PARTIAL REPLACEMENT OF CEMENT IN CONCRETE BY SILICA FUME

Shivam malviya[1], Arbaz baig[2], Yash Liladia[3]

[1]Shivam malviya, Dept. of civil Engineering, Swami Vivekananda College of engineering Indore, M.P
[2]Arbaz baig, Dept. of civil Engineering, Malwa Institute of Technology, Indore, M.P
[3]Yash Liladia, Dept. of Civil Engineering, Acropolis Technical Campus, Indore, M.P

Abstract – *The use of silica fume had a major impact on industries, the ability to routinely & commercially produce silica fume modified concrete of flowable in nature but yet remain cohesive, which in turn produces high early and later age strength including resistant to aggregate environments. This study is an experimental investigator on the nature of silica fume and its influence on the properties of fresh concrete. The cement is replaced by silica fume strength parameter of concrete have been studied. First, the strength parameter of concrete without any replacement was studied. Then strength parameter of concrete by partial replacement with silica fume has been studied. For the study, various cubes, cylinders, and beam have been prepared by replacing cement with 0, 5, 10 and 15 % silica fume. The result showed that partial replacement of cement with silica fume had a significant effect on compressive strength, flexural strength, split tensile strength. The strength of concrete increases rapidly as we increase the silica fume content and the optimum value of compressive strength is obtained at 10 % replacement. After 10% it starts decreasing.*

1. INTRODUCTION

Concrete is a most commonly used building material which is a mixture of cement, sand, coarse aggregate and water. It is used for construction of multi-storey buildings, dams, road pavement, tanks, offshore structures, canal lining. The method of selecting appropriate ingredients of concrete and determining their relative amount with the intention of producing a concrete of the necessary strength durability and workability as efficiently as possible is termed the concrete mix design. The compressive strength of harden concrete is commonly considered to be an index of its extra properties depends upon a lot of factors e.g. worth and amount of cement water and aggregates batching and combination placing compaction and curing. The cost of concrete prepared by the cost of materials plant and labor the variation in the cost of material begin from the information that the cement is numerous times costly than the aggregates thus the intent is to produce a mix as feasible from the practical point of view the rich mixes may lead to high shrinkage and crack in the structural concrete and to development of high heat of hydration is mass concrete which may cause cracking.

1.1 Cement

Cement is considered the best binding material and is being commonly used as a binding material in the construction of various engineering structures these days. Portland cement is referred to as ordinary Portland cement is the most important type of cement and is a fine powder produced by grinding Portland cement clinker. Concrete is prepared by Portland cement, water, and aggregates. Cement constitutes about 20 % of the total volume of concrete. Portland cement is a hydraulic cement that hardens in water to form a water-resistant composite. The hydration goods act as a binder to grip the aggregates together to form concrete. The name Portland cement comes from the fact that the color and class of the resulting concrete are comparable to Portland stone, a kind of limestone found in England.

2. OBJECTIVE

The objective of this study is to find the effect of partial replacement of silica fume on the workability, strength and durability characteristics of concrete. Three percentage levels of replacement i.e. 5, 10 and 15 percent are measured for partially replacing cement with silica fume. M25 concrete grade is initially designed without replacement and subsequently, cement is partially replaced with silica fume. Also, an attempt is made to find the optimum cement replacement level by silica fume for better strength and durability characteristics of High-Performance concrete. Hence, in the present investigation, more emphasis is given to study the strength and durability properties of High-Performance concrete using silica fume so as to achieve better concrete composite and also to encourage the increased use of silica fume to maintain ecology.

3. MIX DESIGN

Water cement ratio w/c = 0.45

water content = 197.4 kg/m^3

Cement content = (197.4/0.44) = 448.6 kg/m^3

Volume of all in aggregate = 1 – [{448.6/(3.15 x 1000)} + (197.4/1000)] = 0.660 m^3

A reduction of 0.05 in w/c will entail and increase of coarse aggregate fraction by 0.01.

