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SELF FIBER COMPACTING CONCRETE (SFCC) PROPERTIES INCORPRATED WITH SILICA FUME AND FIBER

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ABSTRACT

SFCC is one of the self-compacting concrete innovations. With the presence of fiber, this concrete is not only famous for its own compaction process but also has good tensile strength and good ductility when compared to normal Self Compacting Concrete (SCC). Taking into account the environmental and economic factors of the use of cement as a major component in the manufacture of SFCC, this research is innovating by reducing the use of cement and replacing it with the use of silica fume. The silica fume variations used in this study include 5%, 10%, and 15% with the use of 1% nylon fiber. Fresh properties testing including slump flow, T50, V - Funnel, and L - Box for silica fume variations were conducted in this study. Not only that, compressive strength, tensile strength and flexural strength testing are carried out to study the mechanical properties of the SHCC against silica fume variations. The results show that the use of silica fume variations will affect the fresh properties and mechanical properties of the SFCC concrete. The use of 5% silica fume in SFCC concrete is the optimum use to get the optimum compressive strength.

KEYWORDS

Self-fiber Compacting Concrete, Silica fume, Compressive strength, Tensile strength, Flexural strength, Fresh properties

INTRODUCTION

In the construction of concrete structures, the compaction process is generally carried out after the concrete is put into the formwork. However, when casting is carried out on a large scale, it will have an impact on the increasingly difficult process of vibrating work. Therefore, some researchers conducted studies to create concrete technology that is able to overcome this problem known as Self Compacting Concrete. In the mid-1980, Self-compacting Concrete (SCC) was first developed in Japan [1-2]. SCC is a well-known concrete with the ability to compact itself without the help of the vibrating process. SCC is able to flow under its own weight, allowing it to fill in the formwork and reach the highest density [3]. As for some of the other benefits of using SCC including reducing the cost of compaction work, labour time and labour costs, reducing permeability and increasing durability [4-6]. Therefore by considering its benefits, SCC is commonly applied in various infrastructures such as buildings [7], dams [8] and pre-stressed beam girders [9].

Previous researchers have developed SCC with creating the innovations that had reach at SCC's characteristics that are not only able to compacted itself but also have high tensile strength and ductility. For obtaining better tensile performance, commonly previous researchers have added a fiber called self fiber compacting concrete (SFCC). The several types of fiber that have been used by previous researchers such as polyprophylene fibers, steel fibers [10], nylon fiber and zeolite [11] and waste plastic fibers [12, 13]. According to the previous researchers, using fiber does not only effect on increasing the tensile performance but also the flexural performance that triggers for producing the high ductility.

Several studies have perfected the characteristics of SCC to become SFCC. It is very beneficial in the concrete tensile strength performance, but there are some things that need to be considered, namely by considering environmental factors and cost of materials. The use of cement as a main component of SFCC can increase global warming. This is due to the fact that the manufacture of cement produces CO_2 gas which can trigger global warming. By considering it, this research tries to innovate by reducing cement and replacing it by using silica fume variations. Based on previous research, it was revealed that the use of silica fume can improve mechanical properties in concrete. This is due to the presence of CSH. The silica fume reacts with the cement paste to the additional strong form Calcium Silicate Hydrate (CSH) providing higher strength. Silica fume reduces bleeding and enhances the cement paste bond to the aggregates. Thanks to its pozzolanic effect (reaction with $Ca(OH)_2$), and therefore to the strength improvement, silica fume can be used to reduce the cement content of the mix. In addition to the cost-saving benefits, this will reduce the total heat of hydration and can improve the performances of the concrete in terms of chemical resistance.

Some of the previous studies only examined the use of silica fume in SCC but for the use of silica fume in SFCC is something that needs to be developed. Therefore, this study examined the effect of using silica fume variations on the SFCC with variations of 5%, 10%, 15%. The purpose of this study was to determine the fresh properties and mechanical properties of the SFCC against superplasticizer variations. Not only that, to get the right optimum percentage used in SHCC concrete.

