Study on Engineering Properties of GGBS and Silica Fume Admixed High Performance Concrete

M.D.V.S.Sravani[1] | Avvaru Pradeep[2] | J.ManikantaVamsi[3] | S.V.Ganesh[4] | A. Sai Kumar[5]

[1, 2, 3, 4]UG Students, Department of Civil Engineering, Godavari Institute of Engineering and Technology (A), Rajahmundry, Andhra Pradesh, India.

[5]Assistant Professor, Department of Civil Engineering, Godavari Institute of Engineering and Technology (A), Rajahmundry, Andhra Pradesh, India

Abstract: High performance concrete (HPC) is a concrete meeting special combinations of performance and uniformity requirements. This leads to examination of the various admixtures to improve the performance of the concrete. 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 test program has been planned. Different concrete mixtures were prepared and tested with different levels of cement replacement (0 %, 10 %, 20 %, 30% and 40 %) of GGBS with 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 that can be appropriately used in Indian conditions. 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 compare 7days and 28days the strength parameters of concrete i.e., compressive strength, split tensile strength and flexural strength. And also workability and durability characteristics were examined. Key Words: GGBS, Silica fume, super plasticizer, compressive strength, split tensile strength, flexural strength and High performance concrete.

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I. INTRODUCTION

Sustainability was a major problem and concern in making a development. This is because sustainable development has become a key issue in society, economy and development. 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.

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.

PRODUCTION OF GGBS

GGBS is a non-metallic byproduct of the steel produced simultaneously with iron in the blast furnace steel mills industry, which consists essentially of silicates and aluminosilicates of calcium and other bases. Iron ore, limestone and coke are ground and mixed in a blend that constitutes the raw material for iron which is produced in a blast furnace ± 2,700 ° F. The residual molten slag is quenched by immersion in water for glazing material in glassy sand -like substance. This substance is then dried and ground into a very fine powder with at least 80 percent less than 45 microns in size.

Figure 1. **GGBS**

SILICA FUME

Silica fume, also known as micro- silica, is a (noncrystalline) 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.

PRODUCTION OF SILICA FUME

Silica fume is a by-product of high purity quartz carbothermic reduction with carbonaceous materials like coal, coke, wood chips, in electric furnaces in the production of silicon and ferrosilicon alloys. The main source of silica fume is produced as a by-product during the extraction of iron ore.

Figure 2. Silica fume

HIGH PERFORMANCE CONCRETE

Concrete special combinations meeting strength and uniformity requirements 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 highperformance 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.

HIGH PERFORMANCE CONCRETE BENEFITS

The main advantages of high-performance concrete use are: • Using HPC member size can be reduced so that the unusable area may be reduced there, reducing construction costs, reducing the amount of concrete.

- Self weight and super imposed dead weight can be reduced due to which smaller foundations can be employed. • Due to its high age strength gain, costs of monitoring may be reduced and shoring removal time can be reduced.
- In congested areas, we can also built tall buildings thereby reducing the real estate and construction cost. • In buildings which can reduce the thickness of the floor slabs and support beam elements in order to reduce the weight and cost of structures.
- Structures with HPC shows the performance of superior service long term under various loads as static loads, dynamic and fatigue. • High Performance Concrete has low creep and shrinkage problem will be less.
- Due to the increased rigidity of HPC, the elastic modulus will be high.
- Resistance to freezing and thawing, chemical attack will be high. Therefore, there is a significant improvement in long term durability and crack propagation is smaller.
- Maintenance and repair costs will be reduced.
- Can be used in aggressive and severe environment to increase the durability of the structure.
- Compression is good and will be without segregation.

OBJECTIVE OF WORK

1. To use GGBS, an industrial waste for the manufacture of concrete which otherwise would have been available as a waste material.
2. To reduce the amount of cement in concrete manufacture.
3. To reduce the cost of concrete.
4. To increase the strength of concrete by partial replacement of cement with silica fume and GGBS. 4. To conduct tests to assess the strength characteristics of Silica Fume and GGBS admixed concrete
5. To conduct tests to study the durability characteristics.

