STRENGTH AND DURABILITY STUDY OF HIGH PERFORMANCE CONCRETE WITH GGBS AND SILICA FUME

Rasuri Akhil Jayendra
M.Tech Student
Department of Civil Engineering,
Usha Rama College of Engineering & Technology, Telaprolu, Krishna District,
Andhra Pradesh, India, 521109

ABSTRACT: The usage of mineral admixtures in the concrete not only enhances its strength properties but also durability. To study the role of silica fume and ground granulated blast furnace slag (GGBS) on concrete strength characteristics of a high-strength, a test program has been planned. Different concrete mixtures were prepared and tested with different levels of cement replacement (0 %, 10 %, 20 %, 30% and 40 %) with GGBS and active silica fume as addition (0 %, 5 %, 10 % and 15 % by weight of cement). The main objective of this study is to determine the optimal replacement percentages which can be appropriately used to get HPC. To find the optimal replacement GGBS with the addition of silica fume in M60 grade concrete with maintaining water cement ratio of 0.32. This experiment is planned to estimate 28days strength parameters of concrete i.e., compressive strength, split tensile strength and flexural strength.

Keywords: GGBS, Silica fume, super plasticizer, compressive strength, split tensile strength, flexural strength and High performance concrete

1. INTRODUCTION

Sustainable development must meet the needs of the present without compromising the ability of future generations to meet their own needs. It also shows that the development will be done to sustain the planet's resources, using them effectively without unnecessary waste. The cement industry is responsible for major portion of the carbon dioxide emissions. Production of one ton of cement Portland approximately emits several tons of carbon dioxide gas into the atmosphere. The use of Ground granulated blast furnace slag (GGBS) and silica fume to replace cement, can be considered as sustainable approach, because the production of the cement is emits carbon dioxide gas to atmosphere. Carbon dioxide emissions will increase the effect of global warming due to greenhouse effect. Among the greenhouse gases, carbon dioxide contributes about 65% of global warming.

HIGH PERFORMANCE CONCRETE

Concrete special combinations meeting strength and uniformity a requirement that cannot always be achieved by mixing conditions and placing regular concrete is generally known as high-performance concrete. High performance concrete (HPC)is also defined a material that is designed to provide performance characteristics optimized for a given set of materials, use and exposure conditions in accordance with the requirement of cost, useful life and durability. Usually concrete high performance means that the concrete with high strength and high durability. A high strength concrete is generally becomes high-performance concrete, but a high-performance concrete cannot become a high strength concrete. High strengths are possible by reducing the porosity lowering W / C ratios and reducing micro-fissures in the cement paste. The concrete is exposed to problems in coastal and marine environments. In these places the durability of the concrete is reduced and very life of structure is also reducing. To overcome this problem re-research began to find a new material in conventional concrete place which results in high performance concrete invention. HPC usually contains minerals and chemical additives. Thus, the strength development rate is quite different from conventional concrete.

GROUND GRANULATED BLAST FURNACE SLAG

Ground granulated blast furnace slag (GGBS) is a recyclable material created when the molten slag from iron ore is quickly quenched and then ground into a powder. This material has properties and cement has been used as a substitute for cement for over 100 years. Recently, Wisconsin began to use it in some of its road projects. Wisconsin has experienced several problems with GGBS, including slow gain strength and decrease in surface quality. Combating these problems, GGBS concrete has higher resistance and lower permeability. This project investigates these GGBS features and has several objectives. Ground granulated blast furnace slag (GGBS) is a by-product of the steel industry. Blast-furnace slag is defined as “non- metallic product consisting essentially of calcium silicates and other bases that is developed in a molten simultaneously with iron condition in a furnace”. In the production of iron, the blast furnaces are loaded iron ore, fluxes and coke. When the iron ore, which is constituted by iron oxides, silica and alumina, comes together with fluxing agents, iron and molten slag are produced. The molten slag then passes through a specific process, depending on the type of slag that will be. GGBS is produced when the molten slag is rapidly quenched using water jets, which produces a glassy granular aggregate.

Figure 1. GGBS

SILICA FUME

Silica fume, also known as micro- silica, is a (non-crystalline) amorphous silicon dioxide polymorph of silica. It is an ultrafine powder collected as a byproduct of the production of silicon and ferrosilicon alloy and consists of spherical particles with an average diameter of 150 nm particle. The main application field is as pozzolanic material for high-performance concrete. It is often confused with fumed silica. However, the process of production, characteristics of particles and fumed silica fields of application are all different from those of silica fume.

