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THE INFLUENCE OF SILICOFERROCHROMIUM FUME ON CONCRETE PROPERTIES

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ABSTRACT

Silicoferrochromium fume containing 85.5% SiO_2 was investigated to determine whether it could be used as an admixture in concrete to increase its strength. The fume was added at the dosage rates of 0-5 % by weight of cement, and a number of test specimens were prepared from this concrete mixture. The unit weight, ultrasound test, hardness, compressive strength of the concrete specimens were determined. The initial and final time of setting values of the mortar specimens were measured. The test results indicated that the properties of the concrete changed considerably with the addition of the silicoferrochromium fume. The compressive strength of the concrete was observed to be maximum at 2 % fume content.

Introduction

Currently, there is extensive work in making use of by-products or waste materials. It is considered that these materials can be used as an admixture in various products.

During the manufacture of silicoferrochromium, fume is collected in electrostatic filters (1). The main reason is to prevent environmental pollution. A review of the literature shows that researches have been conducted in order to investigate the economical usability of this fume for industrial purposes.

Concrete is a composite material consisting of cement, aggregate, water and admixtures (2). Silica fume, a by-product in the manufacture of ferro-silicon and also silicon metal, has been used as an admixture in concrete since 1950. It is a very efficient pozzolan and its SiO_2 content is in the range of 85 to 98 % (3- 6).

Silica fume can also be used in concrete preparation as a part of cement or an admixture in concrete. Silica fume, which is finer than cement, reacts quickly with $Ca(OH)_2$, the product of cement hydration, and forms calcium silicate hydrates. As a result, water-soluble $Ca(OH)_2$ is stabilized. Also nonreacting particles fill the empty spaces between cement particles causing the concrete to have a less permeable structure (6, 7). It has been reported that the concretes containing silica fume possess high strength and durability. For workability and dispersion of silica fume particles, superplasticizers (high-range, water reducing admixtures) are used (8 - 14). Furthermore, it has been shown that the addition of Silica fume has an effect on curing requirements (15) and set-retarding and setting times (16). Previous studies were focused on using silica fume from 5 % to 40 %. The results of these studies show that the more silica fume was used, the more water and superplasticizers were needed. In this case, the cost of concrete increased by adding more superplasticizers and silica fume.

In this study, silicoferrochromium fume containing 85.5 % SiO_2 was added to concrete as an admixture at various amounts up to 5 %. The properties of concretes were examined.

Experimental Program

a) Materials:

Silicoferrochromium fume: Table 1 gives the chemical and sieve analysis of the silicoferrochromium fume. It has a density of about 0.6-0.7 g/m^3 . As a result of the x-ray diffraction and scanning electron microscopy (SEM) studies on silicoferrochromium fume, it has been shown that its structure is amorphous and consists of spherical particles (17). There is no evidence of health hazard caused by silicoferrochromium fume.

TABLE 1: Chemical composition and sieve analysis of silicoferrochromium fume

Chemical Composition		Sieve Analysis	
Material	%	*mm*	%
SiO_2	85.5		
Cr_2O_3	0.40	+0.250	-
Fe_2O_3	1.83	+0.125	-
Al_2O_3	3.61	+0.075	1.50
CaO	1.56	+0.044	3.50
MgO	3.83	+0.037	5.00
C	0.85	-0.037	90.00
S	0.34		
Ignition loss	2.00		

Cement: The cement used was Type II. It has 21.0 and 32.5 MPa compressive strengths at 7 and 28 days respectively.

Aggregate: The sieve analysis of the aggregate is given in Table 2. The blend consists of 15 % crushed stone I, 40 % crushed stone II, 15 % crushed stone III and 30 % sand. The blend conforms to TS 707 (Turkish Codes 707) and ASTM C 33.

TABLE 2: Sieve analysis of the aggregate

Type of material	Sieve size (mm)							
	31.5	16	8	4	2	1	0.50	0.25
Crushed stone I	100	100	86	16	2.87	2.14	1.46	1.20
Crushed stone II	100	85	8.7	3.1	2.05	1.22	1.00	--
Crushed stone III	100	--	--	--	--	--	--	--
Sand	100	100	100	94	61	61	43	5
Mixture	100	64	46	32	20	19	14	2

b) Preparation of test specimens:

Six different batches were prepared for the experiments. In each batch the amount of cement was same however, the amount of the silicoferrochromium fume was varied. Table 3 gives the concrete codes and amounts of the materials used for C 30 which represents standart strength level. The W/C ratio of the samples was 0.50. The concrete was placed in cylindrical moulds having a length of 300 mm and a diameter of 150 mm. There were no chemical admixtures used. For workability of fresh concrete, the slump test was conducted and all the batches have approximately slump value of 80 mm. Each specimen was consolidated using a vibrating table. They were demoulded after 24 hours and then transferred to the moist-curing room until testing. For K3, K4 and K5, only the batch size was increased in comparison to K0 - K2. On the other hand, all the batches had the same mixing proportions.

