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Strength and Durability Study on Concrete Incorporating with Mineral Admixture

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ABSTRACT: In this study, effects of silica fume on strength and durability were experimentally investigated. The main parameter investigated in this study is M₄₀ grade concrete with partial replacement of cement by silica fume. They were incorporated into concrete at the levels of 0%, 5%, 10%, 15% and 20%. This paper presents a detailed experimental study on compressive strength, split tensile strength and flexural strength at an age of 7, 14 and 28 days. Durability study on water absorption, acid resistance and sulphate attack was also studied and percentage of weight loss is compared with normal concrete. While test result indicate the use of silica fume in concrete has improved the performance of concrete in strength as well as in durability aspect.

KEYWORDS: Silica fume, Fly ash, Compressive Strength, Split tensile strength, Flexural strength, Durability, Acid resistance, Sulphate attack, Water absorption.

I. INTRODUCTION

Concrete is a widely used construction material for various types of structures due to its structural stability and strength. The usage, behavior as well as the durability of concrete structures, built during the last first half of the century with Ordinary Portland Cement (OPC) and plain round bars of mild steel, the ease of procuring the constituent materials (whatever may be their qualities) of concrete and the knowledge that almost any combination of the constituents leads to a mass of concrete have bred contempt. The Ordinary Portland Cement (OPC) is one of the main ingredients used for the production of concrete and has no alternative in the civil construction industry. The search for any such material, which can be used as an alternative or as a supplementary for cement should lead to global sustainable development and lowest possible environmental impact. Substantial energy and cost savings can result when industrial by products are used as a partial replacement of cement. Fly ash, Ground Granulated Blast furnace Slag, Rice husk ash, High Reactive Met kaolin, silica fume are some of the pozzolanic materials which can be used in concrete as partial replacement of cement. A number of studies are going on in India as well as abroad to study the impact of use of these pozzolanic materials as cement. Fly ash, Ground Granulated Blast furnace Slag, Rice husk ash, High Reactive Metakaolin, silica fume are some of the pozzolanic materials which can be used in concrete as partial replacement of cement. A number of studies are going on in India as well as abroad to study the impact of use of these pozzolanic materials as cement replacements and the results are encouraging. The strength, durability and other characteristic of concrete depends on the properties of its ingredients, proportion of mix, method of compaction and other controls during placing and curing.

II. MATERIAL PROPERTIES

2.1. SILICA FUME

Silica fume used in high performance concrete is in the form of microscopic glassy spherical particles. The average particle size of silica fume used is 0.12 to 0.2 micron, which is nearly 100 times smaller than that of a cement grain. The low bulk density makes it difficult to handle, store and transport. Therefore, it is processed and supplied in a

densities form. Silica fume due to its physical and chemical properties is very efficient as compared to cement and fly ash in enhancing performance of the concrete. The properties of silica fume are shown in Table.2. 1.

Table.2. 1: Properties of silica fume

S.NO.	Physical properties	Result
1.	Specific Gravity	2.2
2.	Bulk Density	576 (Kg/m3)
3.	Size , (Micron)	0.1
4.	Surface Area , (m2/kg)	20,000

2.2. FLY ASH

Fly ash is like a slag an industrial waste that is widely used as mineral admixture in the cement and concrete industry the chemical composition of fly ash depends on the composition of the original coal ash. Fly ash improves concrete's workability, pump ability cohesiveness, finish, ultimate strength and durability as well as solves many problems experienced with concrete today and all for less cost. The properties of fly ash are shown in Table.2.2.

Table 2.2: Properties of fly ash

S.NO.	Physical properties	Result
1.	Specific gravity	2.12
2.	Physical form	Powder
3.	Size (Micron)	0.1
4.	Colour	Dark grey

2.3. SUPER PLASTICIZERS

Super plasticizer named Conplast SP430 is used. It helps in dispersing cement particles, and they can reduce mixing water requirements by up to 30%, thereby increasing the concrete compressive strengths. The super plasticizer is brought from. The Sulphonated Naphthalene Formaldehyde based super plasticizer (Conplast Super Plasticizer – SP 430). The properties of super plasticizer are shown in the Table.2.3.

