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A STUDY ON PARTIAL REPLACEMENT OF CEMENT WITH GGBS AND SILICA FUME IN CONCRETE

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Abstract: Cement concrete occupies the most important role in the field of civil engineering. It mainly consists of cement, fine aggregate and coarse aggregate. The cement used in the concrete is directly propositional to co_2 emission from the concrete production. One ton of Portland cement produces approximately one ton of co2. So there is a need to find alternative to cement. The efforts have been made and continued to partial replacement of cement with GGBS, Silica fume in view to reduce cost without adverse effect on strength characteristics of concrete. Ground Granulated Blast furnace Slag (GGBS) by product from the blast furnaces used to make iron. These operate at a temperature of about 1500 degrees centigrade and are fed with a carefully controlled mixture of iron ore, coke and limestone. Silica fume is an ultra-fine powder collected as a by- product of silicon and ferrosilicon alloy production and consists of spherical particles with an average particle 150nm. Because of its extreme fineness and high silica content, Silica fume is a very effective pozzolanic material. Addition of silica fume improves its compressive strength, bond resistance and reduces the permeability of concrete to chlorides ions, which protects the reinforcing steel of concrete from corrosion. Cement was partially replaced with 30%(constant) GGBS, and replaced with 0%, 5%,10% and 15% Silica fume for M25 grade of concrete. Tests were performed for the properties of fresh concrete

1. Introduction

Concrete is the most widely used man-made construction material in the world. The utility and elegance as well as the durability of concrete structures, built during the first half of the last century with Ordinary Portland Cement (OPC) and plain round bars of mild steel, the easy availability of the constituent materials of concrete and the knowledge that virtually any combination of the constituents leads to a mass of concrete have bred have gained momentum on its path to self–destruction. The Ordinary Portland Cement (OPC) is one of the main ingredients used contempt. Strength was emphasized without a thought on the durability of structures.

As a consequence of the liberties taken, the durability of concrete and concrete structures is on a southward journey; a journey that seems to for the production of concrete and has no alternative in the civil construction industry. Unfortunately, production of cement involves emission of large amounts of carbon-dioxide gas into the atmosphere, a major contributor for greenhouse effect and the global warming, hence it is inevitable either to search for another material or partly replace it by some other material. The search for any such material, which can be used as an alternative or as a supplementary for cement should lead to global sustainable development and lowest possible environmental impact.

So for this we need to go for the addition of pozzolanic materials along with super plasticizer with having low water cement ratio. Also now a day's one of the great application in various structural field is fiber reinforced concrete, which is getting popularity because of its positive effect on various properties of concrete. The major advantages of fiber reinforced concrete are resistance to micro cracking, impact resistance, resistance to fatigue, reduced permeability, and improved strength in shear, tension flexure and compression.

2. Literature Review

- Sabeer Alavi. C et. al. studied the effects of partial replacement of cement with 10 - 50% of GGBFS and found that 30% GGBFS replacement is good as beyond that the compressive strength starts decreasing. He also concluded that the split tensile strength and flexural strength conducted at 7 and 28 days increases with increase in GGBFS content. It was also found that the workability increases with the increase in percentage of GGBFS.
- Santosh Kumar Karri et. al. Selected 30%, 40% and 50% as cement replacement levels and cured the specimens of M20 and M40 grade of concrete for 28 and 90 days. He found out that the workability of concrete increases with the increase in GGBS replacement level. He observed that the maximum compressive strength, split tensile strength and flexural strength is achieved at 40% cement replacement for both M20 and M40 grade concrete, beyond which the strength decreases slightly. Concrete cubes were also exposed to H_2SO_4 and HCl of 1% and 5% concentration and were tested for compressive strength at 90days.
- M. Rama lakshmi et. Al. Discussed the results of partial replacement of cement with 50% - 80% of GGBFS on compressive strength of concrete at 7, 14 and 28 days. She concluded that slag replacement decreases the strength of concrete in short term when compared to control OPC. However, in long term it exhibits greater final strength. Thus 50% GGBFS as replacement showed maximum compressive strength.
- Yogendra O. Patil et. al. researched on the effects on compressive strength and flexural strength of concrete with partial replacement of cement with various percentages of GGBS. The tests were conducted at 7, 28 and 90 days with replacement ranging from 10% to 40%. It was observed that the strength of concrete is inversely proportional to the percentage of replacement of cement with GGBS. The replacement of OPC by GGBS up to 20% shows the marginal reduction of 4 – 6% in compressive and flexural strength for 90 days curing and beyond that of more than 15%.
- Hanumesh, Varun & Harish observes the Properties of Concrete Incorporating Silica Fume as Partial Replacement of Cement. The main aim of this work is to study the mechanical properties of M20 grade control concrete and silica fume concrete with different percentages (5, 10, 15 and 20%) of silica fume as a partial replacement of cement. The result showed that the compressive strength of concrete is increased by the use of silica fume up to 10% replacement of cement. From 10% there is a decrease in compressive strength and the split tensile strength of concrete is increased by the use of silica fume up to 10% replacement of cement. From 10% there is a decrease in split tensile strength. The optimum percentage of
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replacement of cement by silica fume is 10% for M20 grade of concrete.

