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EFFECT OF SILICA FUME ON PARTIAL REPLACEMENT OF CEMENT ON HIGH STRENGTH CONCRETE

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Abstract

The incorporation of silica fume into the normal concrete in the present days to produce the tailor made high strength concrete the strength of concrete increases with incorporation of silica fume in partial replacement of cement in a high strength concrete. The main objective of this research work has been made to investigate the compressive strength and flexural strength of concrete by incorporating silica fume. In this present research work 5 (five) different mix of concrete were made incorporating silica fume. These experiments were carried out by replacing cement with different percentages of silica fume at a single constant water-cement ratio keeping other mix design variables constant. The silica fume was replaced by 0%, 5%, 10% and 15% with constant water-cement ratio of 0.40. The silica fume incorporated concrete was tested for 1 day, 7 days, 28 days and 60 days compressive strength and flexural strength. Other fresh concrete properties like compacting factor and slump were also determined for five mixes of concrete to find the workability of the concrete.

Keywords
Silica Fume, Compressive Strength, fresh Concrete, High performance concrete, Slump.

1. Introduction

Concrete is one of the most important and widely used man-made construction material. Concrete is a composite construction material, composed of cement (commonly Portland cement), coarse aggregate made of gravels or crushed rocks, fine aggregate (sand), and water. Super plasticizers were added to concrete to get required workability. Concrete is an incredibly useful and flexible building material without which modern architecture and construction would not be possible. It can easily be poured into forms and molds to create different shapes and it will be quickly hardens to become a durable stone-like material. Concrete is used in construction of building components such as beams, columns, foundations, bridges, roads and many other applications.

Most of the normal concrete structures deteriorate after ages especially when they face some challenging environments. Consequently, they require repairs before their expected service life is reached to end. In order for a concrete to be good, it must meet two criteria; firstly the concrete has to be satisfactory in its fresh and secondly in hardened state. Concrete in its fresh state must be consistent and cohesive, In other words, consistency of the mix should be such that it can be compacted easily without excessive effort, and also the mix should be cohesive enough so as not to produce segregation with a consequent lack of homogeneity of the finished product. The significant requirements from a concrete in its hardened state are satisfactory compressive strength and adequate durability (Neville, 1995).

The main aim of this study was as follows;

- To study the behavior of partially replaced silica fume based concrete in fresh state.
- To obtain the compressive strength and flexural strength of the partially replaced silica fume based concrete.

2. Selection of material

Cement; Portland cement is made by heating a finely divided mixture of clay or shale and chalk or limestone in a kiln at a temperature-around 1500^0 C, such that chemical combination occurs between them. Ordinary Portland cement is the cement best suited for general concreting purposes. It is the lowest priced cement and combines a reasonable rate of hardening with moderate heat output.

Coarse aggregate; The coarse aggregate was air dried to obtain saturated surface dry condition to ensure that water cement ratio was affected. Few characteristics of aggregate that affect the workability and bond between concrete matrixes are shape, texture, gradation and moisture content. In this study crushed aggregates from quarry with the nominal size 5-15 mm were used in accordance to BS 882-1992.

Fine aggregate; Fine aggregate is commonly known as sand and should comply with coarse, medium, or fine grading needs. The fine aggregate was saturated under surface dry conditions to ensure the water cement ratio is not affected. The oven dry sand will then be sieved sand passing through the 600μm sieve before it was stored in an airtight container from atmospheric humidity.

Super plasticizer; The Super plasticizer is used for this project is Rheobuild1000. The purpose of super plasticizer is to increase the workability of concrete. The super plasticizer is applied as a constant by 2.5% of total cement.

Silica fume; Silica fume is a by-product in the reduction of high purity quartz with coal in electric arc furnaces during the production of Ferro-silicon metal. Silica fumes are sometimes referred to as micro-silica or condensed silica fumes and it is used as a pozzolanic material. This is due to the fact that it has high glass content (Gambhir, 2004) and fineness of 2x107mm2/g. It is then taken for processing and removing of all the impurities and standardizing the sizes of the particles.

Water; the chemical reaction between water and cement is very significant to achieve a cementing property. Hydration is the chemical reaction between the compounds of cement and water yield products that achieve the cementing property after hardening. Therefore it is necessary to that the water used isnotpolluted or contain any substance that may affect the reaction between the two components, so tap water will be used in this study.

3. Concrete mix design

The present experimental research program was conducted to determine the effect of silica fume on properties of concrete. Experiments performed only for cement replaced by different percentages of silica fume and all the other mix design variables like amount of aggregates, water content and super plasticizer proportions were kept constant. In this work the following ratio used for mix design (cement, sand, coarse aggregate) is 1.2:1:1.5. The mix proportions were summarized in table 1.1.

