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Experimental Performance Analysis And Optimization of Concrete Using Silica Fume And Superplasticizers

N.Vasu Nithyanandam[1] P.S.Kumar[2]

[1]*Teaching Fellow, Department of Civil Engineering, University College of Engineering Ariyalur, Tamilnadu, India*
[2]*Professor, Department of Civil Engineering, University College of Engineering Ariyalur, Tamilnadu, India*

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ABSTRACT- *Improvements to current materials enable technological growth and the creation of more reliable structures without overdesigning in the engineering industry. High-performance concrete (HPC), a common material in heavy structural building, is a low-cost, durable material that may be studied to achieve its best performance. Both the increased strength and the improved microstructure can be used in high-performance concrete constructions. Both features are produced by the use of advanced concrete technology, which includes a very low water-cement ratio as well as the use of silica fume and superplasticizers. At the micro-level, silica fume changes the interfacial transition zone between cement paste and aggregate. When compared to conventional concrete, the properties of both fresh and hardened concrete are significantly altered. This project focuses on an effective dosage of silica fume in high-performance concrete, ranging from 0 to 30% by cement weight. Specimens are cast by replacing cement with silica fume at different percentages, such as 10%, 20%, and 30% by weight of cement. Strength properties such as compressive and tensile strength are assessed.*

Keywords - *Compressive Strength, Flexural Strength, Split Tensile Test, Silica Fume.*

I. INTRODUCTION

When compared to regular concrete, high-performance concrete is a concrete composition with superior durability and strength. One or more cementious ingredients, such as fly ash, silica fume, or crushed, granulated blast furnace slag, are used in this concrete, as well as a superplasticizer. The name "high performance."

It is a little pretentious because the main feature of this concrete is that its materials and quantities are carefully chosen to have properties that are particularly appropriate for the structure's intended use, such as high strength and low permeability. As a result, high-performance concrete isn't a distinct type. It is made out of the same components as traditional cement concrete. Some mineral and chemical admixtures, such as silica fume and superplasticizer, greatly improve the strength, durability, and workability of the material.

Despite its greater initial cost, high-performance concrete proves to be more cost-effective than standard concrete since it extends the structure's service life and causes less damage, lowering overall costs.

High-performance concrete can be developed to provide optimized performance characteristics for a specific set of load, usage, and exposure situations while still meeting cost, service life, and durability requirements. HPC is emerging as a construction material that will suit the essential twin function of strength and durability in the current context. While satisfying cost, service life, and durability requirements, high-performance concrete can be produced to deliver optimized performance characteristics for a specific set of load, usage, and exposure scenarios. In the contemporary setting, HPC is emerging as a construction material that will provide the critical dual functions of strength and durability.

The water-cement (w/c) ratio is the most important factor in the mix design of normal strength concrete (NSC). The difficulty of proportioning concrete mixtures, which now involves more factors than before, has gotten increasingly complicated in recent years. In high-strength concretes (HSC), however, all of the concrete mixture's components are pushed to their limits. There are other elements to consider in the case of HPC, making the selection of ingredients and their right amounts complex. Using the usual empirical approach of making alternative trial mixes of all possible combinations to arrive at the best blend is also uneconomical and time-demanding. As a result, existing mix design methodologies that are routinely used to create NSC mixes cannot be easily transferred to creating HPC mixes. HPC has a different mix design than regular concrete for the following reasons: The water-to-cement ratio is extremely low. Cement replacement compounds are frequently used in concrete, which substantially alters the properties of both fresh and cured concrete. • Using high range water reducing admixture (HRWRA), the slump or compaction factor can be modified without changing the water content.

APPLICATIONS

- As an alternative to steel constructions, this form of concrete is commonly utilized for columns, walls, and other structural elements in high-rise buildings.
- The dense microstructure of HPC is primarily used in situations where additional protection measures are required in normal concrete constructions due to chemical attacks or abrasion.
- The amount of concrete used in the construction of various hydroelectric structures is huge. Its components are lined/coated with high-performance concrete, allowing them to endure high water velocities and a large amount of silt.
- These are utilized in infrastructure such as bridges to provide early high strength, greater span, and decreased member depths, among other benefits.

II. SCOPE AND OBJECTIVE

The purpose of this study is to develop a simplified mix design technique for HPC by altering the percentage substitution of cement by silica fume at 0%, 10%, 20%, and 30% while maintaining a consistent superplasticizer dosage based on Indian standards. HPC can be made using common components and mineral admixtures. Aside from the increase in compressive strength, the durability of the material is also improved. Construction is completed faster, with greater aesthetics, superior durability, and permeability against corrosion, abrasion, and longer life, to increase the concrete mechanical qualities as well as its endurance in the face of harsh environmental and loading conditions.