II. LITERATURE REVIEW

1. SudarsanaRao ,Sashidhar(2013) Studied The "Mix Design Of High Performance Concrete Using Silica Fume And Super Plasticizer", a mix design procedure for HPC using silica fume and super plasticizer is formulated by ACI method. As the silica fume content increases the compressive strength increases up to 15% and then decreases. Hence the replacement is 15%. The 7 days and 28 days cube compressive strength ratio of HPC is 0.84 to 0.9.the percentage replacement of cement by silica fume increases, the workability decreases.

2. Vishal, Deepak (2012) Studied The "Experimental Study On High Performance Concrete",cement replacement up to 10% with silica fume leads to increases in strength parameters. Beyond 10% there is a decrease in strength parameters. The maximum replacement level of silica fume is 10% for m50 grade of concrete. Use of silica fume gives significant result on properties of concrete as compared to normal concrete.

3. H. Katkhuda, B. Hanayneh And N. Shatarat (2014) Studied The "Influence Of Silica Fume On High Strength Light Weight Concrete", in this paper the isolated effect of silica fume on tensile, compressive and flexure strengths on high strength lightweight concrete was studied by carrying out many experiments. The silica fume was replaced by 0%, 5%, 10%,15%, 20% and 25% for water-binder ratios 0.26, 0.3, 0.34,0.38 and 0.42.the isolated effect of sf increases the compressive, splitting tensile and flexure strengths. The highest increase has been found in the flexure strength.

4. Anilkumar, Suresh (2015) Studied The "Effects Of Silica Fume And Fly Ash On Durability", durability characteristics such as water absorption, permeability, sulphate attack resistance and abrasion resistance are low for the fly ash and silica fume based concrete materials as compared with conventional high performance concrete.

Durability characteristics of combination of different percentage of pozzolanic material with partial replacement of cement in concrete can be considered as a scope for further studies.

5. ReshmaRughooputh And JaylinaRana(2010) Studied The " Partial Replacement Of Cement By Ground Granulated Blast Furnace Slag In Concrete", the partial replacement of OPC with GGBS improves the workability but causes a decrease in the plastic density of the concrete. The compressive and tensile splitting strengths, flexure and modulus of elasticity increases with increasing ggbs content. The drying shrinkage shows a slight increment with GGBS. GGBS fails the initial surface absorption test confirming that the surfaces of their concrete mixes were practically impermeable. Based on the results, the optimum mix is the one with 50% opc/50% GGBS.

6. N. K. Amudhavalli, Jeena Mathew (1998) Studied The "Effect Of Silica Fume On Strength And Durability Parameters Of Concrete", the normal consistency increases about 40% when silica fume percentage increases from 0% to 20%.increase in split tensile strength beyond 10 % silica fume replacement is almost insignificant whereas gain in flexural tensile strength have occurred even up to 15 % replacements. When compared to other mix the loss in weight and compressive strength percentage was found to be reduced by 2.23 and 7.69 when the cement was replaced by 10% of silica fume.

7. Sonali K. Gadpalliwar, R. S. Deotale, Abhijeet R. Narde (2012) Studied The "To Study The Partial Replacement Of Cement By Ggbs &Rha And Natural Sand By Quarry Sand In Concrete",by adopting same critical mix and replacing cement by ggbs, it is found that by increasing the percentage of ggbs; workability increases but strength decreases. The maximum 28 days split tensile strength was obtained with 30% ggbs replaced with cement. Good compressive strength is obtained when 22.5% ggbs + 7.5% rha is replaced with cement and natural sand is replaced by 60% quarry sand.

8. Dr. Arun Kumar(2009) Studied The "GGBS As Partial Replacement Of Opc In Cement Concrete – An Experimental Study", the main aim of the study is to obtain the suitability of ggbs as replacement of opc in concrete. It may be observed from the plots that the properties of can be maintained with ggbs as partial replacement of cement up to 20%. The increase in % of ggbs results in decrease in strength of concrete. The reduction in the cost of concrete at the current market rate is 14%, in the case of ggbs as replacement of opc by 20%.

9. Vishal (2012) Studied The "Influence Of Silica Fume On Concrete",with the increase in w/c ratio strength of concrete decreases. The optimum value of compressive strength can be achieved in 10% replacement of silica fume. As strength of 15% replacement of cement by silica fume is more than normal concrete. The optimum silica fume replacement percentage is varies from 10 %

to 15 % replacement level. Workability of concrete decreases as increase with % of silica fume.