- Jain &. Pawade studied the Characteristics of Silica Fume Concrete. The physical properties of high strength silica fume concretes and their sensitivity to curing procedures were evaluated and compared with reference Portland cement concretes, having either the same concrete contents the silica fume concrete or the same water to cementitious materials ratio. The experimental program comprised six levels of silica-fume contents (as partial replacement of cement by weight) at 0% (control mix), 5%, 10%, 15%, 20%, and 25%, with and without super plasticizer. It also included two mixes with15% silica fume added to cement in normal concrete. Durability of silica fume mortar was tested in chemical environments of sulphate compounds, ammonium nitrate, calcium chloride, and various kinds of acids.
- Kumar and Dhaka compose a Review paper on fractional supplanting of bond with silica smoke and its consequences for concrete properties. The primary parameter researched in this examination M35 solid blend with halfway supplanting by silica smolder with shifting 0, 5, 9, 12 and 15% by weight of bond the paper shows an itemized exploratory investigation on compressive quality, flexural quality and split elasticity for 7 and 28 days separately. The aftereffects of exploratory examination demonstrate that the utilization of silica rage in concrete has expanded the quality and strength at all ages when contrasted with ordinary concrete.
- Vishal S. Ghutke et. al. concluded from their result that silica fume was a better replacement of cement. The strength of concrete gained in silica fume was high as compared to the concrete of only cement. They performed various tests by varying the water-cement ratio from 0.5 to 0.6 and analysed their results which concluded -As the water-cement ratio increases the strength of concrete decreases. The target value of compressive strength can be achieved at 10% replacement of silica fume. The strength of 15% replacement of cement by silica fume was greater than the normal concrete. Therefore the optimum silica fume replacement percentage varies from 10% to 15%. Compressive strength decreases when the cement replacement was above 15% silica fume.

3. Research significance

As Cement, GGBS and Silica fume Blends possesses a number of advantages. It is essential that the fundamental behaviour of ternary blended concrete is clearly understood. Hence the present research programme aimed generating experimental data necessary to study the behaviour of concrete with GGBS and Silica Fume.

Objectives

The objective of this work is to develop concrete with good strength. For this purpose, it requires the use of different hydraulic and pozzolanic materials like ground granulated blast furnace slag, and silica fume. So the experiment carried out.

- To determine the mix proportion with silica fume to achieve the desire needs.
- To investigate and compare the strength property of concrete with silica fume and without silica fume.
- To investigate and compare different basic properties of concrete such as compressive strength, splitting tensile strength,

flexural strength using silica fume with normal concrete of grade

4. Experimental Programme

The experimental programme was planned to produce a cement with GGBS and Silica fume in concrete reduced cement contents by adding different percentages of Micro Silica and GGBS. The material used and the experimental procedure for mixing, casting and testing of specimens are described in the following section. Total 120 specimens were casted to determine compressive strength of ordinary Portland cement and Ternary Blended Concrete at the age of 7, 28, and 56days.

A. Materials:

Cement: Ordinary Portland cement of 53 grade having specific gravity of 3.11 was used. The Cement used has been tested for various proportions as per IS 10262-2009 and found to be confirming to various specifications of IS 456 – 2000.

S. No.	Property	Experimental values
1	Fineness of cement	5.61
2	Specific gravity	3.11
3	Initial setting time	84 min
4	Final setting time	194 min

Table 4.1 Physical Properties of Cement

Micro Silica: 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 by-product of the silicon and ferrosilicon alloy production and consists of spherical particles with an average particle diameter of 150 nm. The main field of application is as material for high performance concrete.

Fig.4.1 Silica Fume

S. No	Oxides	values
1	SIO_2	85
2	Al_2O_3	1.12
3	Fe_2O_3	1.46
4	CaO	0.1
5	MgO	0.2
6	K_2O	0.4
7	Na_2O	0.6

Table 4.2 Properties of Silica fume

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 in Table 1.1.

