% for 40% and 50 % replacements respectively with control specimen.

C. Split Tensile Strength Test:

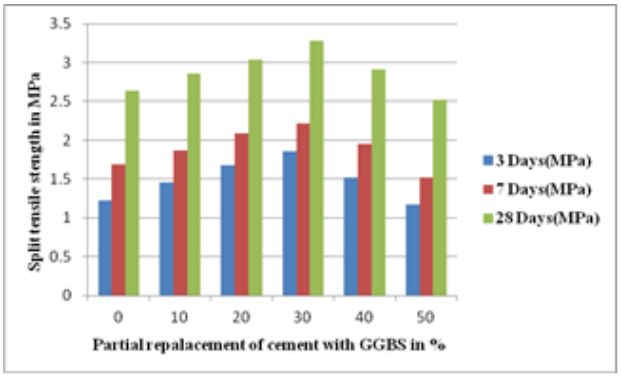

Fig. 7: Variation of Split tensile strength of M20 Grade Concrete

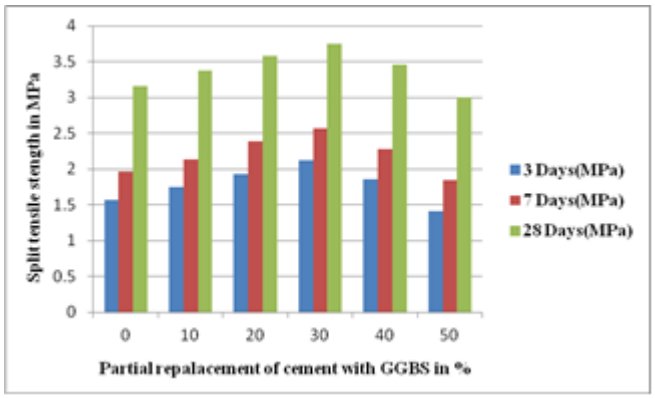

Fig. 8: Variation of Split tensile strength of M30 Grade Concrete

1) Description:

1) From Fig.7&8, It is observed that the 30% replacement of cement with GGBS gave more strength than any other replacement for both M20 and M30 grades.
2) For M20 grade concrete the increase in split tensile strength is in the order 0%, 8.33%, 15.15%, 24.24% for 0%,10%,20% and 30% and decrease by 10.23%, 4.55% for 40% and 50% replacements respectively.
3) For M30 grade concrete the increase in split tensile strength is in the order 0%, 6.65%, 13.29%, 18.67% for 0%,10%,20% and 30% and decrease by 9.49%, 4.43% for 40% and 50% replacements respectively.

D. Flexural Strength Test:

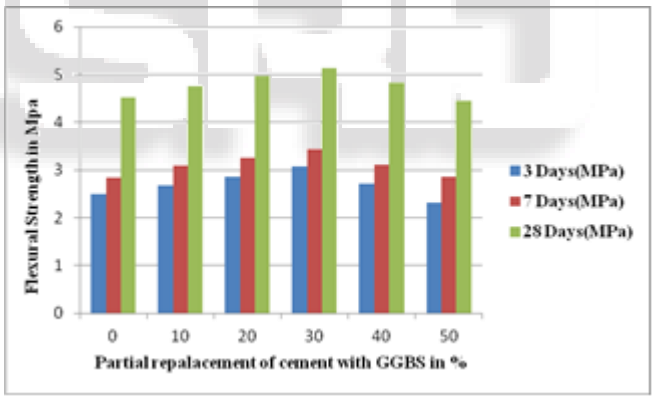

Fig. 9: Variation of Flexural strength of M20 Grade Concrete

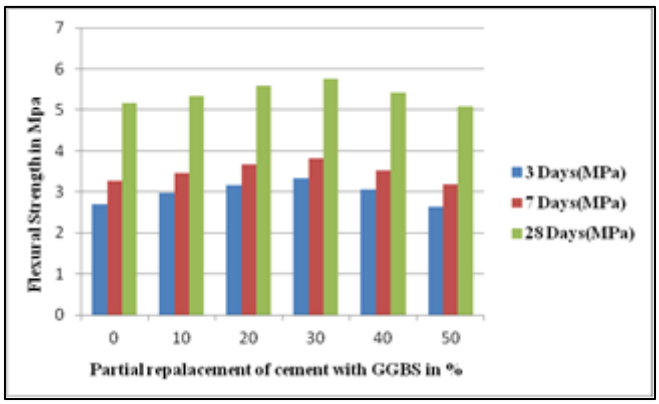

Fig. 10: Variation of Flexural strength of M30 Grade Concrete

1) Description:

