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Effect of Ground Granulated Blast Slag (GGBS) on Characteristics of Concrete

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ABSTRACT

Concrete in its various forms is probably the most widely used construction material in the world for construction works. The development of the construction industry at the global level needs more and more quantity of cement for construction works. But, the production of each one tone of cement clinker releases one tonne of carbon dioxide, which affects the earth's ecosystem. Thus, increasing the production of cement worldwide is aggravating the problems associated with its production kind use. The construction industry is now slowly becoming aware of the environmental issues and other sustainable development issues for cement and concrete industries.

This paper emphasizes on effect of Ground Granulated Blast Slag (GGBS) on characteristics of concrete which is a recent advancement in the field of concrete. GGBS is carried out which is a by-product of the iron industry and also can be used as a replacement with ordinary Portland cement in concrete.

Use of GGBS as cement replacement can simultaneously reduce the cost of concrete and help to reduce the rate of cement consumption and has rapidly drawn the attention of the concrete industry due to its cement saving, energy-saving, cost-saving, and environmental benefits.

In this study cube specimens (150mm×150mm×150mm) are casted using 0%, 10%, 20%, 30%, 40%& 50% replacement of cement with GGBS to assess the compressive strength at 7th& 28th day for M40 grade concrete.

Based on the results of this investigation, it is concluded that GGBS has the potential to replace cement in concrete as its physical properties are well within the range specified by IS 455:1989. Hence the can be safely used in the concrete composition.

Keywords: Cement, Ground Granulated Blast Slag, Workability, Compressive Strength Test.

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1. INTRODUCTION

Concrete is the preferred construction material for a wide range of civil engineering structures. It is essentially a mixture of fine and coarse aggregate, bound together by a hardened cement paste. The use of concrete as a construction material is not a recent development, but dates back to ancient times, several thousand years ago. The ease with which concrete can be made allows anybody to mix and fabricate it since the concrete mix will harden to a great degree even if it is not made with the right proportions or not placed properly. However, the durability of that concrete is not expected to be similar to that of properly constituted, placed, cured concrete which exhibits a long service life under most natural and industrial environments. Concrete is an extraordinary and key structural material in human history. Man consumes no material except water in such tremendous quantities. It is no doubt that with the development of human civilization, concrete will continue to be a dominant construction material in the future. However, the development of the modern concrete industry also introduces many environmental problems such as pollution, waste dumping, emission of dangerous gases, and depletion of natural resources.

The greatest challenge before the construction industry is to serve the two pressing needs of human society namely the protection of the environment and meeting the infrastructural requirement of our growing needs of industrialization and urbanization.

It is looking for ways and means to develop building products, which will increase the life span and quality. In this regard, the merits of using certain industrial by-products such as fly ash, ground granulated blast furnace slag, silica fume, and metakaolin have been well recognized by the construction industry. Therefore, it should be obvious that certain scale cement replacement with industrial byproducts is highly advantageous from the standpoint of cost, economy, energy efficiency, durability, and overall ecological and environmental benefits. An Optimum Consumption of these materials without scarifying the quality of concrete to make them suitable as "Green Building" materials.

Among them, the Ground Granulated Blast Slag,(GGBS) is the waste from of iron manufacturing industry, which may be used as a substitute for cement in concrete due to its inherent cementing properties. To increase the strength of the concrete some of the special cement is used. Among that OPC 53S special cement is used in the construction of railway sleepers which gives more compressive strength compared to OPC cements .this special cement is finer than ordinary cement. The investigation on compressive strength of the concrete at different ages such as 7 days and 28 days are observed when the cement is replaced with ground granulated blast slag (GGBS). The GGBS is obtained from the steel plant in Visakhapatnam District of Andhra Pradesh State.

2. LITERATURE REVIEW

B. Kaviya et al (2017), this study aims to evaluate the performance of partial replacement of cement (OPC- 53 grade) by GGBS. Concrete has become a vital part of our lives, the use of concrete is increasing at a very high rate. One of the main constituents of concrete is Portland cement. The manufacturing of cement results in the emission of large amounts of CO2. Thus the researchers have started finding alternatives for the partial replacements for cement. This main study of this paper is on investigating the behavior of M35 concrete by partially replacing the cement by Ground granulated blast furnace slag (GGBS). Ground-granulated blast-furnace slag (GGBS) is obtained by quenching molten iron slag (a by-product of iron and steel-making) from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder. GGBS is used to make durable concrete structures in combination with ordinary Portland-cement and/or other pozzolanic materials. Cubes and Cylinders are tested for its Compressive and split tensile strength after 7 and 28 days of curing. The replacement percentages of cement by GGBS used are 30, 40, and 50. The water-cement ratio adopted in this work is 0.46. From the experimental investigations, it has been observed that the optimum replacement of Ground granulated blast furnace slag to cement is 30 percentages for M35 grade.

