STUDY ON THE MECHANICAL PROPERTIES OF HIGH STRENGTH CONCRETE USING G.G.B.S AND SILICA FUME AS PARTIAL REPLACEMENT OF CEMENT.

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Abstract - *The aim of this investigation is to assess how mineral admixtures can enhance the compressive and flexural properties of concrete by partially substituting cement. The research will involve conducting trial and error experiments to explore the impact of Silica fume and GGBS when partially replacing cement while maintaining a constant water-cement ratio to produce high-strength concrete. To achieve this, concrete samples of varying percentages of Silica Fume (5%, 8%, and 10%) and GGBS (25-50%) will be casted and evaluated, with partial substitution of cement, in sizes of 150mmx150mmx150mm (cube) and 500 X 100 X 100 mm (beam). The goal of the study is to identify the optimal percentage of Silica fume and GGBS that will provide the highest compressive strength (M65, M70, M75) and flexural strength. The research involves an analysis of how mineral admixtures such as Silica fume and GGBS can be effectively used in cement and concrete construction materials.*

Key Words: **Cement, Concrete, Construction Material, Mix Design, Silica Fume, GGBS**

I.INTRODUCTION

The utilization of triple blended concrete is a method that improves the strength characteristics of concrete by altering its chemical composition, particle size distribution, and fineness. It involves incorporating additives like pozzolana, granulated slag, or inert fillers to modify the concrete's properties. As a result, this technique has led to the development of different cement formulations that conform to both national and international standards. Triple blended cement serves as a promising alternative to mineral admixtures such as fly ash, silica fume, and granulated slag. This type of concrete, known as triple blended concrete, exhibits exceptional physical, chemical, and mechanical properties, making it particularly advantageous in construction applications.

II. MATERIAL AND METHOD

General

In this chapter, you will find comprehensive details regarding the materials used. This includes information about the characteristics of the materials, the types of materials employed, and their respective proportions.

Materials

The materials utilized for the study consist of processed Silica Fume and GGBS as source materials, ordinary Portland cement, aggregates, water, and an admixture.

Cement:

The experimental work utilizes 53 grade ordinary Portland cement. The specific type of cement employed for the experiments can be seen in Figure 1.1. The chemical properties of the cement are outlined in Table 1.1.1, while Table 1.1.2 presents the physical properties of the cement.

Figure 1.1 : Cement Used for experimental work

S.No.	Composition	Opc-53
1	IR	1.30
2	Cao	63.36
3	Sio2	21.52
4	So3	1.87
5	Al2o3	6.16
6	Fe2o3	4.60
7	Mgo	0.83
8	Loss of ignition	1.64

Table 1.1.1 Chemical composition (%) of cement

Sr. No	Properties	Results obtained	Specifications (IS:12269) [18]
1	Compressive Strength (MPa)		
	28 days	54.47	53(min)
2	Setting Time(Minute)		
	a)Initial Setting Time	40	30(min)
	b)Final Setting Time	305	600(max)
3	Soundness		
	a) Le-Chatelier (mm)	1.8	10(max)

Table 1.1.2 Properties Of Cement

A. Ordinary Portland cement of 53 Grade

Purchased from ultratech having soundness property in limit and all other properties according to Indian standards

B. Aggregates of Pertaining Sieve Size (<20mm IS standard)

Collected from Vadgam, Ahmedabad Gujarat having specific gravity 2.6 and all properties according to Indian Standards

C. River Sand of Pertaining Sieve Size (<4.75mm IS standard)

Collected from Vadgam, Ahmedabad Gujarat following zone 2 and all properties according to Indian Standards

D. Super Plasticiser

A modified acrylic super-plasticizer was utilized in the study, which has a low water/cement ratio, long workability times, and very high mechanical strength.

E. Silica Fume

Silica fume is a material that is obtained as a by-product from the ferrosilicon industry and has high pozzolanic properties that can improve the mechanical and durability characteristics of concrete. It can be added directly to concrete as a separate ingredient or mixed with Portland cement. In the US, silica fume is mainly utilized to produce concrete with higher resistance against chloride penetration in parking structures, bridges, and bridge decks.

