Influence of Pulverized Fly Ash on the Properties of Self-Compacting Fiber Reinforced Concrete

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ABSTRACT

Self-compacting concrete (SCC) has high flowability and high resistance to segregation and bleeding. These characteristics facilitate the mixing, casting, and finishing of SCC without using compacting or vibrating machines. Adding mineral admixtures, such as pulverized fly ash (PFA), of polypropylene fibers (PFs) and superplasticizers improves SCC properties by preventing segregation and bleeding and by increasing rheological parameters. SCC requires high flowability under the influence of self-weight to fill completely all mold parts for full compaction. This investigation discusses the results of experimental tests on the properties of SCC and self-compacting fiber reinforced concrete (SCCF) mixtures with the inclusion of PFs 0.22% and containing PFA at replacement rates of 0%, 20%, 40%, and 60 % cement mass. The compressive, flexural, and split tensile strengths of the prepared concrete samples were investigated at ages of 7, 14, 28, and 90 days. The workability of fresh concrete mixtures was also studied through segregation, bleeding, slump flow, slump flow T_{50}, L-box V-funnel T_5, and V-funnel tests. Results showed that the more favorable properties of fresh SCCs were obtained when PFA was added at replacement rates of 20% and 40% cement mass. In addition, the inclusion of PFs at a volumetric ratio of 0.22% decreased segregation and bleeding and improved the flexural and tensile strengths of SCCFs.

Key Words: Cement substitutes, Concrete flowability, Concrete workability, Hardened concrete, High-volume replacement, Pozzolanic materials.

INTRODUCTION

Self-compacting concrete (SCC) and self-compacting fiber-reinforced concrete (SCCF) are special types of concrete mixture characterized by resistance to bleeding and segregation. SCC can be casted without using a vibration machine or compaction. SCC-made products are high in quality, exhibit excellent finish, and are virtually free of flaws, such as large voids, because of the excellent filling ability of SCC without honeycomb formation (Okamura and Ouchi, 2003; Brouwers and Radix, 2005; Nanthagopalan and Santhanam, 2011). SCC is produced with added fine industrial wastes, including PFA, silica fume, and furnace slag (Siddique, 2011). PFA and some types of pozzolanic materials have been successfully used as mineral admixtures in SCC (Gesoğlu and Özbay, 2007; Ramanathan *et al*., 2013). Incorporating mineral admixtures results in sufficient SCC viscosity, consequently reducing bleeding, segregation, and plastic shrinkage. Aside from fine mineral admixtures, agricultural waste materials, including palm oil fuel ash and rice husk ash, can be used as admixtures in SCC (Safiuddin *et al*., 2011; Mohammadhosseini *et al*., 2015). PFA is added to concrete mixtures to prevent segregation and bleeding, increase flowability, and control hardened concrete properties including compressive, indirect tensile, and flexural strengths (Siddique *et al*., 2012; Ashtiani *et al*., 2013; Celik *et al*., 2014). PFA use in SCC production requires the addition of a superplasticizer (SP) to the concrete mix to achieve high workability and appropriate mix proportions. However, high SP dosage increases bleeding and segregation in fresh concrete. These problems can be avoided by adding a viscosity-modifying admixture (VMA) to increase fresh concrete viscosity. Furthermore, fine mineral admixture use can reduce the amount of SPs required to achieve the desired rheology. Moreover, the use of PFA as an alternative material decreases the need for VMAs (Cyr and Mouret, 2003; Felekoğlu *et al*., 2007; Ouchi *et al*., 1997). Nevertheless, replacing the fine mineral admixtures of cement mass, especially at high mass replacement, affects the characteristics of SCCs because of the variations in cement mass and water/cement ratio. Fiber addition improves the flexural strength, toughness, and tensile strength of concrete. The addition of fibers at volumetric ratios of 0.1%–1.0% improves the flexural and tensile strength and some engineering properties of concrete (Banthia and Gupta, 2006; Mohamed, 2006; Al Qadi *et al.*, 2011; Islam and Gupta, 2016; Zeyad, 2017). Richardson showed that the addition of polypropylene fibers (PFs) to concrete negatively affected compressive strength and elastic modulus (Richardson, 2006). This finding is in contrast with that of Alhozaimy *et al.*, which indicated that the addition of PFs to concrete causes no significant effects on concrete compressive strength and toughness (Alhozaimy *et al.*, 1996). The workability and flowability of SCCF decrease upon the addition of PFs. SCCF workability reduction due to fiber addition depends on many parameters, such as fiber type, dosage, and shape (Corinaldesi and Moriconi, 2011; El-Dieb and Taha, 2012). PFA has been successfully added to SCC at replacement rates of up to 60% and 35% cement mass to cement mixtures without PF inclusion. Replacing 30% of cement mass with PFA produces concretes with excellent flowability and workability without fiber addition. The present investigation aims to study the properties of fresh and hardened SCC and SCCF. PFA was added at replacement rates of 0%, 20%, 40%, and 60% cement mass. Subsequently, PFs were added to the cement mixtures at a volumetric ratio of 0.22% to produce SCCF. Segregation, bleeding, slump flow, slump flow T_{50}, L-box V-funnel T_5, and V-funnel tests were conducted on fresh concrete. The compressive, flexural, and tensile strengths of hardened concrete at ages 7, 14, 28, and 90 days were also investigated.

MATERIALS AND METHODS

Cement

Ordinary Portland cement-type I was used. Cement characterization tests were conducted in accordance with ASTM C150 (ASTM, 2004). Tables 1 and 2 show the chemical composition and physical characteristics of cement, respectively.

