STUDY AND EXPERIMENTAL INVESTIGATION ON PERFORMANCE SELF-COMPACTING CONCRETE USING DIFFERENT TYPE OF FIBERS

RAYED ALYOUSEF *
Department of Civil Engineering, College of Engineering, Prince Sattam Bin Abdulaziz University, Al Kharj 11942, Kingdom of Saudi Arabia

Nowadays, the construction industry over the entire world is looking for more economical construction materials. In addition, the existence of self-compacting concrete is facing brittleness problems due to their high binder content and low aggregate amount. On the other hand, the fiber is widely known to enhance the properties of concrete by bridging the crack width and hence, overcoming the brittleness problem in concrete. The goal of this paper is to evaluate the effect of different fibers on the properties of self-compacting concrete such as stand chopped basalt (SCB) and polyvinyl alcohol (PVA) fibers. The experimental work conducted were fresh tests, such as slump flow, slump T_{50} and V-funnel, while the hardened properties were compressive, flexural and bond strength. The results gathered from the empirical work showed that the fibers had a slight effect on the fresh properties and the compressive strength. While the flexural and bond strengths increased with the addition of the fiber content.

Keywords: *Self-compacting concrete, Chopped basalt, Polyvinyl alcohol, Fresh and Hardened test*

1. Introduction

Self–compacting concrete (SCC) is the innovative mix of concrete that has the ability to resist the segregation and to flow under it is own weight [1,2]. The behavior of SCC has been studied in many researches due to it is ability to provide high fresh properties of a concrete mix [3-5]. To achieve the SCC mix it is required to reduce the aggregate contents and increase the binder amount as well as the addition of a chemical admixture, such as a superplasticizer with reducing the water to cement ratio [6,7]. The increase in the binder content will lead to cause the brittleness of the concrete, which can reduce the ductility of concrete. To avoid these problems, the fiber with cementations replacement material (CRM) can be added to the SCC mix because the fiber can bridge the crack and enhance the ductility of the concrete. While the CRM can replace the part of the cement and hence, reduce the total cost [8,9]. Much research has been done to investigate the properties of the fiber reinforced self-compacting concrete (FR-SCC) [10,11]. The disadvantage of the fibers in the concrete mix is clumping because the fibers may adhesive together before they are added to the mix and the normal mixing action will not break down these clumps [12-14].

At the start of the macrocracking, the bridging action of the materials will prevent and controls the opening and development of cracks.

This mechanism raises the necessity for power for that crack to grow. The linear elastic behavior from the matrix is not inspired considerably by low volumetric fiber fractions. However, the post-cracking properties could be greatly modified with rise of the strength, toughness and durability of the fibers [15].

Polyvinyl alcohol fiber (PVA) is recognized as among the most appropriate polymeric materials for use because of the reinforcement of the engineered cementations composites (ECC). PVA fiber has a high strength and modulus of elasticity compared against other general organic fibers commonly employed for cement reinforcement. [16-18] finer kinds of PVA fibers have been utilized for fiber-cement roofing as an asbestos alternative. Furthermore, rougher PVA fibers continue to be usually utilized in civil engineering applications, including tunnel lining, industrial flooring, roadbed overlays and several types of shotcrete [19,20]

Basalt fiber is inorganic fiber created from basalt rock. It is sociable and it has no chemical side effects that could damage health or probably the climate; it is also non-combustible and non-explosive. The addition of basalt fiber can considerably enhance the deformation and absorption capabilities of geopolymer concrete (GC) whilst there is no notable improvement in the dynamic behavior and compressive strength [21,22] have looked into the qualities of concrete that contains continuous basalt fiber. The outcomes

* Autor corespondent/*Corresponding author*,
E-mail: r.alyousef@psau.edu.sa

have shown improvement within the thermal and mechanical qualities of concrete. Limited studies have analyzed the result of utilizing short basalt fiber across the mechanical properties of concrete and no research has been found on its thermal properties [23-25].

Fly ash is the famous type of CRM that can replace the cement amount to increase the workability and long-term properties of the concrete structure [26,27]. Fly ash with different levels of replacement in the SCC mix has been studied to showed the effectiveness and optimum degree of replacement to add the fly ash [28-30].

