Experimental Study On High Performance Concrete

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Abstract — **This paper generalizes the results of study on silica fume based high-performance concrete. The attempt has been made to compare, the 7 days and 28 days compressive strength, splitting tensile strength and flexural strength of concrete by using silica fume with the normal concrete of M60 grade with maintaining the water cement ratio 0.3. The objective of this study is to develop concrete with good strength, less porous, less capillarity, so that durability will be reached. For this purpose, the experiment has been carried out on M60 grade of concrete, using silica fume in different percentage 0%, 5%, 10%, 15% to the weight of cement.**

***Key Words* — Durability, high-performance concrete, silica fume, water cement ratio.**

I. INTRODUCTION

High-performance concrete is defined as concrete that meets special combinations of performance and uniformity requirements that cannot always be achieved routinely using conventional constituents and normal mixing, placing, and curing practices. Ever since the term high-performance concrete was introduced into the industry, it had widely used in large-scale concrete construction that demands high strength, high flow ability, and high durability.

A high-strength concrete is always a high-performance concrete, but a high-performance concrete is not always a high-strength concrete. Durable concrete Specifying a high-strength concrete does not ensure that a durable concrete will be achieved. It is very difficult to get a product which simultaneously fulfills all of the properties.

Concrete is considered as durable and strong material. Reinforced concrete is one of the most popular materials used for construction around the world. Reinforced concrete is exposed to deterioration in some regions especially in coastal regions. There for researchers around the world are directing their efforts towards developing a new material to overcome this problem. Invention of large construction plants and equipment's around the world added to the increased use of material. This scenario led to the use of additive materials to improve the quality of concrete. As an outcome of the experiments and researches cement based concrete which meets special performance with respect to workability, strength and durability known as "High Performance Concrete" was developed.

II. OBJECTIVES

The objective of this work is to develop concrete with good strength, less porous, less capillarity so that durability will be reached. For this purpose it requires the use of different pozzolanic materials like rice husk ash, ground granulated blast furnace slag, and silica fume. So the experiment carried out;

- To determine the mix proportion with silica fume to achieve the desire needs.
- To determine the water/ binder ratio, so that design mix having proper workability
  and strength.
- To investigate and compare different basic properties of concrete such as compressive strength, splitting tensile strength, flexural strength using silica fume with normal concrete of grade M60.

III. RESEARCH SIGNIFICANCE

This paper provides the test data related to behavior of HPC in different strength parameters. The data is useful to construction industry for various work.

IV. PROPERTIES OF HIGH PERFORMANCE CONCRETE

A. Workability

The workability of HPC is normally good, even at low slumps, and HPC typically pumps very well, due to the ample volume of cementing material and the presence of chemical admixtures, particularly HRWR. Due to reduced water-cementing material ratio no bleeding occurs. In the flowing concrete bleeding is prevented by providing adequate fines in the concrete mix. The cohesiveness of superplastisized concrete is much better as a result of better dispersion of cement particles. Cohesion is a function of rheology of concrete mix, which is consequently improved. However, excessive dosages of superplastisizer can induce some segregation, but it has little effect on physical properties of hardened concrete.

B. Rheological Properties

Widening the particle-size distribution of a solid suspension while maintaining constant solid volume reduces the viscosity of the suspension, known as the Farris effect. Thus, the blended or composite cements with wider particle-size distributions can achieve better rheological properties. The OPC-FA-SF ternary-cement concrete requires less water and is less sticky than OPC-SF concrete; however, it requires more water and is stickier than OPC-FA or OPC-GGBFS based concrete. In ternary cements FA seems to compensate for the rheological problems associated with the use of high SF contents. In binary cements containing relatively coarser GGBFS for example, addition of fine pozzolanas, such as SF or rice husk ash, inhibits bleeding problems.

C. Stress-strain Behavior

High performance concrete exhibits less internal micro cracking than lower-strength concrete for a given imposed axial strain. As a result, the relative increase in lateral stain is less for HPC. The lower relative lateral expansion during the inelastic range may mean that the effects of tri axial stresses will be proportionally different for HPC. For example the influence of hoop reinforcement is observed to be different for HPC.

D. Strength

The strength of the concrete depends on a number of factors including the properties and proportions of the constituent materials, degree of hydration, rate of loading, and method of testing and specimen geometry. The properties of the constituent materials which affect the strength are: the quality of fine and coarse aggregates, the cement paste and the paste aggregate bond characteristics, i.e. properties of the interfacial transition zone. These, in turn, depend on the macro- and microscopic structural features including total porosity, pore size and shape, pore distribution and morphology of the hydration products, plus the bond between individual components.

E. Modulus of Elasticity

It is generally agreed that the elastic modulus of concrete increases with its compressive strength. The modulus is greatly affected by the properties of the coarse aggregate; the larger the amount of coarse aggregate with a high elastic modulus, the higher would be the modulus of elasticity of concrete. The concrete in wet condition has about 15 percent higher elastic modulus than that in the dry condition. This is attributed to the effect of drying of transition zone between the aggregate and the paste. The modulus of elasticity increases with the strain rate. It also increases as the concrete is subjected to very low temperatures).

