Variation of different percentages of silica fume on concrete mechanical properties

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***Abstract*— Although the silica fume is a waste of industrial materials, it is relatively more recent pozzolanic material that has received considerable attention in both research and application. It is a byproduct resulting from the use of high quartz with coal in an electric ore furnace in the production of silicon and ferrosilicon alloys. The present study has been undertaken to study the effect of silica fume on the mechanical properties of high strength concrete, when a part of cement is replaced by silica fume in different percentages.**

***Keywords*— Silica fume, mechanical properties.**

I. INTRODUCTION

Recent research aimed at energy conservation in the cement and concrete industry has, in part, focused on the use of less energy intensive materials such as fly ash, slags and natural pozzolans. Lately some attention has been given to the use of condensed silica fume as a possible partial replacement for cement. Silica fume, a by-product in the manufacture of ferrosilicon and also of silicon metal. Silica fume is a by-product of silicon metal or silicon alloy metal factories. Although the silica fume is a waste of industrial materials, it became the most valuable by-product between the pozzolanic materials due to its very active and high pozzolanic property. Currently, it is widely used in concrete or cement as an admixture.

Need of present study:-

The effect of silica fumes on the mechanical properties of high strength concrete by varying the percentage replacement of cement with silica fume (0%, 5%, 10% and 15%).

The mechanical properties which shall be investigated are cube compressive strength, cylinder compressive strength, flexural strength and split tensile strength. The behavior of concrete with silica fumes as an admixture by varying the percentages of silica fume and curing period of 7 days, 28 days and 56 days has been observed.

II. EXPERIMENTAL PROGRAMME

In order to achieve the objectives of the present study, an experimental program was planned to investigate the effect of silica fume on the mechanical properties of high strength concrete, when a part of cement is replaced by silica fume in different percentages i.e. 0%, 5%, 10%, 15% with the use of superplasticisers. The main parameters investigated were compressive strength, split tensile strength and flexural strength.

The aim of studying properties of the materials used in concrete is to check the conformance with codal requirements and to enable an engineer to design a concrete mix for a particular strength. The different materials used in the present study are cement, sand, coarse aggregate, silica fume, superplasticisers and water. Laboratory tests were conducted on these materials and their properties have been reported

Cement: In the present investigation, ordinary Portland Cement 43 grade conforming to IS 8112 (1989)[3] is used. The total quantity of cement needed for the investigation is obtained in one lot from a fresh stock and without any lumps. The cement is tested in accordance with the methods of test specified in IS: 8112 (1989)[3]

Fine Aggregate: Ghaggar river sand available locally was used as fine aggregate. A lump of clay and other foreign materials were separated out carefully. Sand was washed and dried before testing. Sieve analysis of sand was done

Coarse Aggregate: The coarse aggregate used were a mixture of two locally available crushed stone of 10 mm and 20 mm size in 50 : 50 proportion. The aggregates were washed to remove dirt , dust and then dried to surface dry conditions. The specific gravity and fineness modulus was found to confirm the requirements of IS: 383 – 1970[4].

Silica fume: Silica fume is used in cement concrete as a replacement for cement to study the effect on durability characteristics of high strength concrete. Silica fume was obtained from Elkem India Pvt. Limited, New Delhi, India. Silica fume received was grey in color.

Water: The water used in the concreting work was the potable water as supplied in the structures laboratory of our college. Water used for mixing and curing was clean and free from injurious amounts of oils, acids, alkalies, salts and sugar, organic materials or other substances that may be deleterious to concrete. As per IS: 456-2000 potable water is generally considered satisfactory for mixing and curing of concrete. Accordingly potable tap water was used for the preparation of all concrete specimens.

Superplasticisers: Conplast SP430G8 complies with IS: 9103: 1999[17,] BS: 5075 Part 3 - 1985 and ASTM-C494M - 99a, 1999 Type 'G' as a high range water reducing admixture & IS 2645- 2003 as an integral waterproofing compound.

Concrete Mix Design for M 35 grade conventional concrete: In the present investigation the existing method as per IS: 10262 (1982) and SP23 (1983)[2] has been used for selecting the concrete mix $M_{25,}$ however new information given in IS 456 (2000) [18] have been incorporated, procedure is modified to that extent. Specific relationships, charts, graphs that are given in this method of mix design have been developed from extensive experimental investigation at the cement research institute of India as well as on the basis of data on concrete being designed and produced in the country.

Test specimens: various tests conducted on the high strength concrete with varying percentage of silica fume 0%, 5%, 10% and 15%. For each percentage variation of silica fume 3 samples were tested and average value of these three observations was taken as final result. Testing was done to investigate the mechanical properties of high strength concrete by conducting following tests:

- Cubical specimens of size 150mm x 150mm x 150mm and cylindrical specimens of size 300mm x 150mm dia. were tested for the compressive strength of concrete.
- Cylindrical specimens of size 200mm x 100mm dia. were tested for split tensile strength.
- Beam specimens of size 100mm x 100mm x 500mm were tested for flexural strength of concrete.