OBJECTIVE OF WORK

1. To increase the strength of concrete by partial replacement of cement with silica fume and GGBS.
2. To conduct tests to assess the strength characteristics of Silica Fume and GGBS admixed concrete

2. MATERIALS & METHODS

In this experimental program, the primary stage includes the preliminary re-search on selecting the raw materials. Number of conventional trails is prepared and the mix proportions for M60 grade is selected by changing different water cement ratios. By replacing cement with the GGBS in 10%, 20%, 30% and 40% optimum percentage is selected for main trails. The main experimental work also involves the addition of silica fume in 5%, 10% and 15% along cement for M60 grade. The strength and durability properties are studied in this work by comparing both grades.

MATERIALS

Concrete is a composition of three raw materials. They are Cement, Fine aggregate and Coarse aggregate. These three raw materials play an important role in manufacturing of concrete. By varying the properties and amount of these materials, the properties of concrete will changes. The main raw materials used in this experimental work are cement, fine aggregate, coarse aggregate, mineral and chemical admixtures.

CEMENT

Cement is the main ingredient in manufacturing of concrete. The characteristics of concrete will b greatly affected by changing the cement content. The cement used in this project is Ordinary Portland cement of 53 grade confirming to IS 12269 – 1987.

GROUND GRANULATED BLAST-FURNACE SLAG (GGBS)

Ground granulated blast-furnace slag is the granular material formed when molten iron blast furnace slag is rapidly chilled (quenched) by immersion in water. It is a granular product with very limited crystal formation and is highly cementitious in nature.

SILICA FUME

Silica fume also known as micro silica is an amorphous (non-crystalline) polymorph of silicon dioxide, silica. It is an ultrafine powder collected as a byproduct of silicon and production and Ferro-silicon alloy consists of spherical particles with an average particle diameter of 150 nm.

CHEMICAL ADMIXTURE

Chemical admixtures in concrete are confirms to ASTM C 494 Specifications. Chemical admixtures will gives required workability with low water contents. They improve the workability and concrete quality. Hence less cement content is used with reduced water content to achieve same strength. They are also called as super plasticizers. In this Experimental work GLENIUM B233 is used as a super plasticizer.

MIX DESIGN FOR M60 GRADE

This mix design is adopted after conducting several conventional trails. Super plasticizer dosage = 0.3% by cement weight

For M60 Grade:

Cement = 536 Kg/m^3
Fine aggregate = 683 Kg/m^3
Coarse aggregates = 1060 Kg/m^3
Mix ratio:
Cement: Fine Aggregate: Coarse Aggregates: water
1 : 1.27 : 1.97 : 0.32

3. RESULTS AND DISCUSSIONS

In this section the results are tabulated by calculating Fresh and Hardened properties of concrete. The compressive strength, split tensile strength and flexural strength are the main properties for determining the concrete strength. In this the strength properties are calculated by replacing Different concrete mixtures were cast and tested with different levels of cement replacement with GGBS(0 %, 10 %, 20 %, 30% and 40 %) with active silica fume as addition (0 %, 5 %, 10 % and 15 % by weight of cement).

COMPRESSIVE STRENGTH:

Compressive strength is obtained by applying crushing load on the cube surface. So it is also called as Crushing strength. Compressive strength of concrete is calculated by casting 150mm x 150mm x 150mm cubes. The test results are presented here for the compressive strength of 28 days of testing. The water cured specimens are eliminated from moisture content by surface drying before testing in CTM. The detailed test results are summarized as follows

Table 1. Compressive strengths for M60

S.No	Mix Description	Compressive Strength N/mm^2 28 days
1	GGBS 0	64.00
2	GGBS 10	64.88
3	GGBS 20	66.22
4	GGBS 30	68.44
5	GGBS 40	65.33

