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Experimental Investigation for Enhancing the Strength Properties of Rigid Pavement with Ground Granulated Blast Furnace Slag and Silica Fume

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Abstract:
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 accomplished. Different concrete mixtures were cast and tested with different levels of cement replacement, 40 % of GGBS with active silica fume as addition (0 %, 5 %, 10 %, 15 %, 20% and 25% by weight of cement). High performance concrete (HPC) is a concrete meeting special combinations of performance and uniformity requirements. This leads to examine the admixtures to improve the performance of the concrete. The usage of mineral admixtures in the concrete enhances the strength properties of concrete. 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 of GGBS with the addition of silica fume in M30 grade concrete with maintaining water cement ratio of 0.45.It was observed that, 40% GGBS and 15% of Silica fume is optimum percentage replacement of cement in concrete.

Keywords: GGBS, Silica fume, compressive strength, split tensile strength, flexural strength and High performance concrete in rigid pavement.

I. INTRODUCTION

Rigid pavements are generally used in constructing airports and major highways, such as those in the interstate highway system. In addition, they commonly serve as heavy-duty industrial floor slabs, port and harbour yard pavements, and heavy-vehicle park or terminal pavements. Like flexible pavements, rigid highway pavements are designed as all-weather, long-lasting structures to serve modern day high-speed traffic. Concrete is one of the most widely used construction material in the world. The normal concrete is failing its usage in modern days and it does not serve the present needs Concrete is considered as durable and strong material. In the construction industry, mainly the production of ordinary Portland cement (OPC) will cause the emission of pollutants, which results in environmental pollution. Ground Granulated Blast Furnace Slag is one of the important mineral admixtures. It is obtained by material created when the quenching from melted iron ore and then ground into a powder. This is materials has Cementitious properties. It can be used in concrete as a replacement for cement. 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.

II. OBJECTIVES

2.1 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 M30.

2.2 By using silica fume with the normal concrete of M30 grade with maintaining the water cement ratio 0.45.
2.3 To reduce the cement content with industrial waste by products like GGBS and silica fume.

III. MATERIALS USED

3.1. Cement:

In the present research work, ordinary Portland cement of 53 grade is used. The testes on cement were conducted in accordance with Indian standard confirming to IS 12269-1987.

Table.1. Properties of Cement

Properties	Results
Grade	53 grade OPC
Initial Setting Time	131 minutes
Final Setting Time	315 minutes
Normal Consistence	32%
Specific Gravity	3.15

3.2. Fine Aggregates:

Fine Aggregate Locally available manufactured sand was used as fine aggregate.

Table.2. Properties Of Fine aggregate (Manufactured Sand)

Properties	Results
Grading of Sand	Zone II as per IS 383
Specific Gravity	2.57
Water Absorption	2.26%
Fineness Modulus	2.75

3.3. Coarse Aggregate:

Locally available crushed granite coarse aggregate having the maximum size of 20mm are used in this study. The aggregates are tested as per Is: 2386-1963

Table.3. Properties of Coarse Aggregate

Properties	Results
Specific Gravity	2.74
Water Absorption	0.45%

3.4. WATER: In this experiment work, Portable water is used.

3.5. GROUND GRANULATED BLAST-FURNACE SLAG (GGBS) :

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 It is obtained by quenching molten iron blast furnace slag immediately in water or stream, to produce a glassy granular product that is then dried and ground into a fine powder. It is an excellent binder to produce high performance cement and concrete.

Table .4. Properties of GGBS

Calcium Oxide (Cao)	40% - 52%
Silicon Dioxide (Sio_2)	10% -19%
Iron Oxide (FeO) (FeO_2) (Fe_2O_3)	10%- 40% 70% - 80% 20%- 30%
Manganese Oxide (MnO)	5% - 8%
Magnesium Oxide (Mgo)	5% - 8%
Aluminum oxide (Al_2O_3)	1% - 3%

3.6. 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. It is highly reactive pozzolanic material hence the concrete containing silica fume can have very high strength and can be very durable.

Table.5. Properties of Silica fume

Properties	OPC	Silica Fume
Silica Dioxide (SiO2)	22.03	96.0
Aluminum oxide (Al2O3)	4.06	0.1
Iron oxide (Fe2O3)	3.67	0.6
Calcium oxide (CaO)	65.09	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

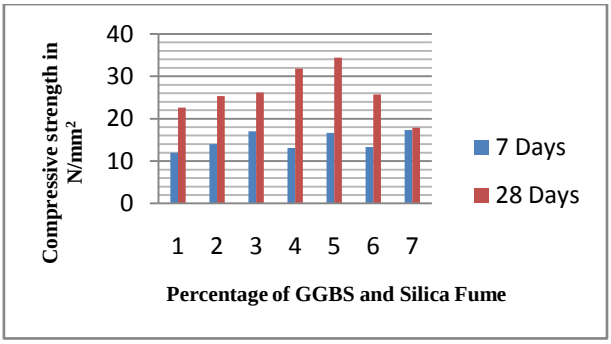
IV. EXPERIMENTAL PROCEDURE

M30 concrete is designed in accordance with the guidelines of code book IS 10262:2009 with replacement of cement by ground granulated blast furnace slag and silica fume. The mix proportion arrived is 1:1.6:2.8 (C:FA:CA) with water cement ratio of 0.45 and GGBS dosage of 40% (by weight of cement). Silica fume is added at varying percentages of 0%, 5%, 10%, 15%, 20% and 25% by weight of cement. The specimen are cast for compressive strength, split tensile strength and flexural strength test. The specimens are cured in water for 7, 28 days. The specimens are removed from water. Then they are tested for their respective strengths.

