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Influence of Aging Time on Compressive Strength of Silica Fume Reinforced High Strength Concrete Composite

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Abstract

The goal of this study is to gather a High Strength Concrete (HSC) composite reinforced by silica fume and superplasticizers. Specimens are Cured by water and tested after aging time of 3, 7, 28 days. Specimens are cubes of 150 and 200 mm and 150x300mm cylinder. The aim is to get mean strength of 80- 85 MPa, and determination of physical properties of the materials used, which are basic components of the High Strength Concrete (HSC) composites. After designing mix proportions, according to design requirements some adjustments were done. Both fresh and hardened properties of the specimens were tested under standard condition (curing schemes, setting time, comp.str. etc). Compressive strength test results were gathered and compared with the requirements.

Keywords: High Strength Concrete, silica fume, aging time, compressive strength.

1. Introduction

Concrete is a composite material composed of aggregate bonded together with a fluid cement that cures over time. Concrete has many properties especially High Strength

Concrete (HSC) due to the combination of different materials (cement, aggregate, water etc.), to addition this includes some admixtures depending on the required situation and concrete is the most important member of the construction.

Due to this design and production of HSC is not a simple process and there are no definite techniques to define proportions of the materials used. In order to gathered safe yield each member of the concrete should be tested. Depend on this situation preparing mixture of the HSC carefully should be done. During this study both fresh and hardened properties of HSC, and also the physical properties of materials used were tested.

In plastic stage of concrete (fresh concrete) some basic tests were done such as slump, Ve-Be, air content, K-slump, unit weight and wet density, also some tests for hardened properties of concrete such as compressive strength, and water permeability. The cast specimens were 150 mm cube, 200 mm cube, and 150x300mm cylinder. For determination of compressive strength, 150 mm cube specimens were used. For the water permeability test, 200 mm cube specimens were used. All specimens were cured in water tank until the specified test age.

The physical properties of materials used, such as specific gravity, absorption, and grading of aggregates, and setting times, specific gravity were determined.

2. Experimental Procedure

2.1 General

Cement, aggregate, water, silica fume, superplasticizers and mixing tests, and properties of proposed HSC composite are performed according to specified standards.

2.2 Components of High Strength Concrete Composite

2.2.1 Cement

Throughout this study, Özgür Çimento PKC/B 52.5 cement was used.

2.2.1.1 Setting Time

For determination of the initial and final setting times, neat cement paste of a standard consistency has to be used. It is, therefore necessary to determine for any given cement the water content of the paste, which will produce the desired consistency.

The consistency was measured by the Vicat Apparatus. A trial paste of cement and water is mixed as prescribed in ASTM C305-94 and tested according to C187-98, to determine the normal consistency of hydraulic cement.

The amount of water, which is required "to prepare hydraulic cement pastes for testing", was determined as 128 gr.

After determination of the normal consistency, again by using Vicat Apparatus with different penetrating attachments, according to C191-92, the (initial and final) time of setting of hydraulic cement was determined and found to be for initial setting time 3 hr 40 min and final setting time 4 hr 15 min.

2.2.2 Aggregates

In this study Limestone crushed rock aggregate were used and obtained from Beşparmak Mountains. 4 types Aggregates designed as grading Type 1,2,3, and 4 having max sizes 20, 14, 10, and 5 mm respectively. Only type 4 is taken as fine aggregate and the remaining are coarse aggregates. The properties of aggregates are given in Table (1);

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Table (1): Physical Properties of Aggregates

	Coarse Aggregate Type 1 (T1)	Coarse Aggregate Type 2 (T2)	Coarse Aggregate Type 3 (T3)	Fine Aggregate Type 4 (T4)
SG (SSD)	2.68	2.67	2.68	2.68
Absorption (%)	0.47	0.80	1.01	2.56
Dmax (mm)	20	14	10	5

2.2.2.1 Sieve Analysis

Sieve analysis was done according to BS 882: 1992 for every aggregate blend. Using these results all in aggregate grading obtained by trial and error and checked according to BS 882-1992 limits as shown in figure (1). The percentages by weight of aggregates for 5500 gram of sample mix are given in Table (2). The result of sieve analysis of all in aggregate is listed in Table (3).

