Sirte University Scientific Journal (Applied Sciences) *Vol.13(2), Dec. 2022*

The Effect of Polypropylene Fiber on the properties of fresh and hardened self-compacting concrete (SCC)

Ghusen M. AL Kafri [1], *Ahmed. M. Alsadaai* [2]
[1]*E-mail:* galinak66@yahoo.com

[1,2]*Civil Engineering Department, Faculty of Engineering Sirt University, Libya.*

Abstract

The Self-compacting concrete (SCC) defines as a highly flowable, non-segregating concrete that fills uniformly and completely every corner of formwork by its own weight and encapsulate reinforcement without any vibration, whilst maintaining homogeneity. This research conducted to evaluate the effects of polypropylene fiber addition on characteristics and properties of SCC mixes in fresh and hardened state of SCC. In this study, the concrete mixes were added with polypropylene fiber of 0.0 %, 0.05%, 0.1 %, and 0.15 % Of volume fraction, mineral admixture i.e., silica fume 10% of weight of cement and chemical admixture i.e., Super Plasticizer 1.2% of cement and silica fume is used with constant w/(c+s) ratios which equal 0.49. For determining the self-compact ability properties like passing ability, flowability, viscosity, and segregation resistance the following tests such J-ring, Slump flow, V-Funnel and L-Box tests were performed. After 7 and 28 days of curing, cubes, cylinders, prisms, compressive, splitting and flexural strengths were tested. Tests results indicate that polypropylene fibers tend to reduce the flowability and passing ability but will increase viscosity and segregation resistance of SCC. Furthermore, it can be concluded that polypropylene fiber reduces deformability of SCC in the fresh state. After7and 28 days of curing, concrete specimens' tests indicate that polypropylene fiber addition up to 0.15% of volume fraction tend to improve the compressive strength, tensile strength, and flexural strength of hardened SCC. It also can be suggested that polypropylene fibers allowed to be added into SCC mixes up to 0.15% by volume of concrete.

Keywords: *Fresh properties, Harden properties, flow ability, viscosity, passing ability, segregation, Self-Compacting Concrete*

1. Introduction

1.1 Background of Study

Self-compacting concrete (SCC) is highly flowable, non-segregating concrete that can spread into place, fill the formwork, and encapsulate the reinforcement without any mechanical consolidation [1]. In general, SCC is concrete made with conventional concrete materials and, in some cases, with a viscosity-modifying admixture (VMA).

The use of SCC has gained wide acceptance in Japan since the late 1980s [2]. Initially, it was developed to ensure proper consolidation in applications where concrete durability and service life were of concern. SCC was later used to facilitate construction operations and reduce construction time and cost. For example, it has been used to cast sections with highly congested reinforcement and areas that present restricted access to placement and consolidation, including the construction of tunnel lining sections and the casting of hybrid concrete-filled steel tubular columns. The following references provide various examples of the early use of SCC in civil engineering applications: Tanaka et al. (1993); Hayakawa et al. (1993, 1995); Miura et al. (1993); Okamura and Ozawa (1994); Takeuchi et al. (1994); Izumi et al. (1995); Fukute et al. (1995); Kitamura et al. (1996); and Ushijima et al. (1995). SCC has recently been used in concrete repair applications in the world, including the repair of bridge abutments and pier caps, tunnel sections, parking garages, and retaining walls, where it ensured adequate filling of restricted areas and provided high surface quality (Jacobs and Hunkeler 2001; Khayat and Morin 2002).Since the early development of SCC in Japan, this new class of high-performance concrete has been employed in several countries in cast-in-place and precast applications (RILEM 2000; Khayat and Aïtcin 1998; Skarendahl 2001; Walraven 2001; Ouchi 2001).

