IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684, p-ISSN: 2320-334X
PP 44-47
www.iosrjournals.org

Influence of silica fume on concrete

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ABSTRACT: *Traditionally, Ordinary Portland cement is used for making the civil structures. Portland cement can be partially replaced by silica fume. Silica fume is non metallic and non hazardous waste of industries. It is suitable for concrete mix and improves properties of concrete i.e. compressive strength etc. The main objective of this research work is to determine the optimum replacement percentages which can be suitably used under the Indian conditions. To fulfill the objective various properties of concrete using silica fume have been evaluated. Further to determine the optimum replacement percentage comparison between the regular concrete and concrete containing silica fume is done .It has been seen that when cement is replaced by silica fume compressive strength increases up to certain percentage (10% replacement of cement by silica fume).But higher replacement of cement by silica fume gives lower strength. The effect of Silica fume on various other properties of Concrete has also been evaluated. This paper is a very good tool for the beginners to understand the effect and have an overlook of Silica Fume on Concrete.*

Keywords: *Compressive strength, optimum, Silica fume, Slump test, w/cm ratio*

I. INTRODUCTION

Mineral admixture are widely used in concrete for various reasons especially for reducing the amount of cement required for making concrete which shows to a reduction in construction cost. Moreover most pozzolanic materials are byproduct materials. The use of these materials shows the reduction in waste, freeing up valuable land, save in energy consumption to produce cement and save the environment. Durability of portland cement concrete is defined as its ability to resist weathering action, chemical attack, abrasion, fire or another process of deterioration. In other words, cement concrete will be termed durable, when it keeps its form and shape within the allowable limits, while exposed to different environmental conditions. Durability of concrete has been a major concern of civil engineering professionals. Also, it has been of considerable scientific and technological interest over the last few decades [1, 2]. The American concrete institute (ACI) defines silica fume as a ‘‘very fine noncrystalline silica produced in electric arc furnaces as a byproduct of production of elemental silicon or alloys containing silicon’’. Silica fume is also known as micro silica, condensed silica fume, volatized silica or silica dust. It is usually a grey colored powder, somewhat similar to Portland cement or some fly ashes. It can exhibit both pozzolanic and cementitious properties. Silica fume has been recognized as a pozzolanic admixture that is effective in enhancing the mechanical properties to a great extent. Addition of silica fume to concrete improves the durability of concrete and also in protecting the embedded steel from corrosion. When fine pozzolana particles are dispersed in the paste, they generate a large number of nucleation sites for the precipitation of the hydration products. Therefore, this mechanism makes the paste more homogeneous and dense as for the distribution of the fine pores. This is due to the reaction between the amorphous silica of the pozzolanic and the calcium hydroxide produced by the cement hydration reactions [3].Silica fume is a byproduct and it is the most beneficial uses in concrete. Because of its chemical and physical properties, it is a very reactive pozzolana. Concrete containing silica fume can have very high strength and can be very durable. In this paper the advantages of using silica fume in concrete in partial replacement of cement are found. The present experimentation has been carried out to determine the mechanical properties of conventional concrete and concrete using silica fume. Suitability of silica fume has been discussed by replacing cement with silica fume at varying percentage and the strength parameters were compared with conventional concrete.

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II. EXPERIMENTAL INVESTIGATION

2.1 Materials

2.1.1 Cement

Ordinary Portland Cement of Ultratech brand of 53 grade confirming to IS: 12269-1987(9) was used in the present study.

2.1.2 Coarse Aggregate

Crushed aggregate confirming to IS: 383-1987 was used.

2.1.3 Fine Aggregate

The Wainganga sand was used as fine aggregate.

2.1.4 Water

Water conforming to as per IS: 456- 2000 was used for mixing as well as curing of concrete specimens.

