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Study on Effect of Silica Fume on Properties of M_{40} Grade of Concrete

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Abstract- **One of promising new field of science is nanotechnology. Concrete being one of the most largely used material is also being modified for the better by introduction of nanomaterials like nano-silica, nano-alumina etc. The present study incorporates silica fume as partial replacement of cement.**

In this study, properties such as Compressive strength, Split tensile strength, Flexural strength and Sulphate resistance of M_{40} grade of concrete using micro silica are studied. The cement (OPC Grade 43) was replaced by 0%, 5%, 8%, 10%, 12%, and 15% silica fume. The cubical specimens of standard size (150mm) were casted and tested at 7, 14 and 28 days respectively to calculate compressive strength. The results showed that 8% replacement of cement by silica fume gave maximum compressive strength and beyond that compressive strength of the specimen decreased. For split tensile and flexural strength, cylindrical specimens (300×150) mm and beam specimens (750×150×150) mm were casted respectively. For sulphate resistance, cement is replaced by 0%, 5%, 8% and 15% silica fume and standard cubical specimens were casted. The tests for split tensile strength, flexural strength were performed on standard specimens at 7, 14 and 28 days. The results showed Silica Fume has marginal effect on these properties. The cubical specimens were tested for sulphate resistance at 7, 28 and 56 days respectively. The results showed that 8% replacement of cement by Silica fume gives less loss of compressive strength at all ages.

Key words: Silica fume (SF), Compressive strength (CS), Split tensile strength (ST), Flexural strength (FS), Super plasticizer (SP).

1. INTRODUCTION

One of the materials used on large scale in world is concrete. The main constituents of concrete are cement, aggregate and water. Researchers are continuously trying to modify the constituents of concrete to achieve better strength, durability etc. One of the areas of research focuses on replacement of cement by pozzolanic materials. Out of these pozzolanic materials, silica fume is one of the extensively used materials nowadays. It is produced as a by-product during production of silicon. Silica fume plays three important roles in concrete. It causes pore size refinement, reacts with free lime and strengthens the transition zone.

Sobolev (2004)[1] studied the effect of silica fume on compressive strength. He observed that when cement is replaced by silica fume, compressive strength increases.Verma ajay et al. (2012)[2] studied effect of silica fume on concrete. They observed that there occurs an increase in compressive strength as well as reduction of capillary pores. Hootan (1993)[3] reported that for silica fume concrete split tensile strength increases only at 28 days. Rao (2003)[4] studied effect of silica fume on cement pastes. He observed that consistency of cement increase with increase in silica fume content .Alshamsi et al (1993)[5] concluded that addition of silica fume lengthens the setting time. Khatin and Aitcin (1993)[6] reported that addition of super-plasticizer is necessary to maintain workability in silica fume concrete. Cohen and Bentur (1988)[7] studied resistance of silica fume mixes to sulphate. They observed silica fume reduced loss of strength in concrete when exposed to sulphate environment.

2. RESEARCH METHODOLOGY

In the present research cement has been partially replaced by silica fume in M_{40}Grade of concrete. The replacement levels are 5%, 8%, 10%, 12% and 15% by weight of cement. The properties investigated are consistency, workability, compressive strength, split tensile strength, flexural strength and sulphate resistance. The specimens of standard cubes (150mm×150×mm×150mm), standard cylinders (150mmdia×300mm height) and standard beams (150mm×150mm×700mm) were cast from different mixes having different replacements levels of SF. The specimens were cured in water for required time. For Sulphate resistance when specimens were de-moulded after 24hours of casting, equal no of specimens were placed in water and sulphate tank. Sodium sulphate in powder form was used to prepare 10% solution.

3. MATERIALS USED AND THEIR PROPERTIES

In the present study materials used are Cement, Fine aggregate, Coarse aggregate, Silica Fume and Super-Plasticizer.

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3.1CEMENT

An OPC 43 grade Ultra Tech Cement was used in this study. The physical properties were found using respective IS codes. The properties are given in table below:-

Table: 1-Properties of Cement

Property of cement	Results	IS-Code
Normal Consistency	32 (%)	IS: 4031-PART 5-1988
Initial Setting Time	50	IS: 4031-PART 5-1988
Final Setting Time	250	IS:4031-PART 5-1988
Specific gravity	3.11	IS:4031-PART 11 1988

3.2 Fine Aggregate

Locally available sand was used in this study. The properties of sand obtained using respective codes are given in table below.