1) From Fig.9&10, It is observed that the 30% replacement of cement with GGBS gave more strength than any other replacement for both M20 and M30 grades.
2) For M20 grade concrete the increase in flexural strength is in the order 0%, 5.31%, 10.18%, 13.71% for 0%, 10%, 20% and 30% and decrease by 6.86%, 1.77% for 40% and 50% replacements respectively.
3) For M30 grade concrete the increase in flexural strength is in the order 0%, 3.29%, 7.93%, 11.22% for 0%, 10%, 20% and 30% and decrease by 5.03%, 1.74% for 40% and 50% replacements respectively.

IV. CONCLUSIONS

1) GGBS is a good alternative for cement for M20 grade of concrete and it gives more strength in order of 20.72%, 9.88% increase for 30%, 40% by partial replacement of cement with GGBS. Partial replacement of cement with GGBS by 30% has given more strength and durability.
2) GGBS is a good alternative for cement for M30 grade of concrete and it gives more strength in order of 14.70%, 7.00% increase for 30%, 40% by partial replacement of cement with GGBS. Partial replacement of cement with GGBS by 30% has given more strength and durability.
3) The workability of concrete measured from Slump cone, Compaction factor is increasing with increasing in GGBS partial replacement and Vee Bee time is decreasing as the proportion of replacement of GGBS in place of cement increases.
4) In slump cone test, to have the slump in the range of 50-100 mm, for M20 mix concrete, the percentage of admixture required by weight of cement is 0.05, 0.1, 0.25,0.4 and 0.5 for 10%, 20%, 30%, 40%, 50% GGBS proportions respectively.
5) In slump cone test, to have the slump in the range of 50-100 mm, for M30 mix concrete, the percentage of admixture required by weight of cement is 0.1, 0.25, 0.45, 0.55 and 0.6 for 10%, 20%, 30%, 40%, 50% GGBS proportions respectively.
6) The compressive strength of M20 grade concrete for partial replacement of cement with GGBS increased in the order of 0%, 6.24%, 14.76%, 20.72% for 0%, 10%, 20%, 30% proportions and decreased by 9.88%, 4.7% for 40% and 50% proportions replacements respectively.
7) The split tensile strength of M20 grade concrete for partial replacement of cement with GGBS increased in the order of 0%, 8.33%, 15.15%, 24.24% for 0%, 10%, 20%, 30% proportions and decreased by 10.23%, 4.55% for 40% and 50% proportions replacements respectively.
8) The flexural strength of M20 grade concrete for partial replacement of cement with GGBS increased in the order of 0%, 5.31%, 10.18%, 13.71% for 0%, 10%, 20%, 30% proportions and decreased by 6.86%, 1.77% for 40% and 50% proportions replacements respectively.
9) The compressive strength of M30 grade concrete for partial replacement of cement with GGBS increased in the order of 0%, 3.19%, 9.50%, 14.70% for 0%, 10%, 20%, 30% proportions and decreased by 7.0%, 3.43% for 40% and 50% proportions replacements respectively.
10) The split tensile strength of M30 grade concrete for partial replacement of cement with GGBS increased in the order of 0%, 6.65%, 13.29%, 18.67% for 0%, 10%, 20%, 30% proportions and decreased by 9.49%, 4.43% for 40% and 50% proportions replacements respectively.
11) The flexural strength of M30 grade concrete for partial replacement of cement with GGBS increased in the order of 0%, 3.29%, 7.93%, 11.22% for 0%, 10%, 20%, 30% proportions and decreased by 5.03%, 1.74% for 40% and 50% proportions replacements respectively.

V. IS CODES

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