III.EXPERIMENTAL PROGRAM

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.

WATER

Water conforming to as per IS: 456- 2000 was used for mixing as well as curing of concrete specimens.

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. It is ground to cement fineness and hydrates like Portland cement. Properties of GGBS are shown.

Table 1. Properties of GGBS

Ingredient	Content in %
Calcium Oxide (CaO)	40% - 52%
Silicon Dioxide (SiO2)	10% -19%
Iron Oxide (FeO)	10%-40% (70%-80%, FeO2, 20-30% Fe2O3)
Manganese Oxide (MnO)	5-8
Magnesium Oxide (MgO)	5-10
Aluminium Oxide (Al2O3)	1-3

SILICA FUME

Silica fume also known as micro silica is an amorphous (noncrystalline) 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.

Table 2.Properties Of Silica Fume

Properties	OPC	Silica fume
Silicon dioxide (SiO2)	22.03	96.0
Aluminium oxide (Al2O3)	4.03	0.1
Iron oxide (Fe2O3)	3.67	0.6
Calcium oxide (CaO)	65.19	0.1
Magnesium oxide (MgO)	0.88	0.2
Sulphite (SO3)	2.86	-
Sodium oxide (Na2O)	0.12	0.1
Potassium oxide (K2O)	0.20	0.4

FINE AGGREGATE

Locally available river sand was used as fine aggregate and confirmed to grading zone –II as per IS-383-1970 specifications.

COARSE AGGREGATE

Aggregates of size more than 4.75mm are generally considered as coarse aggregate. The maximum size of coarse aggregate used in this experimental are 12.5mm. A good quality of coarse aggregates is obtained from nearest crusher unit. The coarse aggregates are selected as per IS-383 specifications.

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.

GLENIUM B233

BASF glenium B233 is a super plasticizing admixture. Glenium B233 is an admixture of a new generation based on modified polycarboxylic ether. The product has been primarily developed for applications in high performance concrete where the highest durability and performance is required. Glenium B233 is free of chloride & low alkali and compatible with all types of cements.

Table 3. Properties of GLENIUM B233

Type	Ploycorboxylic ether
Colour	Light brown
Specific gravity	1.04
Dosage	500 – 1500 ml per 100kg of cement
Standard confirming	ASTM C494 Type-F

It is confirming to "Type F" means water reducing, high range and retarding agent. In this experimental work, the amount of SP used is of 0.3% by cement weight.

ADVANTAGES OF GLENIUM B233

- Elimination of vibration and reduced labour cost in placing.
- Marked increase in early & ultimate strengths.
- Higher Young"s modulus.
- Improved adhesion to reinforcing steel.
- Better resistance to carbonation and other aggressive atmospheric conditions.
- Increased durability.
- Reduced shrinkage and creep. Table 4. Summary of test results

Property		Result
Specific gravity		2.8
Water absorption		0.1%
Impact value		19.50%
Bulk density	Loosely packed	1585.5 Kg/m³
	Compacted	1657.4 Kg/m³
Flakiness index		12.49
Elongation index		64.50

IV.MIX DESIGN

Mix design is an essential part in the manufacture of concrete. Proper design Mix method gives better properties for the concrete. In this experimental work, the mix design

method used is ACI 211.1 -1991

MIX DESIGN FOR M60 GRADE

This mix design is adopted after conducting several conventional trails. The final mix design procedure is tabulated as follows

- Target mean strength (f''_{ck}) = $f_{ck} + k(s)$
  = 60 + 1.65(6)
  = 69.9 Mpa
- Water cement ratio = 0.32 [from Table A 1.5.3.4 (a) and Table A 1.5.3.4 (b) of ACI 211.1-91]
- Range of slump = 25 – 100mm [from Table A 1.5.3.1 of ACI 211.1-91]
- Actual water content = 199 lit/m³ [from Table A 1.5.3.3 of ACI 211.1-91]
- On experience the water content usage is 171 lit
- Cementitious materials = 171/0.32 = 534.25 kg/m³ Take 536 kg/m³.