Table 1: Chemical Composition and Main Compounds of cement

Oxide composition	Content (%)	Limit in ASTM specification
CaO	63.68	60-67
SiO_2	20.68	14-25
AL_2O_3	6.12	3-8
Fe_2O_3	3.80	0.5-6
SO_3	2.68	1-3
Na_2O	0.29	0.2-1.3
K_2O	0.42	
MgO	1.21	0.1_4
L. O. I	1.55	≤ 4
C_3S	41.51	45-55
C_2S	28.16	20-30
C_3A	9.87	8-12
C_4AF	11.57	6-10

Table 2: Cement Physical Characteristics

Physical properties	Test Results	Limit in ASTM specification
Specific Surface area (Blaine method, cm^2/g)	3220	≥ 2300.0
Initial Setting time, min Final Setting time, min	120 480	Minimum 30 Maximum 365
Compressive strength of mortar (14-days, MPa)	27	Minimum 19

Pulverized Fly Ash

PFA meets the general requirements of ASTM C618 Class F (ASTM, 2004). Table 3 presents the chemical composition and physical characteristics of pulverized fly ash .

Table 3: Chemical and Physical Properties of Pulverized Fly Ash

Oxide composition	Content %	Limit of ASTM C618 specification (Class F)
SiO_2	51.45	>70%
Fe_2O_3	5.19	
Al_2O_3	27.26	
CaO	7.73	-
MgO	5.16	-
SO_3	0.50	5.0 max
K_2O	2.50	-
L.O.I	0.19	6.0 max
Physical Properties		
Fineness (Blain method)	4020 cm^2/g	-
specific gravity	2.32	-

Aggregate

A crushed basalt rock with a maximum size of 12.7 mm was used as a coarse aggregate (CAgg), and natural sand was used in the concrete mixtures as a fine aggregate (FAgg). The CAgg and FAgg showed 2.63 and 2.71 specific gravities and 0.6% and 0.9% water absorptions, respectively.

Fine Aggregate

The particle shape and grade of FAgg are important factors in SCC production. Natural sand, which conforms to ASTM C33 specification (ASTM, 2004), was used. Table 4 shows the FAgg grading analysis.

Coarse Aggregate

Table 4 shows that the grading of the CAgg, which conforms to the ASTM C33 specifications (ASTM, 2004).

Table 4: Grading of Coarse and Fine Aggregate

Sieve size (mm)	Passing by weight (%)	
	FAgg	CAgg
19.00	100	100
12.50	100	95
9.50	100	66.3
4.75	96.4	4.3
2.36	92.5	1.4
1.18	78.4	0
0.60	40.8	0
0.30	11.6	0
0.15	3.1	0
Fineness Modulus	2.8	-

Polypropylene Fibers

The PF percentage used was selected from previous research and experimental mixes. Many researchers report 0.1%–0.30% as optimum percentage of concrete volume to avoid the compressive strength decline of concrete (Alhozaimy *et al*., 1996; Richardson, 2006; Ponikiewski and Katzer, 2016). The PF physical properties are provided in Table 5.

Table 5: Physical Properties Polypropylene Fibers

Properties	PFs
Form	White color fibers
Density	0.91 kg/l
Fiber Length	12 mm
Fiber Diameter	18 microns
Softening point	160 °C
Specific surface area	200 m^2 / kg
Tensile strength (MPa)	350 MPa

Superplasticizer

SP, a new generation of copolymer-based sue perplasticizer designed for SCC production (Viscocret 5030), was used in this study.

Mix Design Methods

Mix design methods for SCC considerably differ from the regular conventional concrete design. Many mix design methods exist. Estimating the required batch weights involves a sequence of steps fitting a proportioning procedure that includes the selection of aggregate to provide the desired passing ability, cement (powder)/water ratio and mortar-paste fraction ratio that have been historically proven to produce SCC with the required slump flow, and stability. These steps, in combination with appropriate admixture addition, should yield a trial batch with the desired fresh SCC properties. The following presents a summary of steps to determine the performance requirements and proportioning of SCC mixes.

Step 1: Determine slump flow performance requirements;

Step 2: Select coarse aggregate and proportion;

Step 3: Estimate the required cementitious content and water;

Step 4: Calculate paste and mortar volume;

Step 5: Select admixture;

Step 6: Produce trial batch mixtures;

Step 7: Test. When assessing the workability attributes of SCC, namely, stability, filling ability, and passing ability, the slump flow test and a test to evaluate stability and passing ability, such as column segregation or L-box), should be run; and

Step 8: Adjust mixture proportions based on the test results, and then re-batch with further testing until the required properties are achieved.

The concrete mixture proportions are summarized in Table 6.

Table 6: Concrete mixture proportions

Mixture	Cement	PFA	CA_{gg}	FA_{gg}	PFs	Water	SP
	(kg/m^3)						
SCC0	500	0	794	809	0	200	7.5
SCCF	500	0	794	809	0	200	7.5
SCC20	400	100	794	809	0	200	7.5
SCCF20	400	100	794	809	2	200	7.5
SCC40	300	200	794	809	0	200	7.5
SCCF40	300	200	794	809	2	200	7.5
SCC60	200	300	794	809	0	200	7.5
SCCF60	200	300	794	809	2	200	7.5

Mixture Proportions

The preliminary investigations of this study include equipment evaluation and test procedures; evaluation of the selected mixture proportioning method, mixing procedure, and PFA replacement; and PFs and SP dosage. Testing for these initial investigations is limited on fresh concrete properties.

Mixing and Casting of Specimens

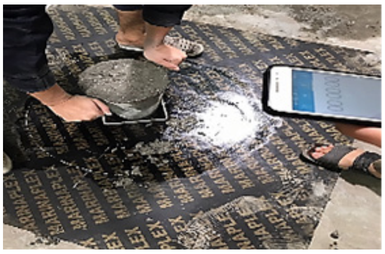
The required material quantities were weighed for the correct mixing proportions, and the cement was mixed with pulverized fly ash. The mixture was added to the CAgg and FAgg. All materials were mixed and dried for 2 min. Water was added to the mixtures in two stages, in which half of the amount of water was initially added at the start of concrete mixing, and the remaining was added after 30 s of concrete mixing. To obtain a homogeneous mixture, the concrete was continuously mixed for 3 min after water addition. After carrying out tests for fresh concrete properties, we performed casting immediately following mixing. The specimens were removed from molds after 24 h of storage under laboratory conditions. Storage conditions were in accordance with ASTM.

