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Early Age Properties Of Silica Fume Modified Cement Mortar With M Sand As Fine Aggregate

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ABSTRACT
This paper emphasizes on the influence of silica fume on the early age properties of cement mortars incorporated with silica fume as cement replacement material. Silica fume was varied at different percentages. The water-binder ratio was fixed according to the workability of each mix. The workability and density of conventional mortar, consistency and setting times of cement pastes with varying percentages of silica fume were studied. The experimental results showed that, the water demand was increasing with increasing replacement level of silica fume. The consistency of cement was increased with increase in silica fume content.The initial setting time was decreasing with the increase in silica fume content and the final setting time seems to be not influenced by the silica fume.The density increased up to 10% of replacement level and it was decreased with increasing percentages of silica fume.
Keywords-Consistency,Mortar,Setting time,Silica fume,Workability

I. INTRODUCTION

Silica fume (SF) is a by-product of the smelting process in the silicon and ferrosilicon industry. The reduction of high-purity quartz to silicon at temperatures up to 2,000 ^{0}C produces SiO_2 vapours, which oxidizes and condense in the low temperature zone to tiny particles consisting of non-crystalline silica. By-products of the production of silicon metal and the ferrosilicon alloys having silicon contents of 75% or more contain 85–95% non-crystalline silica. The by-product of the production of ferrosilicon alloy having 50% silicon has much lower silica content and is less pozzolanic. Therefore, SiO_2 content of the silica fume is related to the type of alloy being produced. Silica fume is also known as micro silica, condensed silica fume, volatilized silica or silica dust.

Rheological properties of a fresh cement paste play an important role in determining the workability of concrete. The water requirement for flow,hydration behaviour, and properties of the hardened state largely depends upon the degree of dispersion of cement in water. Properties such as fineness, particle size distribution, and mixing intensity are important in determining the rheological properties of cement paste. Due to the charges that develop on the surface,cement particles tend to agglomerate in the paste and form flocs that trap some of the mixing water. Factors such as water content, early hydration, water reducingadmixtures and mineral admixtures like silica fume determine the degree of flocculation in a cement paste.

Silica fume has been used in different percentages ranging from 5% to 20%.Silica fume varies in colour from white to pale grey to black with a specific surface area.

II. MATERIALS

Ordinary Portland cement was used throughout the present program. The silica fume was used as a partial replacement of cement in the mortar mixes. The silica fume content was varied between 0 and 20 percent by weight of cement at a constant increment of 5 percent. Specific surface area of the silicafume is 22m^2 /g. M sand was used as fine aggregate. The specific gravity of sand is 2.63.The mortar mix is designed for a ratio of 1:3 modified by replacing cement by silica fume.

III. EXPERIMENTAL PROGRAM

A. Flow Table Test

Workability is defined as the ease with which mortar can be mixed placed compacted and finished. Flow table test was done to determine the workability of mortar. Workability of mortar is its ease of use measured by the flow of mortar. The standard flow test uses a standard conical frustum shape of mortar with a diameter of four inches. This mortar sample is placed on a flow table and dropped 25 times within 15 seconds. As the mortar is dropped, it spreads out on the flow table. The initial and final diameters of the mortar sample are used to calculate flow. Flow is defined as the increase in diameter divided by the original diameter multiplied by 100.Laboratory mixed mortar, where conditions are more controlled, should have a flow of approximately 110.In the field, mortar is usually mixed to a flow of about 130-150.As mortar sits, its flow decreases, to maintain workability, water can be added, this is called retempering.

$$Flow = \frac{D_f - D_i}{D_i} \times 100$$

Where,
D_f = final diameter
D_i = initial diameter

B. Consistency and Setting time

The standard consistency tests were done for each mix. Based on the consistency,initial and final setting times of the pastes were determined. The basic aim is to find out the water content required to produce a cement paste of standard consistency as specified by the IS: 4031 (part 4)-1988.The principle is that standard consistency of cement is that consistency at which the Vicat plunger penetrates to a point 5-7mm from the bottom of Vicat mould. Apparatus used – Vicat apparatus conforming to IS: 5513-1976, Balance, whose permissible variation at a load of 1000g should be +1.0g.Gauging trowel conforming to IS: 10086-1982.