Table (2): Percentages and Weights of Aggregates

Type 1	Type 2	Type 3	Type 4
%11	%18	%24	%47
605 gr	990 gr	1320 gr	2585 gr

Table (3): Combined Aggregate Sieve Analyses

Sieve no	Wt.+Ret.	Cum.Wt	Cum % Ret	Cum % Pass.
28	0	0	0	100
20	28	28	1.0	98.97
14	325	354	13	87.0
10	255	609	22.36	77.64
5	646	1255	46	53.93
2,36	493	1747	64.13	35.87
1,18	310	2057	75.51	24.49
0,6	208	2265	83.15	16.85
0,3	146	2411	88.15	11.49
0,15	96	2506	92.03	7.97
Pan	217	2724	100	0

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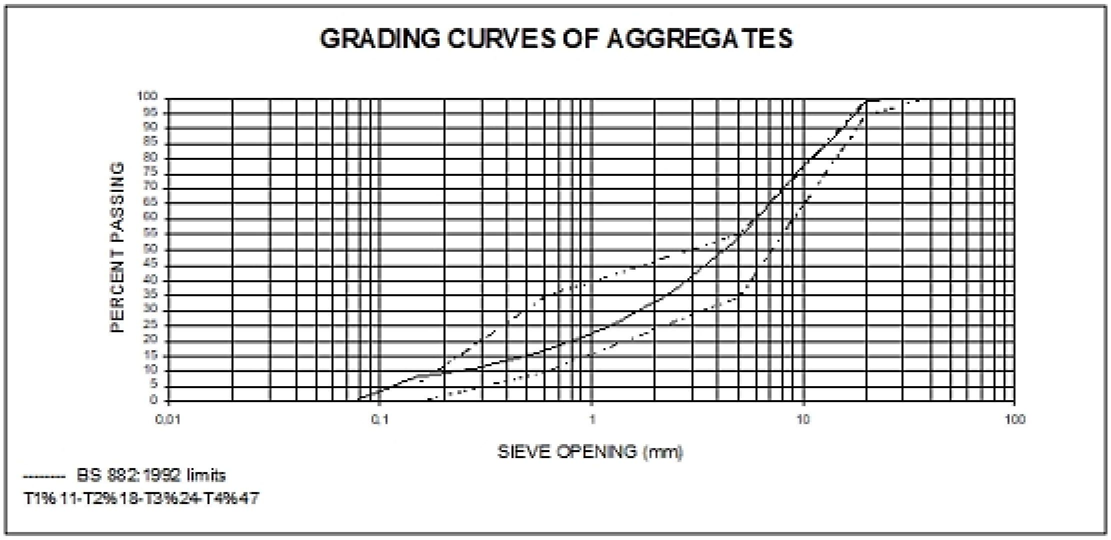

Figure (1): Grading curve of aggregate

2.2.3 Water

Tap water was used as mixing water throughout this study, also the same water was used for providing water curing in curing tanks as well.

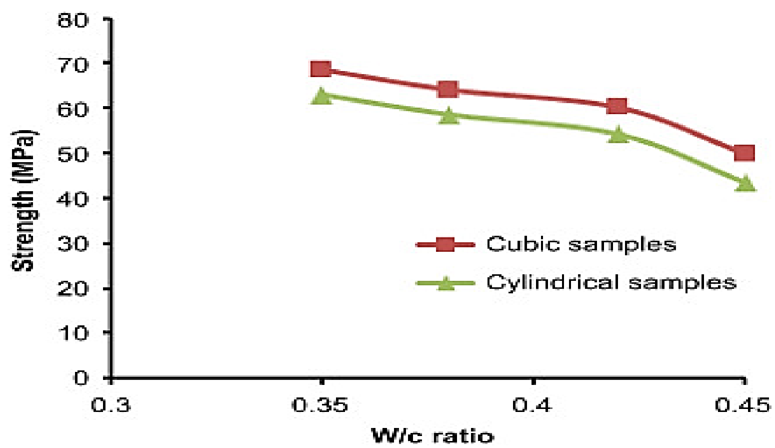

Figure (3): the relationship between w/c ratio and concrete strength

2.2.4 Admixtures

2.2.4.1 Silica Fume

To improve the strength of the hardened concrete composite, reinforcement material should be added to the concrete mix. Silica fume was used as reinforcement material, and it was at 10 % addition by weight of the cement. Silica fume is similar to fly ash, but has a particle size 100 times smaller. This results in a higher surface-to-volume ratio and a much faster pozzolanic reaction. Silica fume is used to increase strength and durability of concrete, but generally requires the use of superplasticizers for workability. The chemical composition of silica fume used in this project is shown in Table (4).