TESTING OF SAMPLES

Fresh Concrete Tests

To determine the SCC properties at fresh concrete state, we performed the slump flow, slump flow T_{50}, V-funnel, V-funnel T_5, L-box, segregation, and bleeding tests. To reduce the influence of workability loss on the test results of the concrete samples, it was determined the properties of fresh concrete within 20 min of water addition. Figures 1 a, b, c, d, e and f show the fresh concrete tests. All fresh concrete tests were performed in accordance with the European Guidelines for SCC (EFNARC) standards (EPG, 2005).

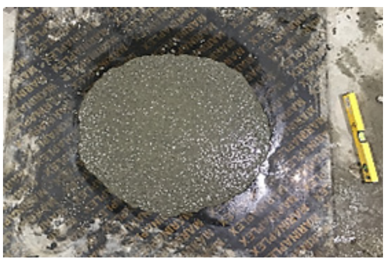
- The slump flow test was performed in accordance with EFNARC standards (EPG, 2005). It includes measuring slump flow diameter (D) after lifting the cone and measuring the time taken for the concrete to spread at a 50-cm diameter (T_{50}).
- V-funnel test was performed in accordance with EFNARC standards. A V-funnel was used to evaluate the fluidity, passing ability, and SCC segregation. The test time of V-Funnel was the time (s) it took until light above the device was seen after opening the outlet at the bottom of the device. A test time between 6-12 s is required to obtain suitable properties of fresh SCC concrete.
- L-box test was performed in accordance with EFNARC standards. An L-box was used to assess the possibility of obstructing the filling capacity of concrete in confined construction elements. The filling capacity is determined as the ratio of the height of the concrete in exit outlet (H1) to the end of L-box (H2) (H1/H2), which must be >0.8.
- Segregation test was conducted by filling the concrete into a cylinder with 66 cm height and 20 cm diameter split into three parts. The bottom, middle, and top parts are 16.5, 33, and 16.5 cm in height. After filling the apparatus, the concrete was left undisturbed and without movement for 15±1 min. The concrete from the top and bottom parts was then collected and washed over a 4.75 mm-diameter sieve to maintain the CA. The relative weight of CA from the top and bottom of the apparatus was used as an indication of segregation resistance.



(a):Slump flow T50 test

(c): Bleeding test

(e): Segregatin test



(b): Slump flow test

(d): V-Funnal test

(f): L-Box test

Fig. 1: Fresh concrete tests

- Bleeding test was performed in accordance with ASTM C232. The surrounding temperature was maintained at 18-24 °C, and the mass of the container and its contents was immediately recorded. The container was then placed on a level platform free from vibration and kept covered for the full test duration to inhibit the evaporation of water from the concrete sample. The accumulated water on the surface was removed using a pipet or a similar instrument every 10 min through the first 40 min and every 30 min thereafter until bleeding cessation.

Hardened Concrete Tests

The hardened concrete tests performed were compressive, indirect tensile, and flexural strength in accordance with ASTM C39, ASTM C496, and ASTM C78, respectively. For the compressive, indirect, and flexural strength tests, 150 mm × 150 mm × 150 mm standard cubes, 150 mm diameter × 300 mm height standard cylinder, and 100 mm × 100 mm × 400 mm standard prisms were used, respectively. All tests were conducted at 7, 14, 28, and 90 days. The average value of the three specimens for each test age was determined and recorded. According to ACI 318, the results of indirect tensile strength (f_{ct}) depended on compressive strength in accordance with Equation (1).

$$f_{ct} = k\sqrt{fc'} \qquad Eq.(1)$$

RESULTS AND DISCUSSION

Table 7 shows the results of the slump flow test, representing the maximum spread, which is the final diameter of slump flow, and T_{50}, which is the time required for the concrete flow to fill a 50 cm-diameter circle. EFNARC recommends that concrete mixtures must have slump flow diameters of 55-75 cm to be considered as self-compacting (EFNARC, 2002). Slump flow >75 cm diameter may cause concrete to segregate, whereas that with <55 cm diameter may indicate concrete with flow rates that are insufficient for passing through an overcrowded reinforcement. The results showed that the slump flow requirements for SCCs were satisfied in concrete mixtures of SCC with (SCCF) and without PFs and with PFA at replacement rates of 20% and 40% cement mass. For concrete mixtures with PFA at replacement rates of 0% and 60%, cement mass exhibited low slump flow. The results showed a wide range of variations, illustrating the effects of PFA replacement rates and PF addition on SCC and SCCF flowability. The decrease in the workability and flowability of SCC might be attributed to the addition of a high volume of PFA as an alternative material. Slump flow rates increased by 40% and 34% when PFA was added at replacement rates of 20% and 40% cement mass, respectively. The workability and flowability of all SCCF mixtures were lower than those of all SCC mixtures. Moreover, the flowability of SCC and SCCF mixtures containing PFA at replacement rates of 60% cement mass did not satisfy the minimum requirements of the T_{50} test. Results also showed that the slump flow rates of SCCFs decreased by 21%, 12%, and 17% when PFA was added at replacement rates of 0%, 20%, and 40% cement mass compared to the control, respectively. In general, increasing the replacement rates of PFA from 20% to 40% cement mass did not significantly decrease concrete workability. Adding PFA to cement at a replacement rate of 60% negatively affected the properties of SCC, which might be attributed to the high PFA volume. Using a high PFA volume led to increased surface area, which demand additional water.