From the above literature review it has been noted that there have not been enough studies carried out on the self-compacting concrete produced with fly ash and PVA or/and SCB fibers. The objectives of the current study are the utilization of different fibers in the self-compacting concrete, such as stand chopped basalt (SCB) and polyvinyl alcohol (PVA) fibers, along with their effectiveness on the properties of SCC. The fresh parameters are slump flow, slumpT_{50} and V-funnel; while the hardened characteristics are compressive, flexural and bond strength.

2.Material and Method

2.1. Material Selection

ASTM, type-1 ordinary Portland cement (OPC) have been exploited within the experiment effort; its chemical component is presented in Table 1. The fly ash used in this research was class F based on the BS EN 450:1995. The chemical compositions are supplied in Table 1.

The fine aggregate chosen in the experimental work was clean natural sand with a specific gravity of 2.61, a fineness modulus of 2.76 and the maximum size was only 3. 35mm. The coarse aggregate used was (10 - 5) mm crushed granite stone based on the BS:812-103.2 1989 having a specific gravity of 2.66 in SSD and the impact value of the aggregate was 43.38%. While the silt content result demonstrated that the quantity of the dreg in the sand was below 8% water weight. The HRWR superplasticizer from SIKA-KIMIA, Malaysia have been tried for proving the workability of concrete. It is an impressive liquid-based superplasticizer for producing free flowing concrete that complied by using the needs of BS: 5075. The two kinds of fibers were synthetic fiber formed from solutions of polyvinyl alcohol, mainly by wet spinning symbolized as PVA and a new type of continuous natural fibers were used in the mixes. This new fiber was stand chopped basalt called SCB fiber which is made from basalt rock and manufactured in China. Its characteristics are tabulated in Table 2.

2.2. Mix proportion

Table 3 shows the development of 14 mixes of fiber reinforced self-compacting concrete divided into two groups, each group contained 7 different percentages of PVA and SCB fiber as 0%, 1.0%, 1.5 % and 2.0% by weight of the total binder. The cement content, superplasticizer, and fine and coarse aggregates were kept constant as 600kg/m^3, 12kg/m^3, 900kg/m^3 and 750kg/m^3, respectively. In group one, the total binder was 100% OPC while group two contained 30% fly ash. The fresh properties of the FR-CSS mix were checked by slump flow, slump T_{50} and V-funnel. The result was compared by the Specification of European Federation of Producers and Applicators of Specialist Products for Structures – EFNARC [31]. The compressive strength at 7, 28 and 90 days with the flexural and bond strength at 28 days

Table 1

Chemical composition of the binder

Chemical Composition	Percentage	
	OPC	FLY ASH
SiO_2	20.3	56.39
Al_2O_3	4.2	17.57
Fe_2O_3	3	9.07
CaO	62	11.47
MgO	2.8	0.98
SO_3	3.5	0.55
K_2O	0.9	1.98
Na_2O	0.2	1.91

Table 2

Physical Characteristics of the fibers

Physical Characteristics	PVA Fiber	SCB Fiber
Length (mm)	30.0	25.0
Diameter(mm)	0.70	0.18
Density (g/cm^3)	2400	4100-4840
Tensile Strength (MPa)	1.30	2.65
Elastic Modulus (MPa)	25-40	100-110
Aspect ratio	42-86	138.89

Table 3

Result of Fresh Test

Groups	NO.	Code Mix	Slump Flow (mm)	Slump T_{50} (Sec)	V-Funnel (Sec)
Group 1 100% OPC	1	G1-M1-00	760	3	9
	2	G_1-M_2-1.0% PVA	725	4	10
	3	G_1-M_3-1.5% PVA	695	6	12
	4	G_1-M_4-2.0% PVA	630	7	15
	5	G_1-M_5-1.0% SCB	695	5	12
	6	G_1-M_6-1.5% SCB	630	6	14
	7	G_1-M_7-2.0% SCB	610	8	18
Group 2 70% OPC	8	G_2-M_1-00	790	2	7
	9	G_2-M_2-1.0% PVA	740	3	9
	10	G_2-M_3-1.5% PVA	720	5	11
	11	G_2-M_4-2.0% PVA	690	6	14
	12	G_2-M_5-1.0% SCB	740	3	11
	13	G_2-M_6-1.5% SCB	680	5	12
	14	G_2-M_7-2.0% SCB	650	6	16

was gathered in order to investigate the hardened properties of the FRSCC mix.