Table: 2-Properties of Sand

Property of Sand	Results	IS-Code
Fineness Modulus	3.2	IS: 383-1970
Zone	II	IS: 383-1970
Water Absorption	1.2(%)	IS: 2386-1963
Specific Gravity	2.67	IS: 2386-1963

3.3 Coarse Aggregate

In this study locally available crushed aggregate of sizes 20mm and 12.5mm in ratio 1:1 were used. The aggregates were tested and following results were obtained:-

Table: 3-Properties of Coarse aggregate

Property of Aggregate	Results	IS-Code
Specific Gravity	2.72	IS: 2386-1963
Water Absorption	0.5%	IS: 2386-1963

3.4 Silica Fume

The Silica Fume Was purchased from Advance Chemical Sales Corporation (Delhi). The Silica Fume used in these experiments conforms to ASTM C 1240 and IS 15388: 2003. The properties as specified by supplier are given below:-

Table: 4-Properties of Silica Fume

Properties	Results
Form	Ultra Fine amorphous powder
Colour	Greyish Black
Specific Gravity	2.63
Particle Size	15 μm
SiO_2 Content	99.89%

3.5 Super- Plasticizer

Fosroc Aura Mix 400 was used in the mix. It is a third generation super plasticizer .It belongs to carboxylic group. The properties as specified by supplier are:-

Table: 5-Properties of super Plasticizer

Property	Results
Colour	Light yellow
PH	6

4. MIX DESIGN

The mix design was done using IS: 10262-2009 and IS: 456-2000. The calculated proportion for $1m^3$ is given below:-

Table: 6-Mix proportion for $1m^3$

Material	Quantity
Grade	M_{40}
Cement	400 kg/m^3
Fine Aggregate	685.4 kg/m^3
Coarse Aggregate	1263.1 kg/m^3
Water	166.4 kg/m^3
W/C ratio	0.38
Super-plasticizer	As required to get desired workability(by weight of cement)

5. RESULTS

5.1 Test on Cement and SF pastes

a) Consistency:-

The consistency of cement changes when silica fume is added. The consistency of different pastes is given below:-

Table: 7-Consistency of Pastes

Silica Fume (%)	Consistency (%)
0 (Control)	32
5	33
8	35
10	37
12	38
15	39

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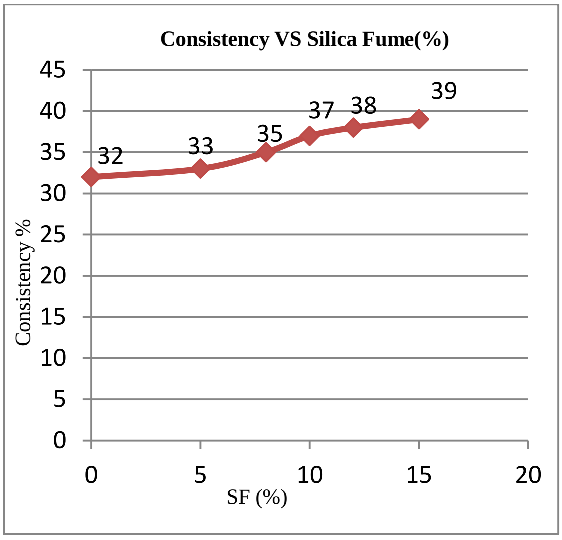

Figure: 1-Variation of consistency with SF (%)

5.2 Tests on Fresh Concrete

a) Slump Test and Super Plasticizer dosage:-

The Slump Values change when cement is replaced by Silica Fume in the mixes. It can be clearly seen as replacement levels increase slump decreases. The desired workability is attained by changing dosage of Super Plasticizer (%).