METHODS

Material properties

The material used in making SCC consists of sand, gravel, cement, fiber, water and silica fume. Type I cement was used in this study. As for some preliminary tests conducted to determine the characteristics of sand and gravel including testing water content, specific gravity, absorption, mass density, mud content and roughness content. Specific gravity results for sand and gravel are 2.76 and 2.58. The size of coarse aggregate granules in this study was used at 19 mm. The results of sand grain gradation analysis can be seen in Figure 1. The quality of sand and gravel aggregates can be seen in Table 1. While the type of fiber used in this study is nylon fiber which cut per 5 cm that can be seen in Figure 2. Nylon fiber is used as much as 1% of the weight of cement. Silica fume is a type of pozzolan or material containing silica and alumina compounds, this study uses silica fume from PT. Sika Indonesia. Superplasticizer is an added ingredient that works to reduce water usage. This research uses a superplasticizer in the form of Sikament LN from PT. Sika Indonesia.

Tab. 1 - Specification of fine aggregate and coarse aggregate

Test Item	Unit	Fines Aggregate	Coarse Aggregate
Water Content	%	1.97	0.71
Specific Gravity	-	2.76	2.58
Absorption	%	2.81	0.75
Mass Density	gr/cm^3	1.72	1.55
Mud Content	%	4.01	0.91
Roughness content	%	-	32.87

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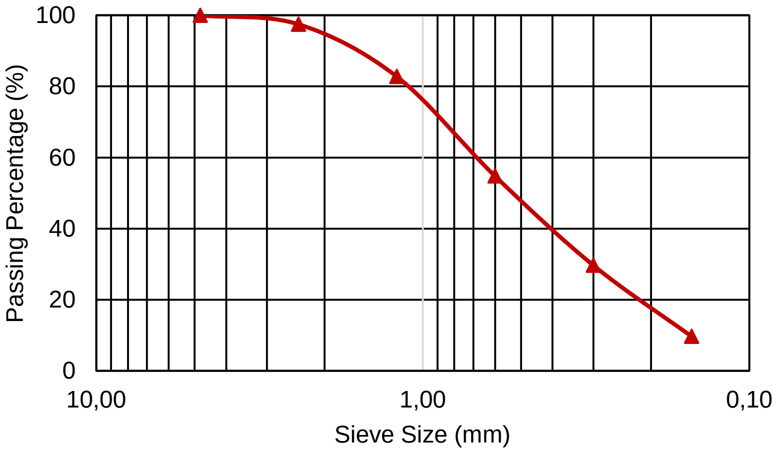

Fig. 1 - Gradation of fine aggregate

Fig. 2 - Nylon fiber

Mix design

The mix design used in this study uses a 30 MPa compressive strength plan with a fas value of 0.23 and refers to research by Aggarwal et al. (2008) [14] . The percentage of silica fume used is 0%, 5%, 10%, and 15% with 1% nylon fiber percentage. Table 2 presents the concrete design mix of Self-Compacting Concrete (SCC) per m^3. Material mixing method is carried out by the stages of mixing fine materials such as cement, silica fume, and fine aggregate into the mixer and followed by the addition of coarse aggregate then stirring evenly. Water and superplasticizer are added gradually until the mixture is homogeneous. Nylon fiber is added little by little, each addition of fiber to the mixture, the mixer is rotated 1 to 2 times to flatten the nylon fiber. Mixing that is the same when given fiber will cause clumping of the fiber to the mixture.

Tab. 2 - Mix design of SFCC per m3

Materials (Kg)	0% SF	5% SF	10% SF	15% SF
Cement	485.00	460.75	436.5	412.25
Silica Fume	-	24.25	48.5	72.75
Fines Aggregate	600	600	600	600
Coarse Aggregate	561	561	561	561
Superplasticizer	7.275	7.275	7.275	7.275
Nylon Fiber	-	4.85	4.85	4.85
Water	135	135	135	135

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Fresh properties test

To determine the concrete characteristics of Self-Compacting Concrete (SCC), fresh properties need to be examined to obtain the value of filling ability, passing ability, and flowability with the slump flow, T50, L-box, and V-funnel. T50 test was conducted to determine the flowability and flow rate at SCC without any obstructions. This test uses a cone cone and T50 cm. V-funnel testing is performed to determine the value of viscosity and filling ability in self-compacting concrete. The tool used in this test is a V-shaped funnel, at the bottom there is a door that can be opened and closed. The v-funnel test results from self fiber compacting concrete (SFCC) with the addition of silica fume variation of 0%, 5%, 10%, and 15% in a row that is 4.48 seconds, 9.06 seconds, 10.08 seconds , and 11.15 seconds. The V-funnel test results can be seen in Figure 3(a). The criterion in the concrete mixture that flows out of the funnel has duration of 6 -12 seconds [15]. L-box testing is carried out to determine the passing ability of self-compacting concrete in flowing through tight holes including the space between reinforcing steel reinforcement and other obstructions without segregation. L-box test results can be seen in Figure 3(b). The criterion used is the ratio h2/h1 which is between 0.8 - 1. Slump flow testing is carried out to determine the flowability which is the main examination that the consistency of fresh concrete meets the specifications. Slump flow testing requirements on self-fiber compacting concrete (SFCC), which is between 550 - 850 mm.