Table 1: Physical and Chemical Properties of Silica Fume

Table 1. Physical and Chemical Properties of Silica Fume

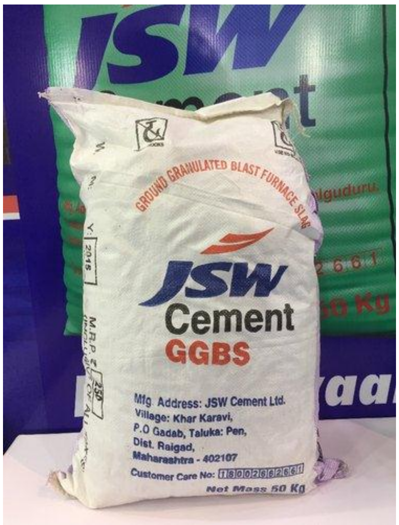
Properties	OPC	Silica Fume
Physical		
Specific gravity	3.1	2.2
Mean grain size (μm)	22.5	0.15
Specific area cm^2/gm	3250	150000-300000
Colour	Dark Grey	Light to Dark Grey
Chemical compositions (%)		
Silicon dioxide (SiO_2)	20.25	85
Aluminium oxide (Al_2O_3)	5.04	1.12
Iron oxide (Fe_2O_3)	3.16	1.46
Calcium oxide (CaO)	63.61	0.2-0.8
Magnesium oxide (MgO)	4.56	0.2-0.8
Sodium oxide (Na_2O)	0.08	0.5-1.2
Potassium oxide (K_2O)	0.51	
Loss on ignition	3.12	<6.0

F. GGBS

which stands for Ground Granulated Blast Furnace Slag, is a product that is eco-friendly and derived from a by-product of the iron manufacturing process. It is known for its high quality and low CO2 emission characteristics. Due to its low embodied CO2, GGBS is an ideal material for designing sustainable concrete mixes for construction purposes.

SR.NO	PHYSICAL PROPERTIES	
1	COLOUR	OFF WHITE
2	SPECIFIC GRAVITY	2.9
3	BULK DENSITY	1200 kg/m3
4	FINENESS	350m2/kg

SR.NO	CHEMICAL COMPOSITIONS	
1	CALCIUM OXIDE	40%
2	SILICA	35%
3	ALUMINA	13%
4	MAGNESIA	8%



Sr. no.	Characteristic	Test Results	Requirement as per ISstandard-12089[20?]
1	Colour	White	-
2	Specific surface area (sq.mt./ kg)	379	275 min
3	Loss of Ignition (%)	0.6	3 max
4	SiO2	36.8	-
5	Al2O3	17.12	-
6	CaO	34.4	-
7	Fe2O3	0.92	-
8	Glass content	92.5	85 min
9	Specific gravity	2.91	-

G. Admixture

To achieve the desired level of workability in regular concrete, Superplasticizer is employed. MAPEI Dynamon SX 550 is utilized to improve workability and decrease the water-to-cement ratio in fresh concrete.

Table 2:- Properties of Admixture

Appearance:	liquid
Colour:	amber
pH:	7.0 ± 1
Chemical name of active ingredient	Poly carboxylic ether
ensity according to ISO 758 (g/m^3):	1.110 ± 0.03 at +25°C
Main action:	increase workability and/or reduction of mixing water
Classification according to EN 934-2	high range water reducing superplasticizer, tables 3.1 and 3.2
Classification according to IS 9103-1999	Superplasticizer, water reducing Clause 3.6
Classification according to ASTM C49	type F
Water-soluble chloride content according to EN 480-12 (%):	< 0.1 (absent according to EN 934-2)
Alkali content (equivalent Na_2O) according to EN 480-12 (%):	< 2.5

III. PROCEDURE

This research paper includes experiments carried out on several high strength concrete grades, in which a partial replacement of cement was made with GGBS and silica fume to determine the most optimal mix design. All the mix designs used in this study were in compliance with Indian Standards. The different mixes included M65 (with a target strength of 73N/mm2), M70 (with a target strength of 79N/mm2), and M75 (with a target strength of 783N/mm2) grades of concrete, with silica fume and GGBS being replaced by varying percentages ranging from 5 to 10% and 25 to 50%, respectively.

The main objectives of this study are :-

• The aim of this study is to investigate the effects of partially replacing cement with pozzolanic materials like silica fume and GGBS in concrete.

• The study aims to determine the compressive and flexural strength of the triple-blended concrete with the combined effects of silica fume and GGBS.

• The main objective is to identify the optimal replacement of cement with the pozzolanic materials.