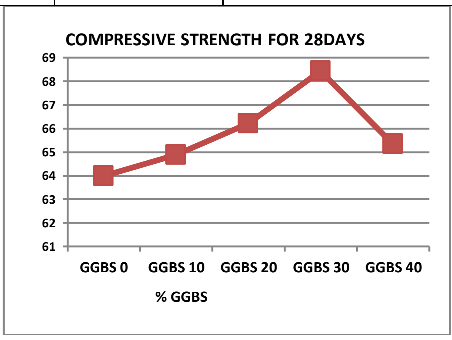

Figure 2. Compressive strength for M60 grade at 28 days using GGBS

Table 2. Split Tensile strengths for M60

S. No	Mix Description	Split tensile Strength N/mm^2 28 days
1	GGBS 0	5.09
2	GGBS 10	5.23
3	GGBS 20	5.52
4	GGBS 30	5.80
5	GGBS 40	5.37

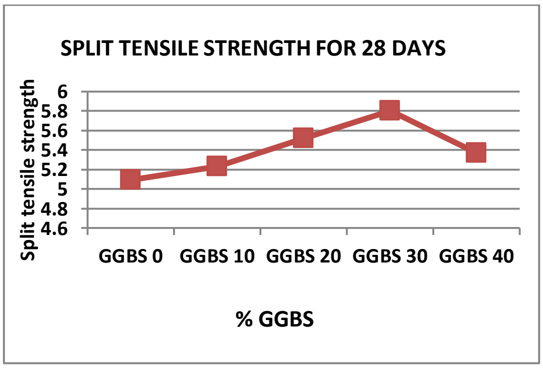

Figure 3. Split tensile strength for M60 grade at 28 days using GGBS

Table 3. Flexural strengths for M60

S. No	Mix Description	Flexural Strength N/mm^2 28 days
1	GGBS 0	5.8
2	GGBS 10	6.0
3	GGBS 20	6.6
4	GGBS 30	7.4
5	GGBS 40	6.8

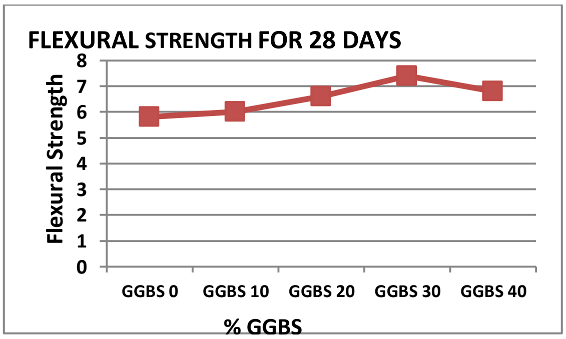

Figure 4. Flexural strength for M60 grade at 28 days using GGBS

Table 4. Compressive strengths for M60 (Cement replaced with silica fume)

S.No	Mix Description	Compressive Strength N/mm^2 28 days
1	SF 0	64.00
2	SF 5	65.77
3	SF 10	68.00
4	SF 15	65.33

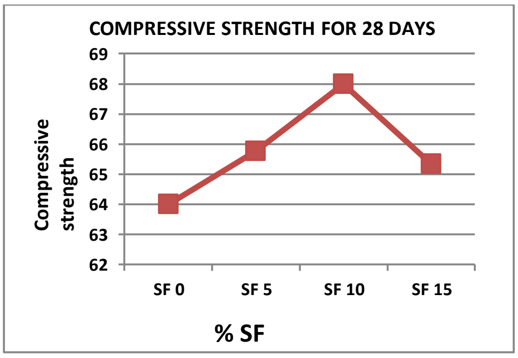

Figure 5. Compressive strength for M60 grade at 28 days using Silica Fume

Table 5. Split tensile strengths for M60 (Cement replaced with silica fume):

S.No	Mix Description	Split tensile Strength N/mm^2 28 days
1	SF 0	5.09
2	SF 5	5.37
3	SF 10	5.66
4	SF 15	5.5

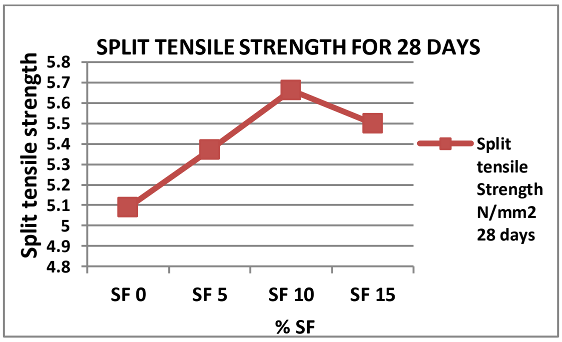

Figure 6. Split tensile strength for M60 grade at 7 & 28 days using Silica Fume

Table 6. Flexural strengths for M60 (Cement replaced with silica fume):