Fig. 4.2. GGBS

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S. No.	Ingredient	Content (%)
1	CaO	40- 50
2	SiO_2	10-19
3	FeO	10-40
4	MnO	5-8
5	MgO	5-10
6	Al_2O_3	1-3

Table 4.3 Properties of GGBS

B. Fine aggregates: Locally available river sand conforming to grading zone II of IS 2386-1963 has been used as fine aggregate. The fineness modulus is 2.72 Specific gravity is 2.51.

D. Coarse Aggregates: The Coarse aggregate used is crushed (angular) aggregate conforming to IS2386:1963. Various sizes of aggregates are used in experiment as 10mm, 12mm and 20mm. The results of sieve analysis conducted as per the specification of IS 383 -1970 (IS383-1970). Fineness modulus is 5.22, specific gravity is 2.75

E. Water: Clean potable water is used for casting and curing operation for the work

5. Mix Design

The proportions in this mix was designed using fine aggregates and natural aggregate as a coarse aggregate with0.48 water cement ratio. Table 4 & 5 represent the mix proportions & ratios respectively

Properties	F.A	C.A	Properties
Partial Shape and Size	Round, 4.75 mm down	Angular, 20 mm	Partial Shape and Size
Fineness Modulus	2.72	5.22	Fineness Modulus
Specific gravity	2.51	2.75	Specific gravity
Bulk of sand	4.16%		Bulk of sand
Bulk density	1590 kg/m^3	1520 kg/m^3	Bulk density
Surface moisture	Nil	-	Surface moisture
Water absorption	1.45%	0.5	Water absorption

Table 5.1 Properties of Fine aggregate and Coarse aggregate

Material Description	Weight (kg/m^3)
Cement (OPC) 53 grade	387.5
Natural Fine sand	618.12
Natural coarse aggregate	1220.219
Water	186
Water- cement ratio	0.48

Table 5.2 Various Mix Proportions of M- 30 Control mix

Mix	Description
M0	Cement
M1	Cement +GGBS (30%) +SF (0%)
M2	Cement +GGBS (30%) +SF (5%)
M3	Cement +GGBS (30%) +SF (10%)
M4	Cement +GGBS (30%) + SF (15%)

Table. 5.3 Mix designation

CASTING AND CURING:

After mixing, the concrete was transferred to concrete moulds and was properly compacted using a vibrator to avoid voids and honeycombing. Then it was left as it is for 24 hours. Then it was demoulded and kept it in clean water for curing for 7days, 28 days and 56 days

Fig.5.1 Casted specimens

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Fig. 5.2 Specimen curing

Workability:

Workability is property of fresh concrete. It is however, also a vital property as far as the finished product is concerned because concrete must have workability such that compaction to maximum density is possible with reasonable amount of work or with the amount that we prepared to put in under given condition

6. Testing & Results

6.1 COMPRESSIVE STRENGTH TEST

Standard concrete cube specimen of size 150 x 150 x 150 mm were used for this test. Samples were tested for 7 and 28 days using the compression-testing machine of 2-ton capacity.

This test was done as per IS 516-1999.

Compressive strength = (Load / C.S area of specimen) in N/mm2

The test results for every mix is shown in a table below and expressed graphically in fig

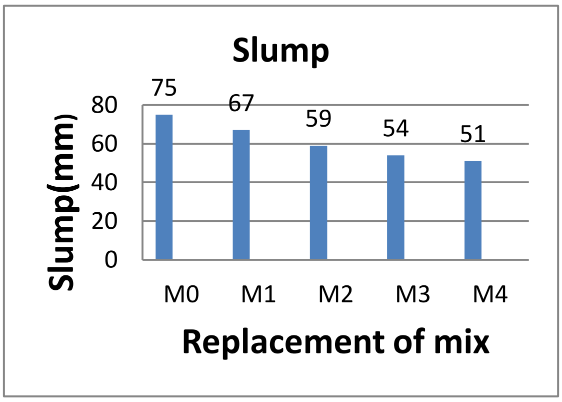

Fig.6.1 Compressive Strength Test

Mix	Compressive strength test results	Mix	Compressive strength test results
	7days	28 days	56 days
M0	24.14	32.14	35.2
M1	25.59	35.1	37.82
M2	25.8	37.4	39.09
M3	26	39.1	43
M4	25.6	35.8	38.19