The compressive strength tests were performed following the guidelines outlined in IS 1489-199, and the flexural strength tests were conducted in accordance with IS:516-1959.

The mix groups for 70 Grades were created as follows:

Group A

D1 (with Cement: 70%, Silica fume: 5%, GGBS: 25%)
D2 (with Cement: 65%, Silica fume: 5%, GGBS: 30%)
D3 (with Cement: 60%, Silica fume: 5%, GGBS: 35%)
D4 (with Cement: 55%, Silica fume: 5%, GGBS: 40%)
D5 (with Cement: 50%, Silica fume: 5%, GGBS: 45%)
D6 (with Cement: 45%, Silica fume: 5%, GGBS: 50%)

Group B consisted of the following mixtures:

D7 (with 67% cement, 8% silica fume, and 25% GGBS)
D8 (with 62% cement, 8% silica fume, and 30% GGBS)
D9 (with 57% cement, 8% silica fume, and 35% GGBS)
D10 (with 52% cement, 8% silica fume, and 40% GGBS)
D11 (with 47% cement, 8% silica fume, and 45% GGBS)
D12 (with 42% cement, 8% silica fume, and 50% GGBS)

C. Group C

D13 (Cement: 65%, Silica fume: 10%, GGBS: 25%)
D14 (Cement: 60%, Silica fume: 10%, GGBS: 30%)
D15 (Cement: 55%, Silica fume: 10%, GGBS: 35%)
D16 (Cement: 50%, Silica fume: 10%, GGBS: 40%)
D17 (Cement: 45%, Silica fume: 10%, GGBS: 45%)
D18 (Cement: 40%, Silica fume: 10%, GGBS: 50%)

Mix groups were prepared for the 65 Grades as follows:

"D. Group D

J1 (Cement: 70%, Silica fume: 5%, GGBS: 25%)
J2 (Cement: 65%, Silica fume: 5%, GGBS: 30%),
J3 (Cement: 60%, Silica fume: 5%, GGBS: 35%),
J4 (Cement: 67%, Silica fume: 8%, GGBS: 25%),

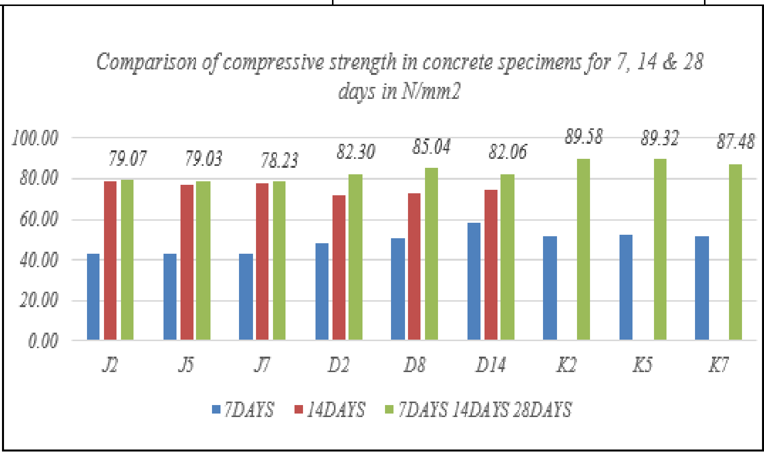
J5 (Cement: 62%, Silica fume: 8%, GGBS: 30%),
J6 (Cement: 57%, Silica fume: 8%, GGBS: 35%)
J7 (Cement: 65%, Silica fume: 10%, GGBS: 25%),
J8 (Cement: 60%, Silica fume: 10%, GGBS: 30%),
J9 (Cement: 555%, Silica fume: 10%, GGBS: 35%)
For the 75 grades, the following mixture groups were created -"