Table 7: Results of Slump flow Tests

Mixture	Slump flow (mm)	T_{50} (sec)
SCC0	520	8
SCC20	730	2.3
SCC40	700	2.5
SCC60	470	-
SCCF	410	-
SCCF20	640	5
SCCF40	580	4
SCCF60	460	-

In addition to the slump flow test and slump flow T_{50}, the V-funnel test was conducted to estimate the flowability of SCC and SCCF mixtures. The V-funnel flow time (s) was calculated as the time it took from bottom outlet opening until light from the bottom outlet became noticeable. EFNARC recommends that concretes should have V-funnel flow times of 6–12 s and an L-box ratio H2/H1 of >0.80 to be considered as SCCs (EFNARC, 2002). Table 8 shows the results of the V-funnel test and L-box, indicating that SCC mixture containing PFA at replacement rates of 0% of cement mass satisfied the requirements, whereas that at replacement rates of 20% and 40% of cement mass consumed less time than ree quired in the specifications. SCCF mixtures containing PFA at replacement rates of 20% and 40% cement mass also met the requirements for SCC. By contrast, SCC and SCCF mixtures with PFA at replacement rates of 0% and 60% cement mass did not fulfill the requirements for SCC. The decrease in the passing and filling abilities of SCCs likely resulted from the high volume of added PFA. Moreover, all SCCF mixtures exhibited lower passing and filling abilities than SCC mixtures, except for PFA at replacement rate of 40% of cement mass, which obtained the highest value in the L-box test. SCC and SCCF mixtures containing PFA at a replacement rate of 60% cement mass did not satisfy the specification requirements for the V-funnel and L-box V-funnel T_5. The results sugu gested that increasing the replacement rate of PFA to 60% cement mass exerted the greatest negative effect on the passing and filling abilities of the cement mixtures.

Table 9 shows the results of the bleeding and segregation tests. SCC and SCCF mixtures that contained PFA at replacement rates of 20% or 40% and 0% or 60% cement mass exhibited high and the lowest rates of bleeding and segregation, respectively. The addition of a high volume of PFA likely decreased the bleeding and segregation of SCCs. Furthermore, the bleeding and segregation rates of SCCF mixtures were lower than those of SCC mixtures.

Table 8: Results of L-box and V-funnel tests

Mixture	V-funnel (sec)	V-funnel (T_5) (sec)	L- Box ratio (H_2/H_1)
SCC0	10	17	0.76
SCC20	5.2	7	0.86
SCC40	5.3	8	0.88
SCC60	14	16	0.71
SCCF	-	-	0.55
SCCF20	6.3	9	0.81
SCCF40	7.6	10	0.89
SCCF60	17	26	0.59

Table 9: Results of bleeding and segregation tests

Mixture	Segregation index %	Total bleeding water (ml/cm^2)
SCC0	3.2	0.08
SCC20	5.6	0.12
SCC40	7	0.18
SCC60	2.5	0.02
SCCF	2.3	0.0
SCCF20	3.5	0.09
SCCF40	4.1	0.09
SCCF60	1.8	0.0

Compressive Strength

Figures 2, 3, and 4 show the compressive strength test results for SCC and SCCF at ages 7, 14, 28, and 90 days. Results showed that the evolution of compressive strength varied in SCC and SCCF. The decline in compressive strength became apparent when the PFA replacement ratio was increased to 60% cement mass. The decline in the compressive strength of SCC and SCCF might be attributed to the addition of PFA at a high replacement rate of 60% cement mass, which introduced air bubbles in hardened concrete and decreased compressive strength (Mohammadhosseini *et al.*, 2015). The best compressive strength of SCCs at ages 7, 14, 28, and 90 days was obtained when PFA was added at a replacement rate of 20%. The compressive strength of SCCs increased by 16.1%, 7.4%, 3.9%, and 1.2% at ages 7, 14, 28, and 90 days, respectively, when PFA was added at the replacement rate of 20% cement mass. In addition, the compressive strength of SCCs increased by 8.5% and 1.5% at ages 7 and 28 days, respectively, when PFA was added at the replacement rate of 40% cement mass. Compressive strength decreased by 18.8%, 24.1%, 15.9%, and 11.8% at ages 7, 14, 28, and 90 days, respectively, when PFA was added at the replacement rate of 60% cement mass. The compressive strength of SCCFs was lower than that of SCCs, except after PFA replacement by 40% of cement mass, in which the compressive strength was the highest. Adding PFA to cement at a replacement rate of 60% negatively affected the strength of SCCs and SCCFs, which might be attributed to the high PFA volume. Use a higher volume of PFA up to 60% leads to the slow hydration due to the activation of the PFA (Mohammadhosseini *et al*., 2015). The percentages of decrease in compressive strength were higher in SCCF mixtures. Thus, this finding might be attributed to the negative effect of fibers on concrete rheology, which affected the degree of concrete compaction and consequently decreased the compressive strength of concrete (Akinpelu *et al*., 2017).