The concrete samples - by means of cube, cylinders and prisms - were removed from the molds after 24 hours of casting; they were then put into a curing room at 23.2^0 C with 95% humidity until testing. The compressive strength was founded upon crushing the 100 mm3 cubes according to BS1881-part 116:1983 at 7, 28 and 3 months. The pull-out test was carried out to look for the bond strength by pulling the reinforcement bar from the 100*200 mm cylinders according to ASTM C 900-06 at 28 days. Throughout the pull-out test, the load-transverse displacement history as much as the failure was recorded with a computer assisted data acquisition system. Several 100 mm^3 cubes were utilized to determine the 28-day density. The 28-day flexural strength of FR-SCC was based on using 500*100*100 mm beams with a four-point loading, according to ASTM C 78. The loads were applied at a loading rate of 0.200 MPa/min and a computer-aided data acquisition system was used to record the load-central deflection response up to the failure. In each test, three specimens were tested at each age, and the mean values were reported

2.3. Experimental Procedure

The methodology of the experiment was tested; firstly, was the fresh test, which were the slump flow, slump T_{50} and V-funnel. When the freshness requirement was achieved, then the hardened tests, such as compressive, bond and flexural strengths, were conducted. The FR-SCC mix was prepared using a drum mixer. The mix was first washed with water to ensure that there was no absorption. Then, both of the aggregates were mixed with half of the water and left for 2 minutes to let the water be completely absorbed with the aggregate. Next, the cement and fly ash (if needed) was added to mix with the remaining water and the superplasticizer for 4 minutes to provide the complete reaction of the chemical admixture. Finally, the fibers were added and the mixer was left for 4 minutes to allow the fiber to be distributed uniformly through the concrete mix.

3. Result and Discussion

3.1.Fresh Properties

3.1.1. Effect of fly ash on the water content

The superplasticizer and aggregate contents were kept constant in order to examine the effect of the fly ash on the SCC. The water to cement ratio in group 1 was 0.34 while the result of group 2 was 0.32; these results show how much the fly ash reduced the total cost and increased the flowability of the FR-SCC mix.

3.1.2.Slump Flow test

Table 3 demonstrated the result of the fresh test, which included slump flow, slumpT_{50} and V-funnel. The slump flow of group 2 was found to be higher than that of group1 because the fly ash increased the flowability of the mixture. Although the two kinds of fiber caused a decrease in the flowability, still the result refers to the self-compatibility of the mixture. Figure 1 shows the effect of the different fiber contents on the slump flow. The slump flow of the two groups decreased with the increase in the fiber content; the 1.0% of fiber did not affect the result while the 1.5% and 2.0% showed much influence.

3.1.3 Slump T_{50} test

The slump T_{50} was conducted to evaluate the time of the mixture to flow up to the 500mm diameter; the results are kept in Table 3. The result promoted the positive effect of the fly ash in order to compare the binder content of the groups. Figure 2 indicates that group 2, which contained 30% fly ash, showed less time than that of the 100% OPC of group 1. From Table 4, it can be seen that the time of the flow increased with the increasing of fiber content.

3.1.4. V-Funnel test

The results of the V-funnel test are presented in Table 3 and also shown in Figure 3. The passing ability of the FR-SCC mix through the

