Experimental Study on M25 Grade Self-Compaction Concrete By Using Silica Fume As A Partial Replacement of Cement And Aluminium Slag With Fine Aggregate

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Abstract- *The aim of this study is to evaluate the performance of Silica fume replacement with cement and aluminium slag replacement with fine aggregate as a mineral admixture in concrete to improve the concrete workability, durability and strength of concrete using OPC (53-Grade).*

This study investigates the performance of concrete mixture in terms of Compressive strength, split tensile strength and flexural strength for 7, 14 and 28 days respectively of M25 grade concrete. This thesis deals with the self-compacting concrete where the replacement OPC by Silica Fume were 3%, 6%, 9% and 12% by weight and Aluminium slag by weight of fine Aggregates in various percentages such as 10%, 20%, 30%, 40%. Here in this project 1.2% of super-plasticizer was used in all the test specimens for better workability at lower water binder ratio and to identify the sharp effects of Silica fume and Aluminium slag on the properties of concrete. These Concrete specimens were deep cured in water under normal atmospheric temperature.

Keywords- Silica Fume, Aluminium slag, Compressive strength, split tensile strength, flexural strength.

I. INTRODUCTION

Self-consolidating concrete is a highly flowablity type of concrete that spreads into the form without the need for mechanical vibration. Self-Compacting Concrete is a non-segregating concrete that is placed by means of its own weight. The importance of self-compacting concrete is that maintains all concrete's durability and characteristics, meeting expectedperformance requirements. In certain instances the addition of super plasticizers and viscosity modifier are added to the mix, reducing bleeding and segregation.

Concrete that segregates loses strength and results in honeycombed areas next to the formwork. A well designed SCC mix does not segregate, has high deformability and excellent stability characteristics. Self-consolidating concrete (SCC) owns over three key characteristics those are Filling Ability, Passing Ability and Segregation resistance. These characteristics were made possible by the development of highly effective water reducing agents (super plasticizers), those usually based on poly-carboxylate ethers. The mixture composition of SCC deviates from conventional concrete. The powder contents of SCC are normally lying above those of conventional concrete.

OBJECTIVE OF THE STUDY

1. To study the effect of silica fume and Aluminium slag in the properties of Self compacting Concrete (SCC).
2. To find the optimum replacement levels of silica fume and Aluminium slag in Self Compacting Concrete (SCC).
3. To determine the percentage growth rate in hardened properties like compressive strength, split tensile strength and flexural strength.
4. To study the fresh and hardened properties (i.e., compressive strength, split tensile strength and flexural strength) with partial replacement of cement by silica fume in three different percentages such as 3%, 6%, 9%, 12% and find the optimum percentage of strength.
5. To study the fresh and hardened properties of SCC with partial replacement of cement by silica fume with optimum percentage and with partial replacement of fine aggregate by Aluminium slag in four different percentages such as 10%, 20%, 30%, 40% are evaluated.

II. LITERATURE REVIEW

1. **Dinesh and B. Chandan et.al. (2016),** Concluded that cement replacement with fly ash and copper slag studies M50 grade of concrete. The cement and fine aggregate is partially and fully replaced with fly ash and copper slag.

Replacement of copper slag by weight of fine Aggregates in various percentages such as 10%, 20%, 30%, and 40% up to 100% does not have any adverse effect on strength. Water consumed by the copper slag when compared with river sand is very less. Use of copper slag and fly ash in construction is very cheap and gives good result. The 30% replacement of sand with copper slag and 40% replacement of weight of cement with fly ash significantly increase the compressive strength of concrete mixtures.

