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Partial Replacement of OPC by Silica Fume with M60 Grade Concrete

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Abstract—*The aim of this study is to evaluate the performance effects on concrete by mineral admixture such as silica fume (as a partial replacement of cement) in concrete when it is mixed in cement concrete for workability, durability and strength of concrete using OPC (43 grade). Silica fume is a supplementary cementitious material that can be utilized to produce highly durable concrete composites. In this study, Silica fume has been used to replace OPC which varies from 2.5% to 10% at interval of 2.5% by total weight of OPC.A total ten mixes (trial mix, control mix and variation mix) were prepared for M60 grade of concrete. This study investigates the performance of concrete under influence of silica fume in terms of slump, compressive strength at 7 days and 28 days, flexural strength of beam at 28 days and splitting tensile strength of Cylinder at 28 days. Total number of specimens for cubes, cylinders and beams were 50, 30 and 30 respectively, which were casted for testing to study the influence of Silica fume on concrete. These Concrete specimens were deep cured in water under normal atmospheric temperature. On the basis of that result, by using Silica fume, concrete was found to increase in all strength (Compressive, Flexural & Splitting Tensile strength) and durability of variation mix of concrete on all age when compared to normal concrete. Its use should be promoted for better performance as well as for environmental sustainability.*

Keywords*: Concrete, Silica Fume, Workability, Compressive Strength, Flexural Strength, Splitting Tensile Strength*

1. INTRODUCTION

Concrete is a composite material which is prepared with mix of cement, fine aggregate, coarse aggregate and water. It can be widely used for any type of structure as per choice and demand and percentage constituents of concrete can be changed as per load and strength requirement of construction work. Concrete is economical as compared to steel structure and it has also low cost of maintenance, easy mechanism for work

Aggregates

Aggregates shall consist of naturally occurring (crushed or uncrushed) stones, gravel and sand or combination thereof. They shall be hard, strong, dense, durable, clear and free from adherent coating; and free from injurious amounts of disintegrated pieces, alkali, vegetable matter and other deleterious substances. As far as possible, flaky and elongated pieces should be avoided. There are mainly two type of aggregate which are used for this study are given as follows:

1. Coarse Aggregate
2. Fine Aggregate

Coarse Aggregate

It is the aggregate most of which is retained on 4.75 mm IS sieve and contains only so much finer material as is permitted for the various types described in IS-383:1970.

Fig. 1: Coarse Aggregate(20mm & 10mm)

According to size coarse aggregate is described as graded aggregate of its nominal size i.e. 40 mm, 20 mm, 16 mm, 12.5 and 10 mm etc. for example a graded aggregate of nominal size 20 mm means an aggregate most of which passes 20 mm IS sieve.

Table 1 Properties of Coarse Aggregate of 10mm &20mm size

Properties	Value	
	10mm	20mm
Density (OD)	1352 kg/m^3	1476 kg/m^3
Density (SSD)	1478 kg/m^3	1560 kg/m^3
Bulk Density (Dry)	1525 kg/m^3	1481kg/m^3
Sp. Gravity (OD)	2.62-2.65	2.62-2.65
Sp. Gravity (SSD)	2.60-2.65	2.60-2.65
Water Absorption	0.46%	0.46%

Fine Aggregate

It is the aggregate most of which passes 4.75 mm IS sieve and contains only so much coarser as is permitted by specification. According to size, the fine aggregate may be described as coarse sand, medium sand and fine sand. IS specifications classify the fine aggregate into four types according to its grading as fine aggregate of grading Zone-1 to grading Zone-4. These grading zone classified as per pecentage passing material from various sieves and there are mainly four zones and they all have different passing percentage

Fig. 2: fine aggregate(natural sand)

The fine aggregate is taken from Banas,Tonk,Rajashtan and designated IS- Sieve for the material passing through Zone-II is found.

Table 2: Properties of Natural Fine Aggregate

Properties	Value
Density (OD)	1625 kg/m^3
Density (SSD)	1675 kg/m^3
Bulk Density (Dry)	1625 kg/m^3
Bulk Density (SSD)	1675 kg/m^3
Sp. Gravity (OD)	2.62-2.65
Sp. Gravity (SSD)	2.60-2.65
Water Absorption	1.15 %

Cement

Cement is a binder, a substance that sets and hardens and can bind other materials together. Cements used in construction can be characterized as being either hydraulic or non-hydraulic, depending upon the ability of the cement to be used in the presence of water.