TABLE 3: Concrete codes and mix proportions, (kg/m^3)

Specimen Code	Cement	W/C	Crushed Stone I	Crushed Stone II	Crushed Stone III	Sand	Fume %*
C30-K0	364	0.5	273	728	277	564	0
C30-K1	364	0.5	273	728	277	564	1
C30-K2	364	0.5	273	728	277	564	2
C30-K3	387	0.5	289	764	290	590	2.82
C30-K4	387	0.5	289	764	290	590	3.76
C30-K5	387	0.5	289	764	290	590	4.7

* Percentage is weight percent of cement

c) Method:

Cylindrical specimens were prepared for 7 and 28 days compression tests. Before the compression tests, unit weight of the specimens were determined. Then non-destructive ultrasound test were conducted on each specimen. For the compression test, a 250-ton press was used. The loading rate was 2 kg/cm^2- sec. During the test of specimens the machine was stop at 4- ton load. The surface hardness was found with Schmidt hammer.

Results and Discussion

The results of unit weight, ultrasound, hardness, compressive strength tests at 7 days and 28 days are given in Table 4. Moreover, Figure 1 gives the initial and final time of setting of the specimens. Measurements for time of setting were taken in the normal laboratory environments.

TABLE 4: Test results

Specimen Code	Unit Weight (kg/m3)		Ultrasound Velocity(km/sn)		Hardness		Compressive Strength(MPa)	
	7days	28days	7days	28days	7days	28days	7days	28days
C30-K0	2.46	2.48	3.20	3.30	19.0	27	19.24	29.81
C30-K1	2.43	2.42	3.25	3.40	19.6	28	21.51	30.37
C30-K2	2.44	2.44	3.50	3.55	21.8	31	24.50	39.61
C30-K3	2.42	2.42	3.15	3.20	20.2	30	22.50	34.52
C30-K4	2.40	2.40	3.11	3.12	19.8	29	20.75	33.75
C30-K5	2.48	2.38	3.06	3.02	19 .2	29	20.17	32.82

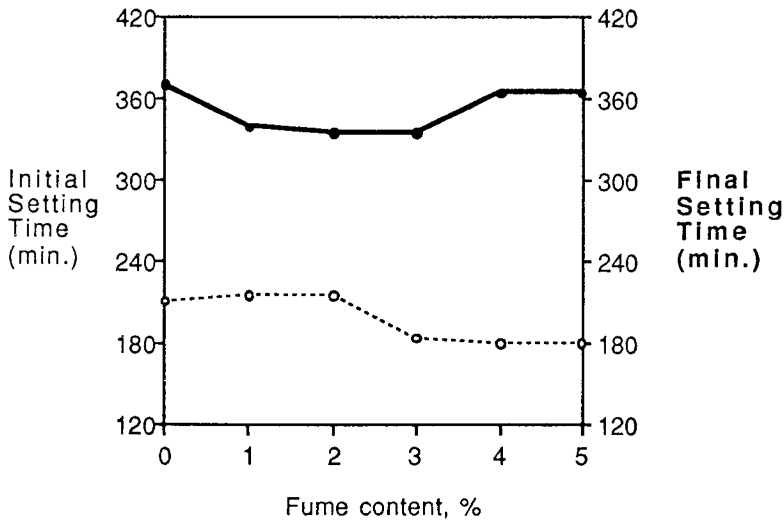

Figure 1. The initial and final setting times of the specimens

The addition of silicoferrochromium fume to concrete affects the time of setting in such a way that it didn't have an influence in the initial time of setting and accelerated the final time of setting between 0 and 2 %. However, the fume addition between 3 and 5 % accelerated the initial time of setting and delayed the final time of setting.

As can be seen from Figure 2, the fume addition caused the concrete to be lighter. For C 30 - K5, about 4 % decrease in unit weight was found.