2. **Susan Bernal, Ruby De Gutierrez, (2015),** carried out Research work in Performance of an alkali-activated slag concrete reinforced with steel fibers. Their conclusion is that the developed AASC present higher compressive strengths than the OPC reference concretes. Splitting tensile strengths increase in both OPCC and the AASC concretes with the incorporation of fibres at 28 curing days.
3. **HishamQasrawi, Faisal Shalabi, Ibrahim Asi (2015),** carried out Research work in Use of low CaO unprocessed steel slag in concrete as fine aggregate. Their conclusion is that regarding the compressive and tensile strengths of concrete steel slag are more advantageous for concretes of lower strengths.
4. **O. Boukendakdji, S. Kenai, E. H. Kadri, (2015),** carried out Research work in Effect of slag on the rheology of fresh self-compacted concrete. Their conclusion is that slag can produce good self-compacting concrete.
5. **H. TahirGonen, L. SalihYazicioglu (2014),** studied the influence of binary and ternary blend of mineral admixtures on the short and long term performances of concrete and concluded many improved concrete properties in fresh and hardened states.
6. **Mateusz Radlinski, Jan Olek, (2014),** in their experimental work entitled Effect of mixture composition and Initial curing conditions on the scaling resistance of ternary concrete have find out effect of different proportions of ingredients of ternary blend of binder mix on scaling resistance of concrete in low temperatures.

III. EXPERIMENTAL PROGRAMME ON SCC

The present chapter deals with the presentation of results obtained from various tests conducted on material used for the concrete. In order to achieve the objectives of present study, an experimental programme was planned to investigate the effect of silica fume and aluminum slag on compressive strength, split tensile strength and flexural strength of self-compaction concrete.

Cement:

Portland cement referred as (Ordinary Portland Cement) is the most important type of cement and is a fine powder produced by grinding Portland cement clinker. The OPC is classified into three grades, namely 33 Grade, 43 Grade, 53 Grade depending upon the strength of 28 days.

Aggregates:

The aggregates must be proper shape, clean, hard, strong and well graded. The aggregate which is retained over IS Sieve 4.75 mm is termed as coarse aggregate. The normal maximum size is gradually 10-20 mm. The aggregates most of which pass through 4.75 mm IS sieve are termed as fine aggregates. According to size, the fine aggregate may be described as coarse, medium and fine sands. Depending upon the particle size distribution IS: 383-1970 has divided the fine aggregate into four grading zones (Grade I to IV). The grading zones become progressively finer from grading zone I to IV.

Water:

The potable water is generally considered satisfactory for mixing and curing of concrete. Accordingly potable water was used for making concrete available in Material Testing laboratory. This was free from any detrimental contaminants and was good potable quality.

Admixtures&Super plasticizers:

The most important admixtures are the Super plasticizers (high range water reducers), used in this work is Conplast SP430, which complies with IS: 9103:1979 and BS: 5075 Part 3 and ASTM-C-494 type „F" as a high range water reducing admixture. Conplast SP 430 is a ready to use admixture that is added to the concrete at the time of batching. Conplast SP430 is differentiated from conventional super plasticizers in that it is based on aqueous solution of lignosulphonates, organic polymer with long lateral chains. This greatly improves cement dispersion. Conplast SP430 is supplied as brown liquid instantly dispersible in water and specially formulated to give high water reduction up to 25% without loss of workability. Specific gravity is 1.22 to 1.225 at 30^{o}C. This admixture helps to provide very good homogeneity and reduces the tendency to segregation.

SILICA FUME

Physical and chemical composition of silica fume used in the experiments is given in the table 3.7 & 3.8. Silica fume is Pale Gray in colour.

Fig 3.3: Pale Gray colour Silica fume

Table 3.7: Physical Properties of Silica Fume

S.No	Characteristics	Value
1.	Specific gravity	2.30
2.	Bulk density()	300 kg/m^3
3.	Colour	Gray
4.	Specific Surface Area (m^2/kg)	2000 m^2/kg

Table 3.8: Chemical Composition of Silica Fume

S.No	Chemical Component	Constituents	Percentage
1.	Silica dioxide	SiO_2	90 to 96
2.	Alumina oxide	Al_2O_3	0.5 to 0.8
3.	Magnesium oxide	MgO	0.5 to 1.5
4.	Ferric oxide or Iron oxide	Fe_2O_3	0.2 to 0.8
5.	Calcium oxide	CaO	0.1 to 0.5
6.	Sodium oxide	Na_2O	0.2 to 0.7
7.	Potassium oxide	K_2O	0.4 to 1.0
8.	carbon	C	0.5 to 1.4
9.	Sulfur	S	0.1 to 0.4

ALUMINIUM SLAG:

Aluminium slag is one of the materials that are considered as a Recycling and reutilization of industrial waste and by-products are subjects of great importance today in any sector and more in construction industry as partial or full replacement of either cement or aggregates. Aluminium is the most widely used nonferrous metal in the world.