  Cementitious materials includes cement, fly ash and silica fume
- Bulk density of coarse aggregate = 1657 kg/m³
- Volume of coarse aggregate required = 0.64 (from Table A 1.5.3.6 of ACI211.1-91)
- Weight of Coarse aggregate = 1657x0.64
  = 1060 kg/m³
- First estimate density of fresh concrete = 2450 kg/m³
- Required water content: Cement = 536 kg/m³

  Water = 536x0.32 = 171.4 lit/m³◎Weight of fine aggregate required:

Fine aggregate content = estimate density – (cement
+ water + CA)
= 2450 – (536 + 171 + 1060)
FA = 683 kg/m^3

- Super plasticizer dosage = 0.3% by cement weight
- Mix ratio **= 1: 1.27: 1.97: 0.32**

For M60 Grade:
Cement = 536 Kg/m3
Fine aggregate = 683 Kg/m3
Coarse aggregates = 1060 Kg/m3
Mix ratio:
Cement: Fine Aggregate: Coarse Aggregates: water
1 : 1.27 : 1.97 : 0.32

V.CASTING OF SPECIMENS

After completing the mix proportioning of materials concreting is done to represent the characteristics. Three types of concrete specimens are prepared in respective moulds in casting procedure. The types of specimens are
Cubes, Beams and Cylinders

CASTING OF CUBES:

For each trail 6 cube specimens were casted for calculating 7 days and 28 days strengths. The dimensions of specimen for cube are of 150mm x 150mm x 150mm.

CASTING OF CYLINDERS:

For each trail 6 cylinder specimens were casted for calculating 7 days and 28 days strengths. The dimensions of
the cylindrical specimen are of
Height = 300mm
Diameter = 150mm

CASTING OF BEAMS:

For each trail 6 beam specimens were casted for calculating 7 days and 28 days strengths. The dimensions of the beam specimen are of 500mm x 100mm x 100mm. FOR **DURABILITY STUDIES**

For measuring the durability of concrete, cubes of size 100mm x 100mm x 100mm are casted.

CURING OF SPECIMENS

Curing is most important process in concreting. Concrete strength increases with age of curing. The specimens should keep in curing tank for better improvement in strength. Generally curing is done by ponding curing tanks. The water used for concrete curing should be free from salinity, scrap, vegetation and chemicals. We need to change the water for every 7 days of curing. The specimens are tested for 7 days and 28 days curing.

VI.TESTING OF SPECIMENS

Calculation of Fresh and Hardened properties is the main thing in concrete testing. The well cured specimens in curing tank are tested for compressive strength, split tensile strength and modulus of rupture. By taking out the specimens from the curing tank, the specimens were exposed to sun light for surface drying. After the drying process, the specimens are processed for testing. The specimens are tested for 7 days and 28 days strengths. In this chapter the testing procedures and formulations are discussed and presented as follows.

COMPRESSIVE STRENGTH

Compressive strength or crushing strength is the main property observed in testing the cubes. Cubes are tested to calculate compressive strength by applying gradual loading in Compression Testing Machine. The reading of the failure load is occurred on the top of the machine in the indicator. The compressive strength has been calculated by the formula

Compressive strength (f_{ck}) = applied load/cross sectional area
(N/mm^2)

SPLIT TENSILE STRENGTH

Split tensile strength is the most important property of concrete. Concrete is generally weak in tension. So to improve tensile behavior of concrete, split tensile strength is important. It is also important in reducing formation of cracks in concrete. Cylinders are casted for calculating split tensile strength. The cylindrical specimens are also tested in compression testing machine. The cylinders are placed in axial direction by facing cylindrical face to the loading surface. Here the cylinder split into the two parts and reading observed on the top of the machine.

The split tensile strength has been calculated by the formula

Split tensile strength (f_{spt}) = 2P / Π Ld
P = failure load (applied load)
L = height of the cylinder specimen
D = diameter of mould

FLEXURAL STRENGTH

Most of the beam failures are occurred due to their failure in flexural strength. It is important that prediction of flexural strength by calculating modulus of rupture for reducing failure problems in beams. The calculation of modulus of Rupture in terms of Flexural strength is the main aim in casting beam specimens. In this modulus of rupture is calculated by testing specimens in the universal testing machine. In this line of facture is the main important property in formulating the modulus of rupture.