The specimens were subjected to the ultrasound test in order to evaluate the dynamic modulus of elasticity of the concrete and compare the results

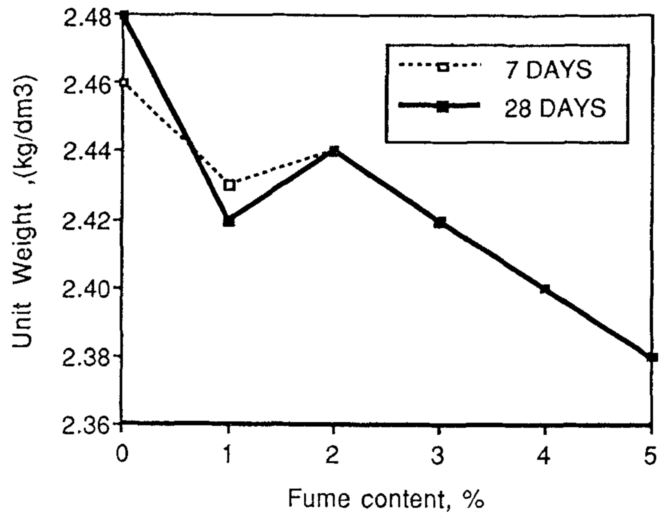

Figure 2. The relation between unit weight and fume content

with the compressive strength test results. Figure 3 shows that maximum ultrasound velocity was obtained at 2 % fume. A decrease was observed in ultrasound velocity between 2 and 5 % fume.

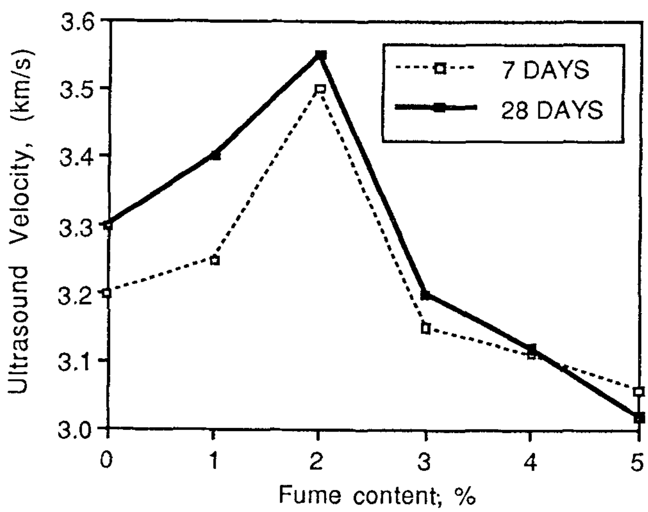

Figure 3. The relation between ultrasound velocity and fume content

As a result of the hardness measurements, it was found that the hardness values were similar in trend to those obtained by ultrasound test or the compressive strength results. Figure 4 shows that the hardness values of specimens containing 5 % fume were almost identical with those containing no fume.

The compressive strength test results have been found to be in line with the previous studies (18, 19). As can be seen from Figure 5, the compressive strength increased up to 2 % fume; after that, increasing fume amount caused a decrease in compressive strength. The 28 days compressive strength of concrete containing 2 % fume was 33 % higher than that with no fume. The fume addition up to 2% improves the properties of cement paste and strengthen bond between the paste and aggregate. Furthermore, it fills the spaces between particles. As a result, the strength is increased.

