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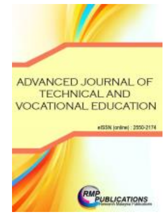

Effect of Silica Fume On The Strength Of Concrete with Portland Composite Cement

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Abstract: The addition of some other materials may change the properties of concrete. Mineral additions which are also known as mineral admixtures have been used with cements for many years. This works aims to study the effect of partial substitution of Portland Composite Cement (PCC) by silica fume (SF) on the physico-mechanical properties especially compressive strength of the hardened PCC–SF composite cement pastes. Properties of cement containing different dosages of Silica Fume and mixture of Silica Fume were prepared. Silica fume is produced in electric arc furnace as a by-product of the production of elemental silicon's or alloys containing silicon. Firstly, SF was used to replace PCC at dosage levels of 5%, 10%, 15% and 20% by weight of cement in concrete. The results show that the PCC-SF exhibited lower early age strength but the strength at 28 days and 56 days was improved. The utilization of SF resulted in significant improvement in the strength of concrete. Silica fume or micro silica was initially vied as cement replacement material and silica fume micro silica may be used as pozzolanic admixtures.

Key words: *Silica Fume, Portland Composite Cement, Mechanical Properties, Compressive Strength, Pozzolanic.*

1. INTRODUCTION

Concrete is the most important engineering material which is a mixture of cement, coarse aggregate, sand and water. Cement is becoming a common product worldwide because of its growing demands day by day. The construction doings in last few decades have increased especially the developing countries and it is time to search such alternative materials that would partially or fully replace cement used in concretes or mortars without affecting its strength, quality and other characteristics. Silica Fume (SF) in concrete has engineering potential and economic advantage. Silica fume will produce a much less permeable and high strength concrete, but it will not produce a concrete with a higher mass per unit volume. Addition of silica fume to concrete has many advantages such as durability, mechanical properties and reduction in cement manufacture. The optimum silica fume replacement percentage for obtaining maximum 28 days strength of concrete between from 10 to 20 % [1-2].

Silica fume, also known as micro silica, is an amorphous polymorph of silicon dioxide. It is an ultrafine powder collected as a by-product of the silicon [3] and ferrosilicon alloy production and can be used either as a densified or undensified powder or as a combination at the concrete mix [4]. The main field of application is as pozzolanic material for high performance concrete. Silica fume is an ultrafine airborne material with spherical particles less than 1 μm in diameter, the average being about 0.1 μm. This makes it approximately 100 times smaller than the average cement particle. The unit weight, or bulk density, of silica fume depends on the metal from which it is produced. The majority of silica fume composites contain of the silicon dioxide (SiO_2) in noncrystalline (amorphous) form depending on the process, 94% - 98% SiO_2 from silicon production and 85% – 90% SiO_2 from ferrosilicon production [5]. When water is added to cement, hydration PCC + H_2O _CSH (Calcium silicate hydrate) + $Ca(OH)_2$. In the presence of SF, the silicon dioxide from the silica fume will react with the calcium hydroxide to produce more aggregate binding CSH as follows: $Ca(OH)_2$ + SiO_2 _ H_2O +CSH. The reaction will decrease the amount of calcium hydroxide in the concrete [6-7]. Silica Fume is an extremely fine

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material with an average diameter 100 times finer than cement.

The Portland Composite Cement (PCC) is one of the main ingredients used for the concrete mixture and has no alternative in the civil construction industry. Unfortunately, production of cement involves emission of large amounts of carbon-dioxide gas into the atmosphere, a major contributor for greenhouse effect and the global warming, hence it is inevitable either to search for another material or partly replace it by some other material [8]. Fly ash in concrete will improves the workability and reduces the water required with respect to conventional concrete and also minimizes the rising production cost of cement. In this study, strength of four different dosages of SF has been investigated with the ages 7, 28 and 56 days and investigates the strength properties of concrete with PCC.

2. MATERIAL AND METHODS

This investigation represents a commonly scenario of the strength of concrete with Portland Composite Cement (PCC) and Silica Fume (SF) both at early and later ages. The experimental work is prepared using locally materials such as sand (river sand), coarse aggregate and cement (Portland composite).