Coarse aggregate fraction = 0.558 +.01 =.568

Volume of fine aggregate = 1 – 0.568 = 0.432

Mass of coarse aggregate = 0.660 x 0.568 x 2.84 x 1000 = 1064.65 kg/m^3 Mass of fine aggregate = 0.660 x 0.432 x 2.64 x 1000 = 752.71 kg/m^3

Cement = 358.9 kg/m^3

Water = 197.4 kg/m^3

FA = 821 kg/m^3

CA = 1070.75 kg/m^3

$$V = \left[W + \frac{C}{S_c} + \frac{1}{p}\frac{f_a}{S_{fa}}\right] \times \frac{1}{1000}$$

$$V = \left[W + \frac{C}{S_c} + \frac{1}{1-p}\frac{C_a}{S_{ca}}\right] \times \frac{1}{1000}$$

3.1 Mix Design for Cube

M25 = 1:1:2

For cube with 0% silica fume

Total volume of 1 cube = 8 kg

Total cube = 9

Total volume = 9 x 8 = 72 kg

Weight of Sand = 18 kg

Weight of Coarse aggregate = 36 kg ‘

Weight of Cement = 18 kg

Weight of Water 0.45 x 18 kg = 6.75 kg

For cubes with 5% silica fume

Total volume 1 cube = 8kg

Total cubes = 9

Total volume = 72 kg

Weight of Sand = 18 kg

Weight of Coarse aggregate = 36 kg

Weight of Cement = 0.95 x 18 = 17.1 kg

Weight of Silica fume = 0.05 x 18 = 900 gm

Weight of Water = 0.45 x 18 = 6.75 kg

For cube with 10% silica fume

Total volume of 1 cube = 8 kg

Total cube = 9

Total volume = 9 x 8 = 72 kg

Weight of Sand = 18 kg

Weight of Coarse aggregate = 36 kg ‘

Weight of Cement = 0.90 x 18 = 16.2 kg

Weight of Silica fumes = 0.10 x 18 kg = 1.8 kg

Weight of Water 0.45 x 18 kg = 6.75 kg

For cube with 15% silica fume

Total volume of 1 cube = 8 kg

Total cube = 9

Total volume = 9 x 8 = 72 kg

Weight of Sand = 18 kg

Weight of Coarse aggregate = 36 kg ‘

Weight of Cement = 0.85 x 18 kg =16.2 kg

Weight of Silica fume = 0.15 x 18 kg = 2.7 kg

Weight of Water 0.45 x 18 kg = 6.75 kg

3.2 Mix Design For Beam

For beam with 0% silica fume

Total volume of 1 beam = 12 kg

Total beam = 6

Total volume = 6 x 12 = 72 kg

Weight of Sand = 18 kg

Weight of Coarse aggregate = 36 kg ‘

Weight of Cement = 0.85 x 18 kg =16.2 kg

Weight of Silica fume = 0.15 x 18 kg = 2.7 kg

Weight of Water 0.45 x 18 kg = 6.75 kg

For beam with 5% silica fume

Total volume of 1 beam = 12 kg

Total beam = 6

Total volume = 6 x 12 = 72 kg

Weight of Sand = 21 kg

Weight of Coarse aggregate = 56 kg ‘

Weight of Cement = 0.95 x 27 = 25.65 kg

Weight of silica fume =0.05 x 27 kg = 1.35 kg

Weight of Water 0.45 x 12 kg = 12.15 kg

For beam with 10% silica fume

Total volume of 1 beam = 12 kg

Total beam =

Total volume = 6 x 12 = 72 kg

Weight of Sand = 21 kg

Weight of Coarse aggregate = 56 kg ‘

Weight of Cement = 0.90 x 27 = 24.3

Weight of silica fumes = 0.10 x 27 = 2.7 kg

Weight of Water 0.45 x 18 kg = 12.15 kg

For beam with 15% silica fume

Total volume of 1 beam = 12 kg

Total beam =

Total volume = 9 x 12 = kg

Weight of Sand = 21 kg

Weight of Coarse aggregate = 56 kg ‘

Weight of Cement = 0.85 x 27 = 22.95 kg

Weight of silica fume = 0.15 x 27 = 4.05 kg

Weight of Water 0.45 x 27 kg = 12.15 kg

3.3 Mix Design For Cylinder

For cylinder with 0% silica fume

Total volume of 1 cylinder = 12 kg

Total cylinder =

Total volume = 9 x 12 = kg

Weight of Sand = 21 kg

Weight of Coarse aggregate = 56 kg ‘

Weight of Cement = 0.85 x 27 = 22.95 kg