Santosh Kumar Karri et al (2015) studied Strength and Durability Studies on GGBS Concrete and Concluded that the Workability of concrete increases with an increase in the GGBS Replacement level.

Krishnamoorthy et al (2015) in this paper they have studied on the Strength and Corrosion Resistance Properties of Ggbs Concrete Containing Quarry Dust as Fine Aggregate and concluded that Ground granulated blast furnace slag also has a lower heat of hydration and, hence, generates less heat during concrete production and curing. It leads to increased resistance to chemical attack. The results of the compressive test show that the strength of the concrete increases to the percentage of GGBS slag added by weight of fine aggregate up to 50% of replacement. Therefore, the replacement of 50% GGBS is the better corrosion resistance.

3. OBJECTIVE OF STUDY

- To obtain compressive strength results of the mixed design of M40 Grade concrete and replacement of Cement with GGBS for 7 & 28 days.
- To conduct a preliminary test on cement, fine aggregate, and coarse aggregate.
- To obtain the workability of concrete at various proportions.
- To conduct a compressive strength test on 150mm x150mm x 150mm concrete cubes.

4. EXPERIMENTAL PROCEDURE

The Experimental procedure is planned as follows.

1. To Mix proportions of OPC concrete for M40 is prepared following the IS standard IS-10262-2009.
2. The concrete mix proportions for the cement, fine, and coarse aggregate were 1:1.78:3.07respectively, and W/C ratio was 0.38 by weight.
3. The mix proportion with partial replacement such as 0%, 10%, 20%, 30%, 40% and 50%of GGBS with OPC.
4. The concrete specimens are prepared such as cubes(150 cm X 150 cm X 150 cm) for compressive strength in the laboratory with 0%, 10%, 20%, 30%, 40% and 50%replacement of GGBS with OPC for M40 grade concrete and after pouring the concrete in the mold and tamped properly so as not to have any voids.
5. After 24 hours these molds are removed and test specimens are put in water for curing. The top surface of these specimen should be made even and smooth. This is done by putting cement paste and spreading smoothly on the whole area of the specimen.
6. These specimens are tested by the compression testing machine after 7 days and 28 days curing. Load at the failure divided by area of specimen gives the compressive strength of concrete.
7. The materials were first to dry mixed then mixed with water and superplasticizer thoroughly. A slump test was conducted to measure the degree of workability.

5. PRELIMINARY TEST RESULTS

5.1 Cement

Ordinary Portland cement of 53 grades, conforming to IS12269-1987has been procured for experimentation work and tests have been carried out according to the specifications. It is necessary to know the properties of cement in the mix design procedure. Specific gravity, fineness, normal consistency, initial and final setting times and compressive strength of cement were determined in the concrete technology laboratory.

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TABLE 1.The physical properties of cement

S. No	Parameter	Value Obtained	Permissible limit as per IS:12269-1987
1	Fineness of cement	9.8%	The standard cement should have fineness less than 10 % as per IS Recommendations.
2	Normal consistency	33%	-
3	Initial setting time	30MIN	Not less than 30minutes
4	Final setting time	600MIN	Not more than 600minutes
5	Specific Gravity	3.12	Not less than 3.15

5.2 FINE AGGREGATE

Natural River sand is used as a fine aggregate. The bulk specific gravity in oven-dry condition and water absorption as per IS:2386 (Part-III, 1963) is 2.65 and 1 percent respectively. The bulk density is 1495kg/m3.

5.3 COARSE AGGREGATE

Crushed granite aggregate available from local sources has been used and procured from "SITAM COLLEGE AREA " in the Vizianagaram district. The maximum size of the coarse aggregate chosen in the experimentation is +20mm. Before using this aggregate into concrete, it is necessary to determine the specific gravity, bulk density, and water absorption of procured aggregate. Accordingly, tests have been carried out as per the procedure given in IS 2386 (part-III)-1963[76] and the results are presented in Table.