Procedure to determine consistency of cement:

1) Weigh approximately 400g of cement and mix it with a weighed quantity of water. The time of gauging should be between 3 to 5 minutes.
2) Fill the Vicat mould with paste and level it with a trowel.
3) Lower the plunger gently till it touches the cement surface.
4) Release the plunger allowing it to sink into the paste.
5) Note the reading on the gauge.

Repeat the above procedure taking fresh samples of cement replacing with varying percentages (5%, 10%, 15%, and 20%) of silica fume.

Procedure to determine initial and final setting time:

1) Prepare a cement paste by gauging the cement with 0.85 times the water required to give a paste of standard consistency.
2) Start a stop-watch, the moment water is added to the cement.
3) Fill the vicat mould completely with the cement paste gauged as above, the mould resting on a non-porous plate and smooth off the surface of the paste making it level with the top of the mould. The cement block thus prepared in the mould is the test block.

A) Initial Setting Time

Place the test block under the rod bearing the needle. Lower the needle gently in order to make contact with the surface of the cement paste and release quickly, allowing it to penetrate the test block. Repeat the procedure till the needle fails to pierce the test block to a point 5.0±0.5mm measured from the bottom of the mould. The time period elapsing between the time, water is added to the cement and the time, the needle fails to pierce the test block by 5.0±0.5mm measured from the bottom of the mould, is the initial setting time.

B) Final Setting Time

Replace the above needle by the one with an annular attachment. The cement should be considered as finallyset when, upon applying the needle gently to the surface of the test block, the needle makes an impression therein, while the attachment fails to do so. The period elapsing between the time water is added to the cement and the time, the needle makes an impression on the surface of the test block, while the attachment fails to do so, is the final setting time.

C. Determination of density

The mortar cube specimens of 5x5x5cms were cast. The weights of the specimens were taken after demoulding.The density of the mortar was calculated by dividing mass of the cube specimens by its volume.

$$\text{Fresh density} = \frac{mass}{volume}$$

IV. RESULTS AND DISCUSSION

A. Flow Table Test

The result shows that higher the replacement level, the larger the water demands. Silica fume in the amount exceeding 5% from the mass of cement considerably increases the fine fraction volume and hence the water requirement of the binder. Workability of mortar slightly decreased as the silica fume content increased. This has been due to the higher specific surface of silica fume, which needs more water for complete hydration and for workability. When very fine particles of silica fume are added to the mortar, the size of flow channels further reduced because these fine particles are able to adjust their positions to occupy the empty spaces between cement particles.

Table 1: Silica fume percentages and water-cement ratio for each replacement level

Replacement %	W/B RATIO
0	0.55
5	0.57
10	0.64
15	0.72
20	0.74

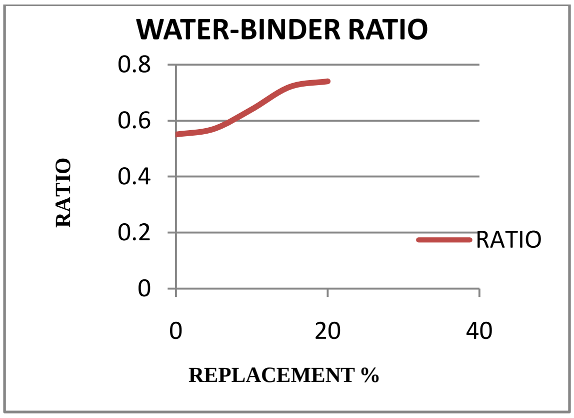

Fig.1: Effect of silica fume on workability of mortar

B. Determination of Consistency and Setting time

Consistency

Silica fume was varied from 0 to 20% at a constant increment of 5% by weight of cement. Since the SF is finer than the cement, the specific surface increased with increase in SF content. The standard consistency of pure cement paste was found out to be 27.50%; while at 20% SF, it was 35%. It was observed that the consistency of cement increased with the increase in SF content.