Weight of silica fume = 0.15 x 27 = 4.05 kg

Weight of Water 0.45 x 27 kg = 12.15 kg

For cylinder with 5% silica fume

Total volume of 1 cylinder = 12 kg

Total cylinder =

Total volume = 9 x 12 = kg

Weight of Sand = 21 kg

Weight of Coarse aggregate = 56 kg ‘

Weight of Cement = 0.85 x 27 = 22.95 kg

Weight of silica fume = 0.15 x 27 = 4.05 kg

Weight of Water 0.45 x 27 kg = 12.15 kg

For cylinder with 10% silica fume

Total volume of 1 cylinder = 12 kg

Total cylinder =

Total volume = 9 x 12 = kg

Weight of Sand = 21 kg

Weight of Coarse aggregate = 56 kg ‘

Weight of Cement = 0.85 x 27 = 22.95 kg

Weight of silica fume = 0.15 x 27 = 4.05 kg

Weight of Water 0.45 x 27 kg = 12.15 kg

For Cylinder with 15% silica fume

Total volume of 1 cylinder = 12 kg

Total cylinder =

Total volume = 9 x 12 = kg

Weight of Sand = 21 kg

Weight of Coarse aggregate = 56 kg ‘

Weight of Cement = 0.85 x 27 = 22.95 kg

Weight of silica fume = 0.15 x 27 = 4.05 kg

Weight of Water 0.45 x 27 kg = 12.15 kg

4. EXPERIMENTAL PROGRAM

To achieve the objectives of this study, an experimental programming was planned to investigate the effect of silica fume on compressive strength. This test has been conducted on cement, fine aggregate, coarse aggregate, water, silica fumes and on the hardened concrete specimen after suitable time period of curing 7, 14 and 28 days with and without replacement of cement with silica fume.

4.1 Compressive Strength of Concrete

There mix proportion was 1:1:2 (M-25), the water/cement ratio was kept as 0.5. Three cubes of each sample were prepared and cured for 7 days, 14 days and 28 days.

Experiment specimens of size 150mm�50mm�50mm were prepared for testing the compressive power concrete. The concrete mixes of changeable percentages (0%, 5%, 10%, 15%) of silica fume as partial substitution of cement were cast into cubes for subsequent testing. In this job, to build the concrete coarse aggregate of dimension 20mm, fine aggregates sand of zone II, Ordinary Portland cement (OPC), and Silica fume were assorted properly with right proportions for dry mix followed by addition of water and then mixed efficiently to achieve uniform and high workable mix. earlier than placing concrete in the moulds the interior face of the moulds and the base plates were oiled with oil before the concrete has been located than the concrete has been located in 150 mm �50 mm�50 mm cube. The concrete is packed up to 1/3rd height of the mould. Every coating is tamped at least 35 strokes of the tamping rod. After 24 hours the specimens were removed from the moulds and placed in clean fresh water at a temperature of 27 ± 2�. The sample was cast were experienced after 7, 14 and 28 days of curing calculated from the time specimen placed for curing.

The load was applied axially without shock till the specimen was compressed. Consequences of the compressive strength test on concrete with and without varying proportions (5%, 10% and 15%) of silica fume replacement at the age of 7days, 14 days and 28 days were noted. The cubes were tested using compression testing machine (CTM).