F. Poisson's Ratio

Experimental data on values of Poisson's ratio for HPC are very limited. Pernchio and Klieger reported values for Poisson's ratio with a compressive strength ranging from 55 to 80 MPa between 0.2 and 0.28. They concluded that Poisson's ratio tends to decrease with increasing water-cement ratio. Kaplan found values for Poisson's ratio of concrete determined using dynamic measurements to be from 0.23 to 0.32 regardless of compressive strength, coarse aggregate, and test age for concretes having compressive strengths ranging from 17 to 79 Mpa. Based on the available information, Poisson's ratio of HPC in the elastic range seems comparable to the expected range of values for lower strength concrete.

G. Modulus of Rupture

For usual concrete modulus of rupture and splitting tensile strength are quite low and don't vary much, because they are very much influenced by the tensile strength of the hydrated cement paste. However, this is no longer the case for high performance concrete, for which the water binder ratio and the compressive strength can vary over a wide range. The relationships that have been suggested between compressive strength and modulus of rupture for usual concrete lose some of their predictive value when going from usual concrete to high performance concrete.

H. Splitting Tensile Strength

Dewar studied the relationship between the indirect tensile strength and the compressive strength of concretes having compressive strengths up to 83 MPa at 28 days. He concluded that at low strengths, the indirect tensile strengths may be as high as 10 percent of the compressive strength but at higher strengths it may reduce to 5 percent. He observed that the tensile splitting strength was about 8 percent higher for crushed rock aggregate concrete than for gravel aggregate concrete. He also found that the indirect tensile strength was about 70 percent of the flexural strength at 28 days.

I. Shrinkage

Little information is available on the shrinkage behaviour of High-Performance concrete. A relatively high initial rate of shrinkage has been reported, but after drying for 180 days there is little difference between the shrinkage of high-strength and lower strength concrete made with dolomite or limestone. Reducing the curing period from 28 to 7 days caused a slight increase in the shrinkage. Shrinkage was unaffected by w/c ratio but is approximately proportional to the percentage of water by volume in the concrete. Other laboratory and field studies have shown that shrinkage of high-performance concrete is similar to that of lower strength concrete. Nogataki and Yonekurus reported that the shrinkage of high performance concrete containing high-range water reducers was less than for lower-strength concrete.

J. Creep

Creep, the flow of the material under sustained load, is a very important factor in the long-term deformational performance of structures. It has been found that the specific creep and hence the creep coefficient value are less in high-performance concrete (HPC) than in normal-strength concrete.

K. Ductility

Compression tests show that the stronger the concrete the more brittle it is. This could be of concern since modern design methods take into account the plasticity of materials. Flexural tests run on the reinforced HPC beams show that their ductility is similar to that of beams with ordinary concrete.

L. Fatigue Strength

As the static strength of concrete increases, it becomes increasingly more brittle and its ultimate strain capacity does not increase proportionately with the increase in strength. Therefore high performance concrete would be vulnerable to fatigue loading.

V. EXPERIMENTAL PROGRAMME

Twelve specimens of concrete were cast and tested in Laboratory. Silica fume is used in concrete in different percentage i.e, 0%, 5%, 10%, 15% to the weight of cement and study the 7 days and 28 days compressive strength, splitting tensile and flexural strength of concrete. The details are listed in the Table 1 below:

Sr.no.	Specimen	Size	No.
1	Cube	150mm	08
2	Cylinder	Diameter- 150mm, Length- 300mm.	04
3	Beam	150X150X700mm	04

Table no.1: Details of test specimen

Test Materials used are given below:

M. Cement

Ordinary Portland cement (53 grade) whose Fineness – 340 m^2/kg ,Specific gravity- 3.1 Initial setting time - 90 min, Final setting time – 190 min. was used.

N. Fine aggregate

In this study used sand of Zone-II, known from the sieve analysis using different sieve sizes (10mm, 4.75mm, 2.36mm, 1.18mm, 600µ, 300µ, 150µ) adopting IS 383:1963. Whose Specific Gravity is 2.65, Water absorption 0.6% and Fineness Modulus 2.47 was used.

O. Coarse Aggregate

The coarse aggregate used here with having maximum size is 12.5mm. We used the IS 383:1970 to find out the proportion of mix of coarse aggregate. Whose Specific Gravity is 2.65, Water absorption 0.4% and Fineness Modulus 4.01 was used.

P. Water

Portable water free from any harmful amounts of oils, alkalis, sugars, salts and organic materials was used for proportioning and curing of concrete.

Q. Super plastisizer

In the present experimental investigations superplasticizer Conplast SP430(G) was used for enhancing workability and supplied as a brown liquid instantly dispersible in water. Conplast SP430(G) has been specially formulated to give high water reductions upto 25% without loss of workability or to produce high quality concrete of reduced permeability. The properties were Specific gravity 1.20 to 1.22 at 300C, Chloride content Nil. as per IS:9103-1999 and BS:5075, Air entrainment Approx. 1% additional air over control. The optimum dosage is best determined by site trials with the concrete mix, the rate of addition is generally in the range of 0.6 - 1.5 liters /100 kg cement.