Fig. 3: OPC 43-Grade (Cement)

Table 3: Properties of Cement(OPC 43 grade)

Chemical Composition	Value
Surface Area	3000-3300 (cm^2/gm)
CaO	62%-67%
SiO_2	17% - 25%
Al_2O_3	3% - 8%
Fe_2O_3	3%-4%
MgO	0.1%-3%
SO_3	1%-3%
Na_2O	0%-0.5%
Gypsum ($CaSO_4.2H_2O$)	2.5%
Specific Gravity	3.05-3.15

Silica Fume

Silica fume is a product resulting from reduction of high purity quartz with coal in an electric arc furnace in the manufacture of silicon or ferrosilicon alloy. It cools, condenses and is collected in cloth bags. It is further processed to remove impurities and to control particle size. The use of silica fume in conjunction with super plasticizer has been the backbone of modern high performance concrete. Silica fume by itself, do not contribute to the strength dramatically, although it does contribute to the strength property by being very fine pozzolanic material and also creating dense packing and pore filler of cement paste. Silica fume also exhibits large reduction in bleeding and concrete with micro silica could be handled and transported without segregation.

Fig. 4: Silica fume

The mineral admixture is used for this experimental work is silica fume and properties (physical& chemical) are taken from the supplier M/S Elkem south Asia Pvt. Ltd. 307/308-B wing, Bsel Tech Park 3rd floor opp. Vashi railway station Navi Mumbai.

Table 4: Physical and Chemical Properties of Silica Fume

Properties	Approximate value
Surface Area	150000-200000 (cm^2/gm)
Specific gravity	2.21
SiO_2	90.2%
Al_2O_3	1.7%
Fe_2O_3	0.4%
CaO	2.1%
MgO	1.7%
Na_2O	0.7%
K_2O	0.7%
SO_3	0.5%

Chemical Admixture

Chemical admixtures are the ingredients in concrete other than Portland cement, water, and aggregate that is added to the mix immediately before or during mixing. Concrete producers use admixtures primarily to reduce the cost of concrete construction; to modify the properties of hardened concrete to ensure the quality of concrete during mixing, transporting, placing, and curing and to overcome certain emergencies during concreting operations. There are various type of chemical admixture which are used in construction such as retarding admixture, accelerating admixture, water reducing admixture, air-entraining admixture, super plasticizing admixture and retarding super plasticizing admixture.

Super plasticizers, also known as plasticizers or high-range water reducers (HRWR), reduce water content by 12 to 30 percent and can be added to concrete with a low-to-normal slump and water-cement ratio to make high-slump flowing concrete. In this thesis i.e. naphtha based water reducing super plasticizer as per IS 9103:1999 used. The super plasticizer which was used for the experimental performance is Kavassu Plast SP-431/ Shaliplast SP-431.

Table 5: Properties of Chemical Admixture

Properties	Sulphonated Naphthalene Formaldehyde (Value)
Type of admixture	Super plasticizer chloride free, as per ASTM C 494 & IS: 9103
SP. GRAVITY@27ºC	1.20 ± 0.04
DRY MATERIAL %	41- 45 %
CHLORIDE %	NIL
ALKALIES	NIL
ASH CONTENT	10.00 - 14.00%
PH	7-9
COLOUR	Faint Black Brown Liquid

2. RESULTS AND DISCUSSIONS

Introduction

In this chapter, the results of experimental work have been analyzed and tabulated for all blends/mixes in which there was lot of variations in results of different mixes. Results have been tabulated and have also been graphically presented for density, slump, compressive, flexural and split tensile strength.

The variations have been made with cement by replacing percentage of cement with silica fume which varies from (silica fume 0% to 10% at interval of 2.5%) for both concrete mixes of M60.

Tests have been conducted for results of slump, density, compressive strength, flexural strength & splitting tensile strength.

3. RESULTS OF CONCRETE

Workability Test Result

Slump of all mixes are taken and shown in tabular form and graphical form. The design slump was 152 mm and the maximum slump value found was 166mm for M60 grade concrete. Many variations have been seen while checking for slump of different concrete mixes. The variations have been made with cement by replacing percentage of cement with silica fume which varies from (silica fume 0% to 10% at interval of 2.5%) for concrete mix of M60. The results are tabulated and graphs plotted based on these results are as follows:-

Table 6: Slump on Replacement of OPC by Silica Fume for M60

Sl. No	%Mix (Cement + Silica Fume)	Slump (mm)
1.	OPC+ SF (100+0)	166
2.	OPC+ SF (97.5+2.5)	162
3.	OPC+ SF (95+5)	158
4.	OPC+ SF (92.5+7.5)	155