III. MATERIALS

The properties of the materials utilized in this study were determined by testing cement, fine aggregate, and coarse aggregate; the test results are listed below.

A. Cement

The cement used is ordinary Portland cement 43 grade. To avoid lumps, the cement was packaged in normal gunny bags and afterward stored in an airtight container.

B. Fine Aggregate:

River sand was used as the fine aggregate for all of the specimens. The sand was sieved, and the maximum fine aggregate size was determined to be 4.75 mm. The sand was tested according to Indian Standard Specification IS 383-1970. Fine aggregate has a specific gravity of 2.61.

C. Coarse Aggregate:

The type of coarse aggregate used was irregularly shaped aggregates with a rough surface. The aggregate was crushed stone with a nominal maximum size of 20 mm. The aggregates' physical parameters were determined according to IS: 2386-1997. The value of a coarse aggregate is the specific gravity of 2.78.

D. Water

Concrete examples were mixed and cured using water from the campus.

E. Properties of Silica fume

Table I lists the physical properties of the Silica fume employed in this study. The Chemical Composition of Silica Fume is shown in Table II.

TABLE I
PHYSICAL PROPERTIES OF SILICA FUME

Si. No	Properties	Values
1	Specific gravity	2.2
2	Mean grain size (μm)	0.1
3	Specific area (cm^2/g)	200000
4	Color	Light to dark grey

TABLE II
CHEMICAL COMPOSITION OF SILICA FUME

Si No	Oxide	% content
1	SiO_2	96.0
2	Al_2O_3	0.1
3	Fe_2O_3	0.6
4	CaO	0.1
5	MgO	0.2
6	SO_3	-
7	Na_2O	0.1
8	K_2O	0.4
9	Loss ignition	1.7

F. Admixture

It is added in a calculated amount of 0.3% of the cement's weight. When a high degree of workability and retention is necessary, delays in transportation or placement are probable, or high ambient temperatures cause rapid slump loss, Conplast SP430 is utilized. It makes it easier to make high-quality concrete.

IV. CONCRETE MIX DESIGN

Mix Design for M50 Concrete (Is 10262:1982) is listed in Table III.

TABLE III
MIX DESIGN FOR M_{50} CONCRETE

Water	Cement	Fine Aggregate	Coarse Aggregate
0.35	1	1.472	3.043

V. TESTING

A. Compressive Strength (Cube Strength)

For the compression test, the specimen measured 150mm x 150mm x 150mm in size. The Compression Testing Machine is depicted in Fig. 1. The test was conducted on cube specimens in cubes, not to the top and bottom. The specimen's axis was precisely aligned with the center of the spherically seated plate's thrust.

$$f = P/A \text{ N/mm}^2$$

Where
f is the compressive stress in N/mm^2
p is the load at which specimen fails in N
A is the area over which the load is applied in mm^2

Table 4 describes the compressive test results for 3 days, 7 days, and 28 days.

Fig. 1 Compression Testing Machine

TABLE IV
COMPRESSIVE TEST RESULTS

Specimen	Age of curing in days	Percentage of replacement of SilicFume			
		100%	**90%**	**80 %**	**70%**
Cube	3	24.31	29.22	38.34	31.26
	7	37.10	12.24	42.22	41.30
	28	32.10	41.32	55.60	43.60

The percentage change in compression strength is shown in Fig. 2. On the 28th day, the strength of the cement was improved by 28.72% by replacing 10% of it with silica fume. Strength is boosted by 73.2% when 20% of the original material is replaced. Finally, the strength of 30 % is boosted by 35.82%.

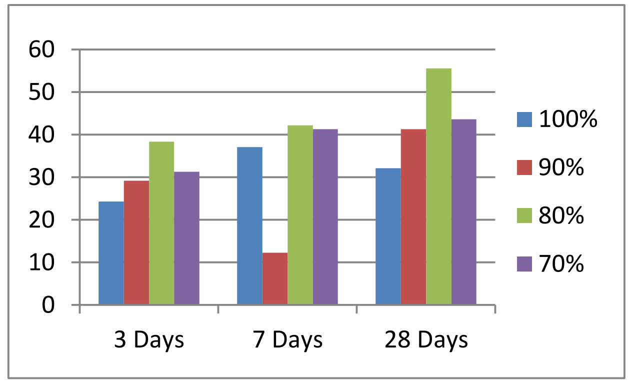

Fig. 2 Percentage of Change of Compression Strength

B. Split Tensile Test (Cylinder Strength)

After 7, 14, and 28 days of curing, the cylindrical specimens were evaluated for split tensile strength. The results of the tests were given in Table V after the specimens were taken out of the water. The split tensile test is shown in Fig. 3. (Cylinder Strength)

$$\text{Tensile strength} = (2P / \Pi DL) \text{ N/mm}^2$$

Where,
P is the load at which specimen fails in N
L is the length of the cylinder in mm
D is the diameter of the cylinder in mm