V. EXPERIMENTAL RESULTS

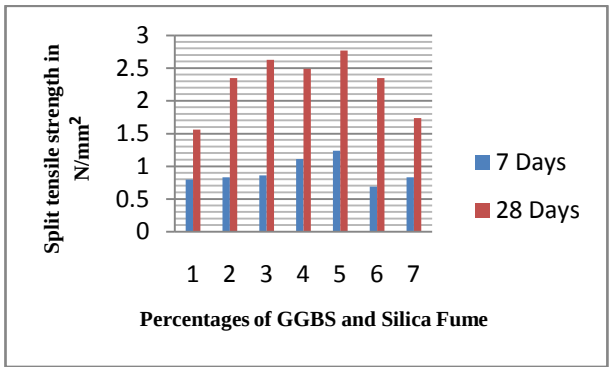
5.1 Compressive Strength Test Results

SL No	GGBS	Silica fume	Compressive strength in N/mm^2	
			7 Days	28 Days
1	0%	0%	11.95	22.6
2	40%	0%	13.952	25.31
3	40%	5%	17	26.16
4	40%	10%	13.08	31.82
5	40%	15%	16.66	34.416
6	40%	20%	13.33	25.72
7	40%	25%	17.33	17.87



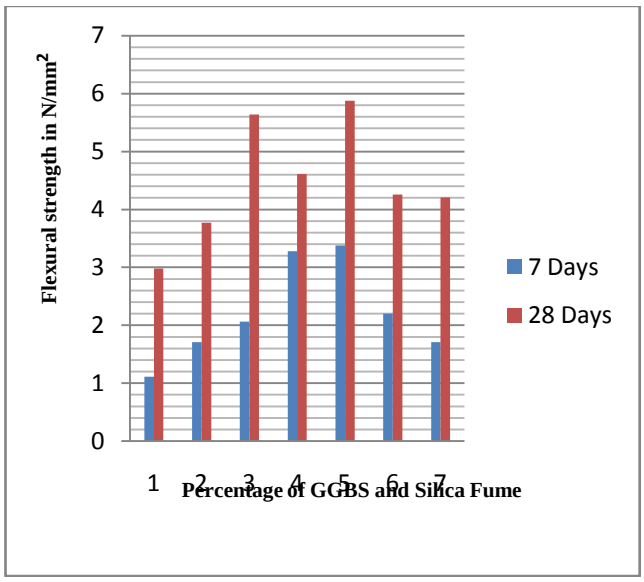
5.2 Split Tensile Strength Test Results

SL No	GGBS	Silica fume	Split tensile strength in N/mm^2	
			7 Days	28 Days
1	0%	0%	0.80	1.56
2	40%	0%	0.83	2.35
3	40%	5%	0.86	2.63
4	40%	10%	1.11	2.49
5	40%	15%	1.24	2.77
6	40%	20%	0.69	2.35
7	40%	25%	0.83	1.736



5.3 Flexural Strength Test Results

SL No	GGBS	Silica fume	Flexural strength in N/mm^2	
			7 Days	28 Days
1	0%	0%	1.11	2.98
2	40%	0%	1.71	3.77
3	40%	5%	2.06	5.64
4	40%	10%	3.28	4.61
5	40%	15%	3.38	5.88
6	40%	20%	2.20	4.26
7	40%	25%	1.716	4.21



VI. OBSERVATION AND DISCUSSION

It is observed that, the compressive strength of conventional mix for 7 days and 28 day is 11.95 N/mm^2 and 22.6 N/mm^2 respectively, for split tensile strength is 0.80 N/mm^2 and 5.6 N/mm^2 and for Flexural strength is 1.11 N/mm^2 and 2.98 N/mm^2 respectively. It is observed that, when the silica fume is added to the Portland cement primarily chemical reactions produce two chemicals such as calcium silicate hydrate (CSH) and calcium hydroxide (CH) as a byproduct which is responsible for the strength of concrete It is observed that, the compressive strength of the concrete will increases as the percentage of GGBS and silica fume. This is true for 7 days and 28 days compressive strength is 16.66 N/mm^2 and 34.4 N/mm^2 with respect 40% of GGBS and 15% of Silica fume It is observed that the split tensile strength will increase as the percentage of GGBS and Silica fume. This is true for 7 days and 28 days Split tensile strength is 1.24 N/mm^2 and 2.75N/mm^2 with respect 40% of GGBS and 15% of silica fume, there after the tensile strength shows a decreasing trend. Thus the higher value of tensile strength is obtained by using 15% of silica fume. It is observed that the flexural strength will increases as the percentages of GGBS and Silica fume. This is true for 7 days and 28 days flexural strength is 3.38 N/mm^2 and 5.58N/mm^2 with respect 40% of GGBS and 15% of silica fume, there after the flexural strength shows a decreasing trend thus the higher value of flexural strength is obtained by using 15% of silica fume in concrete.

VII. CONCLUSIONS

1. The higher strength was gained up to 40% of cement replacement with GGBS than the normal concrete and then after strength decreases.
2. The silica fume content increases the compressive strength at the replacement of 15% and then after further increase of silica fume will decreases the compressive strength .
3. Upto 28kg of cement can be reduced for of 1m×1m×0.15m size of slab for rigid pavement.
4. For increasing the percentage of silica fume decreases the workability.
5. The addition of silica fume improves the bond strength of concrete.
6. The compressive strength, flexural strength and split tensile strength are increased in combination of partial replacement of cement by GGBS in 40% and addition of silica fume in 15%.

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