2.1.5 Silica Fume

Silica fume was procured from Black Cat Industries, Nagpur. The Silica fume is used as a partial replacement of cement. The chemical composition of silica fume are:

Contains more than 90 percent silicon dioxide

Other constituents are carbon, sulphur and oxides of aluminium, iron, calcium, magnesium, sodium and potassium

The physical composition of silica fume are:

Diameter is about 0.1 micron to 0.2 micron

Surface area about 30,000 m^2/kg

Density varies from 150 to 700 kg/m^3

2.2. Mix Proportioning

For this study, M 20 grade of concrete and two water cementitious ratios are used (w/cm 0.5, w/cm 0.6), the quantities of materials used for two w/cm ratio are worked out. Four types of concrete mix are prepared, the first one (type I) was conventional concrete (0% Silica Fume) with w/cm ratio 0.5, the second one (type II) was conventional concrete (0% Silica Fume) with w/cm ratio 0.6, the third (type III) was combination of Portland cement and various % of silica fume (5%, 10%,15%, 20% and 25%) with w/cm ratio 0.5 and the fourth one (type IV) was combination of Portland cement and various % of silica fume (5%, 10%,15%, 20% and 25%) with w/cm ratio 0.6.

Workability of Concrete

Workability is defined as the properties of freshly mixed concrete or mortar which determines the homogeneity with which it can be mixed, placed, consolidated and finished. In general terms, workability represents the amount of work which is to be done to compact the concrete in a given mould. A workable mix should not segregate. In this study workability was measured by conducting slump cone test.

Table 1- Slump cone Test value

% Cement Replaced by Silica Fume	w/cm = 0.5	w/cm = 0.6
0	67 mm	76 mm
5	58 mm	67 mm
10	49 mm	58 mm
15	31 mm	40 mm
20	22 mm	31 mm
25	15mm	20 mm

2.4. Experimental Procedure

The specimen of standard cube of (150 mm x 150 mm x 150 mm) was used to determine the compressive strength of concrete. Three specimens were tested for 3, 7 & 28 days with each proportion of silica fume replacement. Total 108 cubes were casted for compressive strength test. The

material was weighed and the materials were mixed in electrical mixer. The water cementitious ratio (w/cm) adopted was 0.5 and 0.6. The concrete was filled in different layers and each layer was compacted. The specimen was removed from mould after 24 hrs, cured in clean water for 3, 7 & 28 days and then tested for compressive strength as per Indian Standard. The temperature of the cured water and the test room was 27 ± 2° C. The materials for each batch of moulds mixed separately using the quantities of dry materials, conforming to the proportions and the quantity of water was determined.

III. TEST RESULTS AND DISCUSSIONS

Table 1 show that the workability of concrete reduces with increase in silica fume content of concrete. The workability of silica fume concrete differs from conventional concrete because silica fume grains are ultra fine and hence fill the voids between the cement grains making the silica fume concrete more cohesive which is further enhance by thixotropic nature of silica fume cement paste. Spherically shaped silica fume particles give ball bearing action when energy is applied to silica fume concrete mix causing the mix flow easily. For equal workability, silica fume concrete will tends to show less slump than conventional concrete.

The results of the compressive strength test for all concrete mixes after 3, 7, and 28 days curing were determined and presented in Table 2, 3 and Fig. 1, 2, 3. Compressive strength of concrete containing various percentage of silica fume was studied. Conventional concrete strength was compared with the strength of concrete containing 5%, 10%, 15%, 20% and 25% silica fume that replaced cement of same percentage.

Table 2 Compressive test result for w/cm = 0.5

%Silica fume	3 Days strength (MPa)	7 Days strength (MPa)	28 Days strength (MPa)
0	13.52	14.6	25.51
5	16.27	16.81	30.05
10	16.38	17.53	31.2
15	15.16	15.92	28.2
20	13.11	13.87	24.22
25	11.34	12.02	22.01

Table 3 Compressive test result for w/cm = 0.6

%Silica fume	3 Days strength (MPa)	7 Days strength (MPa)	28 Days strength (MPa)
0	11.02	12.34	24.49
5	11.78	12.84	28.05
10	13.22	14.24	30.75
15	11.081	12.29	27.02
20	9.43	11.87	22.05
25	8.76	10.56	21.9