Hardened properties test

Concrete compressive strength testing is performed on concrete with ages 7, 14, and 28 days using a compressive machine test. Compressive strength testing is done by applying axial load pressure to the cylinder until a failure occurs [16]. How to calculate the compressive strength of concrete can be seen in Equation 1. P represents the maximum load (kN) and A represents the section area (mm^2).

$$\text{Compressive strength } = \frac{P}{A} \qquad (1)$$

Split tensile testing is carried out at ages 7, 14, and 28 days. Test object placement on a tensile testing machine using a steel plate that functions to distribute the compressive load to all parts of a concrete blanket. Concrete tensile strength testing is done by applying compressive force to the blanket or the diameter of the concrete cylinder which causes tensile collapse [17]. How to calculate the concrete tensile strength can be seen in Equation 2. P represents the maximum load (kN) and D represents the diameter of specimen (mm) and L is the length of specimen (mm).

$$\text{Tensile strength} = \frac{2P}{\pi LD} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (2)$$

Flexural strength testing is performed on concrete with ages 7, 14 and 28 days. In this test uses a point loading in the middle of the specimens [18]. The specimen dimension is 150x150x600 mm. The displacement was measured in the middle of specimens.

RESULTS

Fresh properties characteristic

Figure 3(a) shows the results of the SFCC v-funnel test with silica fume variation of 0%, 5%, 10%, and 15%. From the figure below it can be concluded that the higher the silica fume level, the higher the viscosity level of the mixture. Figure 3(b) shows the results of the L-box test with successive results namely 0.97; 0.93; 0.91, and 0.85. The figure shows that the less of using the silica fume level will effect on the better the ability of concrete for filling space.

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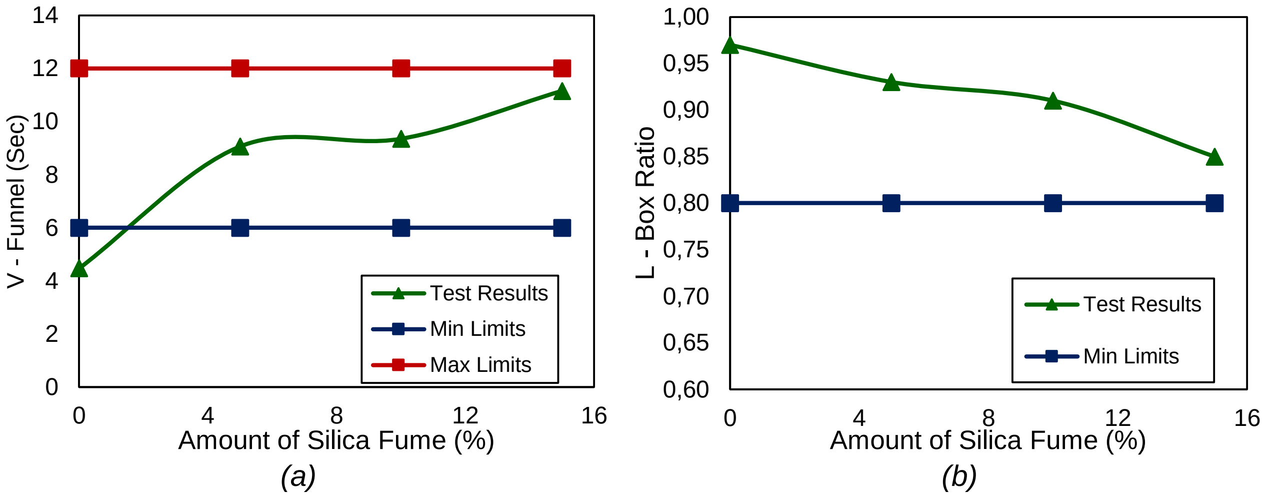


Fig. 3 – (a) V-funnel; (b) L - Box ratio on varying silica fume on SFCC

Figure 4(a) shows the results of slump flow testing with successive results namely 700 mm; 675 mm; 663 mm; and 658 mm. The test results show that the higher the silica fume content used effect on the lower the concrete's ability to spread. Figure 4(b) shows the results of T50 testing with successive results namely 2.53 seconds, 4.60 seconds, 4.65 seconds, 5.00 seconds. The figure shows that the higher the concentration of silica fume used, the longer the time needed for concrete to reach a diameter of 500 mm, this is because the higher the concentration of silica fume used, the concrete mixture will be thicker because silica fume will absorb more water .