1.2 Objectives

This research conducted to investigate effect of polypropylene fiber addition on four mains characteristics of SCC in the fresh state: flowability, viscosity, passing ability and segregation resistance. Effect of polypropylene fiber addition on compressive strength, splitting tensile strength, flexural strength. Based on the results of fresh and hardened SCC tests, prediction of optimum volume fraction of polypropylene fiber in SCC mixes can be determined

2. Experimental programme

2.1 MATERIAL PROPERTIES

The cement used in this work was ordinary normal Portland cement type 42.5N conforming to the requirements of Libyan specification [340/1997] [3] . The specific gravity of cement was 3.15. The initial and final setting times were found as 185 and 270 min, respectively. Fine aggregate used was Sirt sand passing through sieve 4.75 mm obtained from a local source. The specific gravity of sand was found to be 2.65. The 10- and 15-mm size aggregates are used in 2:1 proportion. The specific gravity of Coarse Aggregate was 2.5 for 10mm and 2.45 for 15mm. As mineral admixture Silica fume was used in the present work with 10% of cement weight. Potable fresh water available from local sources was used for mixing and curing of specimens to improve the workability in concrete, super-plasticizers (1.2 % by weight of (cement + silica) had been used. Polypropylene fibers of cut length 12 mm and Specific gravity 0.91 were used. The ultimate tensile strength of fibers was 550 – 700 MPa.

2.2 Mixture proportioning procedure

Concrete mixes were prepared containing 0%, 0.05%, 0.10%, and 0.15% of polypropylene fibers (measured by fibers volume in concrete volume). Detail of mixes proportion for this research can be observed in following Table 2.1

Table 2.1: Mix Proportion

Material	Volume Fraction of Polypropylene Fibers			
	0.0%	**0.05%**	**0.1%**	**0.15%**
Polypropylene fibers (kg/m3)	0	0.45	0.9	1.35
Water (lt/m3)	215	215	215	215
Portland Cement (kg/m3)	400	400	400	400
Silica fume (kg/m3)	40	40	40	40
Coarse Aggregate (kg/m3) 15mm	233.33	233.33	233.33	233.33
Coarse Aggregate (kg/m3)10 mm	466.67	466.67	466.67	466.67
Sand (kg/m3)	700	700	700	700
Super plasticizer (lt/m3)	5.28	5.28	5.28	5.28

The above mix proportion is used throughout testing all strength characteristics i.e., compressive strength of cubes, flexural strength of beams, split tensile strength of cylinders. The unit weight of hardened cubes, and cylinder is also observed after 7- and 28-days curing**.**

2.3 Mixing, casting, curing and testing specimens

The concrete mixtures were prepared in a laboratory mixer. In a typical mixing procedure, the materials were placed in the mixer in the following sequence: first coarse aggregates and fine aggregates and fibers together followed by cement, initially dry material mixed for 1 min and finally addition of 85% of water. After 1.5 min of mixing, the rest of the mixing of water together with the SP was added. All the batches were mixed for a total time of 5 min; in order to prevent fresh concrete from segregation, the mixing duration was kept as low as possible. The specimens for testing the hardened concrete properties were prepared by direct pouring of concrete into moulds without compaction. From each concrete mixture, six specimens were cast in cylindrical moulds of 150 mm diameter and 300 mm height. Six 150 mm cubes were cast and six 150*150*750 mm beams were cast. The cubes were used for compressive strength tests, while the cylinders were used for splitting tensile strength tests and beams were used for flexural strength. After casting, the concrete specimens were kept in the laboratory at room temperature for 24 h. After demolding, they were placed in bath until the time of testing. Curing was performed in accordance with the ASTM C511 standard. It is well recognized that adequate curing of concrete is very important not only to achieve the desired compressive strength but also to make durable concrete. The compressive strength tests were carried out in accordance with ASTM C39-86 at 7 and 28 days. The splitting tensile strength tests were performed according to ASTM C496-87 at 7 and 28 days., flexural strength were determined according to ASTM 293-94 at 28 days.

2.4 Different Test Method for Workability of Self Compacting Concrete

The following fresh properties of SCC are tested in working laboratory set up systematically as per ASTM procedures (ASTM C 1611/C 1611M Slump flow of SCC).

A. Slump Flow Test

The slump flow test is done to assess the horizontal flow of concrete in the absence of obstructions. It is a most commonly used test and gives good assessment of filling ability. It can be used at site. The test also indicates the resistance to segregation. The base plate is placed on the level ground. The slump cone is then placed centrally on the base plate. The cone is filled with the scoop. The concrete level is stroked off with the trowel. The cone is raised vertically and the concrete is allowed to flow freely. The final diameter of the concrete in two perpendicular directions is measured and the average o the two diameters is calculated. This is the slump flow in mm. Figure 2.1(a) shows the slump flow test.