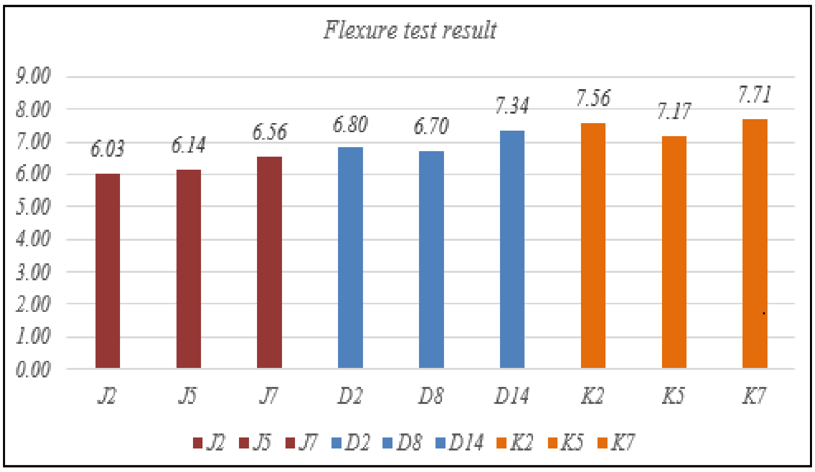
E. Group E

K1 (Cement: 70%, Silica fume: 5%, GGBS: 25%)
K2 (Cement: 65%, Silica fume: 5%, GGBS: 30%)
K3 (Cement: 60%, Silica fume: 5%, GGBS: 35%)
K4 (Cement: 67%, Silica fume: 8%, GGBS: 25%)
K5 (Cement: 62%, Silica fume: 8%, GGBS: 30%)
K6 (Cement: 57%, Silica fume: 8%, GGBS: 35%)
K7 (Cement: 65%, Silica fume: 10%, GGBS: 25%)
K8 (Cement: 60%, Silica fume: 10%, GGBS: 30%)
J9 (Cement: 555%, Silica fume: 10%, GGBS: 35%)

IV. RESULT AND DISCUSSION

Comparison of compressive strength in concrete specimens for 7, 14 & 28 days in N/mm2					
SR NO.	*MIX*	*GROUP*	*AVERAGE COMPRESSIVE STRENGTH RESULT FOR 7 DAYS*	*AVERAGE COMPRESSIVE STRENGTH RESULT FOR 14 DAYS*	*AVERAGE COMPRESSIVE STRENGTH RESULT FOR 28 DAYS*
1	*M65*	*J2*	*43.17*	*78.43*	*79.07*
2		*J5*	*42.79*	*77.16*	*79.03*
3		*J7*	*43.14*	*77.77*	*78.23*
4	*M70*	*D2*	*48.01*	*71.83*	*82.30*
5		*D8*	*50.66*	*72.67*	*85.04*
6		*D13*	*58.33*	*74.59*	*82.06*
7	*M75*	*K2*	*51.35*	*NA*	*89.58*
8		*K5*	*52.29*	*NA*	*89.32*
9		*K7*	*51.48*	*NA*	*87.48*





It was observed that the compressive strength decreases when the GGBS quantity exceeds 35%. Among the mixes for M70 grade, D8 (Cement: 62%, Silica fume: 8%, GGBS: 30%), for M65 grade, J5 (Cement: 57%, Silica fume: 8%, GGBS: 35%), and for M75 grade, K5 (Cement: 62%, Silica fume: 8%, GGBS: 30%) were found to be the optimal mixes. No significant change was observed in flexural strength for any of the trial mixes, except for a slight increase with 10% Silica fume.

V. CONCLUSIONS

- The study concludes that increasing the amount of GGBS in the mix leads to a decrease in compressive strength.
- After 56 days, there is a slight increase in strength of about 4-10%.
- The workability of the concrete is low due to the low water-to-cement ratio, resulting in an average slump value of 30 to 35cm.
- Silica fume is a reactive pozzolanic material in concrete due to its high content of amorphous silicon dioxide. It reacts with the calcium hydroxide released by the Portland cement to form additional binder material called calcium silica hydrate, which improves the hardened properties of the concrete.
- Silica fume particles are about 80 times smaller than cement particles, so they fill the voids between coarse aggregate particles and cement grains, providing a micro-filler effect that significantly increases the strength of the concrete.
- The use of GGBS as a substitute material for concrete can reduce CO2 emissions during production and act as an eco-friendly material, reducing the greenhouse effect.
- The experimental results show that 8% silica fume and 30-35% GGBS provide optimal results in most cases.
- The flexure strength of the concrete does not differ significantly, but a slight increase in flexure strength can be observed with the presence of 10% silica fume.
- In summary, increasing the amount of GGBS results in a decrease in compressive strength but an increase in workability. The initial increase in compressive strength is due to the micro-filler effect caused by the small grain size of silica fume compared to cement particles.

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BIOGRAPHIES

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