Table.2.3 Physical properties of super plasticizer

S.NO	Property	Value
I.	Solid content	42%
II.	Specific gravity	1.22

III.MIX DESIGN

3.1 GENERAL

The process of selection suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of the required strength, durability, and workability as economically as possible, is termed the concrete mix design. The proportioning of ingredient of concrete is governed by the required performance of concrete in two states, namely the plastic and the hardened states. If the plastic concrete is not workable, it cannot be properly placed and compacted. The property of workability therefore becomes of vital importance.

MIX PROPORTIONS

Cement	= 270 kg/m ³
Fly Ash	= 115 kg/m ³
Water	= 140 kg/m ³
Fine aggregate	= 869 kg/m ³
Coarse aggregate	= 1106kg/m ³
Chemical admixture	= 7.7 kg/m ³

Table.3.1. Mix proportioning

Mix proportions	Cement kg/m ³	Fine aggregate kg/m ³	Coarse aggregate kg/m ³	Water kg/m ³	Chemical admixture kg/m ³	Fly ash kg/m ³	Silica fume kg/m ³
Mix 1(0%)	270	869	1106	140	7.7	115	0
Mix 2(5%)	270	869	1106	140	7.7	109.25	5.75
Mix 3(10%)	270	869	1106	140	7.7	103.5	11.5
Mix 4 (15%)	270	869	1106	140	7.7	97.75	17.25
Mix 5(20%)	270	869	1106	140	7.7	92	23

IV. MECHANICAL PROPERTIES

4.1. Compression Test (Ref: IS: 516-1959)

Compression test 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 characteristics properties of concrete are qualitatively related to its compressive strength. Compressive strengths were attained as a result of the compressive tests conducted on the cube specimens of size 100mm x 100mm x 100mm. Cube was placed on the platform of the compression testing machine. The load was applied gradually till the concrete cubes get failed. The specimens are subjected to compressive loads in compression testing machine as per IS: 516-1969 and the crushing load is noted which gives the compressive strength of that cube. The compressive strength is the ratio of crushing load to the surface area of the specimens expressed in N/mm². Similarly the compression strength values of all the cubes are found.

4.2. Flexure Test (Ref: IS: 516-1959)

The flexural strength represents the highest stress experienced within the material at its moment of rupture. It is measured in terms of stress, here given the symbol f_{cr} . The flexural strengths of the respective specimens have been obtained from the flexural tests performed on the prism specimens of size 100mm x 100mm x 500mm. The flexural strength are tested using a two point loading frame machine as per standard.

The modulus of rupture can be determined by using the formula given below

$$f_{cr} = (P_{max} \times l) / bh^2$$

Where,

- fcr = Flexural strength
- P_{max} = maximum load in (N) kg.
- b = width of the prism in mm

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h = depth of the prism in mm

l = span of the prism in mm

The loading must be applied centrally and without subjecting the specimen to any tensional stresses and restraints. The axis of the specimen shall be carefully aligned with the axis of the loading device. The load shall be applied without any shock and increasing continuously at specified rate.

4.3. Split tensile strength Test (Ref: IS: 5816-1999)

Split tensile strength of concrete is usually found by testing plain concrete cylinders. Cylinders of size 150mm x 300 mm were casting using M₄₀ grade concrete. Specimens with Conventional Concrete of different percentages were casted. During casting the conventional concrete cubes were manually compacted using tamping rods. After 24hours, the specimens were removed from the mould and subjected to water curing for 7, 14, 28 days. After curing, the specimens were tested for compressive strength as per IS: 5816-1999 using a calibrated compression testing machine of 2000KN capacity.