B. T50 Slump Flow Test

The procedure for this test is same as for slump flow test. When the slump cone is lifted, stop watch is started and the time taken for the concrete to reach 500mm mark is found. This time is called T50 time. This is an indication of rate of spread of concrete. A lower time indicates greater flowability.

C. V-Funnel Test

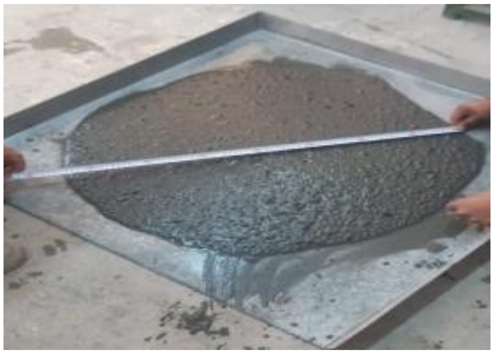
The V-funnel test is used to determine the filling ability of the concrete with a maximum size of aggregate 20mm size. The V-funnel is set up on the firm ground. The inside of the funnel is moistened. The apparatus is completely filled with concrete and leveled. The trap door is opened within 10 seconds and the time taken for the concrete to flow down in recorded After this the funnel can be refilled concrete and left for 5 minutes to settle. if the concrete shows segregation, then the flow time will increase significantly. Figure2. 1(b) shows the V-funnel test for mix.

D. J-Ring Test

It denotes the passing ability of the concrete. The inside of the slump cone and base plate is moistened. The J-ring is placed centrally on the base plate and the slump cone is placed centrally inside the J-ring. The slump cone is filled with a scoop. The surplus concrete is removed with the trowel and the surface is leveled. The cone is raised vertically and the concrete is allowed to flow out through the J-ring. Figure 2.1(c) shows the J-Ring test for mix

E. L-Box Test

The test assesses the flow of concrete and also the extent to which the concrete is subjected to blocking by reinforcement. The vertical section of the apparatus is filled with concrete. It is left to standing for 1 minute. The sliding gate is lifted and the concrete is allowed to flow out into the horizontal section. When the concrete stops flowing, the height H1 and H2 are measured. H2/H1 is the blocking ratio. Figure 2.1(d) shows the L-Box test for mix.



(a)Slump Flow Test

(b) V-Funnel Test

(c) J-Ring Test

(d) L-Box Test

FIG 2.1: WORKABILITY TESTS

3. EXPERIMENTAL RESULTS AND DISCUSSION

3.1. The Effect of polypropylene Fiber on the Fresh Properties of Self- Compacting Concrete

3.1.1. Slump Flow and T500 mm

The filling ability of fresh self-compacting concrete is described by slump flow investigated with Abram's cone. Table (3.1) and Figure (3.1) shows the results of slump flow tests. The values of (D) represent the maximum flow diameter). All the mixtures had a slump flow diameter between (530-755) mm. decrease in slump flow diameter has been observed with incorporating polypropylene fibers in SCC mixes and the percent of decreasing plotted in the fig (3.1), adding polypropylene fibers increases the resistance to flow and reduces the flowability due to increasing the interlocking and friction between fibers and aggregate.

Table (3.1): Results of fresh concrete test

Mix	polypropylene fibers (% by Vol)	D (mm)	T500 (Sec)	Blocking Ratio(BR)	Tv (Sec)
PF1	0	755	2.4	0.92	2.85
PF2	0.05	635	2.52	0.87	3.5
PF3	0.1	585	4.47	084	5
PF4	0.15	530	5.32	0.8	5.5

