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Strength Studies on Silica fume Based Cement Mortar

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ABSTRACT
Silicafume is considered to be the most suitable cementitous material for increasing the strength of mortars. An optimum percentage of cement has to be replaced with silicafume without affecting the workability. This optimum percentage of replacement and optimum water content for the mix has to be fixed by conducting experimental studies. This study deals with the hardened properties of silica fume based cement mortar. Compressive strength,flexural strength and durability of cement mortar modified with silicafume was determined in this study.
Keywords – Microstructure, Pozzolonic reaction, Smelting.

I. INTRODUCTION

Strength and durability of concrete structures is the ultimate aim of a civil engineer. Strength and durability of mortars can be attained through various methods such as; increasing cement content, adopting better mixes and curing practice, adding supplementary cementing materials. Silicafume is considered to be the most suitable material for increasing the strength of mortars. Silica fume (SF) is a byproduct of the smelting process in the silicon and ferrosilicon industry[1]. An optimum percentage of cement has to be replaced with silicafume without affecting the workability. This optimum percentage of replacement and optimum water content for the mix has to be fixed by conducting experimental studies. This study deals with the hardened properties of silica fume modified cement mortar. Compressive strength,flexural strength and durability of cement mortar modified with silicafume was determined.

II. OBJECTIVE AND SCOPE

- To determine the suitability of replacing cement with silica fume and using quarry sand as fine aggregate in masonry mortar
- To study the effect of different replacement levels of silicafume on the strength development of masonry mortar
- To obtain the optimum replacement level of silicafume based on strength requirements.

Adopted binder/sand ratio is 1:3 only. Five mixes are tested. Percentage replacement of cement with silicafume is 0, 5, 10, 15and 20% .Water/binder ratio was varied for obtaining a workability of 110±5 for each mix.

III. EXPERIMENTAL PROGRAM

1. Materials

1.1.Cement

The cement used for the experiment is ordinary Portland cement of grade 53.

1.2. Silicafume

Silica fume of specific gravity 2.22 is used.

1.3. Sand

Manufactured sand (Msand) conforming to zone 2 is used for the specimen preparation.The fineness modulus of sand is 2.79 and specific gravity is 2.63.

1.4.Water

Water used is free from impurities. Neutral water which is of Ph 7 is used for the specimen preparation.

2. Mix Proportion

All mixes were cast with binder /sand ratio of 1:3. Cement is replaced with silica fume for each mix with replacement percentages of 0, 5, 10, 15 and 20.The workability of each mix was fixed as 110±5 and the water/binder ratio was varied accordingly. The details of mixes and their designations are given in Table 1.

TABLE 1. DETAILS OF MIXES

MIX	BINDER /SAND RATIO	PERCENTAGE OF CEMENT REPLACED WITH SILICAFUME	WATER /BINDER RATIO

SF0	1:3	0	0.55
SF5	1:3	5	0.57
SF10	1:3	10	0.64
SF15	1:3	15	0.72
SF20	1:3	20	0.8

3 Testing

3.1.Water Content

Water content for each mix is fixed on the basis of workability. Workability of each mix was tested by flow table test .Water content was varied for obtaining a workability of 110±5 for each mix. The variation of water content with percentage of silica fume replacement levels are as shown in fig.1.

3.2. Compressive Strength

The compressive strength test was carried out as per IS: 1727 – 1967[2]. Mortar cubes of size 50x50x50 mm were cast for each mix and tested at the age of 3 day, 7 day, 28 day and 56 day after water curing. The results were obtained as shown in fig.2

3.3.Flexural Strength

Flexural test was conducted as per ASTM C 348 – 02[3] .The test was carried out on 40x40x160 mm beam specimens. The beams were cast and tested after 28 days of water curing. The beam specimens were tested for flexure under a flexural testing machine subjected to a four point loading. The flexural strength was calculated as:

$$\sigma = \frac{FL}{bd^2} \qquad (1)$$

Where, *F* is the load (force) at the fracture point, *L* is the length of the support (outer) span,
b is width, *d* is thickness. The results are shown in fig.3.