The Slump values and Super Plasticizer dosage are given below:-

Table: 8-Slump Values and Super plasticizer

Silica Fume (%)	Super plasticizer	Slump	
		Immediately	After 15 minutes
0	0.3	50	70
5	0.45	45	75
8	0.7	50	70
10	0.9	43	65
12	1	48	70
15	1.1	46	68

5.3 Tests on hardened concrete

a) Compressive Strength Test:-

Compression Testing Machine [Accro-Tech (Delhi (Ram dia-234)] was used to determine compressive strength of cubical specimens at 7, 14 and 28 days respectively. Load was applied gradually at rate of 5KN/sec as per IS: 516-1959.

There is significant improvement in compressive strength because of Silica Fume. It is evident that maximum compressive strength is attained when replacement level is 8%. Beyond this level compressive strength decreases. The maximum 28-day compressive was 52N/mm^2 when replacement level was 8%.The compressive strength of different mixes is given below:-

Table: 9-Compressive Strength of Specimens

Silica Fume (%)	Compressive Strength (N/mm^2)		
	7-day	14-day	28-day
0	30.5	41	44
5	32.76	43	46
8	36.72	49	52
10	33	44	48
12	29.04	38.08	43
15	28.48	36.5	41.2

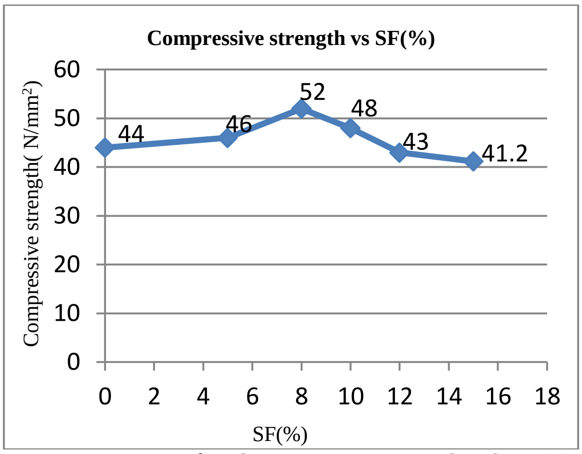

Figure: 2-Variation of 28-day Compressive Strength with SF (%)

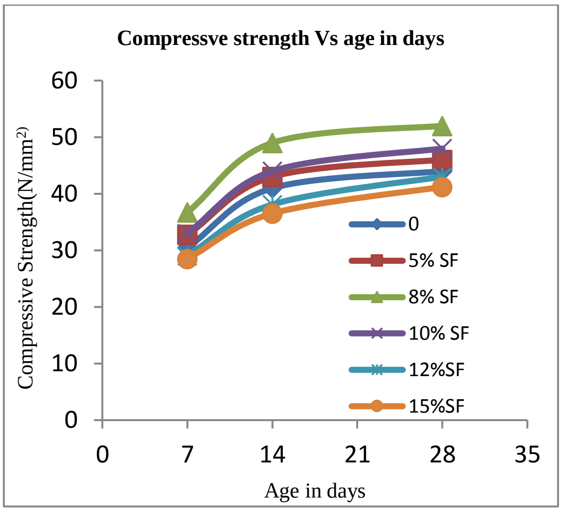

Figure: 3-Comparison of Compressive Strength of different mixes.

b) Flexural Strength Test

Flexural Testing machine [Accro-Tech (Delhi); Ram dia-81mm] was used to determine flexural strength of beam specimens at 7, 14 and 28 days respectively. Load should be applied gradually at rate of 0.065KN/sec as per IS: 516-1959.

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There is marginal increase in flexural strength because of Silica Fume. The maximum 28 day flexural strength was 4.2N/mm^2 when replacement level was 8%. Beyond this level there occurs decrease in flexural strength.