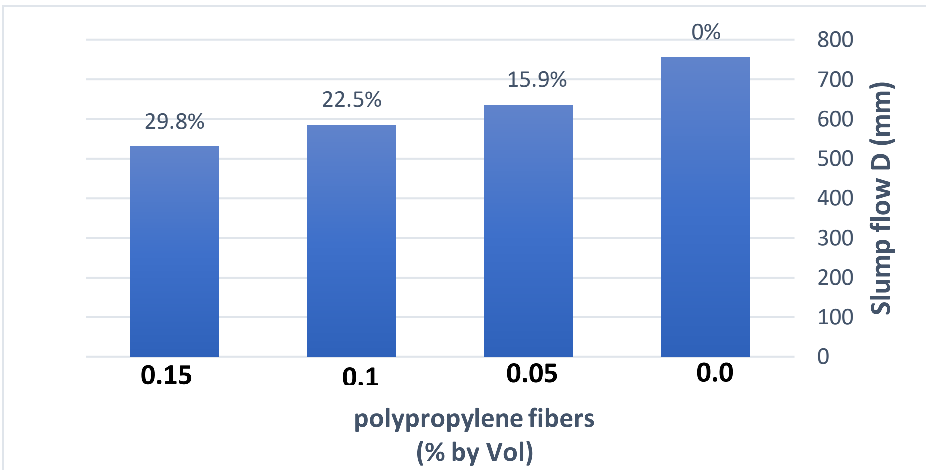


Figure 3.1: Effect of polypropylene fiber content on Slump Flow Test of SCC

Including polypropylene fiber in SCC mixtures resulted in an increase in T500 values. The increase of percentages found to be increase with the increase in fiber content the percent of increasing plotted in the fig (3.2). The increasing of slump time due to increase of internal friction resultant from higher number of *polypropylenes*. fiber. All results of slump flow and slump flow time were conformed with ACI limitations.

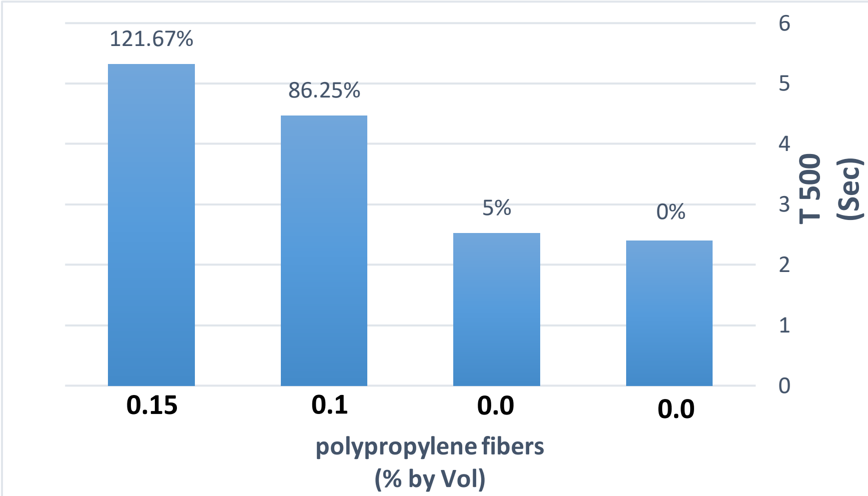


Figure 3.2: Effect of polypropylene fiber content on T 500 Test of SCC

3.1.2. L-Box Passing Ability

The L-Box with 3 bars diameter 14 mm Which was made in the workshop in Sirte was used in this study to assess the passing ability of the mixes. The Blocking Ratios results (BR=H2/H1) of the tests are summarized in Table (3.1) & plotted in Figure (3.3). The results of the BR ranged between (0.8-0.92). The results show that the BR decreased with increasing polypropylene fiber content. The higher the polypropylene. fiber content, the lower the BR was. Introducing polypropylene fibers had its impact on passing ability. The decreased of the BR with increasing poly. fiber content due to internal resistance of flow of concrete result of increasing of number of polypropylene fibers.