The modulus of rupture is denoted by "f_{cr}".

The „f" value is mainly based on the shortest distance of line fracture „a"

If 110mm < a < 133mm, $f_{cr} = 3PL/bd^2$

If a > 133mm, $f_{cr} = PL/bd^2$ If a < 110mm, the test shall be discarded.

DURABILITY STUDIES

The durability of concrete in this experimental work was carried out by measuring acid resistance at different ages of curing. The concrete acid resistance was observed by two types of tests named as Acid attack factor test and Acid durability factor test. The concentrations of acids in water are 5% HCL and 5% H_2SO_4.

VII.RESULTS AND DISCUSSIONS

In this chapter 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).

MIX PROPORTION QUANTITES

Material quantities of mix proportions according to the trail mixes are described as follows

Table 5. Mix proportion quantities of M60 grade(Cement replaced with GGBS):

S. No	% of GGBS	Cement In Kgs	GGBS In Kgs	F.A In Kgs	C.A In Kgs
1	0	536	0	683	1060
2	10	536	53.6	683	1060
3	20	536	107.2	683	1060
4	30	536	160.8	683	1060
5	40	536	214.4	683	1060

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 7 days and 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 6. Compressive strengths for M60

S.No	Mix Description	Compressive Strength N/mm²	
		7 days	28 days
1	GGBS 0	48.88	64.00
2	GGBS 10	50.66	64.88
3	GGBS 20	52.88	66.22
4	GGBS 30	55.11	68.44
5	GGBS 40	52.00	65.33

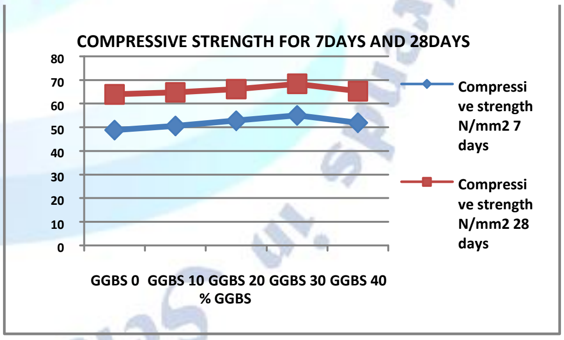

Figure 3. Compressive strength for M60 grade at 7 & 28 days using GGBS

Table 7. Split Tensile strengths for M60

S. No	Mix Description	Split tensile Strength N/mm²	
		7 days	28 days
1	GGBS 0	4.3	5.09
2	GGBS 10	4.6	5.23
3	GGBS 20	4.9	5.52
4	GGBS 30	5.2	5.80
5	GGBS 40	5.0	5.37

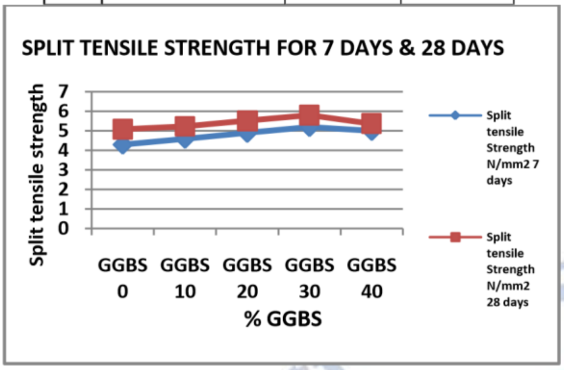

Figure 3. Split tensile strength for M60 grade at 7 & 28 days using GGBS

Table 8. Flexural strengths for M60

S. No	Mix Description	Flexural Strength N/mm²	
		7 days	28 days
1	GGBS 0	5.2	5.8
2	GGBS 10	5.5	6.0
3	GGBS 20	5.8	6.6
4	GGBS 30	6.4	7.4
5	GGBS 40	5.7	6.8