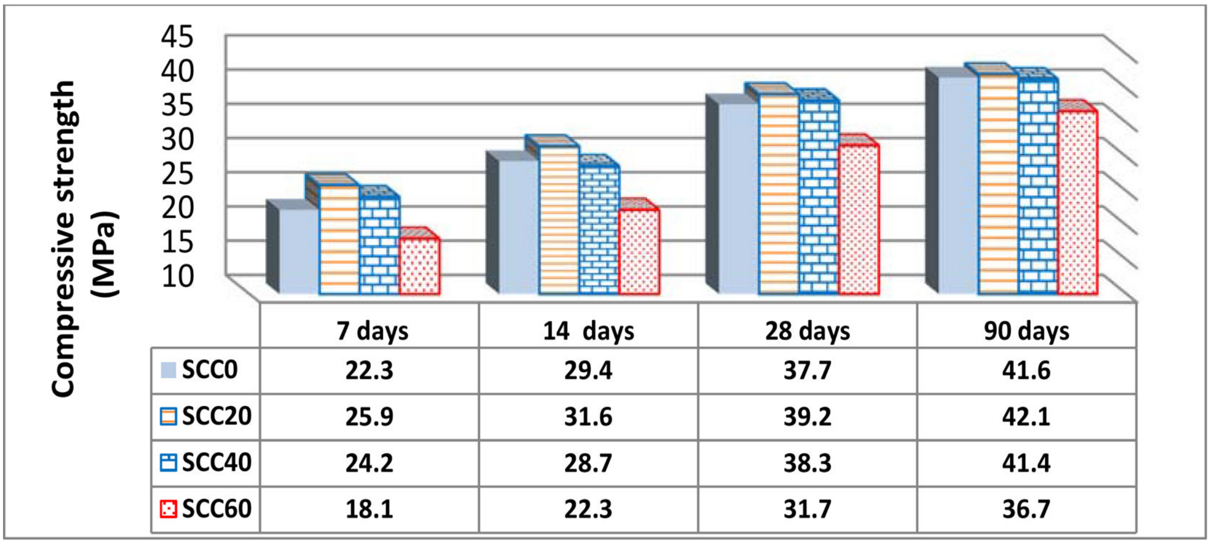


Fig. 2: Results of Compressive Strength Test of SCC

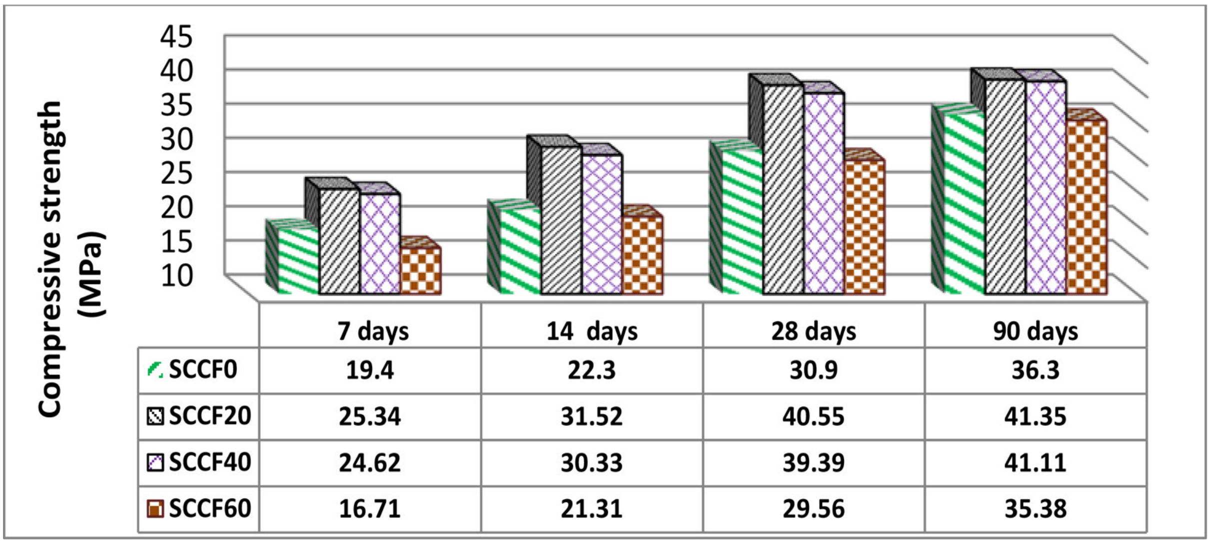


Fig. 3: Results of Compressive Strength Test of SCCF

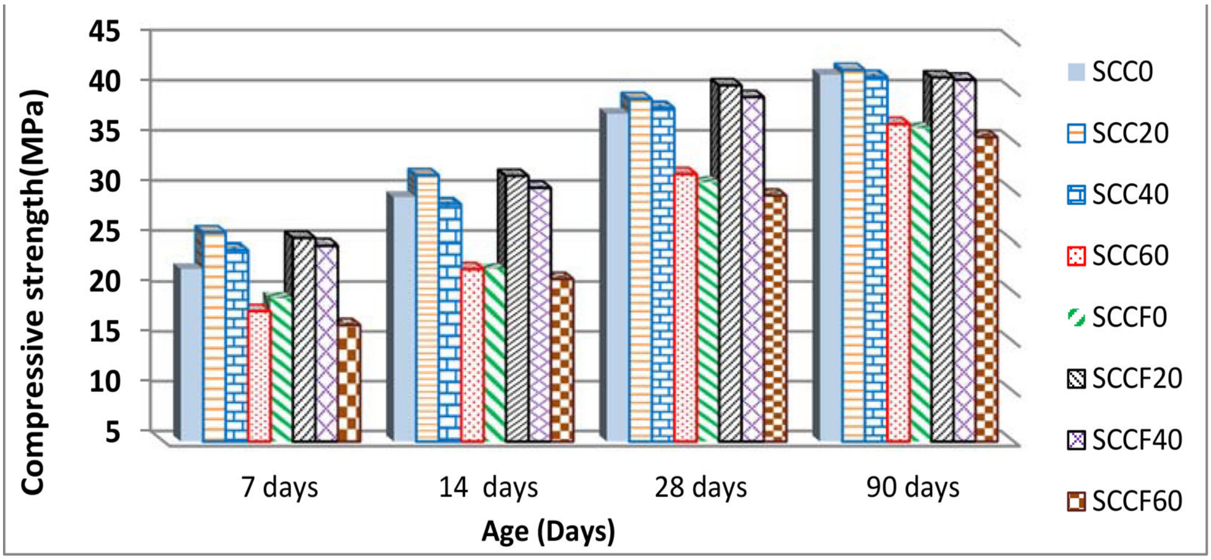
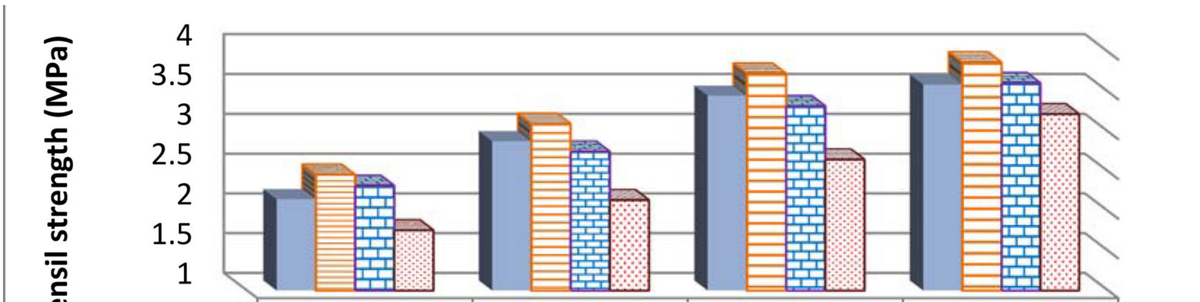