TABLE 2.Physical properties of Natural coarse aggregate

S.No	Property	Value
1	Specific Gravity	2.8
2	Water absorption in %	0.25%
3	Impact value in %	16.05%
4	Crushing value in %	25%
5	Abrasion value in %	35%
	Bulk density in kg/m^3 Loose state Dense state	 1725kg/m^3 1520kg/m^3

5.4 GGBS(Ground Granulated Blast Furnace Slag)

The ground granulated blast furnace slag was obtained from Dileep constructions.
The chemical composition of the granulated blast furnace slag is shown in Table.

TABLE3. Chemical composition of blast furnace slag

Oxides	SiO2	P2O5	Cao	Mno	Feo	Fe2O3
Mass Percentage	11	10	51	08	10	04

5.5 WATER

Municipal tap water having a ph value greater than 6 is taken for mixing and curing as per IS456:2000.

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5.6 SUPERPLASTICIZER

A high-performance concrete superplasticizer based on modified polycarboxylic ether, supplied from M/s Akarsh specialties, Chennai.

6. CONCRETE MIX DESIGN: (M40 Grade)

Design stipulations:

Characteristic compressive strength required in the field at 28 days is $40N/mm^2$

Maximum size of aggregate 20mm (angular)

Degree of quality control Good

Degree of Workability 50-100slump (mm)

Type of exposure Extreme

Test data for materials:

Cement used OPC satisfying the requirements of IS: 269-1967

The specific gravity of cement 3.12

Specific gravity

Coarse aggregate 2.8

Fine aggregate 2.65

Water absorption

Coarse aggregate 0.25%

Fine aggregate 1.01%

Free moisture

Coarse aggregate NULL

Fine aggregate NULL

The Compressive strength of cement for 7 days satisfies the requirement.

Target mean strength:

40+1.65*5=48.25 Mpa

The selection for the w/c ratio for the target means the strength of 48.25 Mpa is 0.38. This is lower than the maximum of 0.40.solution w/c ratio=0.38.

Selection of water and sand content for maximum 20mm size aggregate and confirmed is to grade zoneII. Water content per cubic meter of concrete is 186kg.

Required water content →186+ (3÷100)*186=191.6 lit/cu.m

Determination of water content

W/c ratio =.38 (as per morth code provisions for high-performance concrete)

Water= 191.6 lit

As Superplasticizer is used water content can be reduced up to 20%

Therefore water content= 191.6*0.80=153.3 lit

Cement content=153.3/0.38= 403kg/m3

The cement content is adequate for extreme exposure conditions.

Mix calculations

Volume of cement= (mass of cement / sp. gravity of cement)/1000

= (403/3.12)/1000

= $0.129m^3$

Volume of water = (153.3/1000)

= $0.153m^3$

Volume of admixture = Assuming dosage 0.8% by weight of cement and sp. Gravity of admixture = ((0.8*403)/ (1.1*100))/1000

= $0.0029\ m^3$

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Volume of aggregate = 1-(0.0029+0.129+0.153)
= 0.715 m^3
(NOTE: Table 3 Volume of Coarse Aggregate per Unit Volume of Total Aggregate for Different Zones of Fine Aggregate of IS.10262-2009)

Availability of nominal maximum size of aggregate=20mm
Mass of coarse aggregate= (Volume of aggregate* Volume of coarse aggregate*
Sp. Gravity of coarse aggregate*1000)
= 0.715*0.62*2.8*1000
= 1241 KGS
Mass of fine aggregate = (Volume of aggregate* Volume of fine aggregate*
Sp. Gravity of fine aggregate*1000)
= 0.715*0.38*2.65*1000
= 720 KGS

Mass of admixture = ((403*0.8)/100)
= 3.226 KG/ m^3
Water absorption:

The extra quantity of water to be added for absorption in case of FA as 1.01% of water = (720*1.01)/100= 7.272L
The extra quantity of water to be added for absorption in case of CA as 0.25% of water = (1241*0.25)/100= 3.1025L
The actual quantity of water required to be added =153.3+7.272+3.1025=163.68
Determination of coarse and fine aggregates

Water	**:**	**Cement :**	**fine aggregate**	**:**	**coarse aggregate**
163.68	: 403	:	720	:	1241
	0.0 :	1	:1.78	:	3.07

7. RESULTS AND DISCUSSION

A. SLUMP CONE TEST: The concrete slump test measures the consistency of fresh concrete before it sets as per IS: 1199performed to check the workability of freshly made concrete, and therefore the ease with which concrete flows.