Physical and chemical composition of Aluminium slag used in the experiments is given in the table 3.9 & 3.10. Aluminium slag is Black and glassy in colour as shown in Figure: 3.4

Fig 3.3: Black and glassy colour Aluminium slag

Table 3.10: Physical composition of Aluminium Slag

S.No	Particulars	Values
1.	Particle shape	Irregular
2.	Appearance or Colour	Black and glassy
3.	Fineness modulus	3.58
4.	Specific gravity	3.218
5.	Density	1700 to 2000 kg/m^3

Table 3.9: Chemical composition of Aluminium Slag

S.No	Chemical Composition	Percentage
1.	Aluminum oxide (Al_2O_3)	77.15
2.	Silica dioxide (SiO_2)	1.34
3.	sodium oxide (Na_2O)	6.57
4.	Calcium oxide (CaO)	0.56
5.	Titanium dioxide (TiO_2)	0.14
6.	Magnesium oxide (MgO)	1.86
7.	Potassium oxide (K_2O)	1.48
8.	Zinc (Zn)	0.05
9.	Copper (Cu)	0.48
10.	Manganese (Mn)	0.03
11.	Iron Sulfate (Fe)	1.02
12.	Almetallic	1.26
13.	Aluminum nitride (AlN)	8.06

IV. SCC - MIX DESIGN PROCEDURE

As per Nan Su's method of mix design of Self-Compacting Concrete, the parameters that influence the mix proportions are packing factor, cement content, Silica fume, Aluminum slag content fine aggregate - total aggregate were made with ratio and proportion of admixture content. From the strength and workability studies conducted on SCC in the present investigation, it was noted that there is a significant change in the mix proportions with respect to packing factor, effective size of aggregate, fine aggregate - total aggregate ratio, Silica fuma content, cement content and water content.

Table - 4.1: M25 Grade SCC mix proportions

	Cement	Silca fume				Aluminum Slag				F.A	C.A	S.P	Water, W/B
Quantity (kg/m³)	490	14.7	29.4	44.1	58.8	61.3	122.6	183.9	245.2	613	980	0.882	205.8
Proportions	1	3%	6%	9%	12%	10%	20%	30%	40%	1.25	2.0	0.0018	0.42

Table - 4.2: Trail mix proportions of M25 Grade SCC

Grade	Mix	W/B	Water (Kg/m³)	Cement (Kg/m³)	AS (Kg/m³)	AS (%)	Silica Fuma (Kg/m³)	Silica Fuma (%)	FA (Kg/m³)	CA (Kg/m³)	SP (%)
M25	Trial -1	0.42	205.8	490	0	0	0	0	613	980	0.882
	Trial -2			490	61.3	10	14.7	3	613	980	0.882
	Trial -3			490	122.6	20	29.4	6	613	980	0.882
	Trial -4			490	183.9	30	44.1	9	613	980	0.882
	Trial -4			490	245.2	40	58.8	12	613	980	0.882

V. RESULTS AND DISCUSSIONS

In chapter -3, a detailed experimental investigation covering the various mechanical properties viz. compressive strength, split tensile strength and flexural strength have been studied. The present chapter highlights the results obtained from the above experimental investigation.

Fresh properties of SCC

The details of the fresh properties are shown in Table 5.2, for M30 grade concrete.

Grade	MIX	Slump Flow value	T_{50}	V-Funnel	V-Funnel at T_5 Minutes	L-Box H2/H1 (blocking ratio)
M25	Trial -1	670	3sec	8 sec	8 sec	0.81
	Trial -2	678	3sec	8.5 sec	8.5 sec	0.82
	Trial -3	675	4sec	9.2 sec	9.2 sec	0.84
	Trial -4	673	3sec	8 sec	8 sec	0.81