Table 1.1 Mix proportion

Specimen	Cement (kg/m^3)	Silica fume		Fine Aggregate (kg/m^3)	Coarse Aggregate (kg/m^3)	Water (kg/m^3)	Super plasticizer %
		%	(kg/m^3)				
SF (0%)	700	0	0	596	894	210	2.5
SF (5%)	665	5	35	596	894	210	2.5
SF (10%)	630	10	70	596	894	210	2.5
SF (15%)	595	15	105	596	894	210	2.5

4. Tests on Fresh Concrete

Slump test

Slump test was performed on the fresh concrete to test its consistency or workability followed by compacting factor test to measure its compacting factor and assess its workability.

The concrete slump test was used for the measurement of the property of fresh concrete, more specifically to determine the workability of the concrete mix. The slump test is prescribed by BS 1881: part 102:1983.

Table 1.2: *Slump test results*

Amount of Silica Fume (%)	Slump Height (mm)
0	50
5	20
10	16
15	8

Compaction factor test

The table 1.3 shows the compacting factor for different percentages of silica fume as a replacement of cement. Compacting factor and slump tests both are used for the same purpose which is determination of workability of fresh concrete; it will be helpful to validate the results.

The test was carried out according to BS 1881: part 103:1983. The data shows a similar result as of the slump test. The value of compacting factor for control mix is indicating the highest workability, while it decreases with the enhancement of silica fume amount. Concrete containing 15% of silica fume indicates the lowest compacting factor value. The reduction in workability is due to the enhancement of silica fume.

Table 1.3: *Compaction factor test results*

Amount of Silica Fume (%)	Compacting factor
0	0.950
5	0.945
10	0.930
15	0.915

5. Tests on hardened concrete

Compressive strength test

The compressive strength of concrete specimens is taken as maximum compressive load it can carry per unit area. The specimen usually in the form of a cube is compressed between the platens of a compression testing machine by a gradually applied load. The compressive strength test was carried out on 100 x 200 mm concrete cylinders in accordance with the BS 1881: part 116.

At the ages of 7, 28 and 60 days for three samples of each type of concrete mix (normal concrete and concrete with 5%, 10% and 15% silica fume) were tested for compressive strength and the average value was recorded.

Table 1.4: *Compressive strength test result at the age of 7, 28 and 60 days*

Concrete Mixes	Compressive Strength (N/mm2)		
	7 days	28 days	60 days
SF (0%)	38	59.4	62.7
SF (5%)	41.2	62.2	65
SF (10%)	44.8	67	70.8
SF (15%)	45.3	65.8	69.5