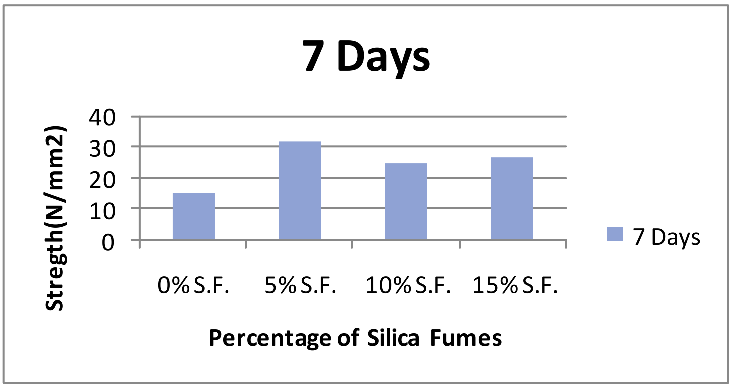
4.2 Test Procedure

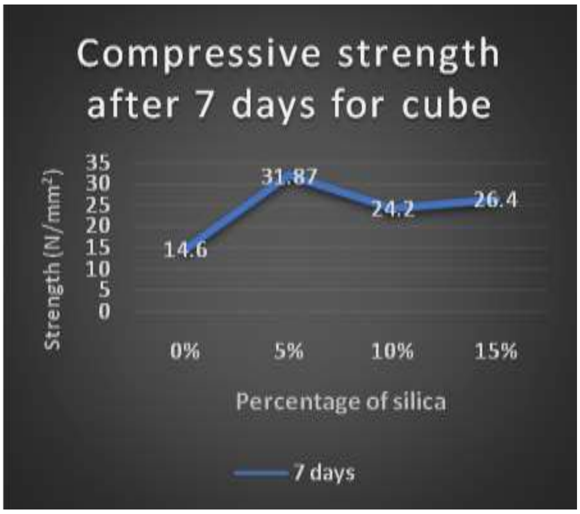
The compressive strength test was done by keeping test done by keeping the cubical specimens century on the location marked of the compression testing machine (CTM) and load was applied continuously, uniformly and without shock. The rate of loading was 250 KN/min. The load was increased till the specimen failed and 7 days, 14 days, 28 days strength was determined. The results are given in table.

5 TEST RESULT

5.1 Compressive strength after 7 days for cube

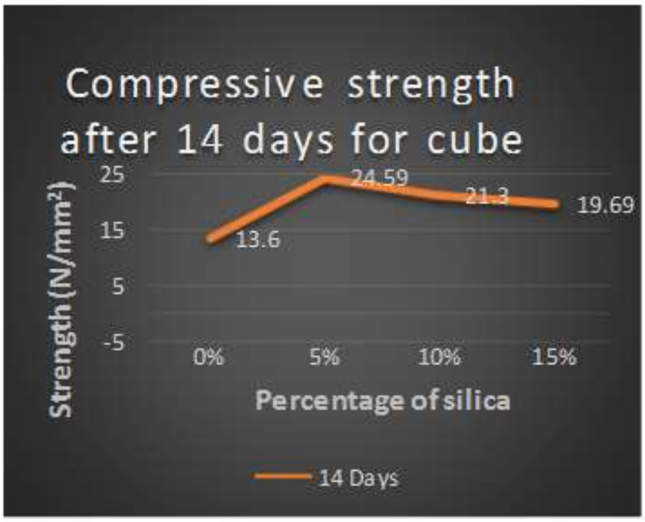
Sr. No.	Mix Description	Failure Load (KN)	Compressive Strength (N/mm2)	Average Compressive Strength (N/mm2)
1	0% S.F. + 100% Cement	249	11.11	14.6
		353.2	15.7	
		379.8	16.88	
2	5% S.F. + 95% Cement	430	32.44	31.87
		640	32.44	
		590	30.66	
3	10% S.F. + 90% Cement	540	24.88	24.2
		400	23.55	
		500	24	
4	15% S.F. + 85% Cement	470	28	26.46
		420	24.8	
		440	26.66	