The flexural strength of different mixes is given below:-

Table: 10-Flexural strength of specimens

Silica Fume (%)	Flexural Strength (N/mm^2)		
	7-day	14-day	28-day
0	1.98	2.64	3.3
5	2.34	3.12	3.9
8	2.52	3.36	4.2
10	2.4	3.2	4
12	2.28	3.04	3.8
15	2.2	2.96	3.7

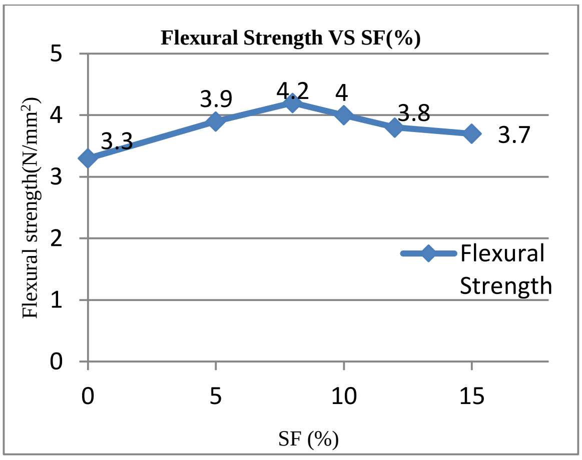

Figure: 4-Variation of 28-day flexural strength with SF (%)

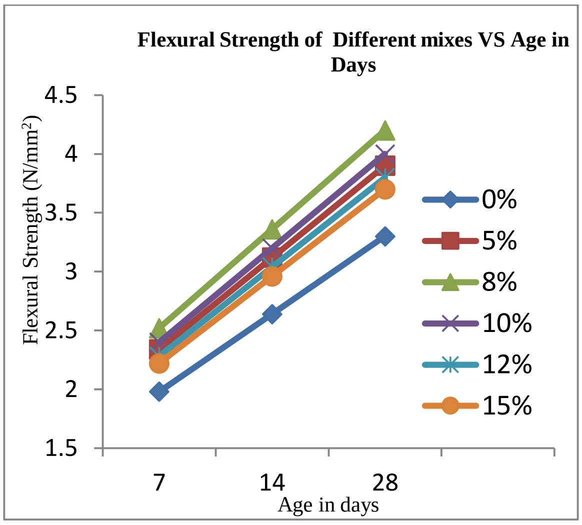

Figure: 5-Comparison of Flexural Strength of different mixes

c) Split Tensile Strength Test

Compression Testing Machine [Accro-Tech (Delhi); Ram dia-234] was used to determine split tensile strength of cylindrical specimens at 7, 14 and 28 days respectively. Load should be applied gradually at rate of 1.67KN/sec as per ASTM C496.

There is marginal increase in split tensile strength because of Silica Fume. The maximum 28 day split tensile strength was 4.4N/mm^2 when replacement level was 8%. Beyond this level there occurs decrease in split tensile strength.

The split tensile strength values are given below:-

Table: 11-Split tensile strength of specimens

Silica Fume (%)	Split tensile strength (N/mm^2)		
	7-day	14-day	28-day
0	2.1	2.5	3.9
5	2.6	3.2	4.2
8	2.9	3.4	4.4
10	2.8	3.2	4.3
12	2.7	3.1	4.1
15	2.3	2.9	4

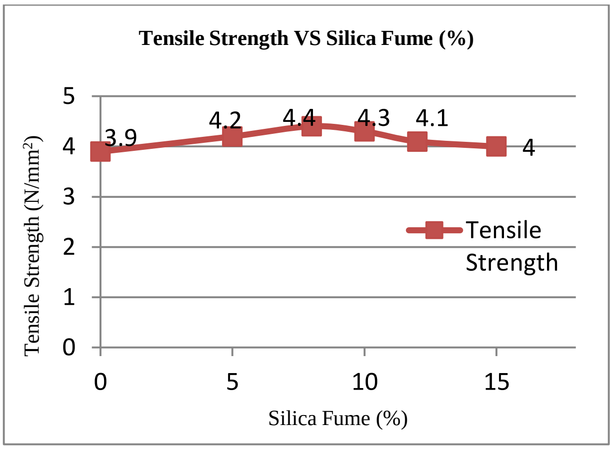

Figure: 6-Variation of 28-day split tensile strength with SF (%).