Sl. No	%Mix (Cement + Silica Fume)	Slump (mm)
5.	OPC+ SF (90+10)	152

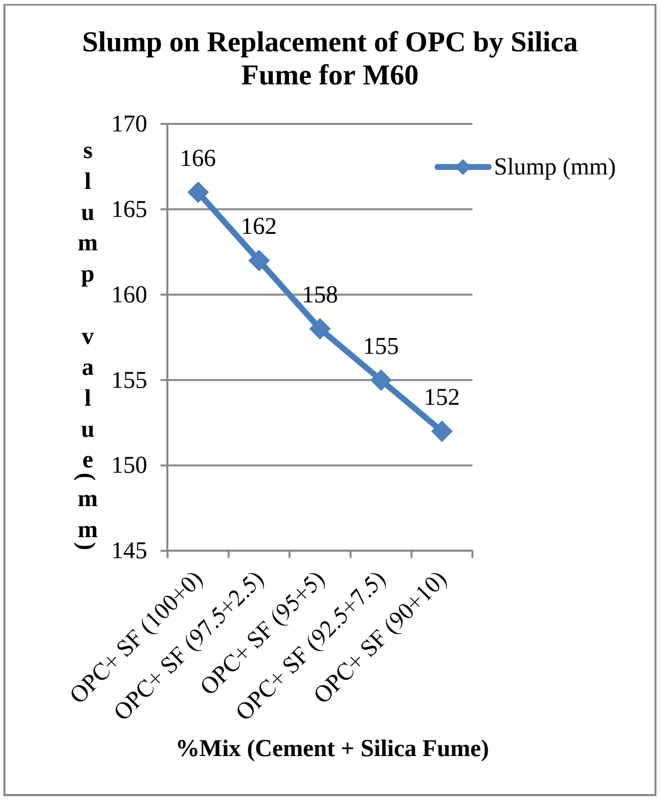

Fig. 5: Effects of Silica fume on Slump of Concrete (M60) on Replacement

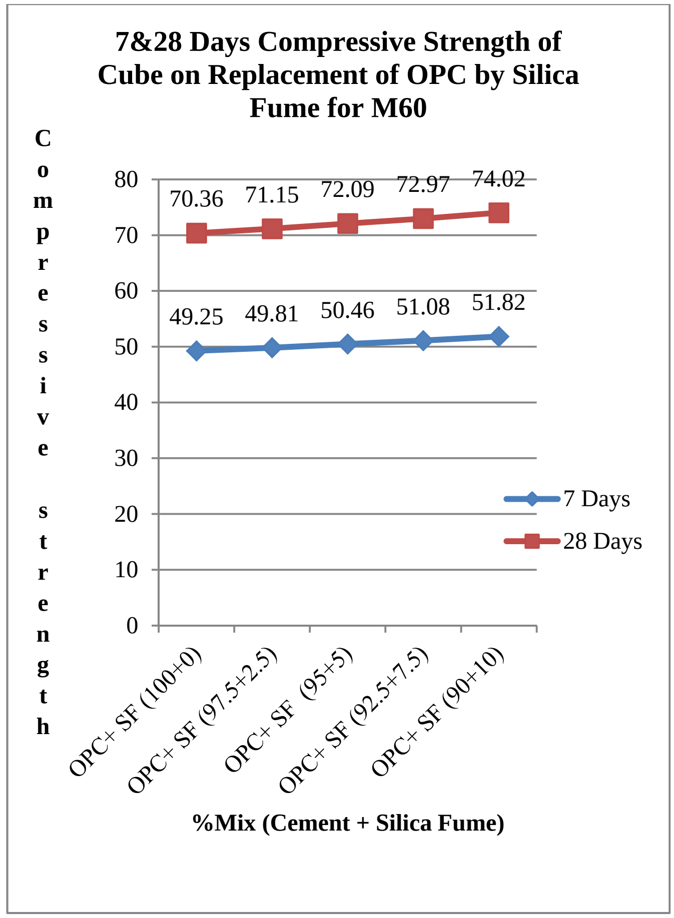

Fig. 6: Effects of Silica fume on Concrete of M60 Grade on Replacement for 7 Days&28 Days Compressive Strength of Cube

Table 7: 7&28 Days Compressive Strength of Cube on Replacement of OPC by Silica Fume for M60

Sl. No	%Mix (Cement + Silica Fume)	Average For Compressive Strength M60 (N/mm^2)	
		7 Days	28 Days
1	OPC+ SF (100+0)	49.25	70.36
2	OPC+ SF (97.5+2.5)	49.81	71.15
3	OPC+ SF (95+5)	50.46	72.09
4	OPC+ SF (92.5+7.5)	51.08	72.97
5	OPC+ SF (90+10)	51.82	74.02

Table 8: 28 Days Flexural Strength of Beam on Replacement of OPC by Silica Fume for M60

Sl. No	%Mix (Cement + Silica Fume)	Average For Flexural Strength M60 (N/mm^2)
1	OPC+ SF (100+0)	8.44
2	OPC+ SF (97.5+2.5)	8.54
3	OPC+ SF (95+5)	8.65
4	OPC+ SF (92.5+7.5)	8.76
5	OPC+ SF (90+10)	8.88

