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A STUDY ON SELF-COMPACTING CONCRETE BY PARTIAL REPLACEMENT OF CEMENT WITH SILICA FUME AND GROUND-GRANULATED BLAST-FURNACE SLAG (GGBS OR GGBFS)

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ABSTRACT: Self-compacting concrete (SCC) can flow and compact under its own weight into a uniform void free mass even in areas of congested reinforcement. This paper focuses on the effects of Silica Fume and Ground-granulated blast-furnace slag (GGBS or GGBFS) on all the main properties of concrete in the fresh and hardened state. The mix design for SCC was arrived as per the Guidelines of European Federation of National Associations Representing for Concrete (EFNARC-2005). In this investigation, SCC was made by usual ingredients such as cement, fine aggregate, coarse aggregate, water and mineral admixture silica fume and GGBS at various replacement levels. The super plasticizer used was Glenium B233. Workability of the fresh concrete is determined by using tests such as: slump flow, L-Box and U-box tests. The mixes were then tested for other mechanical properties like, cube compressive strength at 7th day, 28th day, split tensile strength, and flexural strength at 28th day. For all levels of cement replacement with admixtures concrete achieved superior performance in the fresh and mechanical tests.
Keywords: Self-Compacting Concrete, Silica Fume, GGBS, Glenium B233, Workability, compressive strength, split tensile strength, Flexural strength.

I. INTRODUCTION

Concrete is a strong and versatile mouldable construction material. It consists of cement, sand and aggregate mixed with water. The cement and water form a paste which coats the sand and aggregate. The durability of concrete structures was the main criteria, the creation of durable concrete structures requires adequate compaction by skilled workers .when percentage of reinforcement is high the compaction becomes complex as the reinforcement does not allow insertion of vibrator at some places. Also the vibration leads to noise pollution. Beside thisproblem there is also a gradual reduction in the number of skilled workers around the world .Self-compacting concrete was therefore developed to overcome all these problems. Self-compacting concrete also called as Self-consolidating concrete or self-levelling concrete Self-compacting concrete, it is a flowing concrete mixture that is able to consolidate under its own weight with little or no vibration effort, and which is at the same time cohesive enough to handle without segregation or bleeding of fresh concrete. Self-Compacting concrete mixes usually contain superplasticizer (high water reducing admixture), high content of fines and or viscosity modifying additive (VMA). While the use of superplasticizer maintains the fluidity, the fine content provides stability of the mix as a result resistance against bleeding and segregation increases. The highly fluid nature of Self-Compacting concrete makes it suitable for placing in difficult conditions and in sections with congested reinforcement.

II. OBJECTIVES OF THE PRESENT STUDY

The objectives of the study are:

- To find the properties of the materials such as cement, sand, coarse aggregate, water etc.
- To obtain Mix proportions by considering properties of fresh concrete (according to EFNARC guidelines).
- To caste and cure the concrete specimens such as cubes, cylinders, and beams.
- To evaluate the mechanical characteristics of concrete such as compressive strength, split tensile test, flexural strength.
- To evaluate the results.

III. MATERIAL PROPERTIES

The materials used in this research are:

3.1 Cement

Ordinary Portland cement of 53 grade was used in this investigation.

Table-1: Approximate Oxide Composition Limits of Ordinary Portland cement

Oxide	Percent content
Cao	60-67
Sio_2	17-25
Al_2o_3	3.0-8.0
Fe_2o_3	0.5-6.0
Mgo	0.1-4.0
Alkalies	0.4-1.3
So_3	1.3-3.0

The Details of Tests Conducted on Cement are Described Below.

Table-2: Properties of fine aggregate

S.No	Properties	Values
1	Specific Gravity	3
2	Fineness %(retained on sieve 90mirons	4%
3	Standard Consistency	36%
4	Initial setting time	64 mins
5	Final setting time	6hr 12 mins

3.2 Silica Fume
In this study, silica fume is brought from Astrra chemicals at chennai. Specific gravity of silica fume is 2.4

Table-3: Properties of Typical Silica Fume

Constituents	Percentage
SiO_2	90
Al_2O_3	0.4
Fe_2O_3	0.4
CaO	1.6
SO_3	0.4
Na_2O	0.5
K_2O	2.2

Table-4: Chemical and Physical Requirements as per European Committee for Standardization

Parameters	**EN 13263**
SiO2	>85(%))
Loss On Ignition	<4(%)
Pozz. Activity Index-7days accelerated curing accelerated	>100(%)
Specific surface	>15 m^2/gm&<35 m^2/gm

3.3GGBS
In this study, GGBS is brought from Astrra chemicals at chennai. Specific gravity of GGBS is 2.9 and its chemical composition is shown in table.