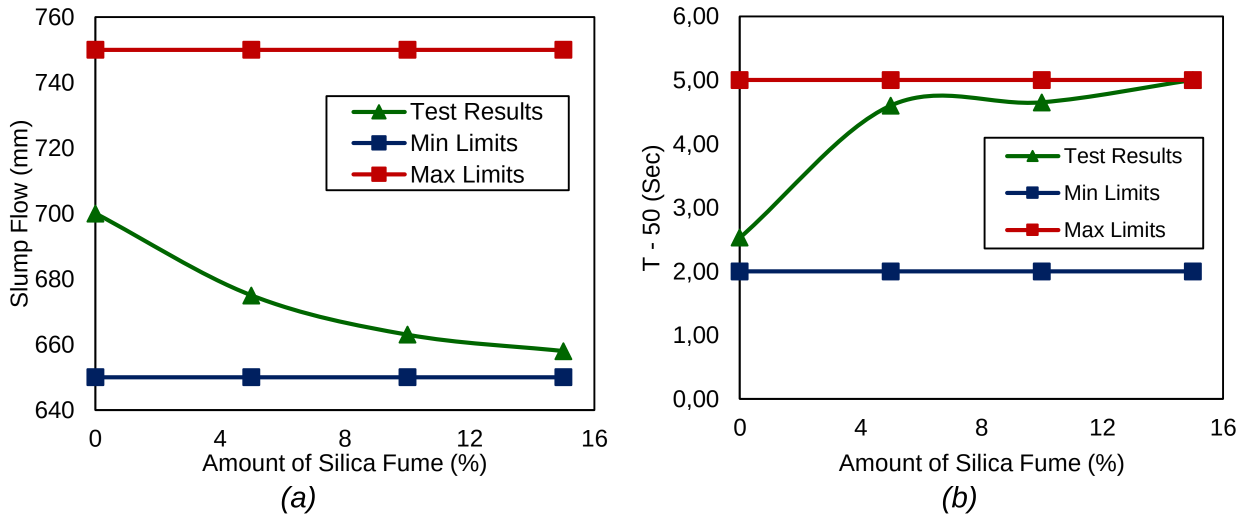
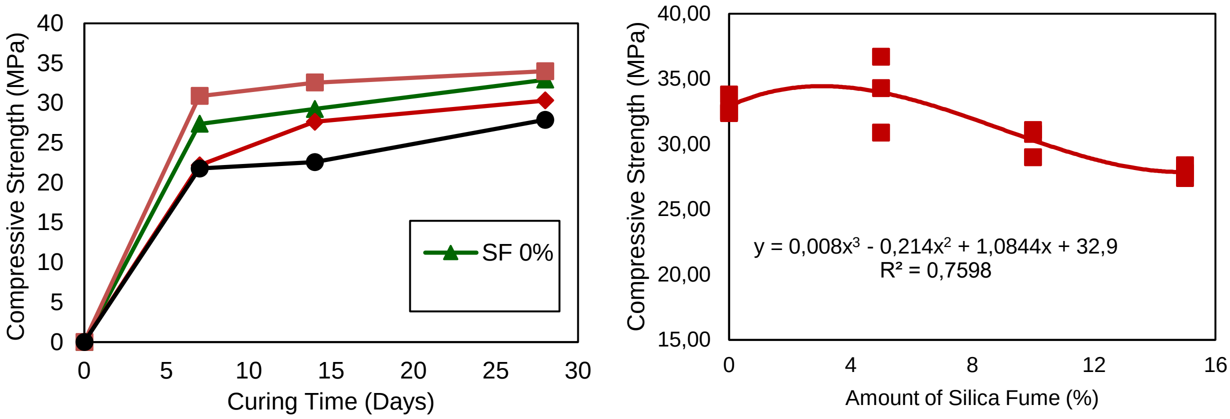