Table (4): Chemical Composition of Silica Fume

Ingredients	%
Insoluble SiO_2	50.66
Soluble SiO_2	25.90
Al_2O_3	0.70
Fe_2O_3	0.42
CaO	1.06
MgO	5.04
SO_3	1.18
Loss on Ignition	3.72

Super plasticizers:

Superplasticizers (also called high-range water-reducers) are a class of plasticizers that have fewer deleterious effects and can be used to increase workability more than is practical with traditional plasticizers. Superplasticizers are used to increase compressive strength. It increases the workability of the concrete and lowers the need for water content by 15–30%. Water reducing admixtures lower the quantity of mixing water required to produce fresh concrete of a given slump. Therefore, they lower the water-cement ratio and improve strength, impermeability and durability of hardened concrete. A high range water-reducing admixture, which is commercially known as Sikament FF- N was used throughout this study. It was stored in a suitable place within the laboratory to protect it from freezing or very cold weather. The properties of Sikament FF-N are as follows:

- Active ingredients: Melamine Formaldehyde.
- Colour: Brown.
- Form: Liquid.
- Dosage range: 0.8-3 % by weight of cement.
- Shelf life: 1 year.
- Agitation needed: Product is not subject to sedimentation. Therefore there is no need for agitation before use.

2.3 Mix Details

The water to cement ratio used for this study was 0.375 for the target mean strength of 80-85 Mpa (150 mm cube) at 28 days. Concrete samples were produced by using silica fume at percentages of 10% by weight of cement for mixes. Proportioning of each material was done by the balance which is weight batching method and it is the best approximation for the determining quantity of each member of the mix. see table (5).

2.4 Mixing and Casting

Before starting to prepare of the mixture materials the mixer controlled and to be sure that the mixer neat and proper for making concrete in this study pan type laboratory mixer was used. The materials loaded into the mixer at a sequence features, firstly aggregate loaded from coarser to finer sizes, then cement, silica fume and water including superplasticizers were put respectively.

The superplasticizers was mixed with water then this was loaded into the mixer the reasons of pouring such mixing to get more efficient and uniform distribution.

In order to precaution differentiation of the mixes the same mixing procedure was applied in all the mixes. Both the total mixing time and vibration time of the poured concrete in cube was 3,1 minutes respectively.

Table (5): Quantities of materials used

80-85 Mpa (Target mean)	
Coarse aggregate (kg/m3)	780
Fine aggregate (kg/m3)	680
Water (kg/m3)	220
Silica fume(kg/m3)	60
Cement (kg/m3)	600
Superplasticizer (kg/m3)	15

2.5 Curing of Test Specimen

The specimens of concrete composite were treated by keeping it in the molds for 24 hours in curing room and after 24 hours these test specimens were immersed into the water-curing tank, the duration of the specimens in this tank depending on the test ages (3, 7, 28 days).

2.6 Mechanical Properties of Hardened Concrete

2.6.1 Compressive Strength Test

The test was applied on 150 mm cubes, the compressive strength results were obtained at 3, 7, and 28 days and 3 test specimens were performed for each age and average value considered. These tests carried out with the help of compressive strength testing machine with a loading rate of 0.5 Mpa/sec.

Water Permeability

This experiment was done according to DIN 1048 (1991). The dimensions of the test specimens were 200x200x200 cubic samples and test age was 28 days curing (both curing room and moist curing). The test specimens were postponed under constant water pressure which is filling direction of mould and at a pressure rate of 0.5 N/mm^2 for a period of 3 days. (Fig. 4).

Fig. (4): Water Permeability Apparatus

After completing test period the test specimen was taken out and split down at the center, which was exposed to water facing down. The broken face of the specimen indicated the sign of drying, after some period of time the maximum depth of penetration was measured.

3. Results and Discussions

3.1 General

In this part of the research test results (slump, K-slump, VeBe time, wet density, air content, compressive strength, tensile splitting strength, Schmidt hammer, Pundit and water permeability) on both fresh and hardened concrete are given. Results and discussions were made about the effects of cement content and bond strength between cement paste and aggregate.

3.2 Tests on fresh concrete

In the fresh state of concrete Slump, K-slump, Ve-Be time (to measure workability), wet density, and air content tests were carried out. Concrete can be seen that workable in order to cast and place of concrete at least one of these methods should be done. The ACI definition of workability, given in ACI 116R-90 is: "that property of freshly mixed concrete or mortar which determines the ease an homogeneity with which it can be mixed, placed, consolidated and finished."

3.2.1 Measurement of Workability:

Unfortunately, there is no acceptable test, which will measure directly the workability. Numerous attempts have been made, however, to correlate workability with some easily determinable physical measurement, but none of these is fully satisfactory although they may provide useful information within a range of variation in workability.

In this study Slump test, K-slump (Nasser's K-tester) and Ve-Be test were performed on fresh concrete to gather workability of the mixes.

3.2.1.1 Slump Test

This is very popular and mostly used in fieldwork all of the construction. The slump test does not measure the workability of concrete, although ACI 116R-90 describes it is a measure of consistency, but the test is very useful in detecting variations in the uniformity of a mixture of a given nominal proportions.