R. Silica fume

Silica fume is a byproduct of producing silicon metal or ferrosilicon alloys.

Fig. 1. Used Silica Fume

S. Mix Design

The high strength concrete mix design was done DOE method. The following mix proportion was arrived as shown in Table 2

Water (lit)	Cement (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)	Silica fume (By Wt. of Cement)	Super Plasticizer (By wt. of Cement)
179.88	600	551	1133	0%, 5%, 10%, 15%	1.5%
0.3	1	0.918	1.88		

Table no.2: Mix Proportion of Concrete

VI. RESULT AND DISCUSSION

Workability of fresh concrete determined by using slump test given below.

Silica fume in %	Slump (mm)
0	40
5	38
10	35
15	32

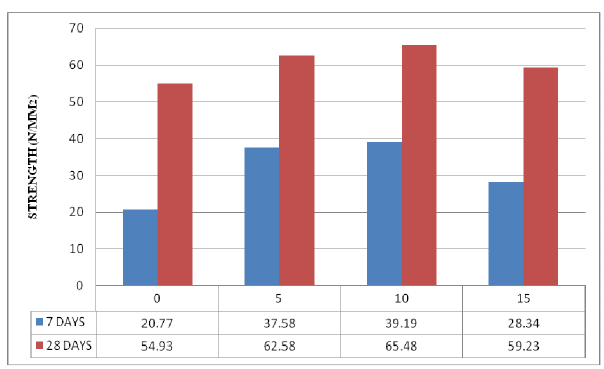
Table no.3: Workability of Concrete

T. Compressive strength

The test was carried out compressive strength of M60grade of concrete. The compressive strength of High-strength concrete with OPC and silica fume concrete at the age of 28 days is presented in Table

Silica fume (%)	Compressive Strength in N/mm^2	
	7 Days	28 Days
0	20.77	54.93
5	37.58	62.58
10	39.19	65.48
15	28.34	59.23

Table. No 4. compressive strength of concrete



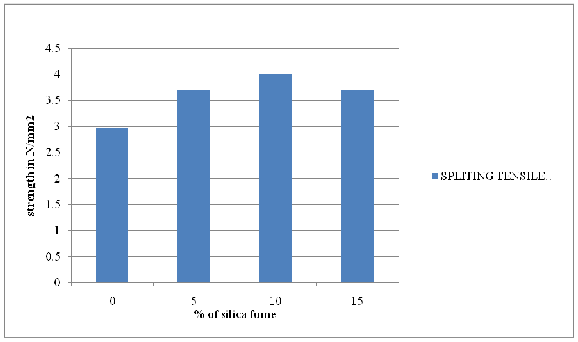
Graph .1: variation of 7 days and 28 days compressive strength.

U. Splitting tensile strength

The test was carried out according to IS 5816- 1999 to obtain the splitting tensile strength of M60 grade concrete. The test results of both the mixes were presented in the Table

Silica fume (%)	Splitting tensile strength (M60) in N/mm^2 28 Days
0	2.97
5	3.68
10	4.0
15	3.71

Table no. 5. 28 days splitting tensile strength of concrete.



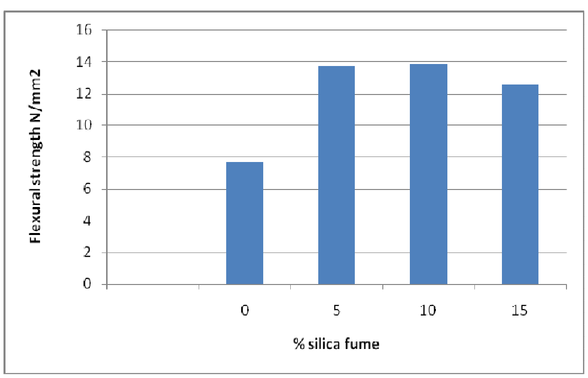
Graph .2: variation of 28 days tensile strength.

V. Flexural strength

The test was carried out on beam specimen, the test results of both the mixes were presented in the Table.

Silica fume (%)	Flexural strength (M60) in N/mm^2 28 Days
0	7.660
5	13.720
10	13.860
15	12.540

Table no. 6. 28 days flexural strength of concrete



Graph 3: variation of 28 days flexural strength.

It can be found that the ultra-fine silica fume particles, which consist mainly of amorphous silica, enhance the concrete strength by both pozzolanic and physical actions. The results of the present investigation indicate that the percentage of silica fume contributing to the mechanical properties is comparable or even more significant than that of normal concrete.

CONCLUSION

With the experimental studies conducted on HPC the following conclusions can be drawn:

- Cement replacement up to 10% with silica fume leads to increase in compressive strength, splitting tensile strength and flexural strength, for both M60grade.
- Beyond 10% there is a decrease in compressive strength, tensile strength and flexural strength for 28 days curing period.
- There is a decrease in workability as the replacement level increases, and hence water Consumption will be more for higher replacements.
- The maximum replacement level of silica fume is 10% for M60grade of concrete.
- Use of silica fume gives significant result on properties of concrete as compared to normal concrete.

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