Table 6.1 Compressive strength test results

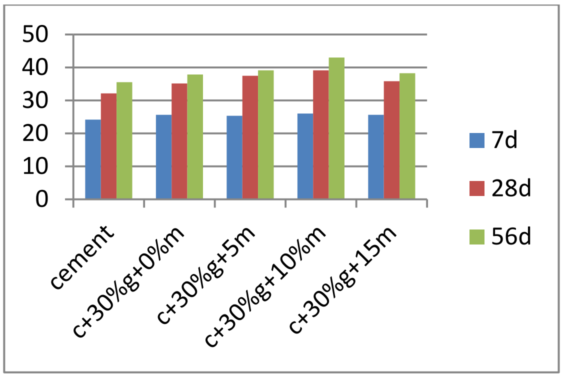

Fig 6.2 Compressive strength test

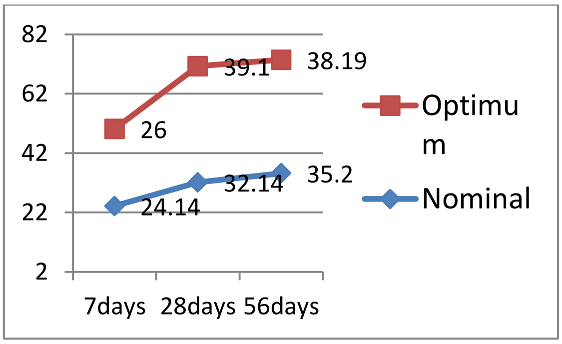

Fig.6.3 Compressive strength Vs. Age of specimen

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6.2 SPLIT TENSILE STRENGTH TEST: Standard concrete cylinder specimen of size 150 x 300 mm cured for 7 and 28 days was used for this test. Split tensile strength = (2w/πdl), where w is the failure load, d and l are the diameter and length of the specimen. The test result for every mix is listed in table 4 and is expressed graphically in Fig 7.

Fig.6.4 Split tensile strength test

Mix	Split tensile strength test results		
	7days	28 days	56 days
M0	1.9	2.4	2.5
M1	1.98	2.59	2.8
M2	2.07	2.87	3.11
M3	2.26	3.4	3.5
M4	2.0	2.78	2.9

Table 6.2 Split tensile strength test results

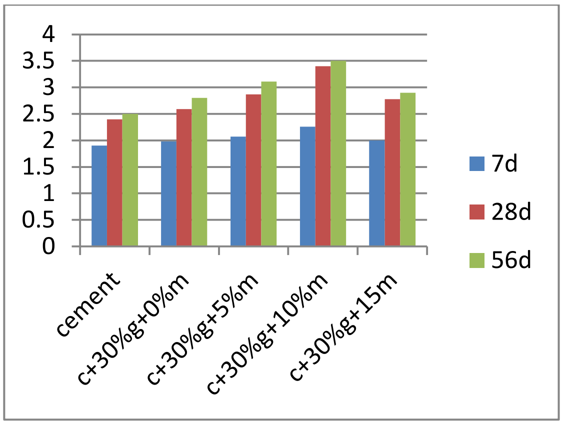

Fig. 6.5 Split tensile strength Vs. Replacement mix

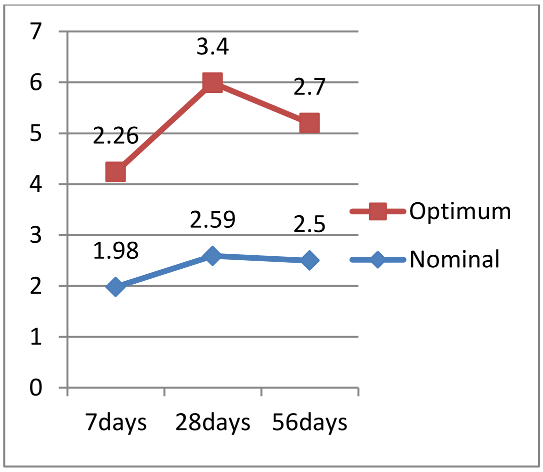

Fig.6.6 Split tensile strength vs. age of specimen

6.3 FLEXURAL STRENGTH TEST

Standard concrete prism specimen of size 100 x 100 x 500 mm cured for 28 days was used for this test. The load is applied in the form of two-point loading system. Flexural strength = (wl/bd2), where w is the failure load, b and d are the width and depth of the specimen. The results are listed in table 5 and showed graphically in fig

Fig. 6.7 Flexural strength test

Mix	Flexural strength test results		
	7days	28 days	56 days
M0	3.71	4.3	4.72
M1	4.21	4.8	4.9
M2	4.58	5.02	5.2
M3	4.83	5.36	5.7
M4	4.18	4.58	4.84