Fig. 4 – (a) Slump flow; (b) T50 result on varying silica fume on SFCC

Mechanic characteristic

Compressive strength testing is done at the age of 7 days, 14 days, 21 days and 28 days. Figure 5(a) shows that the relationship between the varying silica volume and curing age on compressive strength. The result shows that the application of using silica fume affects to the compressive strength. Compressive strength in specimens that do not contain silica fume reaches 32.90 MPa at 28 days. If the compressive strength value of the specimen is compared with the compressive strength of specimens containing silica fume of 5%, an increase of 0.03% occurs. Otherwise, the use of silica fume which exceeds 5% will reduce the compressive strength by

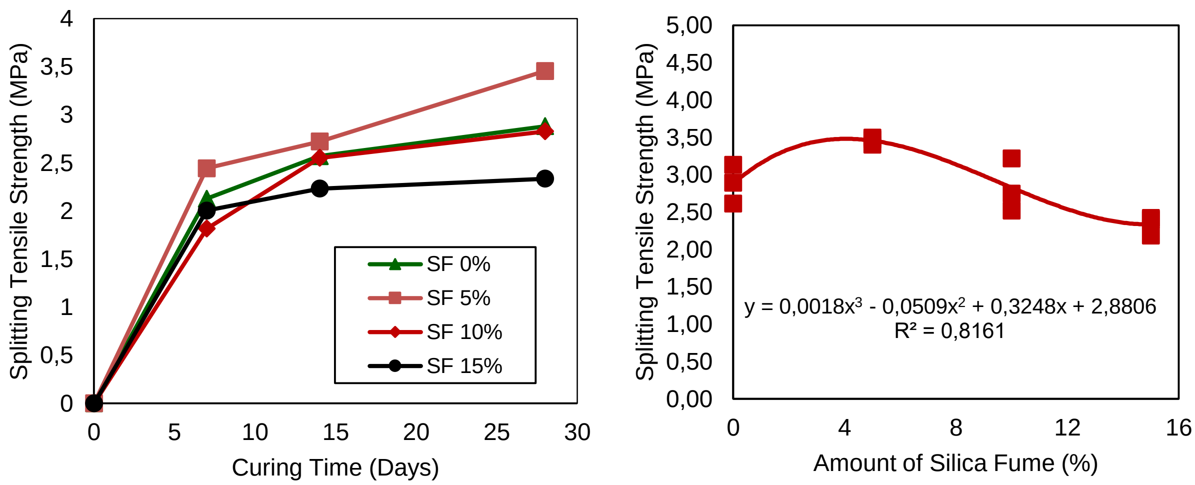
0,07% and 0,15%. This can show that cement replacement by 5% and replacing it with 5% silica fume can increase compressive strength and reduce cement costs. Figure 5(b) illustrates the regression analysis between the amount of silica fume and compressive strength on the specimen at 28 days. From the results of this analysis it is shown that the optimum value of the use of silica fume is limited to 5% to get a good compressive strength. The length of time in the treatment of concrete to be a major factor will affect the value of the compressive strength. This can be seen in Figure 3a that shows the compressive strength value of concrete will increase with increasing concrete curing time that occurs in each silica fume variation.



(a) (b)

Fig. 5 – Effect of varying silica fume and curing age on Compressive strength SFCC in different curing time

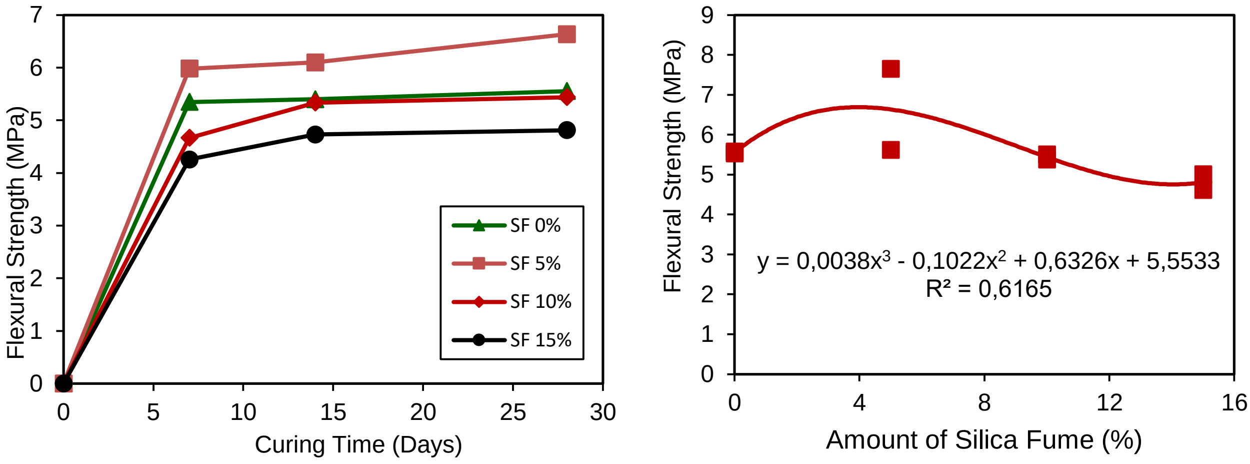
Not only the compressive strength test was carried out in this study, but the split tensile test was also carried out to find out the tensile strength performance of silica fume variations. Figure 6 shows that the application of silica fume in the SFCC mixture effects on the splitting tensile strength. At the 28 curing days of the specimen, the tensile strength of normal SFCC without the silica fume reach 2.88 MPa. By using 5% of silica fume it will be able to increase of tensile strength until 0.2% of normal SFCC otherwise the application of 10% and 15% of silica fume effect on decreasing 0.02% and 0.19% of tensile strength. Therefore, the application of silica fume in the SFCC should limit to 5% that is also proofed in the Figure 6b.