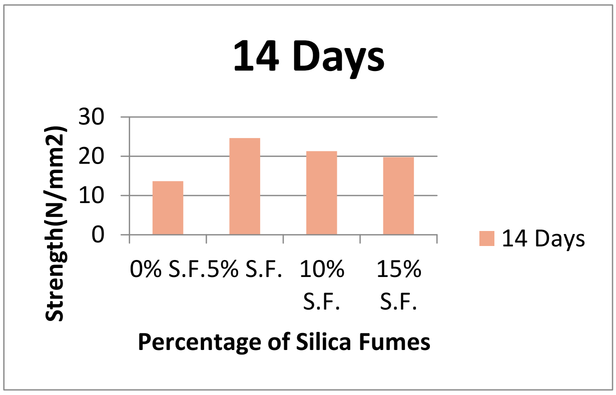




5.2 Compressive strength after 14 days for cube

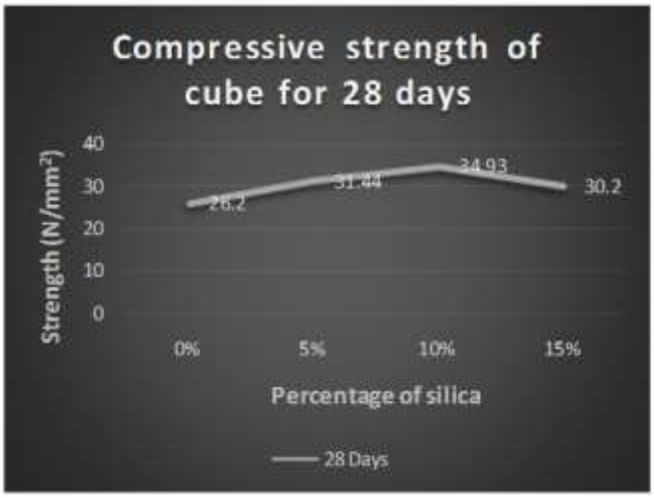
Sr. No.	Mix Description	Failure Load (KN)	Compressive Strength (N/mm²)	Average Compressive Strength (N/mm²)
1	0% S.F. + 100% Cement	1. 250	1. 15	13.6
		2. 355	2. 13	
		3. 380	3. 12.8	
2	5% S.F. + 95% Cement	1. 730	1. 19.11	24.59
		2. 730	2. 28.44	
		3. 690	3. 26.22	
3	10% S.F. + 90% Cement	1. 540	1. 24	21.3
		2. 398	2. 17.7	
		3. 500	3. 22.22	
4	15% S.F. + 85% Cement	1. 630	1. 20.88	19.69
		2. 560	2. 18.66	
		3. 600	3. 19.55	

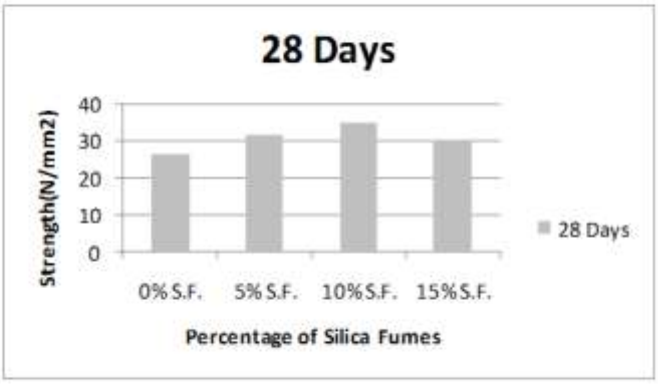




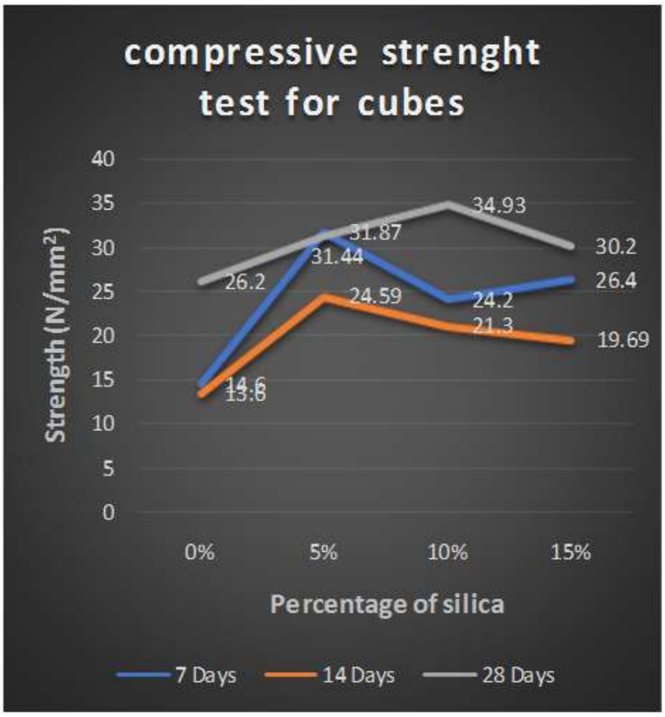
5.3 Compressive strength after 28 days for cube