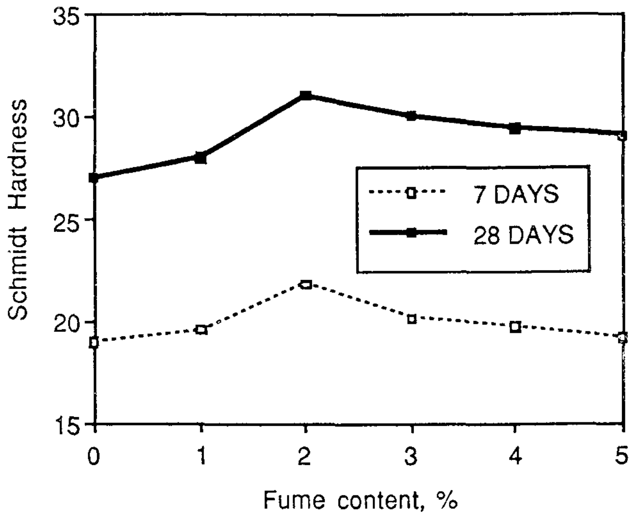

Figure 4. The relation between Schmidt Hardness and fume content

The decrease in the compressive strength for K3, K4 and K5 was thought to be due to the fact that there were not enough water nor superplasticizers for these specimens. The strength variations of the concretes which includes silicoferrochromium fume looks like the strength variations of concretes with silica fume. A change in compressive strength with increasing silica fume (see Figure 6) occurs by pozzolanic and fine particle effects (11). The compressive strength can be raised by using superplasticizer together with silica fume (20), and very high strength concrete can be produced (10, 11). It is necessary to increase superplasticizer in accordance with the amount of silica fume added. As a result, the cost of concrete becomes higher (12).

As can be seen from Figure 6, when the amount of silica fume increases the compressive strength first reaches a maximum, then it decreases. In this study, a maximum strength value was found in the range of 0-5 % fume. The additon of 2 % silicoferrochromium fume resulted in an improvement in the mechanical properties (see Figures 3, 4 and 5). Similar results were observed with use of silica fume (2). In the study, it was shown that the compressive strength can be increased economically by using no other additives such as superplasticizers but only fume. The decrease in strength between 2 and 5 % fume may have been caused by the lack of sufficient amount of water for wetting the fume particles.

In Baradan and Simsek's study (10), concrete was made with fume and superplasticizer additions. Maximum strength was reported at 30 % fume. Moreover, 33.2 MPa and 52.6 MPa strength values were reached at 0 and 10 %

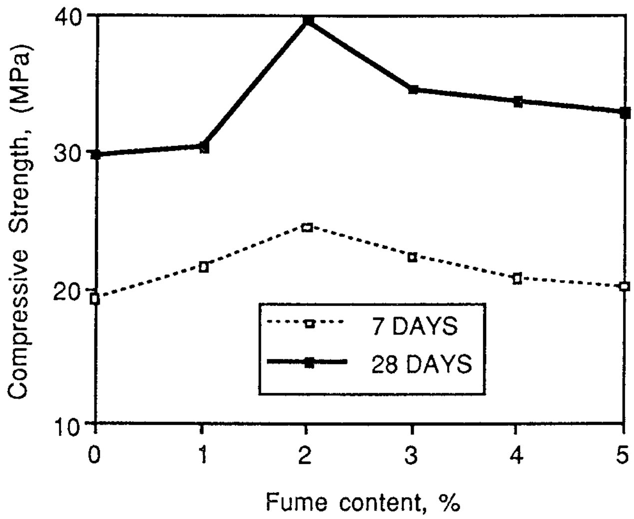

Figure 5. The relation between compressive strength and fume content

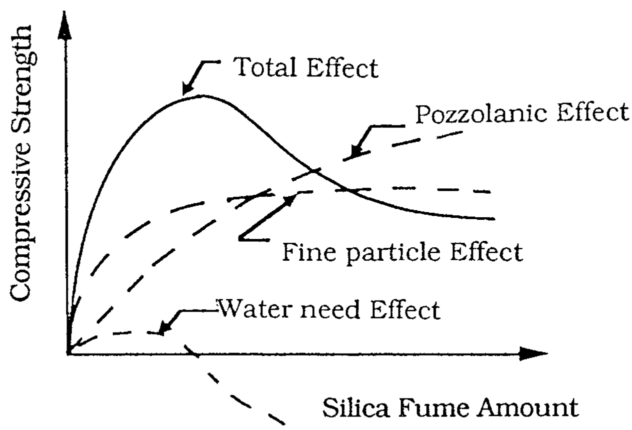

Figure 6. The analysis of the effect of the silica fume amounts on the compressive strength (11)

fume respectively at the end of 28-days experiment. The increase in strength at 10 % fume was 58 %. However, 33 % increase was obtained by the addition of 2 % fume in our study. These results indicate that strength can be increased with the addition of fume even at small amounts, so the use of fume in concrete in this way would be economical.

Conclusion

From the test results obtained in this study, it is concluded that concrete containing fume at a low addition rate of 2 % and W/C ratio of 0.50 can provide satisfactory strength. Moreover, hardness, ultrasound velocity and unit weight can be improved. In this respect, the use of this industrial waste material in concrete would be economical.

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