Two packing strips of plywood 3mm thick were provided between the specimen one at top and another at bottom. The specimen was placed on the plywood strip and aligned so that, the central horizontal axis of the specimen is exactly perpendicular to the load applying axis. The second plywood strip was placed length wise on the cylinder and the top platen was brought down till it touched the plywood. The load was applied without shock and increased continuously until the resistances of the specimen to the increasing load broke down and no greater load can be sustained.

$$\text{Tensile strength of concrete } f_t = \frac{2p}{\pi dl}$$

Where,

P	=	Maximum load in N applied to the specimen
L	=	Measured length in cm of the specimen
D	=	Measured diameter in cm of the specimen

V.RESULTS AND DISCUSSION

5.1 GENERAL

This chapter deals with the results obtained from the various experiments conducted to access mechanical properties. The aim of the study is to determine the compressive strength, flexural strength, split tensile strength and modulus of elasticity. The results of test specimens are presented. The discussion on the results also presented in this chapter.

5.2 MECHANICAL PROPERTIES

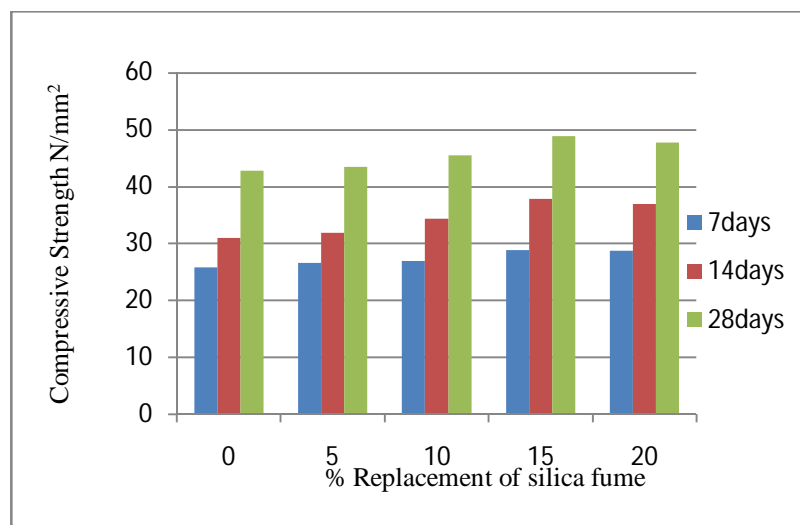
The mechanical properties of concrete such as compressive strength, flexural strength, modulus of elasticity are determined from the standard experiments. They are as follows.

5.2.1 Compressive Strength

The compressive strength of replacement of silica fume is arrived. The compressive strength value for replacement of silica fume compression test results shows in Table 5.1.

Table 5.1: Compressive Strength of Cubes with Partial Replacement of silica fume

COMPRESSIVE STRENGTH N/mm ²	REPLACEMENT PERCENTAGE				
	0%	5%	10%	15%	20%
7 days	25.78	26.54	26.92	28.80	28.65
14 days	30.91	31.85	34.35	37.80	36.96
28 days	42.75	43.44	45.49	48.80	47.70