2.1 Materials

Silica fume can either be added separately at the concrete mixer, where they are referred to as 'additions' or else be incorporated into factory-produced composite cement. The silica fume (SF) with high SiO_2 content more than 92%, Specific surface area 23.7 (m^2/g), specific gravity 2.18, median particle size between 0.1 - 1 µm and with gray color were used and the properties of SF are shown in Table 1. The Silica fume is used as a partial replacement of cement.

Table 1 Chemical compounds of Silica Fume Chemical composition of Silica Fume according to Tayeh et al. (2013)

Components	SF%
SiO2	92.6
AL2O3	0.89
Fe2O3	1.97
CaO	0.94
MgO	0.96
P2O5	-
K2O	1.31
SO3	0.33
TiO2	0.25
MnO	0.11
C	0.07
LOI	4.96

Portland Composite Cement used in this study was supplied by YTL Cement Berhad, Kuala Lumpur Malaysia, complies with MS EN 197-1:2007. The cement is in dry powder form with grey colour and the properties and chemical compositions of the cement are given in Table 2, according to the manufacturer.

Table 2 Properties and Chemical Composition of PCC

Element	Composition by (%) PCC
SiO2	20.60
Al2O3	4.74
Fe2O3	3.28
CaO	64.82
MgO	1.84
SO3	2.4
Na2O	0.21
K2O	0.38

Locally available natural river sand obtained from Nibong Tebal was used as fine aggregate in this study. 12.5 mm maximum size of crushed granite was obtained from Kuad Quarry Sdn Bhd in Penanti, Bukit Mertajam and was used as course aggregate. The specific gravity and water absorption of the course aggregate were found to be 2.66 and 0.98% respectively according to BS EN 1097-6: 2000. A suitable gradiation of an aggregate in PCC mix is important to secure strength of the concrete mix [9].

Cement is the cementitious materials in concrete mixture and the properties of concrete ingredients have been constant. The quantity of cement, fine aggregate, coarse aggregate and water have been mixed for the concrete grade 30 and target strength of concrete 30 N/mm2. A concrete mixture has been using w/c ratios 0.5 and the value of proportion as shown in Table 3.

Table 3 Mix proportions per m3 - SF Concrete of Grade 30

Mix	Cement Kg	SF Kg	Fine Agg Kg	Coarse Agg Kg	Water Kg
Control	20	0	39.6	32.72	10
SF (5 %)	19	1	39.6	32.72	10
SF (10 %)	18	2	39.6	32.72	10
SF (15 %)	17	3	39.6	32.72	10
SF (20 %)	16	4	39.6	32.72	10

Concrete specimen have been casted with cube moulds for compressive strength, cylinder moulds and beams for samples tested for split tensile strength test and flexural strength test. Cube moulds were used for determining the compressive strength, 100x100x100 mm cubes were used for concrete sample and all specimens compacted using a vibrating table. Then, the entire specimen need for leaving the molded concrete specimens for a period of 24 hours and demolded. The total 63 numbers of specimens have been prepared and concrete specimens must been cured continuously until testing for 7, 28 and 56 days under water in the laboratory.

3.0 RESULTS AND DISCUSSION

3.1 Compressive Strength

Figure 1 represents the results of the C30 grade concrete for compressive strength test at 7, 28 and 56 days age. The compressive strength of concrete with replacement of SF was increased gradually up to an optimum dosages level of 15% SF. The maximum compressive strength at 7, 28 and 56 days concrete with 15% of SF was 42.8, 45.83 and 48.17 N/mm2 respectively greater than the controlled concrete. Furthermore, the results indicates that the proposed mixture of concrete with 15% of SF. The influence of silica fume to strength development after 28 days is nominal and SF improves in the strength of concrete because of pozzolanic of the volcanic ash.