III. TEST PROCEDURE

COMPRESSIVE STRENGTH TEST: The cubes were tested at the age of 7, 28 and 56 days. The time was reckoned from the time of addition of water to the dry ingredients. The specimens were tested on 200 tonnes universal testing machine (UTM). The specimens were removed from curing tank and wiped with cloth for any traces of surface water. After keeping at room temperature for half an hour they were placed in position. According to Indian standard procedure laid down in IS: 516-1959

SPLIT TENSILE STRENGTH TEST: The test was conducted according to IS Code 5816-1970[6]. This test was carried out by placing a cylindrical specimen of size 200mm x 100mm dia. horizontally between the loading surfaces of a compression testing machine and the load was applied until failure of the cylinder, along vertical diameter

FLEXURAL STRENGTH TEST: The test was conducted according to IS Code 516-1959[7].The dimensions of each specimen (100mm x 100mm x 500mm) were noted before testing. No preparation of the surface was required. The bearing surfaces and loading rollers are wiped clean, and any loose sand or other material removed from the surfaces of the specimen where they are to make contact with the rollers. The specimen was then placed in the machine in such a manner the load is applied to the uppermost surface as cast in the mould, along two lines spaced 13.3 cm apart. The axis of the specimen

was carefully aligned with the axis of the loading device. The load was applied without shock and increasing continuously at a rate such that the extreme fibre stress increased at approximately at a rate 180 kg/min for the 10.0 cm specimens. The load was increased until the specimen fails, and the maximum load applied to the specimen during the test was recorded

IV. DISCUSSION AND RESULTS

COMPRESSIVE STRENGTH TEST:

Test discussion for cube compressive strength: Silica fume concrete containing 0% silica after 7 days, 28 days and 56 days was found to be having compressive strength 28.37 N/mm^2, 43.47 N/mm^2 and 48.89 N/mm^2 respectively. A gain in strength with age is observed. The increase in strength is 53.23% at 28 days and further increase of 12.47% is observed after 56 days.

Silica fume concrete containing 5% silica after 7 days, 28 days and 56 days was found to be having compressive strength 29.06 N/mm^2, 44.69 N/mm^2 and 52.28 N/mm^2 respectively. A gain in strength with age is observed. The increase in strength is 53.78% at 28 days and further increase of 16.98% is observed after 56 days.

Silica fume concrete containing 10% silica after 7 days, 28 days and 56 days was found to be having compressive strength 33.52 N/mm^2, 45.46 N/mm^2 and 55.63 N/mm^2 respectively. A gain in strength with age is observed. The increase in strength is 35.62% at 28 days and further increase of 22.37% is observed after 56 days.

Silica fume concrete containing 15% silica after 7 days, 28 days and 56 days was found to be having compressive strength 26.42 N/mm^2, 43.77 N/mm^2 and 50.02 N/mm^2 respectively. A gain in strength with age is observed. The increase in strength is 65.67% at 28 days and further increase of 14.28% is observed after 56 days.

CYLINDER COMPRESSIVE STRENGTH: Silica fume concrete containing 0% silica after 7 days, 28 days and 56 days was found to be having compressive strength 22.53 N/mm^2, 31.2 N/mm^2 and 38.65 N/mm^2 respectively. A gain in strength with age is observed. The increase in strength is 38.48% at 28 days and further increase of 23.87% is observed after 56 days.

Silica fume concrete containing 5% silica after 7 days, 28 days and 56 days was found to be having compressive strength 24.03 N/mm^2, 36.29 N/mm^2 and 38.78 N/mm^2 respectively. A gain in strength with age is observed. The increase in strength is 51.02% at 28 days and further increase of 6.86% is observed after 56 days.

Silica fume concrete containing 10% silica after 7 days, 28 days and 56 days was found to be having compressive strength 23.93 N/mm^2, 31.78 N/mm^2 and 41.42 N/mm^2 respectively. A gain in strength with age is observed. The increase in strength is 32.8% at 28 days and further increase of 30.33% is observed after 56 days.

Silica fume concrete containing 15% silica after 7 days, 28 days and 56 days was found to be having compressive strength 20.67 N/mm^2, 27.99 N/mm^2 and 34.12 N/mm^2 respectively. A gain in strength with age is observed. The increase in strength is 35.41% at 28 days and further increase of 21.9% is observed after 56 days.

SPLIT TENSILE STRENGTH TEST:

Silica fume concrete containing 0% silica after 7 days, 28 days and 56 days was found to be having compressive strength 2.66 N/mm^2, 3.96 N/mm^2 and 4.16 N/mm^2 respectively. A gain in strength with age is observed. The

increase in strength is 48.72% at 28 days and further increase of 5.05% is observed after 56 days.

Silica fume concrete containing 5% silica after 7 days, 28 days and 56 days was found to be having compressive strength 3.25 N/mm^2, 4.6 N/mm^2 and 4.76 N/mm^2 respectively. A gain in strength with age is observed. The increase in strength is 41.54% at 28 days and further increase of 3.48% is observed after 56 days.