Fig. 4: Results of Compressive Strength Test of SCC and CCF

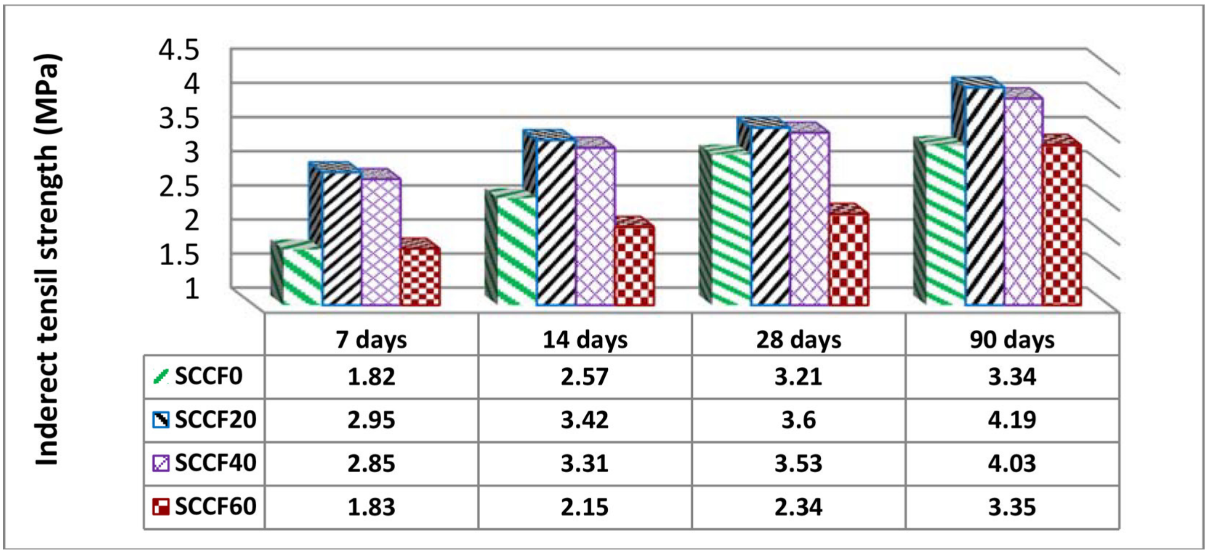
Indirect Tensile Strength

Figures 5, 6, and 7 show the results of the indirect tensile strength for SCC and SCCF mixtures at ages 7, 14, 28, and 90 days. The indirect tensile strength of SCCF was slightly improved compared with that of SCC, suggesting that PF addition improves the tensile strength of hardened concretes. Based on Equation (1), the coefficient (k) values were as follows: 0.52, 0.56, 0.52, 0.47, 0.53, 0.61, 0.60 and 0.48 in SCC0, SCC20, SCC40, SCC60, SCCF0, SCCF20, SCCF40, and SCCF60 respectively, at 90 days test age. Generally, the k values were of 0.47–0.56 IN SCC and 0.48–0.61 in SCCF. A slight increase in coefficient (k) was observed in concretes with PFA addition by 0%, 20%, 40%, and 60% of cement mass. This result may be attributed to the effect of PFs on concrete rheology and ability for full compaction. The slight increase in the indirect tensile strength of the SCC was due to the addition of PF, which was added by 0.22% of the concrete volume (El-Dieb and Taha, 2012). The percentage was appropriate to achieve SCC using pulverized fly ash with replacement rates of up to 40% of the cement mass achieving acceptable properties of the fresh SCC (Gencel *et al.*, 2011)



	7 days	14 days	28 days	90 days
SCC0	2.15	2.88	3.45	3.59
SCC20	2.46	3.1	3.73	3.87
SCC40	2.32	2.75	3.32	3.61
SCC60	1.76	2.14	2.65	3.22

Fig. 5: Results of Indirect Tensile Strength Test of SCC



	7 days	14 days	28 days	90 days
SCCF0	1.82	2.57	3.21	3.34
SCCF20	2.95	3.42	3.6	4.19
SCCF40	2.85	3.31	3.53	4.03
SCCF60	1.83	2.15	2.34	3.35