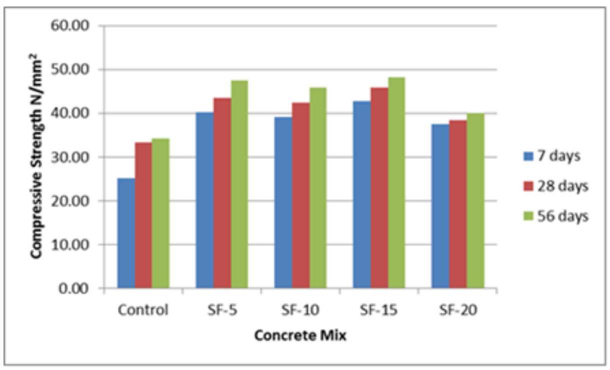

Fig. 1 Effect of silica fume on compressive strength of concrete

3.2 Split Tensile Strength

The results of Split Tensile strength were shown in Figure 2. The test was carried out at the age of 7, 28 and 56 days. The entire sample was tested using Compression Testing Machine (CTM) with capacity 3000 kN. From Fig 2 the increase in strength is 4.18 N/mm2, 4.73 and 4.56 N/mm2at 7, 28 and 56 days. The maximum rise in split tensile strength is observed at 10% replacement of silica fume. The optimum 28-day split tensile strength has been obtained in the range of 10–15% silica fume replacement level.

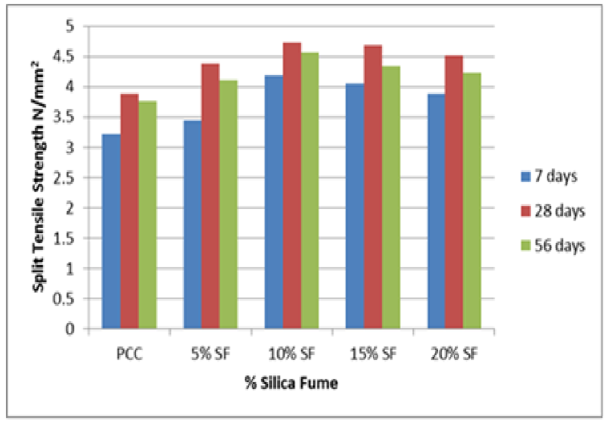

Fig. 2 Effect of silica fume on split tensile strength of concrete

3.3 Flexural Strength

The results of flexural strength of normal concrete and silica fume replaced concrete were presented in Figure 3. The test was obtaining Flexural strength of concrete at the age of 7, 28 and 56 days. The specimens were tested using Universal Testing Machine (UTM) of capacity 1000 tonnes. From Fig 3 the maximum increase in flexural strength is observed as 7.85 N/mm2, 9.45 N/mm2and 8.87 N/mm2 at 7, 28 and 56 days when silica fume is replaced by 15% by cement. The flexural strength at the age of 28 days of silica fume concrete continuously increased 7.17, 8.98, 9.45 N/mm2 at 5%, 10% and 15% replacement level for SF and reached a maximum value of 15% replacement level for C30 grades of concrete.

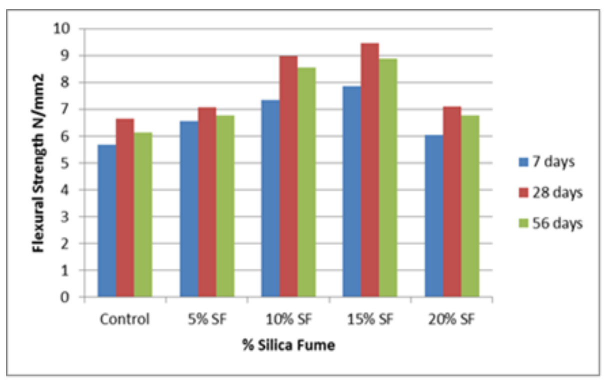

Fig. 3 Effect of silica fume on flexural strength of concrete

4.0 CONCLUSIONS

The addition and replacement of silica fume in concrete reduces workability. The optimum 7 and 28-day compressive strength and flexural strength have been achieved in the range of 10-15 % silica fume replacement level but in split tensile strength obtained 10 % silica fume replacement. Silica fume inclusion increases compressive strength depend the replacement of dosages level. Tensile strength and flexural strength of silica fume concrete is like to that of conventional concrete. These effects are due to chemical reaction between silica fume and Portland composite cement. Addition of silica fume improves bond strength of concrete and previous researcher reported that at 15% replacement level bond strength of silica fume concrete found to be increase in the range of 37-43% as compared to concrete without silica fume.

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