Table-5: Approximate oxides compositions of GGBFS

Constituents	Percentage
CaO	63.00
SiO_2	31.50
Al_2O_3	1.79
MgO	0.004
Mno_2	0.48

3.4 Chemical Admixture
Glamium B233 New Generation Superplasticizeris used. It provides necessary workability. It is light Brown liquid.

3.5 Fine Aggregate
Aggregates smaller than 4.75mm and up to 0.075mm are considered as fine aggregate

Table-6: Properties of Fine Aggregate

S.No	Properties	Values
1	Specific Gravity	2.64
2	Water Absorption	3.1%
3	Fineness Modulus	2.513

SAND BELONGS TO ZONE – III and, it is Fine Sand as Fineness Modulus is less than 2.6.

3.6 Coarse Aggregate
Aggregates greater than 4.75mm are considered as coarse aggregate.

Table-7: Properties of Fine Aggregate

S.No	Properties	Values
1	Specific Gravity	2.7
2	Water Absorption	0.8%
3	Fineness Modulus	6.58

3.7 Water
Water used for concrete and curing is free from harmful impurities.The pH value of water should be not less than 6.

IV. MIX PROPORTIONS

Designing of Mix proportions is the major work in self-compacting concrete. There is no standard method or guidelines for Designing self-compaction mix proportions.
In this Research EFNARC-2005 guidelines are considered as reference to design the Mix proportions. After conducting many practical experiments on SSC they have given these guidelines. According to EFNARC-2005 Mix proportions are designed by considering the test results of Fresh concrete. The ingredients are similar to the other plasticized concrete

V. TESTS FOR FRESH AND MECHANICAL PROPERTIES

5.1 Tests for fresh concrete properties:
5.1.1 Slump Cone Test
The slump flow test is done to assess the horizontal flow of concrete in the absence of obstructions. It is a most commonly used test and gives good assessment of filling ability. It can be used at site. The test also indicates the resistance to segregation.
5.1.2 L-Box Test
The test was developed in Japan.The test assesses the flow of concrete, and also the extent to which the concrete is subjected to blocking by reinforcement.
51.3U-Box Test
The test was developed in Japan. The test is used to measure the filling ability of self-compacting concrete

5.2 Tests for Mechanical Properties
5.2.1 Compression Test
This test is done to determine the compressive strength of

concrete specimens as per IS: 516- 1959. It is done on 150mm cube. It is the most common test conducted on hardened concrete, partly because it is an easy test to perform, and partly because most of the desirable characteristic properties of concrete are qualitatively related to its compression strength.

Table-8: Specifications for fresh Property testing

SNO	METHOD	UNIT	TYPICAL RANGE OF VALUES	
			MINIMUM	MAXIMUM
1	Slump flow by Abrams cone	mm	650	800
2	L-box	(h2/h1)	0.8	1
3	U-box	(h1-h2) mm	0	30

5.2.2 Split Tensile Test

This test is done to determine the Split-Tensile strength of concrete specimens as per IS: 516- 1959. The splitting test is carried out on a standard cylinder specimen of 150mm diameter and 300mm height by applying a line load along the vertical diameter.

5.2.3 Flexural Test

This test is done to determine the Flexural strength of concrete specimens as per IS: 516- 1959. The Flexural strength test is carried out on standard beam specimens 150x150x750mm. The bed of the testing machine shall be provided with two steel rollers, 38 mm in diameter, on which the specimen is to be supported, and these rollers shall be so mounted that the distance from centre to centre is 60 cm for 15.0 cm specimens.

TABLE-9: MIX PROPORTIONS

Mix	Cement Kg/m3	GGBS Kg/m3	Silica Fume Kg/m3	Fine aggregate kg/m3	Coarse aggregate kg/m3	W/C	Super plasticizer 1% Kg/m3
Mix 1 (10% GGBS + 3% Silica fumes	478.5	55	16.5	840	760	0.35	5.5
Mix 2 (10% GGBS + 6% Silica fumes	462	55	33	840	760	0.35	5.5
Mix 3 (10% GGBS + 9% Silica fumes	445.5	55	49.5	840	760	0.35	5.5
Mix 4 (20% GGBS + 3% Silica fumes	423.5	110	16.5	840	760	0.35	5.5
Mix 5 (20% GGBS + 6% Silica fumes	407	110	33	840	760	0.35	5.5
Mix 6 (20% GGBS + 9% Silica fumes	390.5	110	49.5	840	760	0.35	5.5
Mix 7 (30% GGBS + 3% Silica fumes	368.5	165	16.5	840	760	0.35	5.5

VI. RESULTS AND DISCUSSIONS

6.1 Fresh Properties

Table-10: Test Results for Fresh Concrete

Mix	Flow Test Diameter in mm	L-Box(H_2/H_1)	U-Box(H_1-H_2) in mm
Mix-1	696	0.96	11
Mix-2	683	0.92	8
Mix-3	673	0.90	5
Mix-4	694	0.93	4
Mix-5	689	0.87	5
Mix-6	686	0.85	7
Mix-7	683	0.86	7