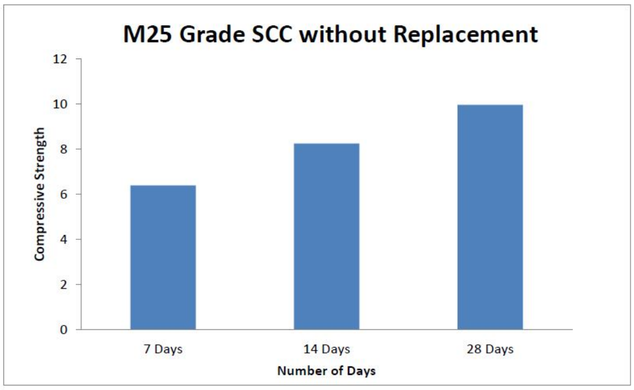
Table: 5.2 Fresh properties of for M30 grade concrete.

COMPRESSIVE STRENGTH

In this experiment the Test specimens (3 each) of 150mm x 150mm x 150mm were cast for testing the compressive strength of concrete at different percentages. The concrete mix with varying quantity of silica fume i.e. 3%, 6%, 9%, 12% as partial replacement to cement and Aluminium slag i.e. 10%, 20%, 30%, and 40% as partial replacement to fine aggregate were cast and tested after curing period of 7,14 and 28 days. The results obtained after curing period of 7, 14 and 28 days for are mentioned.

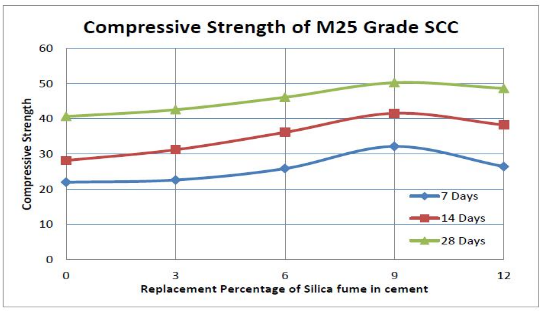
MIX	SILICA FUME (%)	COMPRESSIVE STRENGTH (MPa)		
		7 Days	14 Days	28 Days
M25	0	21.96	28.14	40.65
	3	22.6	31.2	42.58
	6	25.84	36.15	46.12
	9	32.14	41.56	50.26
	12	26.42	38.24	48.65

Table: 5.3 Compressive strength of M25 grade SCC with partial replacement of silica fume



Graph: 5.1 Compressive strength of SCC without Replacement

The optimum Percentage of compressive strength for SCC with Partial replacement of silica fume with cement is 9%. So that optimum percentage of silica fume will be added for cement and aluminum slag with 10%, 20%, 30%, and 40% as partial replacement to fine aggregate.

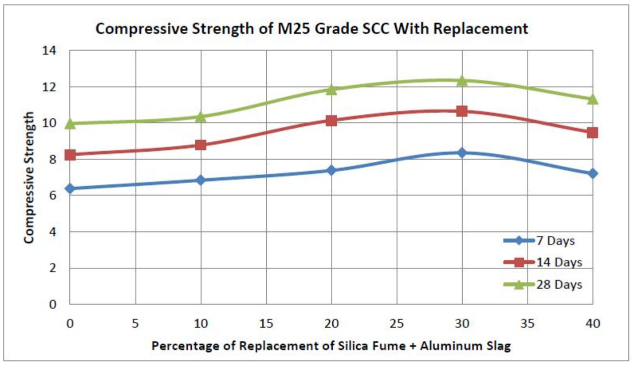


Graph: 5.2 Compressive strength of SCC with partial replacement of silica fume in cement

MIX	SILICA FUME (%)	ALUMINUM SLAG (%)	COMPRESSIVE STRENGTH (MPa)		
			7 Days	14 Days	28 Days
M25	0	0	16.28	24.14	42.65
	9	10	29.97	37.97	53.07
		20	32.74	41.42	57.9
		30	35.42	44.92	62.72
		40	33.79	42.85	58.47

Table: 5.4 Compressive strength of M25 grade SCC with partial replacement of (SF) & (AS)

It can be observed from the above results that the compressive strength of the concrete increases by incorporating silica fume 9% as a partial replacement to cement and aluminum slag up to 40% as partial replacement to fine aggregate in all the concrete mixes andsubsequently increase on further decrease in the aluminum slag concentration in the concrete specimen. The results are plotted graphically for curing period of 7, 14 and 28 days as shown in Graph 5.3.