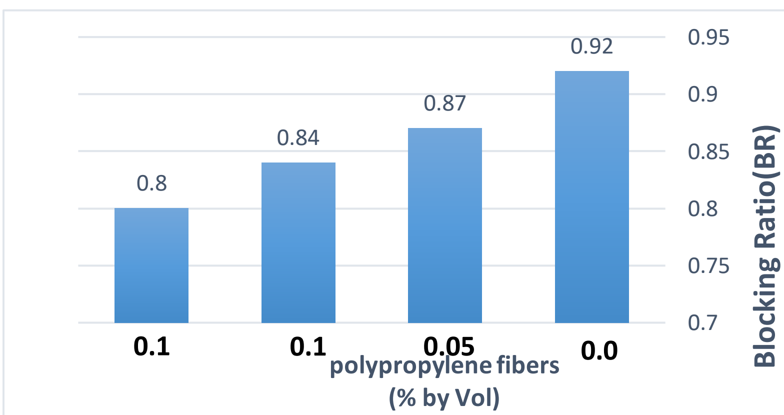


Figure 3.3: Effect of polypropylene fiber content on Blocking Ratio Test of SCC

3.1.3. V-Funnel Flow Time

The V-funnel test is used to assess the viscosity and filling ability of self-compacting concrete. The test results show the V-Funnel flow time increased by incorporating polypropylene fibers in mixes as illustrated in Fig. (3.4). Similar behavior was observed in the T500 test. Besides, the higher the polypropylene fiber content, the higher the flow-time. This can be ascribed to, the increasing in fiber content leads to increase the friction between the fibers and aggregates and the friction of the fibers with each other which could extend the required time to empty the V-funnel

.

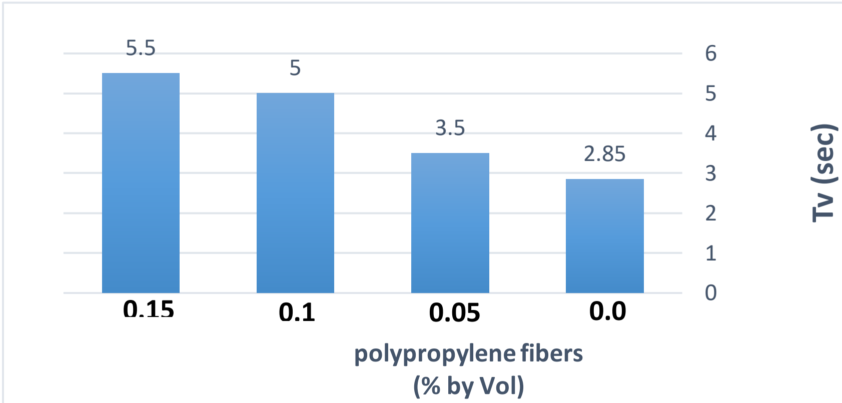


Figure 3.4: Effect of polypropylene Fiber Content on Flow Time at V Funnel (TV) Test of SCC

3.2. The Effect of polypropylene Fiber on Hardened Properties of SCC

3.2.1. Compressive Strength

The compressive strength, is one of the most important mechanical properties of hardened self-compacting concrete. Table (3.2) and Figure (3.5) show the average of the results of the compressive strength test at 7 and 28 days. The results indicate to the. Compressive strength increases with increasing percentage of fibers. The percentage of changes (increase) in compressive strength for all mixes with polypropylene fiber content are represented in Table (3.2). The increase in compressive strength may be associated with uniform dispersion of fine fibers throughout self-compacting concrete of high flowability, leading to consistent internal integrity. Also, this improvement in the compressive strengths of the polypropylene fiber reinforced SCC refer to the control of cracking and the mode of failure by means of post cracking ductility. However, polypropylene fibers caused crack closing forces which led to increase the compressive strength.

Table (3.2): Results of Compressive strength test of scc

Mix	**Compressive strength (Mpa)**		**Change in compressive strength with respect to reference Mix (SP1)%**	
	7day	**28day**	**7day**	**28day**
PF1	37.29	42.93	-	-
PF2	38.43	43.02	3.06	0.21
PF3	38.75	45.92	3.92	6.96
PF4	40.92	51.14	9.73	19.12