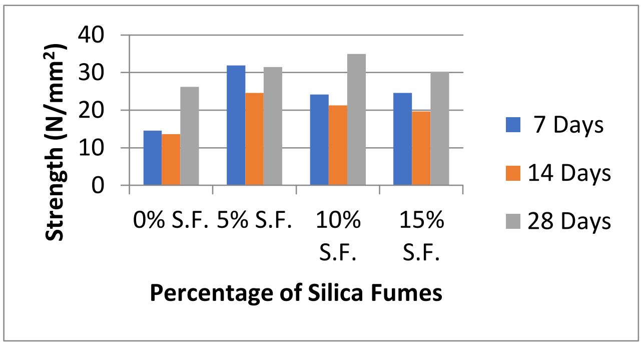
Sr. No.	Mix Description	Failure Load (KN)	Compressive Strength (N/mm²)	Average Compressive Strength (N/mm²)
1	0% S.F. + 100% Cement	1. 582.75	1. 25.9	26.2
		2. 571.5	2. 25.4	
		3. 614.25	3. 27.3	
2	5% S.F. + 95% Cement	1. 684	1. 30.4	31.44
		2. 724.5	2. 32.2	
		3. 713	3. 31.7	
3	10% S.F. + 90% Cement	1. 769.5	1. 35.4	34.93
		2. 746.7	2. 33.19	
		3. 814.5	3. 36.2	
4	15% S.F. + 85% Cement	1. 643.5	1. 28.6	30.2
		2. 711	2. 31.6	
		3. 684	3. 30.4	





5.4 Comparison of compressive strength at 7,14 & 28 days for cube.





6. DISCUSSION OF TEST RESULT

After adding 5% silica fume in the mix, there is an increase in the strength of cube after 7 days as compared to concrete without replacement. And after 14 days there is enormous increase in strength as compared to the control mix. By adding 10% silica fume, there is a gradual decrease in strength after 7, 14 and 28 days respectively. The Compressive strength tends to vary for different percentages of silica fume in the mix and decreases after 10% replacement. The optimum strength of cube is gain at 10% replacement for all 7, 14 days respectively.

7. CONCLUSIONS

In this project, an experimental study has been conducted on concrete by varying the percentage of silica fume as 0%, 5%,10% and 15% respectively to study the increase in the compressive strength of concrete. Based on the experimental investigation, the compressive strength was found to increase at 10% addition of silica fume in the concrete. The compressive strength was found to gradually decrease after 10% addition in the concrete. After performing the test and analyzing their result, the following conclusions have been derived:

The results achieved from the existing study shows that silica fume is great potential for the utilization in concrete as replacement of cement.

8. FUTURE SCOPE

Concrete is a mix of the ingredient of cement, fine aggregate, coarse aggregate & water. It can be molded into any form in the plastic stage. The relative quantity of ingredient controls the property on concrete in the wet stage as well as in the hardened stage. Before two or three decades ago, the manufacture of concrete for construction of structure with OPC with the ease of availability of component of concrete irrespective of quality was in practice without considering the future of concrete structure. Now with the passage of time in the modern era investigation since last two to three decades made by the Engineers & scientists keeping in view the structural stability of structure which needs quality concrete with improved strength, durability & other characteristics of concrete. The demand for these characteristics derives the search for supplementary cementitious materials. Search for any appropriate material in partial substitute of cement which is universally sustainable expansion and lowest possible environmental impact. Cement concrete is the most construction material today. We can say that we are living in the era of concrete. Concrete is prepared by mixing cement, aggregates & water. It is easy to make concrete but actually concrete is complex material. It is a site made material and such its quality, properties and performance can vary to a great extent due to the use of natural material except for cement. In the fast development of infrastructure in the country use of high strength in concrete using silica, fumes can be a key practice. As it increases the properties of concrete like strength, durability, workability and many others. And it is also cheaper than cement.

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