Fig. 6: Results of Indirect Tensile Strength Test of SCCF

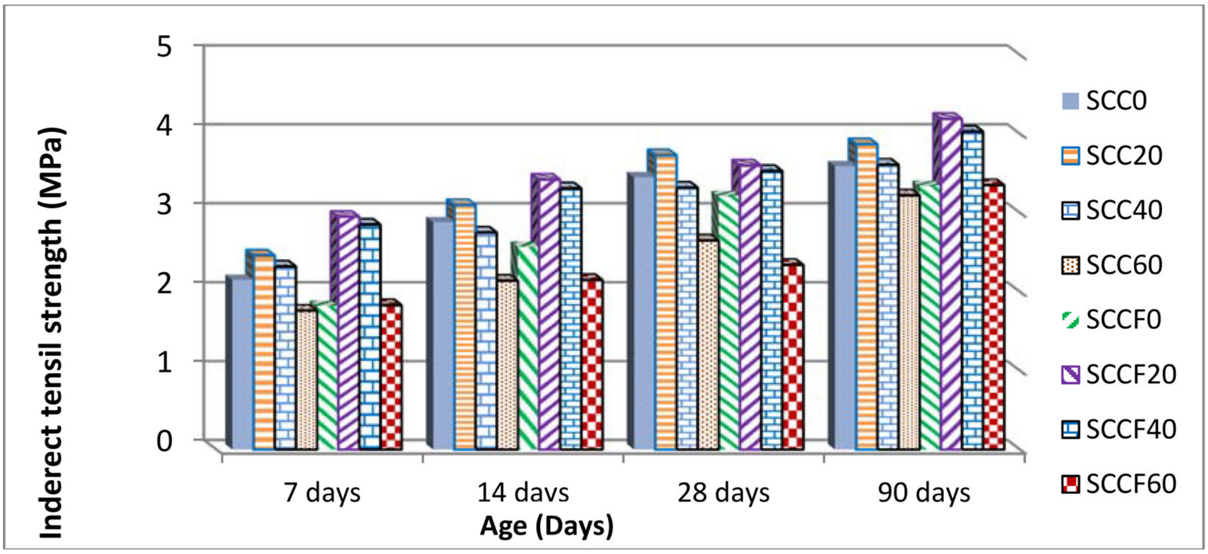
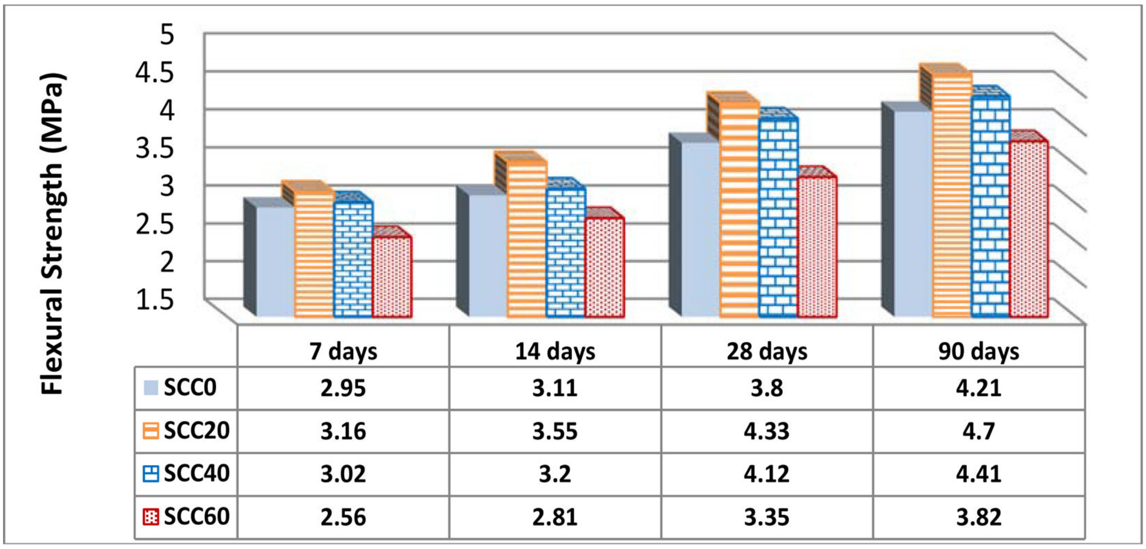


Fig. 7: Results of Indirect Tensile Strength Test of SCC and SCCF

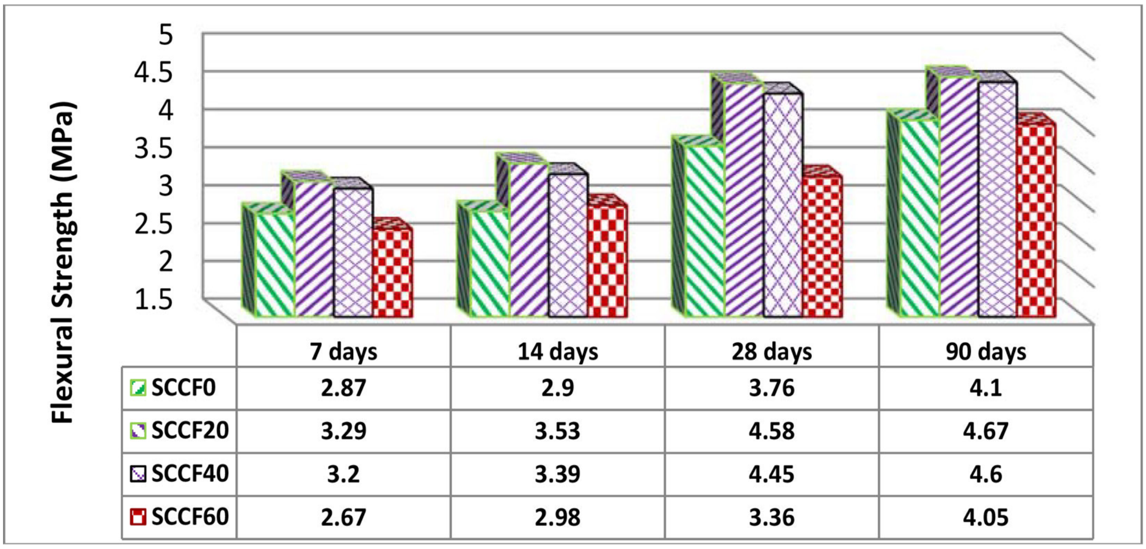
Flexural Strength

Figures 8, 9, and 10 show the results of flexural strength for SCC and SCCF mixtures at ages 7, 14, 28, and 90 days. The results showed that the indirect tensile strength of SCCF was slightly improved compared with that of SCC, indicating that PF addition of improves the flexural strength of hardened concretes. The addition of fiber to the SCC increased flexural strength at increased rates of 1%, 4.3%, and 6.1% for SCCF20, SCCF40, and SCCF60 compared with SCC, respectively, at 90 days test age. Generally, the value of flexural strength for SCC containing PF was between 10.1–11.1% of compressive strength. The flexural strength increase of the SCC was due to the fiber addition. The increase was slight because the added fibers were 0.22% of the concrete volume (Gencel *et al.*, 2011). This was the appropriate addition to achieve SCC using pulverized fly ash with replacement rates of up to 40% of the cement mass while achieving acceptable fresh SCC properties (El-Dieb and Taha, 2012).