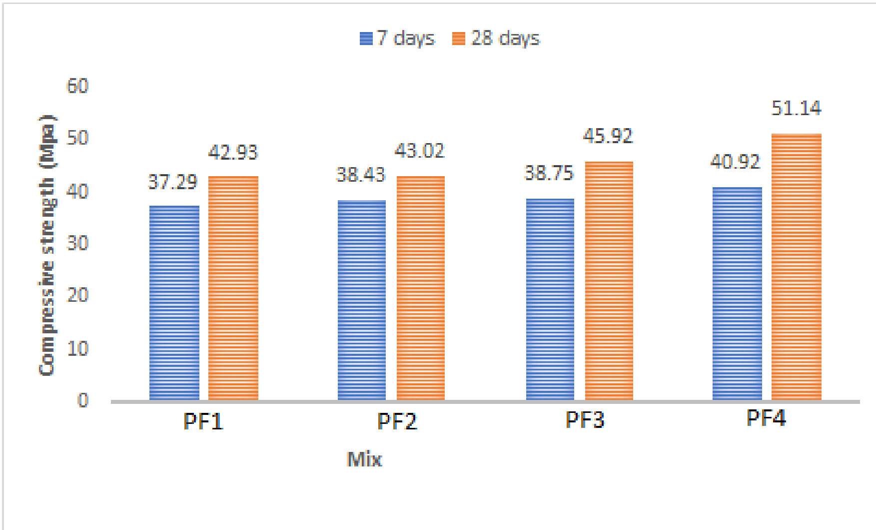


Figure 3.5: Development of compressive strength with age for different PF content in SCC

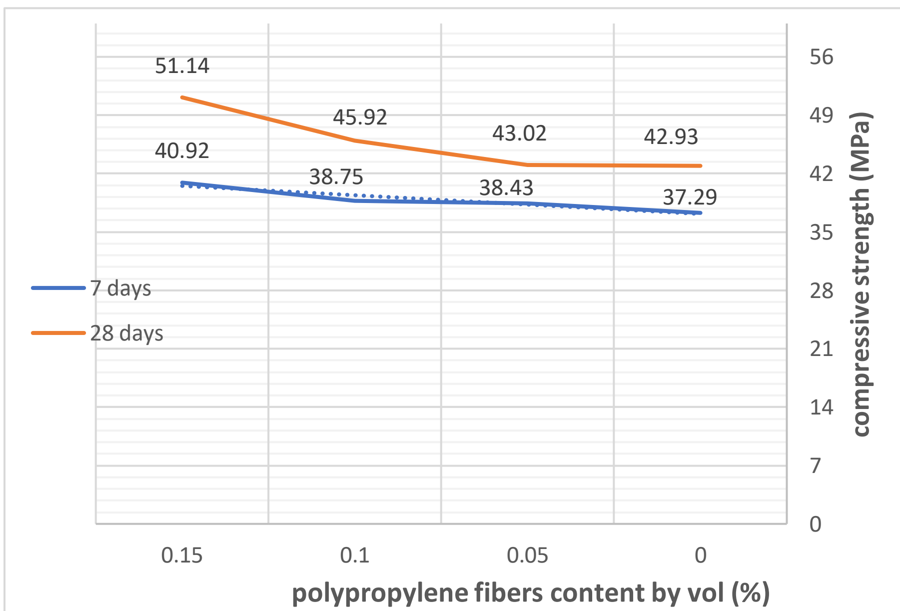


Figure 3.6: Effect of poly. Polypropylene Fiber Content on compressive strength in SCC at age (7&28) days

3.2.2. Splitting Tensile Strength

The results splitting tensile strength indicate that all specimens exhibited a continuous increase in splitting tensile strength with progress in age as summarized in Table (3.4) and Fig. (3.7). Also, the results observed that splitting tensile strength of the SCCs increases with polypropylene fiber content.

The splitting tensile strength increases with increasing in polypropylene fiber volume up to 0.15%. Also, the percentage of increase in splitting tensile strength are listed in Table (3.4) and illustrated in Fig (3.8). The strength increase due to inclusion of polypropylene fibers is attributed to the mechanism of polypropylene fibers in arresting crack progression. Where, the presence of fibers in concrete restrains the development of internal microcracks and thus contributes to an increased tensile strength. Accordingly, the increase in fiber content leads to an increase in the tensile strength of concrete.