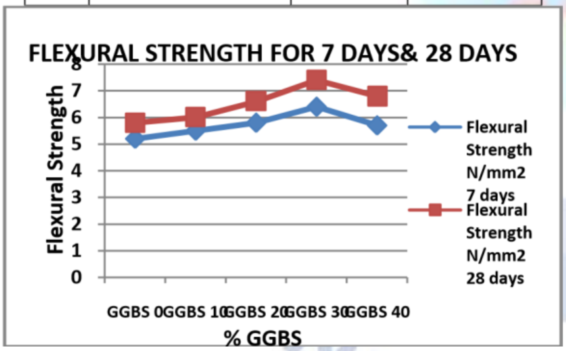

Figure 4. Flexural strength for M60 grade at 7 & 28 days using GGBS

Table 9. Mix proportion quantities of M60 grade(Cement replaced with silica fume)

S.NO	% of silica fume	Cement In Kgs	Silica fume In Kgs	F.A In Kgs	C.A In Kgs
1	0	536	0	737	1044
2	5	509.2	26.8	737	1044
3	10	482.4	53.6	737	1044
4	15	455.6	80.4	737	1044

Table 10. Compressive strengths for M60 (Cement replaced with silica fume)

S.No	Mix Description	Compressive Strength N/mm²	
		7 days	28 days
1	SF 0	48.88	64.00
2	SF 5	55.11	65.77
3	SF 10	57.33	68.00
4	SF 15	56.00	65.33

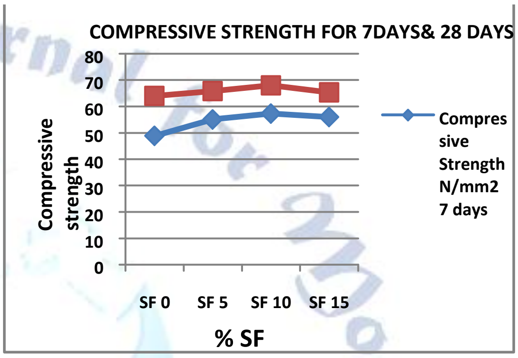

Figure 5. Compressive strength for M60 grade at 7 & 28 days using Silica Fume

Table 11. Split tensile strengths for M60 (Cement replaced with silica fume):

S.No	Mix Description	Split tensile Strength N/mm²	
		7 days	28 days
1	SF 0	4.3	5.09
2	SF 5	4.9	5.37
3	SF 10	5.3	5.66
4	SF 15	5.2	5.5

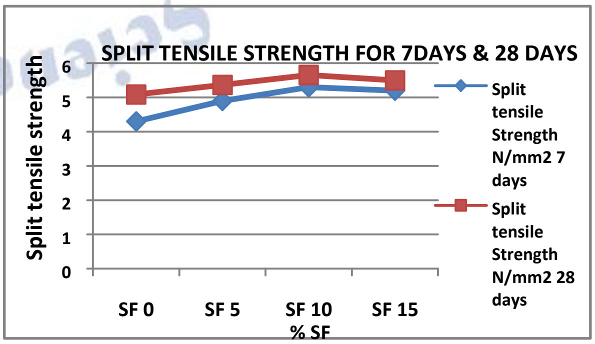

Figure 6. Split tensile strength for M60 grade at 7 & 28 days using Silica Fume

Table 12. Flexural strengths for M60 (Cement replaced with silica fume):

S. No	Mix Description	Flexural Strength N/mm²	
		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

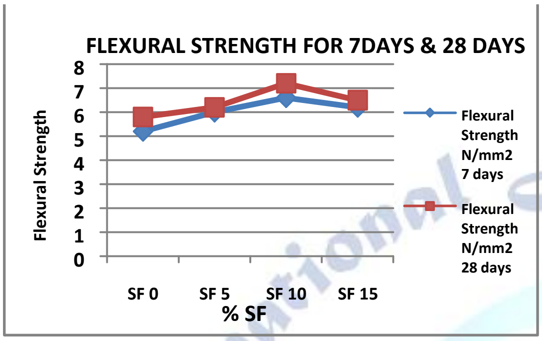

Figure 7. Flexural strength for M60 grade at 7 & 28 days using Silica Fume

Table 13. Mix proportion quantities of M60 grade (Combination of both GGBS and Silica Fume):

Mix name	Mix description	Cement(kg)	Fine aggregate (kg)	Coarse aggregate (kg)	SF (kg)	GGBS (kg)
CM	Control mix	536	683	1060	0	0
HPC1	SF0%+GGBS30%	375.2	683	1060	0	160.8
HPC2	SF5%+GGBS30%	375.2	683	1060	26.8	160.8
HPC3	SF10%+GGBS30%	375.2	683	1060	53.6	160.8
HPC4	SF15%+GGBS30%	375.2	683	1060	80.4	160.8