The slump test was done according to ASTM-C143:90a, during the experimental study. The slump value of the mix is shown in Table (6).

3.2.1.2 K-Slump Test

This test uses a hollow probe with openings through which mortar can enter the tube. It is claimed that, the readings, taken after applying standard test procedure of the devise, give an indication of consistency and workability of the concrete because the probe readings are affected by cohesive, adhesive an friction forces within the mix. The K-Tester has not been standardized and is not widely used.

During the laboratory work, the procedure followed for this test was according to the manual of the devise, which is supplied by manufacturer. The result of the mix is shown in Table (6).

3.2.1.3 Ve-Be Time Test

This is method is also ease to measure workability especially stiffer and dry mixes because the removing air from class surfaces of apparatus and concrete takes few seconds. By using of this method, placing of concrete can be defined according to the test results.

During the laboratory work, the Ve-Be test was carried out according to the standard BS 1881: Part10:1983 and the resulting Ve-Be time for the mix is shown in Table (6).

Table (6): Fresh Properties of Trial Mix

MIX	W/C	% FF-N (SUPERPLASTICIZER)	SLUMP (mm)	Ve-Be (seconds)	K-SLUMP
	0.375	2.5	160	3	0.5

3.2.2 Air Content Test

This test also was performed in fresh state of concrete. At the end of the mixing time of fresh was taken out and placed the Air Entraining Meter apparatus and operated according to ASTM C231. The air content value was 1.3%.

3.3. Compressive Strength Test

The compressive strength test result at a target mean strength 80 - 85 MPa at 3, 7, 28 days are listed in the Table (8).

Table (8): Compressive Strength Results

Test age	Weight (kg)	Force (N)	Compressive strength (MPa)	Average
3	7.820 8.039 8.033	1209 1190 1220	53.7 52.9 54.2	53.6
7	8.116 8.000 8.065	1598 1584 1625	71.0 70.4 72.2	71.2
28	8.080 7.885 8.045	2180 2107 2084	96.9 93.6 92.6	94.4

From Table (8) and figure (5) the samples get 56% of its strength at first 3 days and 75% of it at 7 days.

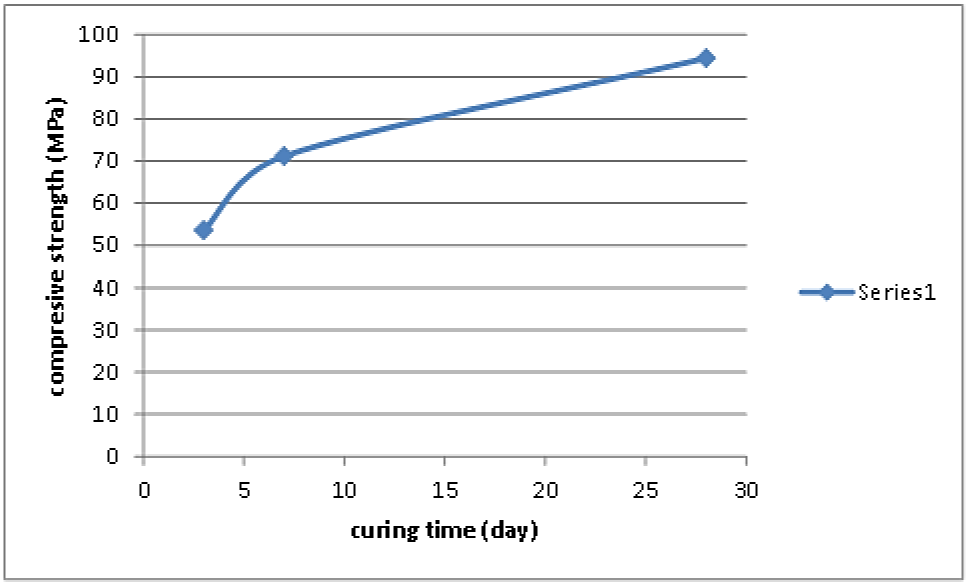

Figure (5): compressive strength results related to curing time

4. Conclusions

- Compressive strength of concrete composite reinforced by silica fume and superplasticizers (HSC) tests were done to the specimens at 3, 7and 28 days, the results after 3 days showed high increasing in compressive strength (about 56% of strength at 28 days), 75% of strength at 28 days was obtained at 7 days. Then the compressive strength increased slightly till 28 days (94.4 Mpa). The high compressive strength was performed because of using low w/c ratio and reinforcing by fine materials.
- It can be concluded that the use of reinforcement materials such as silica fume and fine aggregate lead to gain concrete with low water permeability comparing with NSC.

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