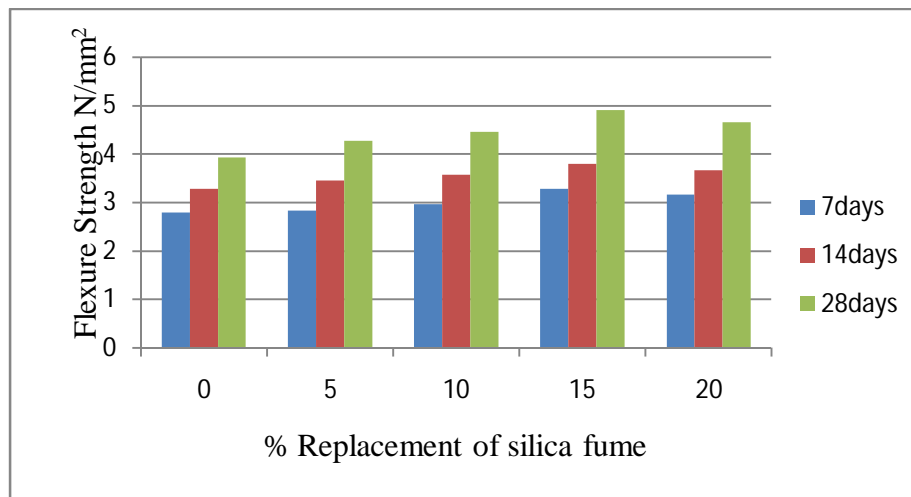


5.2.2 FLEXURAL STRENGTH

The flexural strength of replacement of silica fume is arrived. Table 5.2 shows flexural strength test results.

Table 5.2: Flexural Strength of Beams with Partial Replacement of silica fume

FLEXURAL STRENGTH N/mm ²	REPLACEMENT PERCENTAGE				
	0%	5%	10%	15%	20%
7 days	1.94	2.16	2.40	2.55	2.46
14 days	2.66	2.77	3.25	3.67	3.61
28 days	3.73	3.87	4.21	4.47	4.31

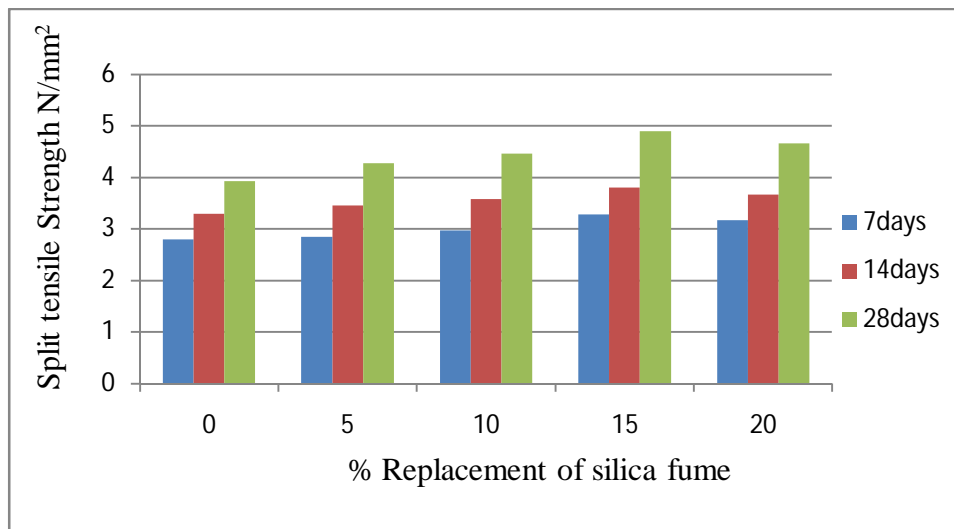


5.2.3 SPLIT TENSILE STRENGTH

The split tensile strength of replacement of silica fume is arrived. The split tensile strength value for replacement of silica fume is shown in Table 5.3.

Table 5.3. Split tensile strength of Cylinder with Partial Replacement of silica fume

SPLIT TENSILE STRENGTH N/mm ²	REPLACEMENT PERCENTAGE				
	0%	5%	10%	15%	20%
7 days	2.80	2.84	2.97	3.28	3.17
14 days	3.29	3.45	3.58	3.80	3.67
28 days	3.93	4.27	4.46	4.90	4.66



VI. DURABILITY TEST

6.1. WATER ABSORPTION

The water absorption values for various mixtures of concrete were determined on 100mm x 100mm x 100mm cubes as per ASTM C 642. Concrete cube specimens were cast and kept in the aggressive medium for the period of 28 days. After 28 days specimens were taken out and placed in oven dry at the temperature of 105°C to remove the moisture content. Then the dry weight of the specimen was measured by using electronic weighing balance and the specimens were immersed in curing tank. After 3 days of water immersion, the specimens were taken out. Dried and wet weights were recorded. Amount of water absorption were calculated with reference to dry weight of the specimen.