Table 4.Results of Various Proportionsof 1m^3Concrete for Workability (Slump)

Mix proportions C:FA:CA:GGBS:W:SP	Grade of concrete	Mix Id	Slump value
403:720:1241:0:153.3:3.226	M40	0%GGBS+SP	70mm
362.7:720:1241:40.3:153.3:3.226	M40	10%GGBS+SP	75mm
322.4:720:1241:80.6:153.3:3.226	M40	20%GGBS+SP	83mm
282.1:720:1241:120.9:153.3:3.226	M40	30%GGBS+SP	95mm
241.8:720:1241:161.2:153.3:3.226	M40	40%GGBS+SP	105mm
201.5:720:1241:201.5:153.3:3.226	M40	50%GGBS+SP	120mm

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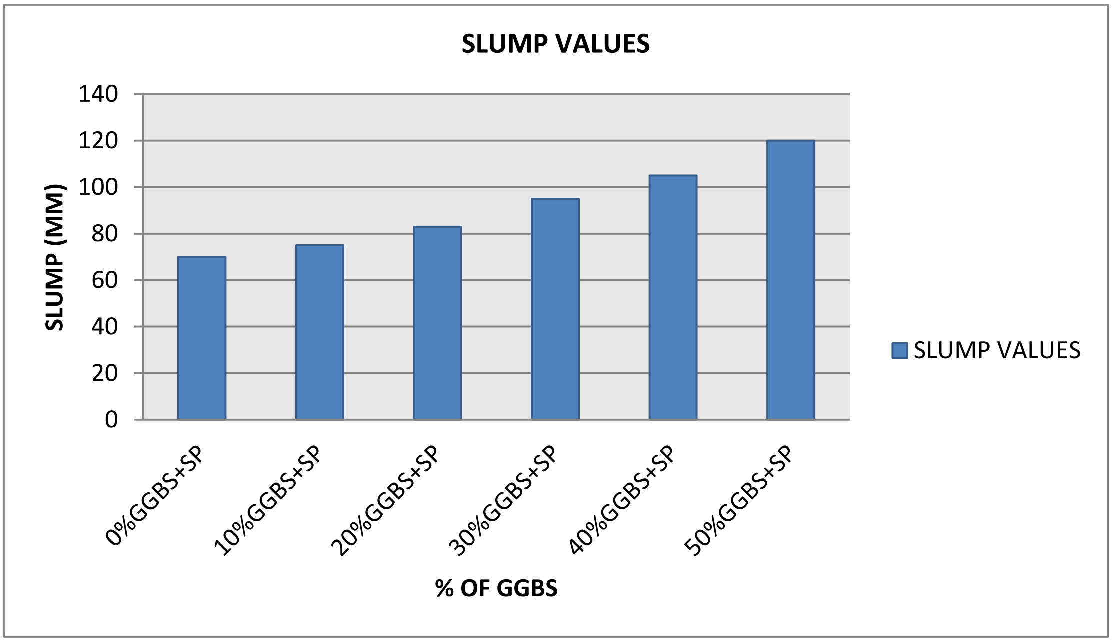
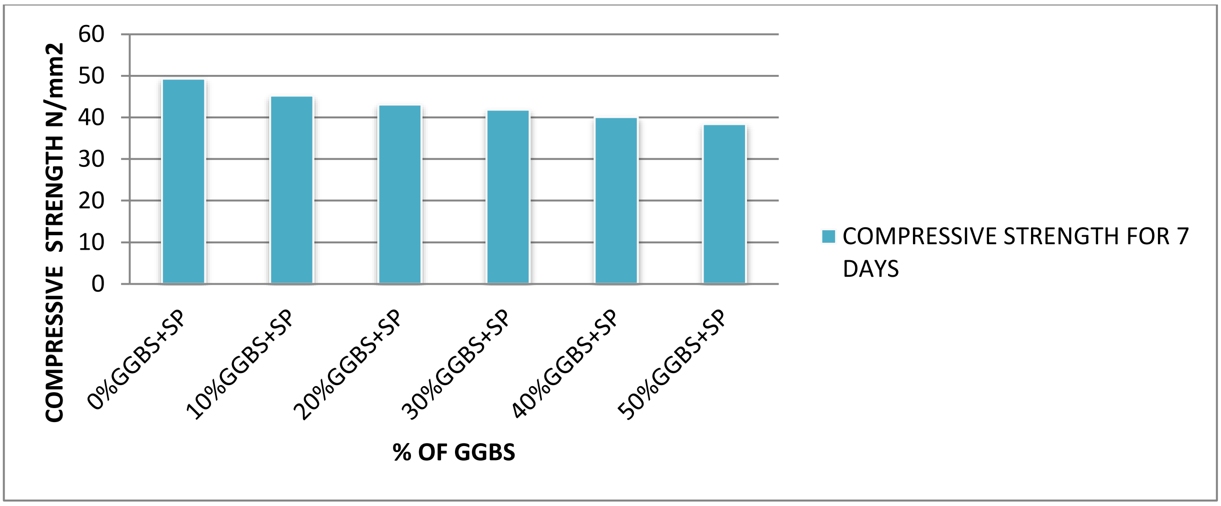