	7 days	14 days	28 days	90 days
SCC0	2.95	3.11	3.8	4.21
SCC20	3.16	3.55	4.33	4.7
SCC40	3.02	3.2	4.12	4.41
SCC60	2.56	2.81	3.35	3.82

Fig. 8: Results of Flexural Strength Test of SCC



	7 days	14 days	28 days	90 days
SCCF0	2.87	2.9	3.76	4.1
SCCF20	3.29	3.53	4.58	4.67
SCCF40	3.2	3.39	4.45	4.6
SCCF60	2.67	2.98	3.36	4.05

Fig. 9: Results of Flexural Strength Test of SCCF

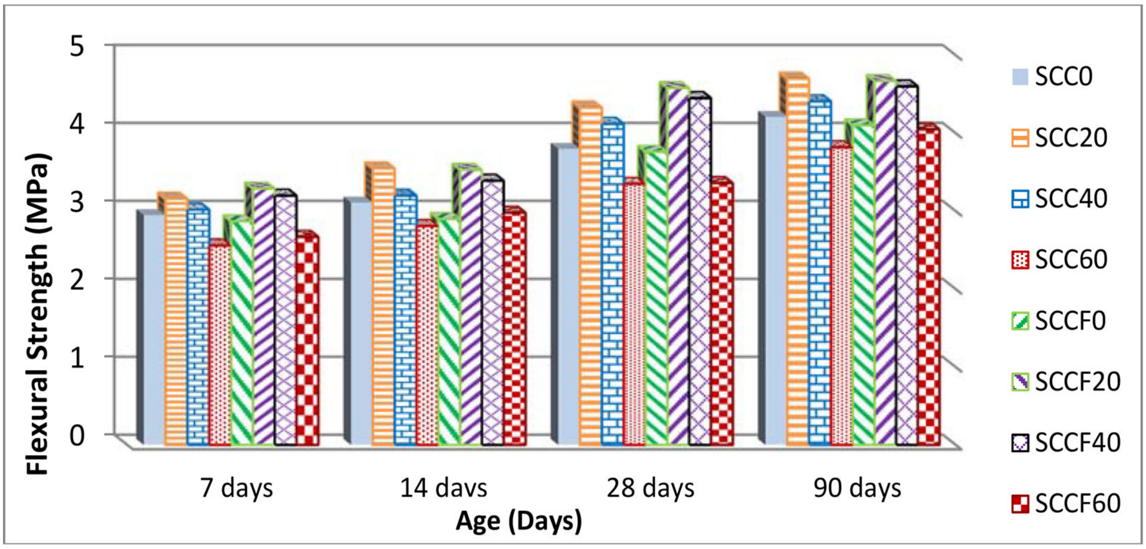


Fig. 10: Results of Flexural Strength Test

CONCLUSIONS

The following conclusions were drawn from the results of this study:

1. he addition of PFA to SCC and SCCF positively affected the properties of fresh concrete with PFA replacement by 20% and 40% of cement mass, except for V-funnel test, in which the time required to pass concrete through the apparatus outlet was faster than the time required in the specification.
2. PFA addition to SCC and SCCF by replacement of 20% and 40% of cement mass increasing the bleeding and segregation.
3. The best SCC workability was obtained when PFA was added at replacement rates of 20% and 40% cement mass without PFs. Fresh SCC samples with this formulation exhibited slump flow diameters of 730 and 700 mm, blocking ratios of 0.86 and 0.88; and flow times of 5.2–5.3 s.
4. The high ash volume as a replacement of the cement mass up to 60% negatively affected the fresh and hardened concrete properties but improved resistance bleeding and segregation in both SCC and SCCF.
5. In general, PF addition by 0.22% of volume concrete decreased the properties of fresh concrete but slightly improved the flexural and indirect tensile strengths.
6. PF addition to SCC decreased bleeding and the segregation. Adding the PF to SCCF with a replacement of 40% of cement mass resulted in best fill ratio in L-box (H2/H1) (0.89).
7. Based on the test results the pulverized fly ash should be replaced by 20% to 40% of cement mass to produce SCC with compressive strength of up to 41 MPa at 90 days in both SCC and SCCF.

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تأثير الرماد المتطاير على خواص الخرسانة ذاتية الدمك المسلحة المعززة بالألياف

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الملخص

الخرسانة ذاتية الدمك لديها قابلية عالية للتدفق، ومقاومة عالية للانعزال والنزيف، وتسهل هذه الخصائص خلط الخرسانة وصبها وتشطيبها دون استخدام آلات الدمك أو الاهتزاز. إضافة المواد المعدنية؛ مثل الرماد المتطاير، والملدن المتفوق، يحسن خصائص الخرسانة ذاتية الدمك عن طريق منع الانعزال والنزيف وزيادة درجة الميوعة. الخرسانة ذاتية الدمك تتطلب تدفقًا عاليًا تحت تأثير وزنها الذاتي؛ لملء جميع أجزاء القالب بكفاءة عالية.

ناقشت هذه الورقة نتائج التحقيق التجريبي على خواص الخرسانة ذاتية الدمك، والخرسانة ذاتية الدمك المسلحة بألياف البولي بروبلين. تحتوي الخرسانة ذاتية الدمك على معدلات إحلال بنسب (0 %)، (20 %)، (40 %)، و(60 %) من كتلة الأسمنت.

وقد تم التحقق من قوة الانضغاط، والانحناء والشد من عينات الخرسانة في سن (7)، (14)، (28)، و(90) يومًا، كما تمت دراسة خواص الخرسانة الطازجة من خلال اختبار الانعزال، النزيف، قطر تدفق الخرسانة، زمن التدفق إلى قطر 50 سم، واختبار حركة الخرسانة الطازجة في الصندوق على شكل(L) و شكل(V) .

أظهرت النتائج أن أفضل خصائص الخرسانة ذاتية الدمك الطازجة تم الحصول عليها عندما تمت إضافة الرماد المتطاير بمعدلات استبدال (20 %)، و(40 %)، كتلة الأسمنت، وبالإضافة إلى ذلك، فإن إدراج الألياف بنسبة (0.22 %) أدى إلى انخفاض العزل والنزيف وتحسين قوة الانحناء والشد في الخرسانة ذاتية الدمك المسلحة بالألياف.

الكلمات المفتاحية: بدائل الأسمنت، قابلية تشغيل الخرسانة، قابلية جريان الخرسانة، معدل استبدال عالٍ، مواد بوزلانية.