S. No	Mix Description	Flexural Strength N/mm^2	
		7 days	28 days
1	SF 0	5.2	5.8
2	SF 5	6.0	6.2
3	SF 10	6.6	7.2
4	SF 15	6.2	6.5

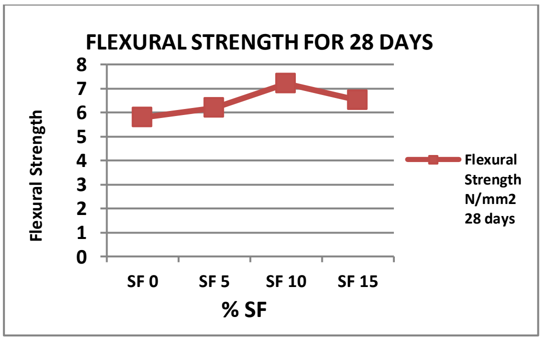

Figure 7. Flexural strength for M60 grade at 7 & 28 days using Silica Fume

Table 7. Compressive strengths for M60 (Combination of both GGBS and Silica Fume):

Mix name	Compressive strength(N/mm^2)
	28days
CM(control mix)	64.00
HPC1	65.77
HPC2	68.44
HPC3	70.66
HPC4	68.88

FLEXURAL STRENGTH: (IS 516-1959)

The modulus of rupture is the main property for the flexural members. To improve the flexural strength of concrete is one main task in present construction activities. Flexural strength for concrete is determined by casting beam specimens. The beam dimensions are of 500mm x 100mm x 100mm. The modulus of rupture values for both grades are described as follows

Table 8. Flexural strength for M60

Mix name	Flexural Strength(N/mm2)	
	7 days	28days
CM	4.8	5.8
HPC1	5.2	6.5
HPC2	6.4	7.4
HPC3	6.6	7.8
HPC 4	5.4	6.4

SPLIT TENSILE STRENGTH: (IS 516-1959)

Out of all the properties of concrete, tensile strength is very important one. The tensile strength is calculated by testing cylindrical specimens of size 300mm height and 150mm diameter. Here each set of specimens are tested for 7 days and 28 days of curing. The details of test results are summarized below

Table 9. Split Tensile strengths for M60

Mix name	Spilt tensile strength(N/mm2)	
	7 days	28days
CM	2.6	3.2
HPC1	2.9	3.6
HPC2	3.2	3.8
HPC3	3.7	4.4
HPC 4	2.9	3.6

4. CONCLUSIONS

These following conclusions are given based on the above experimental results

- In the present investigation possibility of high strength is observed for M60 grade that is successfully achieved.
- It is observed that GGBS based concretes have achieved an increase in strength for 30% replacement of cement at the age of 28 days. Increasing strength is due to filler effect of GGBS.
- The silica fume content increases the compressive strength increases by 10% and then decreases. Hence the ideal replacement is 10%.
- The percentage of cement replacement by silica fume increases, workability decreases.

- The addition of silica fume improves the bond strength of concrete.
- The compressive strength, flexural strength and split tensile strength are increased in combination of partial replacement of cement by GGBS in 30% and addition of silica fume in 10%.
- The use of Glenium B233 as Super-plasticizer at a dosage of 0.3% shows better workability and uniformity in mixing of concrete. It is a good water reducing agent.
- At the replacement of 30% GGBS, maximum compressive strength of 68.44 Mpa, Split tensile strength of 5.80 Mpa and Flexural strength of 7.4 Mpa were observed.
- At the replacement of 10%Silica Fume, maximum compressive strength of 68.00 Mpa, Split tensile strength of 5.66 Mpa and Flexural strength of 7.2 Mpa were observed.
- For M60 grade, maximum compressive strength of 70.66 Mpa, Split tensile strength of 4.4 Mpa and Flexural strength of 7.8 Mpa had occurred for HPC3 i.e., 10% Silica Fume, 30% GGBS.
- In case of durability the HPC 3 i.e., 10% Silica Fume, 30% GGBS has shown better results in attaining resistance when compared with other trail mixes to resist acid action.

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