3.4. Rapid chloride Penetration Test

This test was conducted to measure the permeability of mortar specimen[4]. The rate of chloride ion ingress into concrete is primarily dependent on the internal pore structure. The pore structure in turn depends on other factors such as the mix design, degree of hydration, curing conditions, use of supplementary cementitious materials, and construction practices. Hence the test is conducted to check the durability of mortar made with silica fume. The test was carried out on discs of diameter 150 mm and thickness 50 mm as per ASTM C 1202 – 97.The specimens were tested after 90 days of water curing. The total charge passed through the specimen during an interval of 6 hours is found out using the formula:

$$Q=900(I_0+2I_1+2I_2+\ldots\ldots\ldots.I_n) \qquad (2)$$

The result is plotted on fig.4.

IV. RESULTS AND DISCUSSIONS

1. Water Content

From the results of experiments it was found out that the addition of silica fume in cement mortar reduced the workability of the mix in the absence of a water reducing admixtures. Thus for attaining the optimum workability the water/binder ratio was increased with increase in the percentage of silica fume. The water content for control mix (SF0) was only 330kg/m^3.Whereas for SF20 it is 480kg/ m^3 .So an increase in water content of 45.45% is observed. Since the SF is finer than the cement, the specific surface increased with increase in SF content, so the water content increased[5]. The water content variation with different percentage levels of silica fume is shown in fig.1.

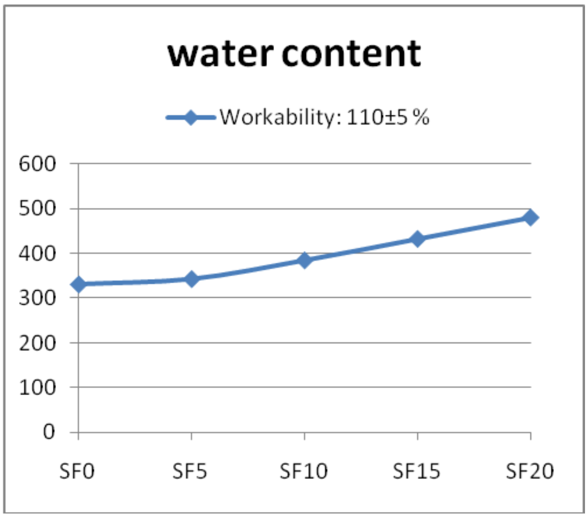

Fig.1.Variation of water content with silica fume replacement levels

2. Compressive Strength

The compressive strength of samples was tested at the age 3 day, 7 day, 28 day and 56 day. From fig .2 we can infer that when silica fume is added to concrete, it resulted in a significant change in the compressive strength of the mix. This is mainly due to the aggregate-paste bond improvement and enhanced microstructure. The addition of silica fume to mortar resulted in an improved bond between the hydrated cement matrix and sand in the mix, hence increasing strength[6]. This improved bond is due to the conversion of the calcium hydroxide, which tends to form on the surface of aggregate particles, into calcium silicate hydrate due to the presence of reactive silica. Of the five mixes SF10 showed maximum compressive strength with an increase of 50.1% at 28 day and 45.5% at 56 day than SF0. The increase in strength for SF15 and SF20 was found to be 31.8% and 1.4% for the 28^{th} day compared to control one. From fig.2 we can infer that silica fume did not produce an immediate strength enhancement;

instead, the blended mixtures only achieved higher strength than the control from 7 days onwards. Strength loss in the early ages, was probably due to the dilution effect of the pozzolan and as well as the slow nature of pozzolanic reaction[7]. The decrease in strength for SF15 and SF20 when compared with SF10 was attributed to the high increase in w/b ratio of the mix.

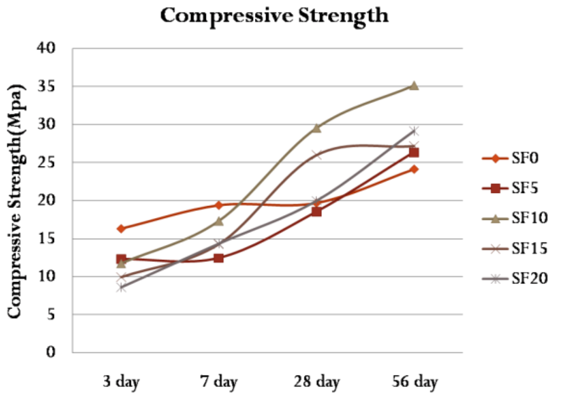

Fig.2.Variation of Compressive strength with age

3. Flexural Strength

The flexural strength of beams was found out after 28 days of water curing. The flexural strength of SF10 is found to be the maximum compared to the other mixes. Flexural strength of SF5, SF15 and SF20 was less than the control one. This may be attributed to their high water /binder ratio. The flexural strength of SF10 showed an increase of 5.38% compared to the control one (SF0).The variation of flexural strength with different percentage replacement levels of silicafume at 28 day is shown in fig.3.