Table 2: Silica fume percentages and Consistency

Replacement %	Consistency (%)
0	27.5
5	29
10	30
15	34
20	35

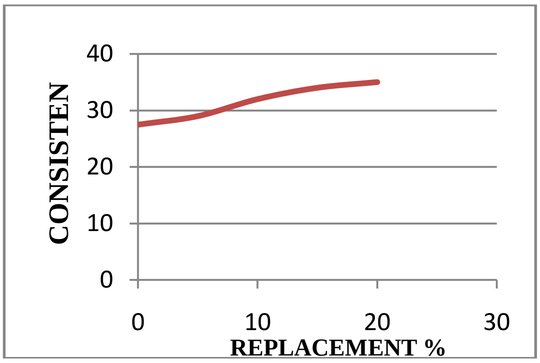

Fig.2: Effect of silica fume on consistency of pastes

Setting time

Figure 3shows the variation of setting times with the addition of silica fume in cement pastes. It was observed that initial setting time decreased with the increase in silica fume content. At smaller contents, the setting time of cement paste did notaffect much. However, at higher silica fume contents, the initial setting time was significantly decreased. At 20% silica fume, the initial setting time had been only 45 mins. The final setting time seem to be not influenced by the silica fume. The pozzolanic action of silica fume seems to be very active at early hours of hydration. Therefore, it can be concluded that silica fume contents result in quick setting of cement.

Table 3: Silica fume percentages and setting times of pastes

REPLACEMENT %	IST(MINS)	FST(MINS)
0	210	295
5	100	320
10	80	315
15	60	312
20	45	308

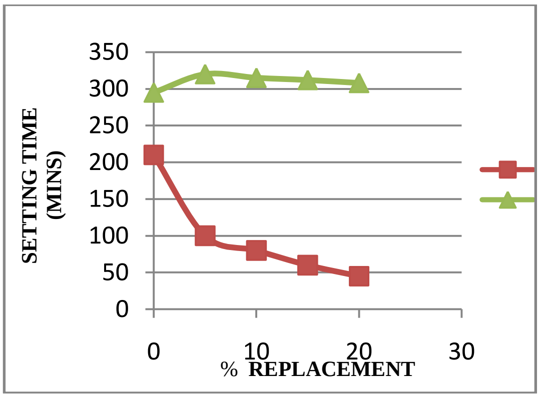

Fig.3: Effect of silica fume on setting time of pastes

C. Determination of density

The following figure and table shows the results of density.

Table 4: Silica fume percentages and density

REPLACEMENT%	DENSITY(Kg/m^3)
0	2395.333
5	2410.667
10	2420
15	2350.667
20	2314

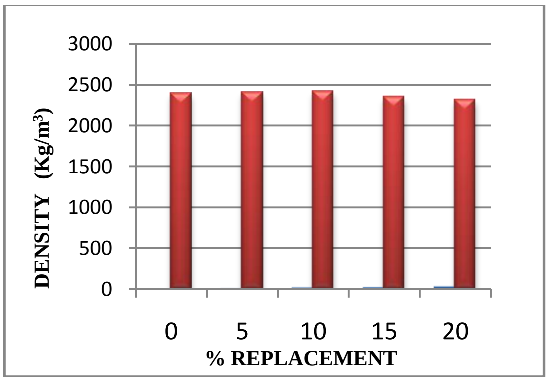

Fig.4: Effect of silica fume on density of mortar

The density of mortar was increased up to 10% of silica fume replacement compared to normal mortar. As the percentage of replacement level increased, the density of mortar decreased.

V.CONCLUSIONS

- The result of workability test shows that higher the replacement level, the larger the water demands.
- The consistency of cement increased with the increase in silica fume content.
- The initial setting time was decreasing with the increase in silica fume content and the final setting time seems to be not influenced by the silica fume.
- The density increased up to 10% of replacement level and it was decreased with increasing percentages of silica fume.

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