(a) (b)

Fig. 6 – Effect of varying silica fume on tensile strength of SFCC in different curing time

Flexural test was conducted to determine the effect of using silica fume on the resulting flexural strength. Figures 7 and Figure 8 show that the application of silica fume on the SFCC effects on flexural strength. The application of 5%, 10% and 15% of silica fume in the SFCC produces the compressive strength 6.63 MPa; 5.44 MPa and 4.81 MPa. The maximum flexural strength is occurred in 5% of silica volume in the SFCC. Not only that, the application of silica fume also effects on the displacement. By using 5% of the silica fume effect on producing of a maximum displacement of around 2.60 mm. Therefore, the optimum level of silica volume that is suitable for mixing SHCC is around 5% according to the compressive strength, tensile strength and flexural strength result.



(a) (b)

Fig. 7 – Effect of varying silica fume on flexural strength of SFCC in different curing time

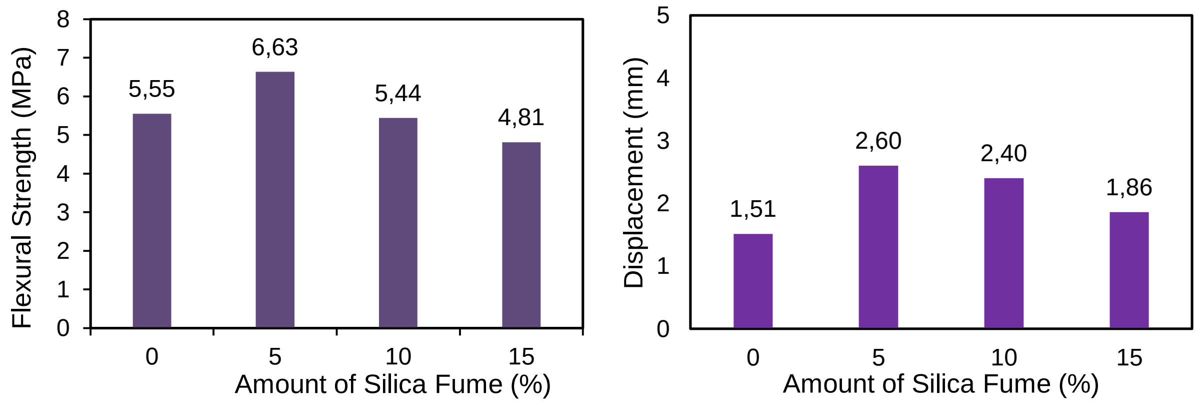


Fig. 8 – Effect of varying silica fume on flexural strength of SFCC in different curing time

CONCLUSION

From the results of the study it can be concluded that:

1. The use of silica fume greatly affects fresh properties. The results of fresh properties testing show that the results obtained from all tests included the terms and conditions of (EFNARC).
2. The use of silica fume which serves as a substitute for cement greatly affects the mechanical properties of concrete. This shows that there are changes in compressive strength, tensile strength and flexural strength when using silica fume.

3. The use of silica fume on SFCC concrete can increase compressive strength, tensile strength and flexural strength. However, its use is only limited to 5%. If the usage exceeds 5% it will reduce the compressive strength of concrete.

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