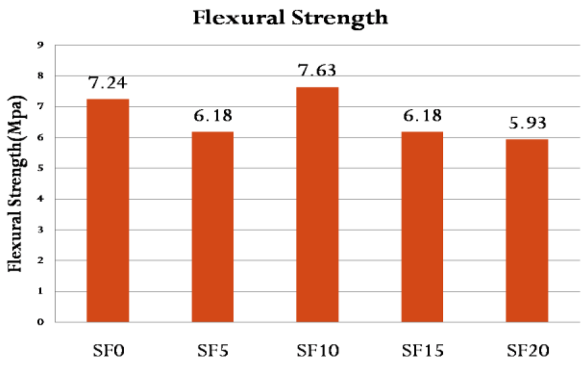

Fig.3.Variation of flexural strength with silica fume replacement level at 28 day

4. Permeability

The permeability of samples was checked using Rapid Chloride Permeability Test (RCPT) after 90 days of water curing. Significant reduction in the chloride-ion diffusion in silica fume mortars was observed and it further decreased with increasing addition of silica fume as shown in Fig.4. Main reason that could be attributed to reduced permeability is that addition of silica fume cause considerable pore refinement i.e. transformation of bigger pores into smaller one due to their pozzolanic reaction concurrent with cement hydration.

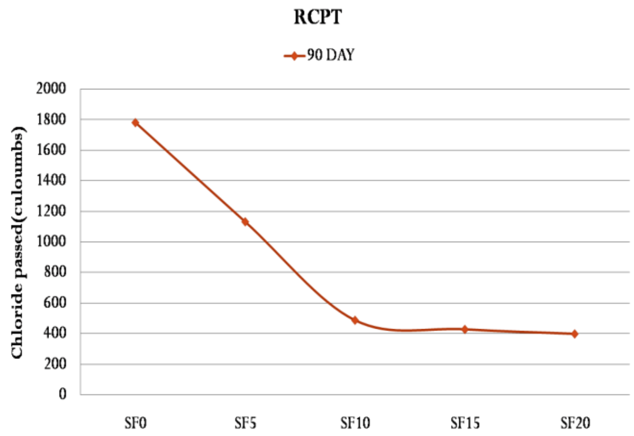

Fig.4.Variation of chloride passed with percentage of silica fume

V. CONCLUSION

The strength studies show that silica fume mortar improved many properties such as compressive strength, flexural strength, permeability etc. It was inferred that for attaining workability for silica fume incorporated mortars, the water/binder ratio has to be increased with increase in percentage of silica fume replacement. Thus silica fume mortars demands high water /binder ratio than the normal mortar[8]. Of the five mixes investigated SF10 showed maximum compressive strength with an increase of 50.1% at 28 day and 45.5% at 56 day than SF0. The increase in strength for SF15 and SF20 was found to be 31.8% and 1.4% for the 28th day compared to control one. Thus the optimum percentage of cement replacement with silica fume is found to be 10%.The increase in strength is mainly due to the aggregate-paste bond improvement and enhanced microstructure. The reason for low strength in the mixes SF15 and SF20, compared to SF10 is attributed to the high water/binder ratio. The results also showed that silica fume did not produce an immediate strength enhancement; instead, the blended mixtures only achieved higher strength than the control from 7 days onwards. Strength loss in the early ages, was probably due to the dilution effect of the pozzolan and as well as the slow nature of pozzolanic reaction. The flexural strength was tested at the age of 28 days. The flexural strength of SF10 showed maximum strength with an increase of 5.38% compared to the control one (SF0). For other mixes the flexural strength reduced. The permeability of silica fume mortar was tested using Rapid Chloride Permeability Test (RCPT).The results showed that all mixes containing silica fume has high resistance to chloride penetration and hence showed very low permeability. From the results we can conclude that silica fume is a suitable supplementary cementitious material which can improve many properties of mortars such as compressive strength, flexural strength, permeability etc.

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