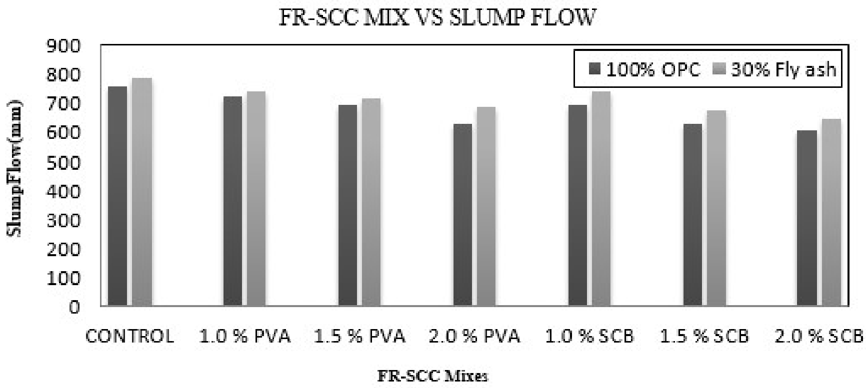

Fig. 1 - Slump Flow of the FR-SCC Mix

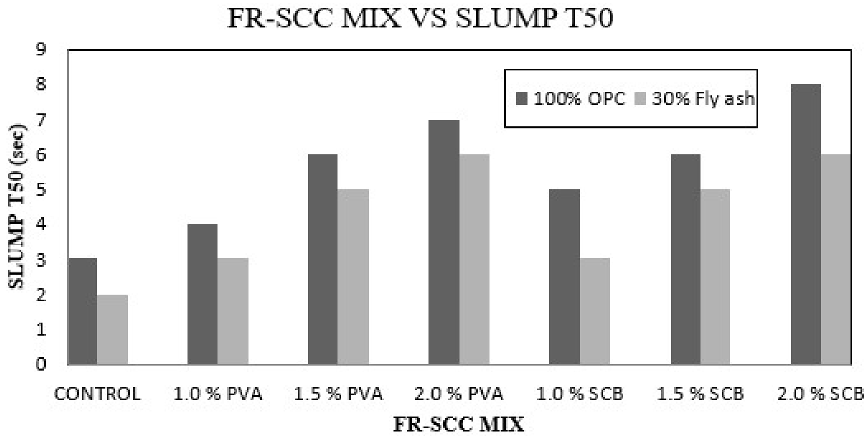

Fig. 2- Slump T_{50} of the FR-SCC Mix.

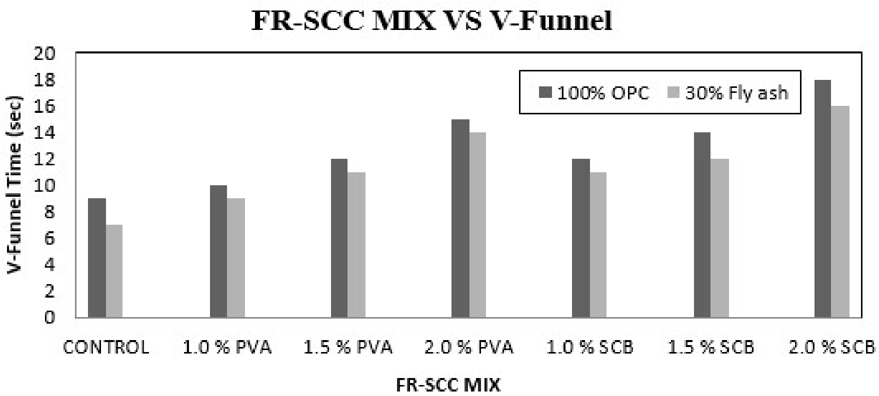

Fig. 3 - V-Funnel time of the FR-SCC Mix

funnel was affected by the type and content of the fibers. The SCB-SCC mix displayed a time that was more than that of the PVA-SCC mixture because the basalt fiber seemed to be the same as cotton that can absorb water during the mixing hence, it reduced the water content. To solve this problem, it is recommended to add more superplasticizer in the case of the SCB fiber.

3.2. Hardened characteristics

3.2.1. Compressive strength

The compressive strength test was conducted for 7, 28 and 90 days per each group; the results represent the mean of 3 cubes already cast for each mix. Figure 4 shows the result of the compressive strength. In order to study the influence of fly ash as the filler type on the compressive strength, anyone can see that the group 2 gained a higher strength than group 1 at the long term and exhibited lower strength after 7 days.

3.2.2. Flexural strength

The flexural strength is the most common measure used to evaluate the quality of hardened concrete. Figure 5 shows the development of the flexural strength of the FR-SCC.