6.2Mechanical Properties

Table-11: Compressive Strength vs Different Mixes

S. NO	MIX DESIGNATION	COMPRESSIVE STRENGTH IN N/ mm^2	
		7 days	28 days
1	MIX 1	41.44	50.2
2	MIX 2	43.12	51.8
3	MIX 3	48.5	58.97
4	MIX 4	53.73	65.30
5	MIX 5	62.5	72.2
6	MIX 6	54.2	68.97
7	MIX 7	50.75	64.4

Table-12: Split Tensile Strength vs Different Mixes

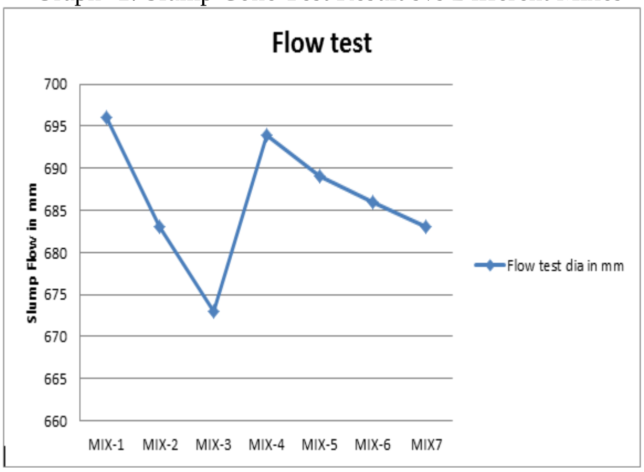
S. NO	MIX DESIGNATION	Split Tensile Strength
		28 days
1	MIX 1	4.4
2	MIX 2	4.5
3	MIX 3	4.88
4	MIX 4	5.35
5	MIX 5	6.2
6	MIX 6	5.55
7	MIX 7	4.92

Table-13: Flexural Strength of Concrete vs Different Mix

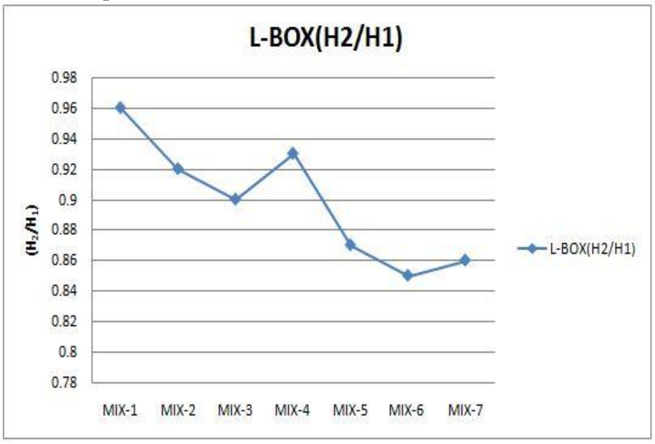
S. NO	MIX DESIGNATION	Flexural Strength 28 days
1	MIX 1	10.55
2	MIX 2	11.52
3	MIX 3	14.56
4	MIX 4	15.36
5	MIX 5	18.66
6	MIX 6	16.64
7	MIX 7	13.5

7.3Graphs

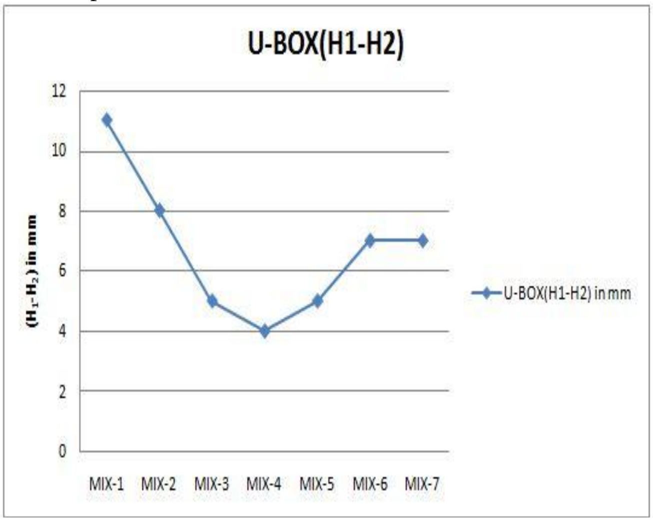
Graph- 1: Slump Cone Test Result svs Different Mixes