Graph: 5.3 Compressive strength of M25 grade SCC with Replacement of SF & AS

From the above results observations we can conclude that the increase of compressive strength results 7 to 14 days is 40.5 percentages increased and for 28 days the increased strength is 91.22 percentages for normal mix. For the partial replacement of cement and fine aggregate with silica fume and aluminum slag the optimum percentage of compressive strength is obtained at 30% of aluminum slag and 9% of silica fume.

From graph results we can observe that decreasing 11% percentage strength start at partial replacement 12% silica fume and 40% aluminum slag of compressive strength at 28 days age.

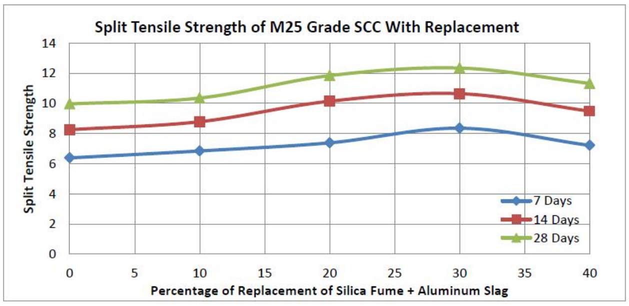
SPLIT TENSILE STRENGTH

The split tensile strength of concrete is tested by casting cylinders of size 150mm x 300mm were cast for testing the split tensile strength of concrete at different percentages. The concrete mix with varying quantity of silica fume i.e. 9% as partial replacement to cement and aluminum slag i.e. 10%, 20%, 30%, and 40% as partial replacement to fine aggregatewere cast and tested after curing period of 7,14 and 28 days. The results obtained after curing period of 7, 14 and 28 days for are mentioned in Table 5.4.

MIX	SILICA FUME (%)	ALUMINUM SLAG (%)	SPLIT TENSILE STRENGTH (MPa)		
			7 Days	14 Days	28 Days
M25	0	0	2.82	3.46	4.22
	9	10	3.25	4.14	4.62
		20	3.64	4.48	4.95
		30	4.12	4.94	5.35
		40	3.54	4.21	4.66

Table: 5.5 Split Tensile strength of M25 grade SCC with Replacement of SF & AS

It can be observed from the above results that the split tensile strength of the blocks is increased by incorporating aluminum slag up to 40% as partial replacement to fine aggregate in all the concrete mixes and this value declines further by increasing the aluminum slag concentration in the concrete specimen. The results are plotted graphically by considering average reading of split tensile strength for curing period of 7, 14 and 28 days as shown in Graph 5.4.



Graph: 5.4 Split Tensile strength of M25 grade SCC with Replacement of SF & AS

From the above results observations we can conclude that the increase of split tensile strength results 7 to 14 days is 38.4 percentages increased and for 28 days the increased strength is 84.6 percentages for normal mix. For the partial replacement of cement and fine aggregate with silica fume and aluminum slag the optimum percentage of split tensile strength is obtained at 30% of aluminum slag and 9% of silica fume.

From graph results we can observe that decreasing 12.89% percentage strength start at partial replacement 12% silica fume and 40% aluminum slag of split tensile strength at 28 days age.

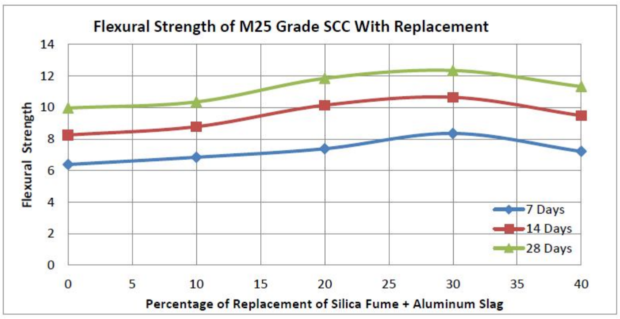
FLEXURAL STRENGTH

The flexural strength of concrete is tested by casting beam of size 150mm x 150mm x 750mm were cast for testing the flexural strength of concrete at different percentages. The concrete mix with varying quantity of silica fume i.e. 9% as partial replacement to cement and aluminum i.e. 10%, 20%, 30%, and 40% as partial replacement to fine aggregate were cast and tested after curing period of 7,14 and 28 days. The results obtained after curing period of 7, 14 and 28 days for are mentioned in Table 5.6.