Table 6.3 Flexural strength test results

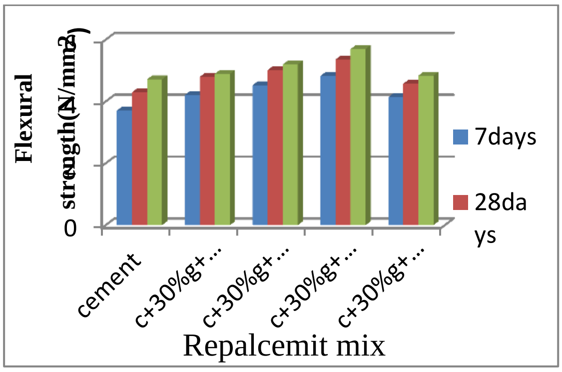

Fig.6.8 Flexural strength Vs. Replacement mix

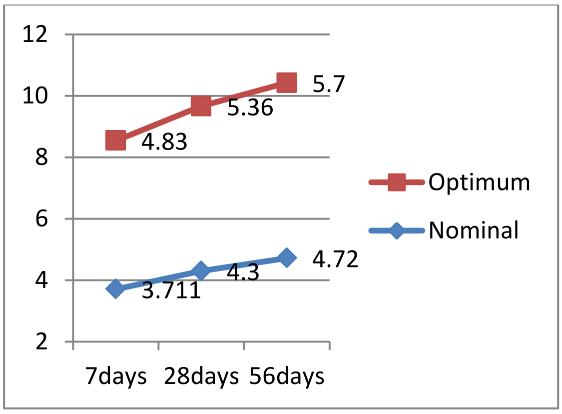

Fig.6.9 Flexural strength Vs. Age of specimen

7. Conclusion and Future Prospects

Based on the analysis of experimental results and discussion there upon the following conclusions can drawn

- Silica fume added to concrete, it results in a significant change in the compressive strength of the mix.
- From the study it is concluded that the cube compressive strength, split tensile strength, flexural strength for 7, 28, 56 days increasing between 0 -10% replacement of silica fume and fixing the GGBS content to 30%. However on further increasing the percentage of silica fume the strength is reduced.
- Workability of concrete increases with the increase in GGBS replacement level.
- Among All the mixes it was found that mix M3 i.e., 10% SF and 30% GGBS has optimum strength values.
- Experimental studies a reveals that, the mineral admixtures plays on excellent performance in developing ternary mixes economically.
- Workability of concrete is getting reduced with increasing the mineral admixtures at higher percentages. These needs super plasticizers to maintain work abilities.
- The combinations of Micro Silica and GGBS is complementary, Micro Silica improves the early age performance of concrete with GGBS by refining the properties of hardened concrete continuously as it mature.

- Even in the early age (7days) compressive strength development of the ternary concrete is slightly more than that of ordinary concrete. This trend is due to the presence of Micro Silica.
- The combination (MS 10% + GGBS 30%) gives more workable and highest compressive strength for all curing days when compared to ordinary concrete.
- Based on the above studies and test results, in case of ternary blended concrete. It is advisable to replace the cement by mineral admixtures at an optimum percentage of Micro Silica (10%) and GGBS (30%).At which we can get better results in workability and compressive strength comparatively with reference to ordinary concrete.
- Experimental studies a reveals that, the mineral admixtures plays on excellent performance in developing ternary mixes economically.
- By using industrial waste materials we can make environment more sustainable.
- Maximum increase in compressive strength obtained at 0.48 w/c ratio with silica fume 10% and GGBS 30% are 26, 39.1, 43 N/mm2 which are 7.7%, 21.6% and 22% more than the reference mix at the age of 7, 28 and 56 days respectively.
- Maximum increase in split tensile strength obtained at 0.48 w/c ratio with silica fume 10%and GGBS 30% are 2.26,3.4,3.5N/mm2 which are 18.94%,41.6% and 40% more than the reference mix at the age of 7,28 and 56 days respectively.
- Maximum increase in Flexural strength obtained at 0.48 w/c ratio with silica fume 10% and GGBS 30% are 4.83, 5.36, 5.7N/mm2 which are 30%, 24% and 20% more than the reference mix at the age of 7, 28 and 56days respectively.

Future Scope:

Various research activities on properties of concrete in aggressive media are carried out; there is a wide scope for research. The following avenues may be investigated

- Further study can be method for same case of loading with different cement and different grades of concrete.
- Effect of different type of admixtures on GGBS, Micro silica cement concrete can be studied.
- Durability test such as Acid test and Chloride test on GGBS, Micro silica cement concrete can be studied.
- The Flexural and Shear strength for long beams will be found out for GGBS, Micro silica cement concrete.
- This work was carried out on replacement of cement without adding any admixtures. The same work has carried out using admixtures and like super plasticizers.

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