3.2.3. Bond strength

The bond strength results were achieved

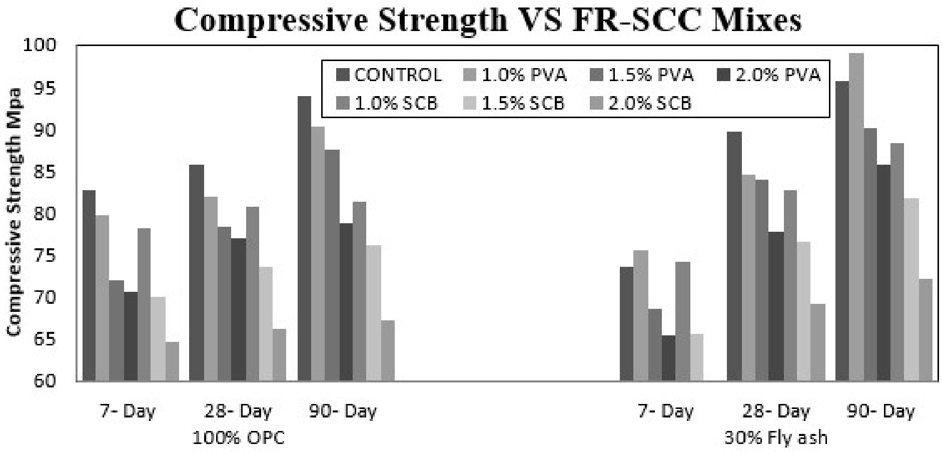

Fig. 4 - Compressive Strength of the FR-SCC Mix.

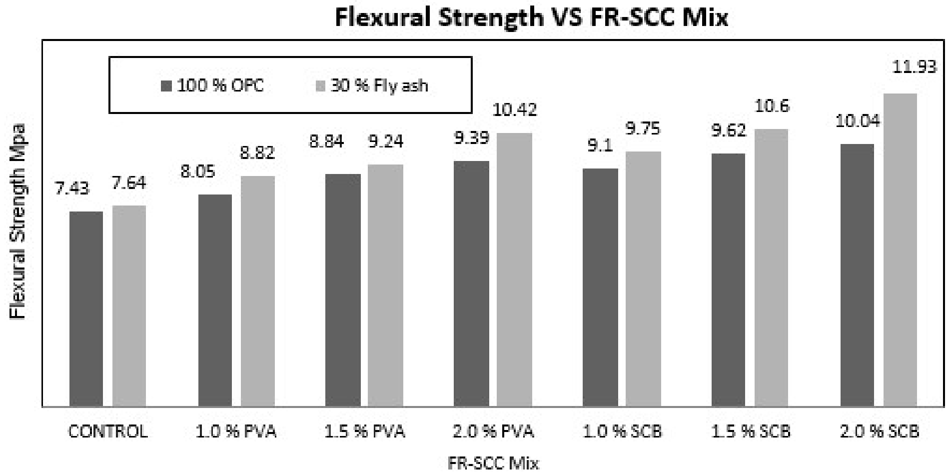

Fig. 5 - Flexural Strength of the FR-SCC Mix.

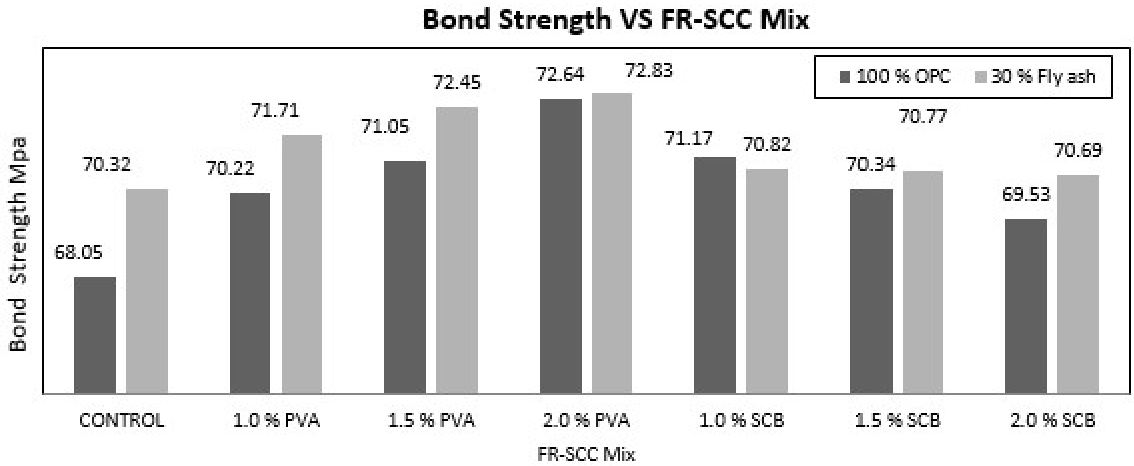

Fig. 6 - Bond Strength of the FR-SCC Mix.

by the pull-out test. Figure 6 proves that the fiber type did not affect, positively, the bond behavior. The effect of 30% fly ash on group 2 is very clear; fly ash increased the bond strength of the concrete cylinder after 28 days due to its fine particles.