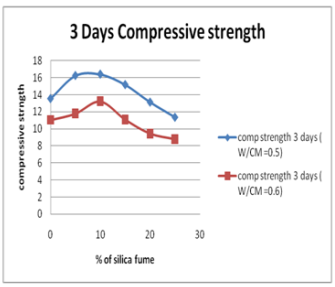

Fig. 1- 3 Days compressive test result

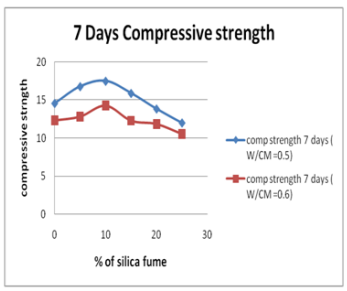

Fig. 2- 7 Days compressive test result

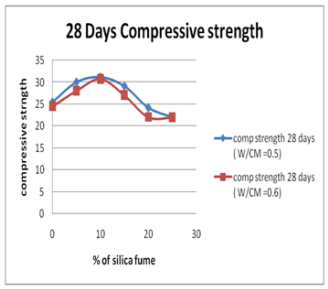

Fig. 3- 28 Days compressive test result

From figure 1, 2 and 3, it is evident that, the compressive strength of control blocks increases with low w/cm ratio 0.5 than w/cm ratio 0.6. It also, shows that, the compressive strength of silica fume block increases as the w/cm ratio decreases. Figure 4 and 5 illustrates the typical development of compressive strength for control and silica fume concrete for 3 days, 7 days and 28 days. It has been seen that when cement is replaced by silica fume compressive strength increases up to certain percentage. 10% replacement of cement by silica fume gives more compressive strength as compare to other replacement. Higher replacement of cement by silica fume gives lower compressive strength. The increase of compressive strength of silica fume concrete may be due to the pozzolanic reaction

silica fume with free lime. The transition zone in concrete is improved by physical and chemical effects of silica fume. Filler effect and pozzolanic reaction of silica fume refine the matrix in silica fume concrete thereby enhancing the degree of impermeability and the strength of concrete.

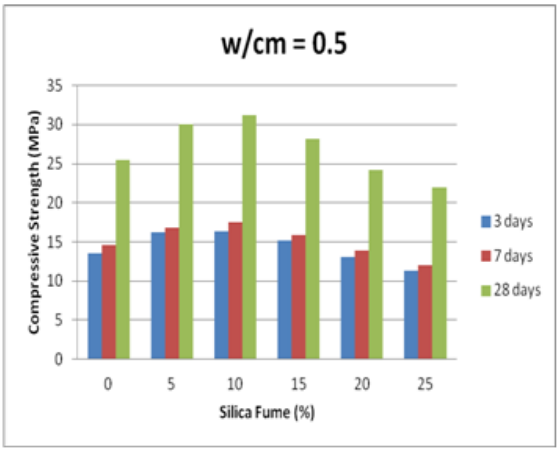

Fig.4- Compressive test result of w/cm ratio 0.5

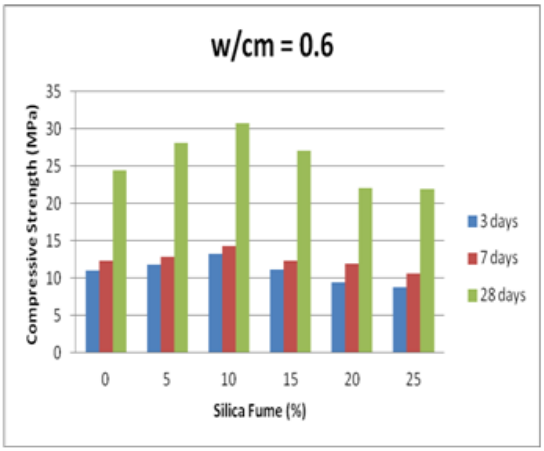

Fig.5- Compressive test result of w/cm ratio 0.6

IV. CONCLUSIONS

From the results it is conclude that the silica fume is a better replacement of cement. The rate of strength gain in silica fume concrete is high. After performing all the tests and analyzing their result, the following conclusions can be derived:

1. With the increase in w/cm ratio strength of concrete decreases.
2. The optimum value of compressive strength can be achieved in 10% replacement of silica fume.
3. As strength of 15% replacement of cement by silica fume is more than normal concrete. The optimum silica fume replacement percentage is varies from 10 % to 15 % replacement level.
4. Workability of concrete decreases as increase with % of silica fume.
5. Compressive strength decreases when the cement replacement is above 15% of silica fume.

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