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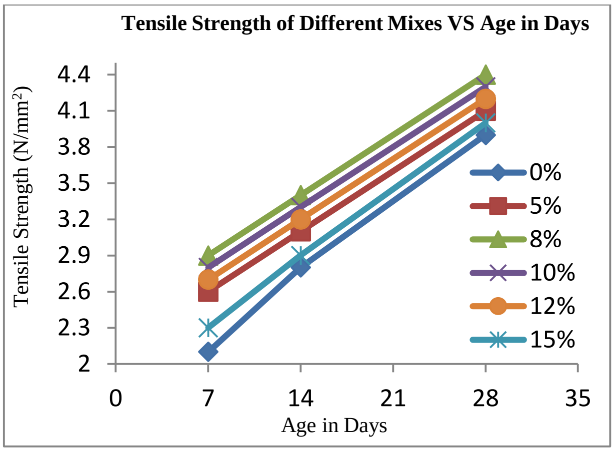

Figure: 7-Comparison of Tensile Strength of different mixes

d) Sulphate Resistance Test

To evaluate sulphate resistance of silica fume, cube specimens were casted. The specimens were de-moulded after 24hours and placed for curing. Equal no of specimens were cured in water and sodium sulphate (10%). The cubes were tested for compressive strength at 7, 28 and 56 days respectively. The procedure followed is same as that in compressive strength test. The results obtained are given below:-

Table: 12-Compressive strength of specimens

SF (%)	Compressive Strength (N/mm^2)					
	7-day		28-day		56-day	
	W-C	C-C	W-C	C-C	W-C	C-C
0	30.5	28.9	41	38.5	41.9	38.9
5	33	31.8	46	44.1	47	44.8
8	37	35.8	52	50.8	53.2	51.1
15	29	27.8	40	38	41	38.7

Table: 13-Loss (%) in compressive strength

SF (%)	Loss (%) in Compressive Strength at		
	7-day	**28-day**	**56-day**
0	5	5.9	7
5	3.5	4.1	4.5
8	3	3.5	3.8
15	4	4.8	5.5