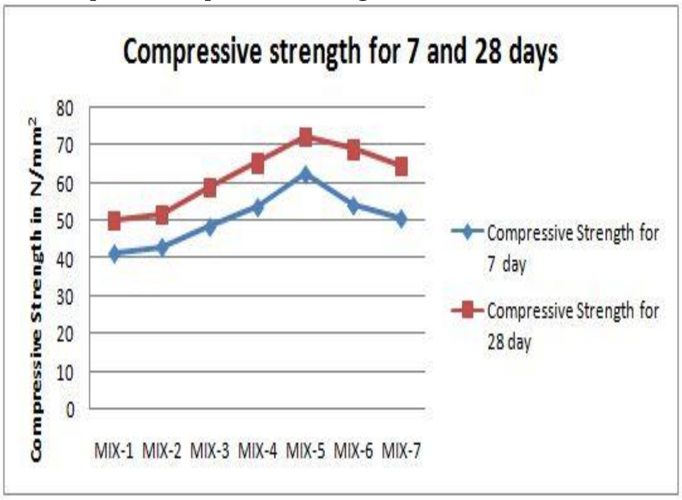
Graph- 2: L-Box Test Results vs Different Mixes



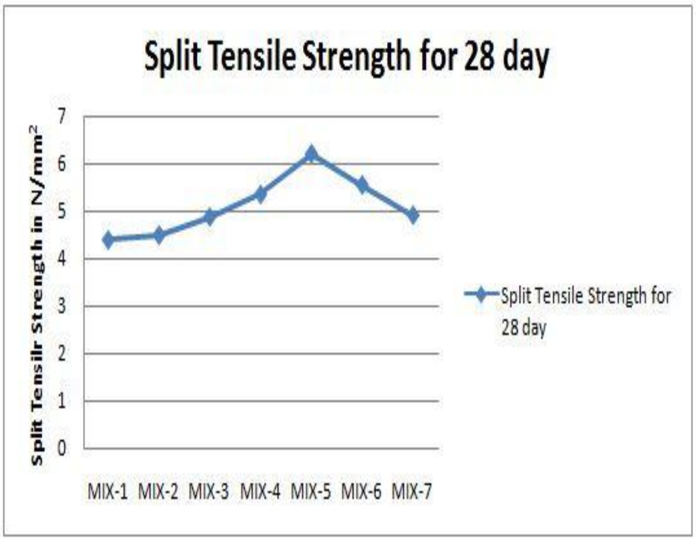
Graph- 5.3: U-Box Test Results vs Different Mixes



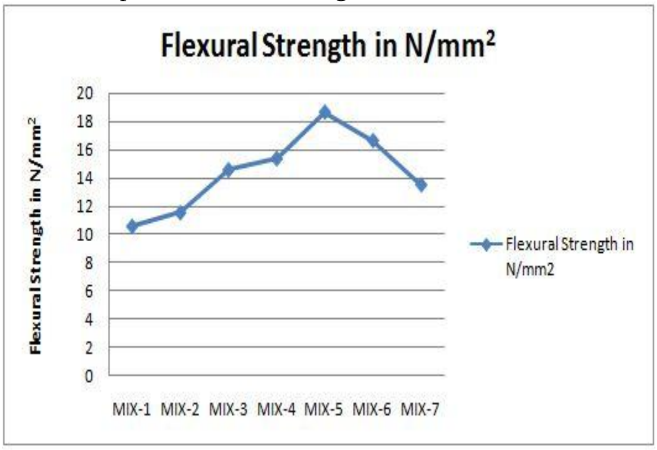
Graph-4: Compression Strength vs Different Mixes



Graph-5: Split Tensile Strength vs Different Mix



Graph-6: Flexural Strength vs Different Mixes



VII. CONCLUSION

The application of silica fume and GGBS in concrete mixture has significantly increasing and enhancing the properties of the concrete whether it is in wet stage or in harden condition. Form results it is clear that silica fume of 6% gives best results. And it is suggested that silica fume while using with GGBS not more than 6% is preferred to replace the cement. Rheological tests conducted were sufficient to ascertain whether the mix will have all the attributes of SCC or not. Silica fume provide mechanical strength to high performance self-compacting concrete by increasing the density. Addition of silica fumes developed filling and passing ability of concrete. From the results of mechanical properties, we know that the compressive strength has shown considerable increase from 7 days curing till 28 days of curing. Similarly flexural strength has increased at that same duration but not as much as the compressive strength of the concrete.In general, SSC with GGBS and silica fumes exhibits better performance in compression as compared to flexure. But setting time increase due to GGBS. Due to this temperature increases gradually, this leads to high strength. As the density and strength increases SSC have good resistance to temperature changes, chemical attacks as a result life span of the structure increases. It is best suitable for marine constructions where there are great chances of chlorine and sulphate attacks. The cost of SCC is higher than the conventional concrete, but it can be ignored by considering its performance.

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