Silica fume concrete containing 10% silica after 7 days, 28 days and 56 days was found to be having compressive strength 3.01 N/mm^2, 4.24 N/mm^2 and 4.89 N/mm^2 respectively. A gain in strength with age is observed. The increase in strength is 40.86% at 28 days and further increase of 15.33% is observed after 56 days.

Silica fume concrete containing 15% silica after 7 days, 28 days and 56 days was found to be having compressive strength 3.07 N/mm^2, 3.6 N/mm^2 and 4.59 N/mm^2 respectively. A gain in strength with age is observed. The increase in strength is 17.26% at 28 days and further increase of 27.5% is observed after 56 days

FLEXURAL STRENGTH TEST: Silica fume concrete containing 0% silica after 7 days, 28 days and 56 days was found to be having compressive strength 4.53 N/mm^2, 5.2 N/mm^2 and 5.33 N/mm^2 respectively. A gain in strength with age is observed. The increase in strength is 14.79% at 28 days and further increase of 2.5% is observed after 56 days.

Silica fume concrete containing 5% silica after 7 days, 28 days and 56 days was found to be having compressive strength 4.93 N/mm^2, 5.33 N/mm^2 and 5.6 N/mm^2 respectively. A gain in strength with age is observed. The increase in strength is 8.11% at 28 days and further increase of 5.07% is observed after 56 days.

Silica fume concrete containing 10% silica after 7 days, 28 days and 56 days was found to be having compressive strength 5.2 N/mm^2, 5.6 N/mm^2 and 5.73 N/mm^2 respectively. A gain in strength with age is observed. The increase in strength is 7.69% at 28 days and further increase of 2.32% is observed after 56 days.

Silica fume concrete containing 15% silica after 7 days, 28 days and 56 days was found to be having compressive strength 4.13 N/mm^2, 4.67 N/mm^2 and 4.8 N/mm^2 respectively. A gain in strength with age is observed. The increase in strength is 13.08% at 28 days and further increase of 2.78% is observed after 56 days.

PERCENTAGE	DAYS		
	7	28	56
0	28.37	43.47	48.89
5	29.06	44.69	52.28
10	33.52	45.46	55.63
15	26.42	43.77	50.02

TABLE 1: RESULT OF CUBE COMPRESSION STRENGTH OF SILICA FUME CONCRETE WITH AGE

PERCENTAGE	DAYS		
	7	28	56
0	22.53	31.2	38.65
5	24.03	36.29	38.78
10	23.93	31.78	41.42
15	20.67	27.99	34.12

TABLE 2: RESULT OF CYLINDER COMPRESSION STRENGTH OF SILICA FUME CONCRETE WITH AGE

PERCENTAGE	**DAYS**		
	7	28	56
0	2.66	3.96	4.16
5	3.25	4.6	4.76
10	3.01	4.24	4.89
15	3.07	3.6	4.59

TABLE 3: RESULT OF TENSILE STRENGTH OF SILICA FUME CONCRETE WITH AGE

PERCENTAGE	**DAYS**		
	7	28	56
0	4.53	5.2	5.33
5	4.93	5.33	5.6
10	5.2	5.6	5.73
15	4.13	4.67	4.8

TABLE 4: RESULT OF FLEXURAL STRENGTH OF SILICA FUME CONCRETE WITH AGE

V. CONCLUSION

On the basis of the results and discussions on this investigation the following conclusions are drawn:

- No early strength was observed in concrete containing silica fume after 7 days of curing.
- The compressive strength of silica fume concrete increased with increase in percentage replacement of silica fume with cement for 5%, 10% and then gradually decreased with 15% replacement.
- The compressive strength and tensile strength of silica fume concrete increased with increase in age i.e. the 56 days compressive strength and tensile strength of silica fume concrete was found to be 15%-25% more as compared to the 28 days compressive strength. and tensile strength.
- The flexural strength of silica fume concrete increased with increase in age i.e. the 56 days compressive strength of silica fume concrete was

found to be 2%-5% more as compared to the 28 days flexural strength.

- After 28 days of curing silica fume concrete having 5% silica fume concentration gave more tensile strength than that of 10% silica fume concrete. But after 56 days of curing silica fume concrete having 10% silica fume concrete gave more tensile strength than that of 5% silica fume concrete.
- The silica fume concrete having 10% silica fume concrete gave more flexural strength than that of 5% and 15% silica fume concrete after 28 and 56 days of moist curing.
- As the compressive strength increases with age upto 56 days, the tensile strength and flexural strength also increases with increase in age of silica fume concrete.

It can be concluded that concrete containing 5% and 10% of silica fume showed significant improvement in strength parameter as compared to conventional concrete. Hence cement can be partially replaced with 5% - 10% of silica fume thereby reducing the environmental hazard and making the concrete economical..

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