Fig.3 Split Tensile Test (Cylinder Strength)

TABLE V
SPLIT TENSILE TEST RESULTS

Specimen	Age of curing in days	Percentage of replacement of SilicFume			
		100 %	**90%**	**80 %**	**70%**
Cylinder	3	1.84	1.62	2.15	2.91
	7	1.71	1.82	2.23	2.01
	28	1.92	2.83	3.25	2.23

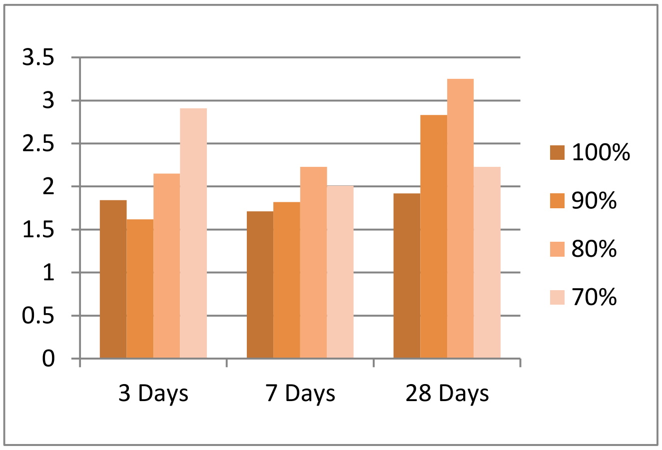

Fig.4 Percentage of Change of Split Tensile Strength

The percentage decrease in split tensile strength is shown in Fig. 4. On the 28th day, the splitting tensile strength was enhanced by 47.39% by replacing 10% of the cement with 10% silica fume. Strength is boosted by 69.27% when 20% of the original material is replaced. Finally, the strength of 30% is raised by 16.14%.

C. Flexural Test (Beam Strength)

After 7, 14, and 28 days of curing, the beam specimens were examined for flexural strength. Fig. 5 shows the flexural test results. The specimen was 100mm x 100mm x 500mm in size. The results of the flexural tests are listed in Table VI.

Flexural strength = PL / bd^2 N/mm^2

Where

P is the load at which specimens fails in N
L is the effective span in mm
b is the breadth of the specimens

TABLE VI
FLEXURAL TEST RESULTS

Specimen	Age of curing in days	Percentage of replacement of SilicFume			
		100 %	90%	80 %	70%
Beam	3	17.61	19.72	22.01	18.77
	7	19.42	23.03	25.07	20.04
	28	20.46	23.15	26.28	22.39

Fig.5 Flexural Test (Beam Strength)

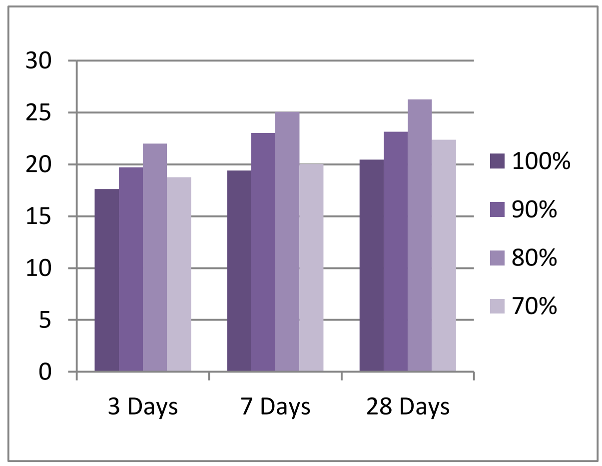

Fig. 6 Percentage of Change of Flexural Strength

Fig. 6 depicts the percent change in flexural strength. The flexure strength was enhanced by 13.14% on the 28th day by replacing 10% of the cement with 10% silica fume. Strength is enhanced by 28.44% when 20 percent of the material is replaced. Finally, the strength of 30% is boosted by 9.4%.

VI. CONCLUSION

The following conclusions have been drawn based on the investigations conducted on HPC mixtures. The addition of silica fume boosts the strength qualities of HPC, according to the test results. For maximum compressive strength, a proportion of cement substitution by silica fume of 20% is recommended. When 20% of the cement is replaced with silica fume, the maximum split tensile strength is attained. For maximum flexural strength, a proportion of cement substitution by silica fume of 20% is recommended. When compared to HPC mixes without silica fume, the percentage of saturated water absorption of HPC mixes, including silica fume, was lower. The workability is affected by the reduction of the water-cement ratio, which is corrected by adding conplast SP430.

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