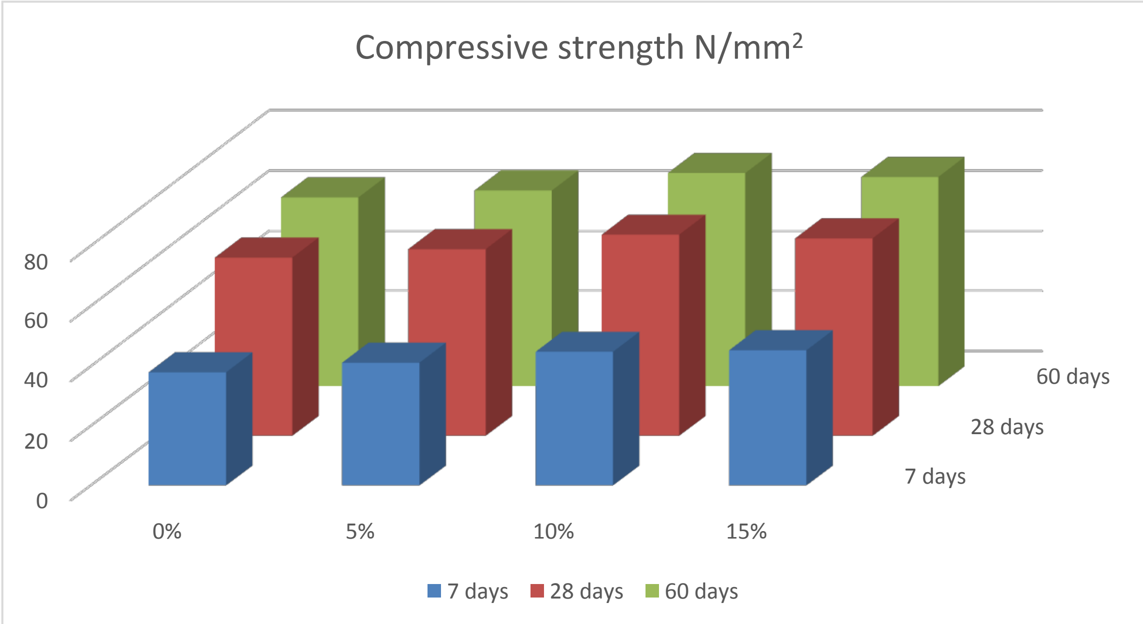

Figure 1

Flexural strength test

Flexural strength test is conducted on unreinforced concrete beam to resist failure in bending. The flexural strength is expressed as modulus of rapture in (MPa). For this research work, flexural strength (modulus of rupture) was determined by centre point loading during which the concrete beam was placed on two rollers and the entire load was applied on its centre. For this research work silica fume was used to investigate its effect on the flexural strength of concrete. Flexural strength test was conducted on 100 x 100x 350 mm beams at the age of 7, 28, 60 days each strength value obtained by the average values of three specimens.

Table 1.5: *Flexural strength results*

Concrete Mixes	Flexural strength (N/mm^2)		
	7 days	28 days	60 days
SF (0%)	2.35	6	6.1
SF (5%)	3.5	7.31	8
SF (10%)	4.37	8.65	8.9
SF (15%)	5.8	9.7	10

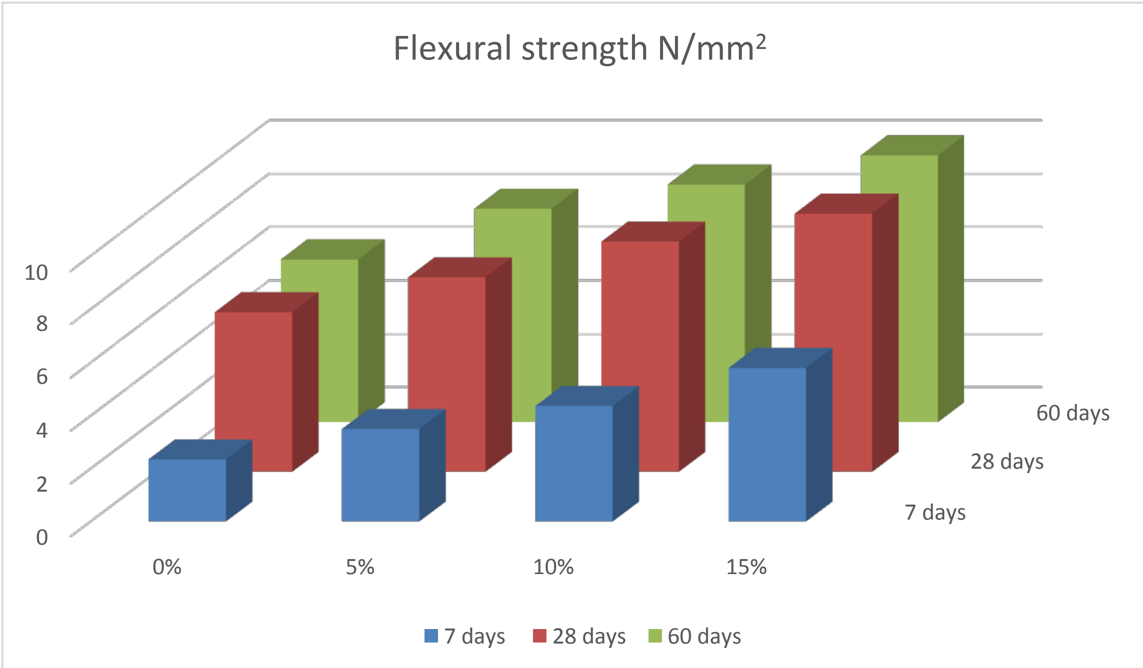

Figure 2

6. Conclusions

- The overall workability of the fresh concrete was low to some extent because a low water/cement ratio was used and the slump loss further increased with the enhancement of silica fume content.
- It was found that up to 10% cement may be replaced by silica fume without harming the concrete workability.
- There is a rapid increase in compressive and flexural strength development between 7 and 28 days, while between 28 and 60 days the development rate reduced. It is due to the fact that concrete gains maximum strength within the first 28 days.
- Concrete containing 15% silica fume replacement achieved the highest compressive strength followed by 10% silica fume replacement with a small difference in strength.
- Flexural strength test showed that with the increase in silica fume content. Based on the flexural test result, concrete with 15% silica fume content achieved the highest flexural strength.

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