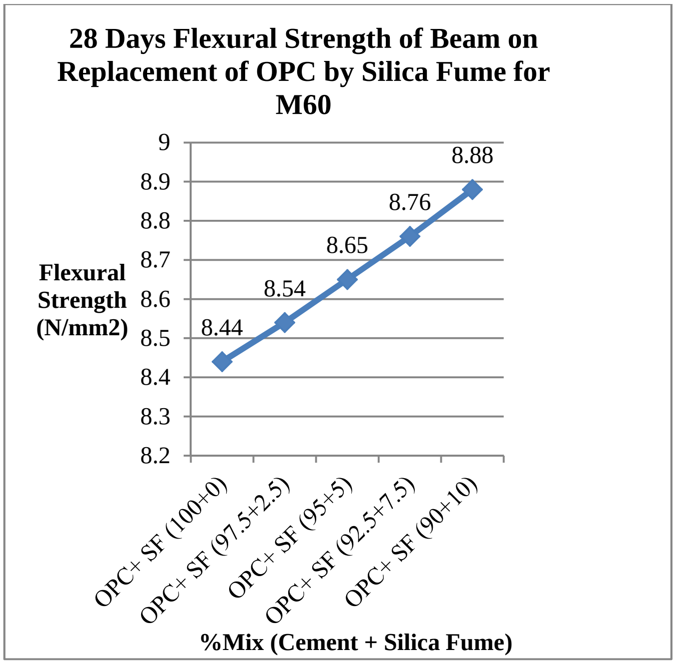

Fig. 7: Effects of Silica fume on Concrete of M60Grade on Replacement for 28 Days Flexural Strength of Beam

Table 9 28Days Splitting Tensile Strength of Cylinder on Replacement of OPC by Silica Fume for M60

Sl. No	%Mix (Cement + Silica Fume)	Average For Splitting Tensile Strength M60 (N/mm2)
1	OPC+ SF (100+0)	5.63
2	OPC+ SF (97.5+2.5)	5.69
3	OPC+ SF (95+5)	5.77
4	OPC+ SF (92.5+7.5)	5.84
5	OPC+ SF (90+10)	5.92

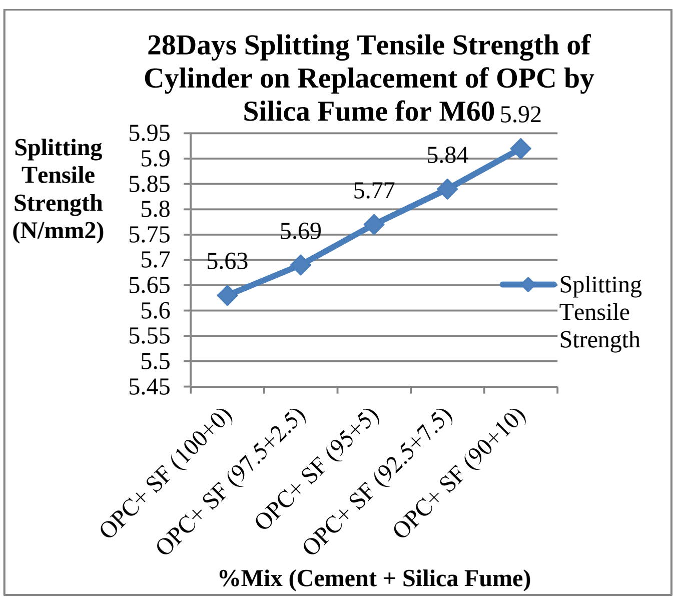

Fig. 8: Effects of Silica fume on Concrete of M60 Grade on Replacement for 28 Days Splitting Tensile Strength of Cylinder

4. CONCLUSION

When silica fume was replacing OPC from 0% to 10% with increment of 2.5% to OPC in higher grade of concrete M60.The best result were found by replacing silica fume 10% by weight of cement

The various properties are change as follows.

1. **Slump-** Higher slump was found as 166 mm in M60 on replacement of cement by silica fume
2. **Density-** A minor increment in Density when silica fume was replace 7.5% by weight of cement by weight of cement.
3. **Compressive Strength-** Maximum compressive strength observed was 74.02 N/mm^2(when 10% silica fume was replaced by weight of OPC) which was 5.20% greater than control mix M60.
4. **Flexural Strength-** maximum flexural strength observed was 8.88 N/mm^2(when 10% silica fume was replaced by weight of OPC) which was 5.21% greater than control mix M60.
5. **Splitting Tensile Strength-** maximum split tensile strength observed was 5.92 N/mm^2(when 10% silica fume was replaced by weight of OPC) which was 5.15% greater than control mix M60.

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