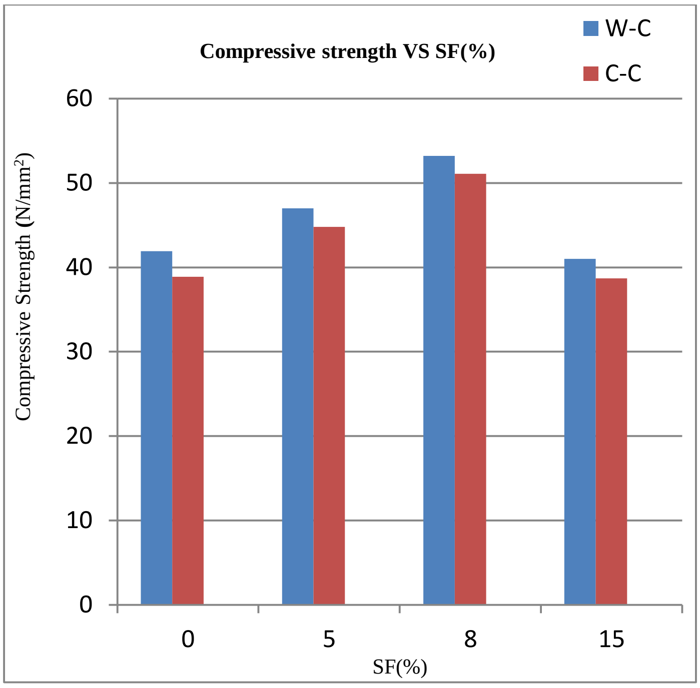

Figure: 8-Comparison of 28-day compressive strength

W-C: - Water cured Specimens
C-C: - Chemical Cured Specimens

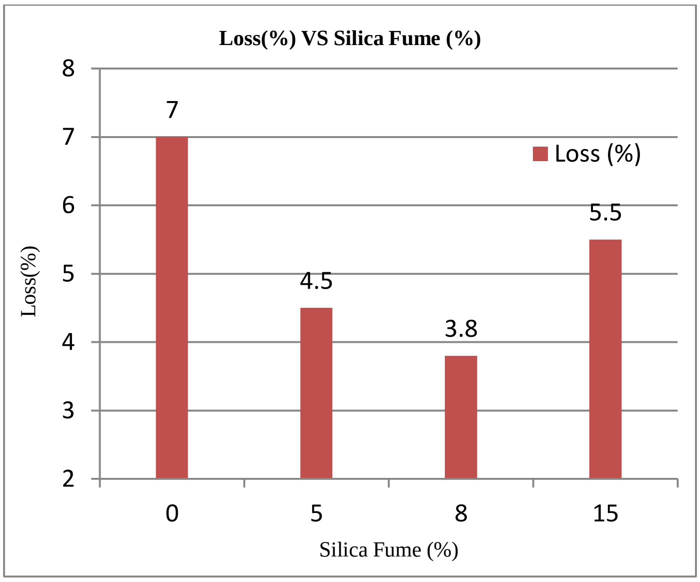

Figure: 9-Loss (%) in compressive strength at 56 day

CONCLUSION

1. From Table-7, it is evident that when cement is replaced by silica fume, water demand increases.
2. From Table-8, super plasticizer requirement increases as silica fume (%) increases.
3. From Table-9 when cement is replaced by silica fume, compressive strength first increases and then decreases. The optimum replacement level for compressive strength is 8%. The maximum 28-day compressive strength at this replacement level is 52N/mm^2 .
4. From Table-10 and Table-11, when cement is replaced by silica fume, there is marginal effect on flexural and split tensile strength. The maximum values are obtained when replacement level is 8%.
5. From Table 13, it is evident that silica fume reduces loss of strength in concrete when exposed to sulphate environment. It can be clearly seen from results that when replacement level is 8%, loss of strength is less (3.8%) compared to Loss (7%) when replacement level is 0%.

REFERENCES

[1] Sobolev, k., (2004). “The development of a new method for proportioning of high performance concrete mixtures.” Cement and Concrete Composites, 26 (2004) Pp 901-907.
[2] Ajay, V., Chandak, R., and Yadav, R.K., . “Effect of micro silica on the strength of concrete with ordinary Portland cement” Research journal of Engineering Science ISSN 2278-9472 vol.1 (3), 1-4, sept (2012).
[3] Hootan.R.D., (1993). “Influence of silica fume replacement of cement on physical properties and resistance to sulphate attack, freezing and thawing, and alkali-silica reactivity”. ACI Materials Journal, 90 (2) Pp 143-152.
[4] Rao, G.A., (2003).“Investigations on the performance of silica fume incorporated cement pastes and mortars”. Cement and Concrete journal, 33(11). Pp 1765-1770.
[5] Alshamsi, A.M., Sabouni, A.R., Bushlaibi, A.H., (1993). “Influence of set retarding super plasticizers and micro silica on setting time of pastes at various temperatures”. Cement Concrete journal Res. 23(3). Pp 592-598
[6] Khayat, K.H., Aitcin, P.C., (1993). “Silica fume: a unique supplementary cementitious material”. In: Ghosh, S.N. (ed.) Mineral Admixtures in Cement and Concrete, vol. 4. Pp 227-265.
[7] Cohen, M. D., Bentur, A., (1988). “Durability of Portland silica fume pastes in magnesium and sodium sulphate solutions”. ACI Materials Journal. 85(3). Pp 148-157.
[8] Kumar, D., and Roy, S., “Effect of Partial Replacement of Cement by Silica Fume on Hardened Concrete”. International journal of engineering Technology and Advanced Engineering (ISSN 2250-2459, volume 2, issue 8, August 2012)
[9] IS 456-Part 4-2000, "Indian Standard Code of Practice for plain and reinforced concrete” .BIS, New Delhi.
[10] IS: 383-Part-2-1970,“Indian standard specification for coarse and Fine aggregates from natural source for concrete. BIS, New Delhi
[11] IS 2386-1963, "Indian Standard Methods of tests for aggregate” BIS, New Delhi.
[12] IS: 10262-1982, “Recommended guidelines for concrete mix design,” BIS, New Delhi.
[13] IS: 4031-PART 5-1988, “Methods of Physical Test for Hydraulic Cement”. BIS, New Delhi.
[14] IS: 516-1959, “Methods of test for strength of concrete.
[15] ASTM C496. “Standard method for determination of splitting tensile strength of concrete cylinders”.
[16] IS: 4031-Part 11-1988, “Methods of Physical Tests for Hydraulic Cement”. BIS, New Delhi.