Table 14. Compressive strengths for M60 (Combination of both GGBS and Silica Fume):

Mix name	Compressive strength(N/mm²)	
	7 days	28days
CM(control mix)	48.88	64.00
HPC1	51.11	65.77
HPC2	53.77	68.44
HPC3	55.11	70.66
HPC 4	54.22	68.88

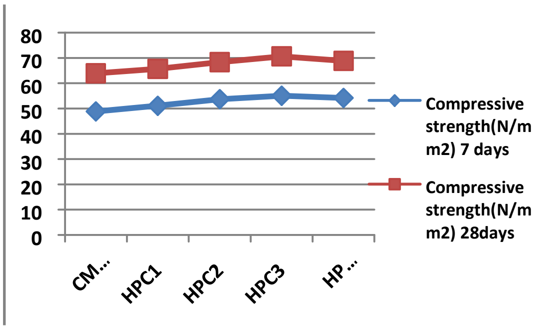

Figure 8. Compressive strength for M60 grade at 7 & 28 days using both GGBS and Silica Fume

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 15. 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

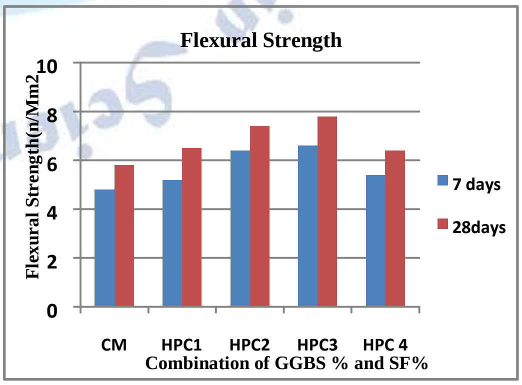

Figure 9. Flexuralstrength for M60 grade at 7 & 28 days using both GGBS and Silica Fume

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 16. 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

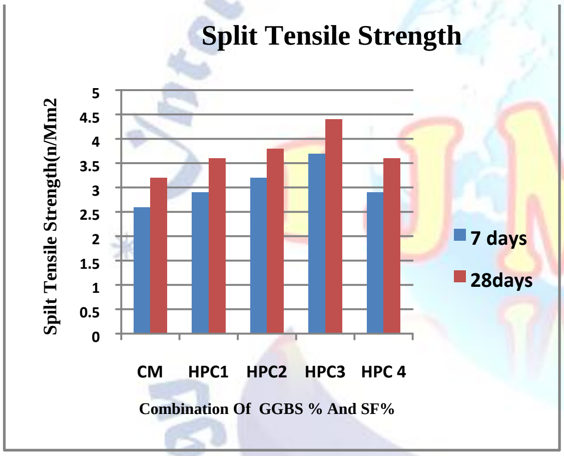

Figure 10. Split Tensile strength for M60 grade at 7 & 28 days using both GGBS and Silica Fume

Table 17. Compressive strength loss in 5% H2SO4 for M60 grade

Mix name	Compressive strength(N/mm²)	
	Before immersing	After immersing 28 days
Trail 1	60.24	58.59
Trail 2	62.56	58.42
Trail 3	64.54	61.35
Trail 4	62.00	57.24
Trail 5	60.54	56.26

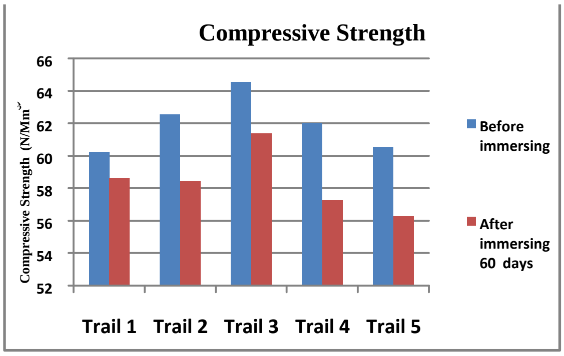

Figure 11. compressive strength loss in 5% H_2SO_4 for M60 grade

VIII.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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