Graph1. Showing Obtained Slump Values

B. COMPRESSIVE STRENGTH AT 7 & 28 DAYS

Table 5.Compressive Strength Values

Percentage of replacement of cement with GGBS	7 Days Avg compressive strength in M. Pa	28 Days Avg compressive strength in M. Pa	Percentage of 7 days strength to reference	Percentage of 28 days strength to reference
0% of GGBS	49.3	58.2	14.63	6.2
10% of GGBS	45.2	56.1	10.53	4.1
20% of GGBS	43.1	55.3	8.43	3.3
30% of GGBS	41.8	54.0	7.13	2.0
40% of GGBS	40.1	52.6	5.43	0.6
50% of GGBS	38.4	49.5	3.73	2.5



Graph2: Showing Compressive Strength For 7 Days

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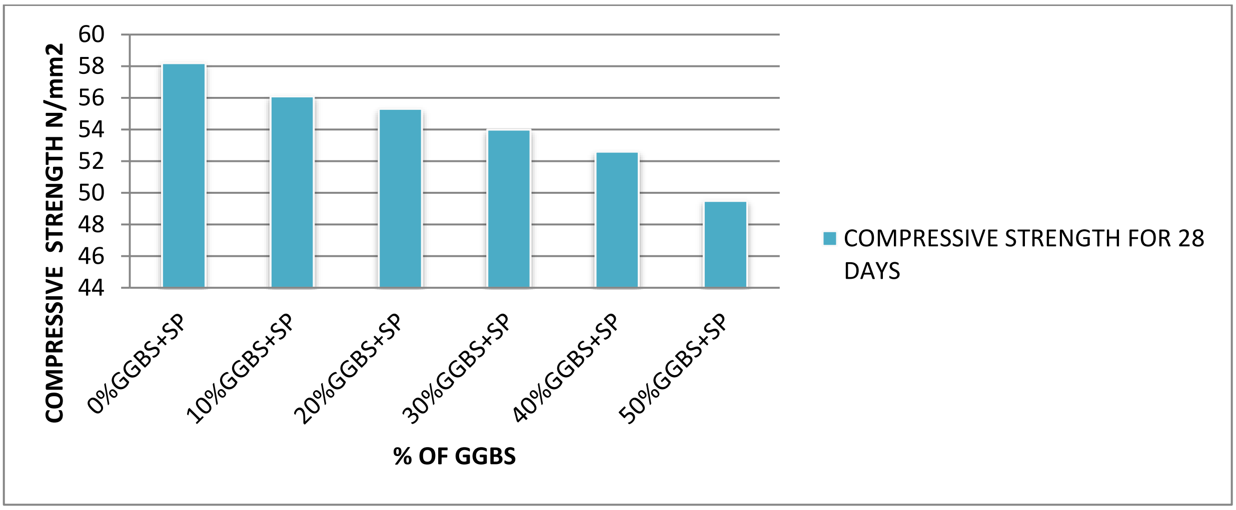

Graph3: Showing Compressive Strength for 28 Days

6. CONCLUSIONS

1. Based on the results of this investigation, it is concluded that GGBS has the potential to replace cement in concrete as its physical properties are well within the range specified by IS 455:1989. Hence the can be safely used in the concrete composition.
2. Effect of the strength of hardened concrete.
3. Keeping strength consideration in view, it is recommended that 40% replacement of cement with GGBS can be safely used in the concrete composition for our target mean strength value of MORTH recommendations and by IS: 456:2000 also required target strength is achieved as per design considerations.
4. Reduction in emission of CO_2.
5. Cost-efficient.
6. Sustainable and eco-friendly building material.

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