4. Result and Discussion

After studying the whole of the parameters, the result can be drawn as follows:

1- Fiber reinforcement self-compacting concrete (FR-SCC) has been developed by using locally available materials with two types of fibers, such as polyvinyl alcohol and stand chopped basalt fibers, along with 30% fly ash. The30% of fly ash actually reduced the water content of the FR-SCC and then enhanced its ability to flow more due to the highly finer particles of the fly ash.

2- Fibers have been found to decrease the fresh properties of the FR-SCC mix; the reduction varied with the increasing of the fiber content and with the type. The SCB-SCC mix flow was less than that of the PVA-SCC mix; it can be seen the PVA decreased the slump of the control mix at 6.33%, 8.86% and 12.65 for 1.0%, 1.5% and 2.0%, respectively. While the reductions of the SCB were 12.03%, 20.25% and 22.78%. It is recommended to use fiber in SCC but with the filler material, such as fly ash, to overcome the problem of the reduction in the flowability of the FR-SCC.

3- The result of T_{50} showed a difference when being compared with the European standard (EFNARC) in which the recommended time of T_{50} should be in the range of 2-5 seconds; due to the fiber content, some mixes exhibited a flow time of more than 5-seconds. But, it can be considered as SCC because the difference was not too much and there was no segregation or bleeding. The passing ability of FR-SCC mix decreased with the increasing of the fiber contents; some concrete mixes, as in slump T_{500}, showed the time of the V-funnel more than that of the EFNARC standard. But, still the mix can be considered as SCC. Based on that, the flowing time of the slump can be accepted with the range time of 2-7 second while the funnel time can be standardized as 6-20 seconds.

4- It can be seen that the fibers decreased the compressive strength of the FR-SCC as compared with the control mixes of the two groups; this is because the fibers may affect the Interfacial Transition Zone (ITZ) between the paste and the aggregate due to its size and shape. Successful mix of fibers with concrete mix required to avoid the clump of fiber to product their ITZ area. PVA fiber can produce voids inside the paste form while the basalt fiber will absorb the mixing water and hence, reduce the compressive strength. The SCB fibers have been found to decrease the strength more than the PVA fibers. On the other hand, the reduction in the strength gradually increased with the increasing in the fiber content.

5- The SCB fibers have been found to contribute more than the PVA fibers to enhance the flexural behavior due to their high tensile strength. But, the study of the ductility of the concrete beams after testing showed that the beams of the SCB fiber could not hold the beam itself in that the beams had been divided into two parts, while the PVA fiber beams-maintained cohesion because the aggregate may harm the SCB fiber at the Interfacial Transition Zone (ITZ) area at increasing of the loading on the beams.

6- The pull-out test was performed to investigate the bond strength values for all of the mixes of the FR-SCC. The fibers did not increase the bond behavior because the fibers may have affected the ITZ area and hence, reduced the bonding behavior between the concrete and the reinforcement bar.

6. Conclusion

Based on experimental results, the following conclusion can be drawn:

1. In the present study self-compacting concrete with different type of fiber were developed without using viscosity modifying agent.
2. Addition of fiber to self-compacting concrete mix lead to decrease its fresh characteristics due to the size and shape of fiber type.
3. Fibers have been found to affect negatively the fresh properties of the FR-SCC mix. The reduction varied with the increasing of the fiber content and with the type. Basalt fiber decreased significantly the fresh properties of developed concrete, basalt fiber can absorb some water of mixing, and hence decreased the capability of concrete mix to flow more.
4. Compare to PVA fiber, basalt fiber showed less contribution to enhance the compressive and bond strength of self-compacting concrete.

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5th International Conference on Concrete Repair, Rehabilitation, and Retrofitting (ICCRRR 2018), Cape Town, South Africa, 19-21.11.2018, Cape Town, South Africa

Conference themes

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