$$WA = ((W_2 - W_1) / W_1) * 100$$

Where,

WA - Saturated Water Absorption in percentages

W₂ - Weight of the specimen at fully saturated condition in grams,

W₁ - Weight of oven dried specimens in grams

6.2. SULPHATE RESISTANCE TEST

The acid resistance tests are carried out 100x100x100 mm size cube specimens at the age of 28 days curing. Then the cube specimens are allowed to dry and note the initial weight. The surface of the specimen is thoroughly prepared. Then 5% Na₂SO₄ is mixed per litre of ordinary water. Cube specimens are then immersed completely in the sulphate solution for 28 days. After 28 days the cube specimen are taken out from the sulphate solution and kept dried. Then the specimens are weighed and tabulated.

6.3. ACID RESISTANCE TEST

The acid resistance tests are carried out 100x100 mm size cube specimens at the age of 28 days curing. Then the cube specimens are allowed to dry for 5 days and note the initial weight. The surface of the specimen is thoroughly prepared. Then 5% HCL is mixed per litre of ordinary water. Cube specimens are then immersed completely in the acid solution for 28 days. After 28 days the cube specimen are taken out from the acid solution and kept dried. Then the specimens are weighed and tabulated.

VII.DURABILITY TEST RESULTS FOR CONCRETE

7.1. WATER ABSORPTION

The water absorption test results are shown in table 7.1.

TABLE.7.1.TEST RESULT FOR WATER ABSORPTION TEST

REPLACEMENT PERCENTAGE OF SILICA FUME	WET WEIGHT (Kg)	DRY WEIGHT(Kg)	WATER ABSORPTION
0%	2.51	2.42	3.58
5%	2.52	2.44	3.17
10%	2.53	2.47	2.37
15%	2.58	2.55	1.16
20%	2.56	2.50	2.34

7.2. ACID RESISTANCE TEST

The acid resistance test results are shown in table 7.2.

TABLE.7.2.RESULTS OF ACID RESISTANCE TEST

REPLACEMENT PERCENTAGE OF SILICA FUME	DRY WEIGHT (Kg)	WEIGHT AFTER IMMERSSED IN ACID (Kg)	WEIGHT LOSS (%)
0%	2.411	2.318	3.86
5%	2.425	2.338	3.59
10%	2.438	2.354	3.44
15%	2.442	2.367	3.07
20%	2.457	2.377	3.26

7.3. SULPHATE RESISTANCE TEST

The sulphate resistance test results are shown in table 7.3.

TABLE.7.3.RESULTS OF SULPHATE RESISTANCE FOR SILICA FUME

REPLACEMENT PERCENTAGE OF SILICA FUME	DRY WEIGHT (Kg)	WEIGHT AFTER IMMERSSED IN ACID (Kg)	WEIGHT LOSS (%)
0%	2.319	2.229	3.88
5%	2.436	2.349	3.57
10%	2.449	2.365	3.42
15%	2.453	2.378	3.05
20%	2.361	2.281	3.38

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VIII.CONCLUSION

The compressive strength of concrete increased when cement is replaced by silica fume for m40 grade of concrete at 15% replacement, the compressive strength has maximum. The split tensile strength of concrete is also increased when cement is replaced by silica fume at 15% replacement; the split tensile strength has maximum. The flexural strength of the concrete is also increased when cement is replaced by silica fume at 15% replacement, the flexural strength has maximum. Test results shows that use of silica fume in concrete has improved the performance of concrete in strength at a 15% percentage replacement. Although the highest compressive strengths of concretes observed was 15% silica fume mix for ordinary Portland cement and were reduced as the increase in the replacement ratios. When compared to other mix, the loss in weight percentage has found to be reduced when cement is replaced by 15% of silica fume.

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