MIX	SILICA FUME (%)	ALUMINUM SLAG (%)	FLEXURAL STRENGTH (MPa)		
			7 Days	14 Days	28 Days
M25	0	0	6.38	8.25	9.96
	9	10	6.84	8.78	10.35
		20	7.38	10.14	11.84
		30	8.35	10.64	12.34
		40	7.21	9.48	11.32

Table: 5.6 Flexural strength of M25 grade SCC with Replacement of SF & AS

It can be observed from the above results that the flexural strength of the blocks is increased by incorporating aluminum slag up to 30% as partial replacement to fine aggregate in all the concrete mixes and this value declines further by increasing the aluminum slag concentration in the concrete specimen. The results are plotted graphically by considering average reading of split tensile strength for curing period of 7, 14 and 28 days as shown in Graph 5.5.



Graph: 5.3 Flexural strength of M25 grade SCC with Replacement of SF & AS

From the above results observations we can conclude that the increase of flexural strength results 7 to 14 days is 43.6 percentages increased and for 28 days the increased strength is 88.7 percentages for normal mix. For the partial replacement of cement and fine aggregate with silica fume and aluminum slag the optimum percentage of split tensile strength is obtained at 30% of aluminum slag and 9% of silica fume.

From graph results we can observe that decreasing 9.65% percentage strength start at partial replacement 12% silica fume and 40% aluminum slag of split tensile strength at 28 days age.

It can also be observed that a further increase in percentage of aluminum slag beyond 40% results in a decrease in strength to a value below the normal mix. Thus, it can be concluded that the optimum percentage level of replacing fine aggregates with aluminum slag is 30% only.

VI. CONCLUSIONS

The present work investigated the influence of silica fume and aluminium slag as partial replacement of cement and fine aggregate (sand) on the properties self-compacting concrete. On the basis of the results from the present study, the following conclusions can be drawn from this study, based on the results obtained.

1. Self-compacting concrete is a relatively new form of concrete which is used for general applications. The main advantages that SCC has over standard concrete is its high compressive strength and self-compacting properties, crawled high flowability ,workability and passing ability.
2. In this super plasticizer (Conplast SP 430) is water reducing agent in the range of (0 to 25%) of water. The optimum dosage of chemical admixture is 1.5% to 1.8% of super plasticizer (Conplast SP 430) chemical composition is aqueous solution of lignosulphonates, organic polymer with long lateral chains of the self-compatibility of concrete.
3. It is recommended that 9% of silica fume can be used as replacement of cement, and 30% of aluminium slag can be used as replacement of fine aggregate in order to obtain high strength self-compacting concrete with good property.
4. Use of aluminium slag and silica fume in construction is possible to work and it is very cheap and gives good result.
5. This study points out the beneficial aspects of using aluminium slag as a replacement material of fine aggregate.
6. So compared to conventional concrete, self-compacting concrete (SCC) gained higher compressive strength.
7. The percentage of Silica fumes and aluminium slag in the mix will affects the Workability and Mechanical characteristics of SCC.
8. The compressive strength, Split tensile strength and flexural strength is Maximum for 9% silica fume + 30% aluminium slag.
9. Compressive strength, Split tensile strength and flexural strengths increased 30.46%, 16.48% and 64.83% when conventional mix is held.
10. Compressive strength, Split tensile strength and flexural strengths increased 43.52%, 22.99% and 85.33% when silica fume 9% and aluminium slag 30% used as a mineral admixture.

11. An industrial waste like silica fume and aluminium slag helps in the strength development of claimed products and hence it can be used in construction industry for preparation of concrete replacing some quantity of cement and quantity of fine aggregate, which is a valuable ingredient of concrete to achieve economy.
12. The workability of SCC is equilibrium of fluidity, deformability filling ability and resistance to segregation. This equilibrium has to be maintained for a sufficient time period to allow for transportation, placing and finishing.

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