Table (3.4): Results of Splitting tensile strength test of scc

Mix	**Splitting Tensile strength (MPa)**		**Change in Splitting Tensile strength with respect to reference Mix (SP1)%**	
	7day	**28day**	**7day**	**28day**
PF1	3.395	4.44	-	-
PF2	3.72	4.61	9.57	3.83
PF3	3.82	4.81	12.52	8.33
PF4	3.885	4.95	14.43	11.49

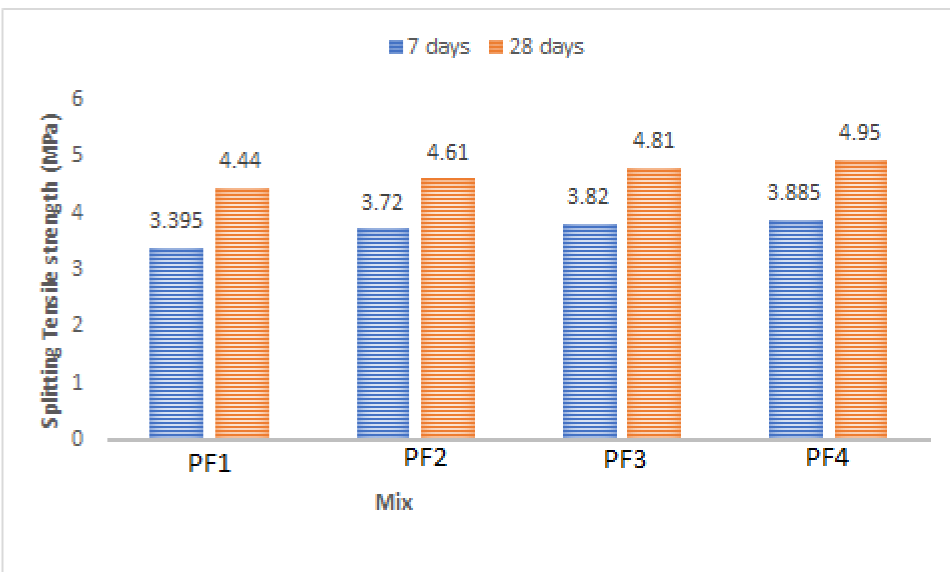


Figure 3.7: Development of splitting tensile strength with age for different PF content in SCC

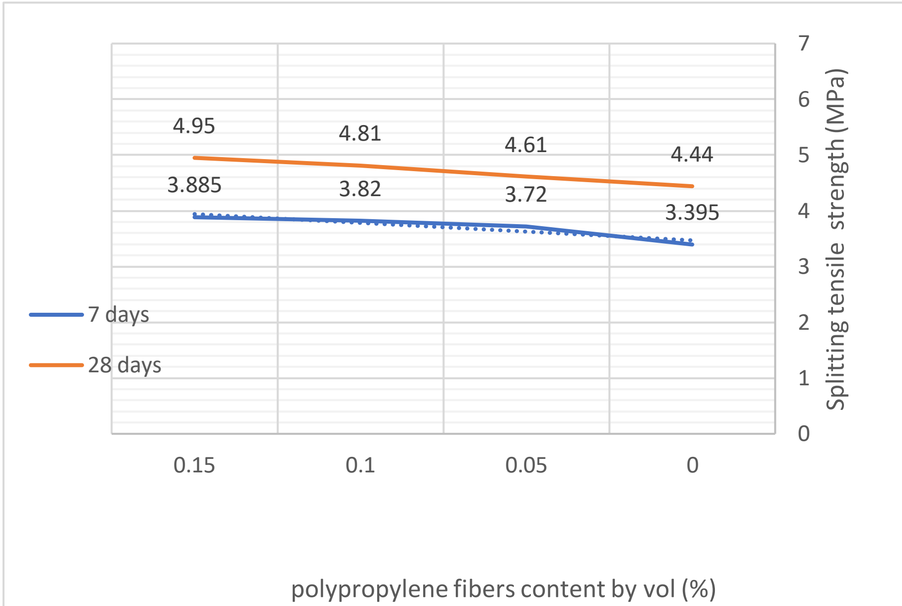


Figure 3.8: *Effect of Polypropylene* Fiber *Content on splitting tensile strength in SCC at age (7,28) days*

3.2.3. Flexural Strength

Similar to splitting tensile strengths of concrete, the results indicate that all specimens exhibited a continuous increase in flexural strength with progress in age as shown in Table (3.5) and Figure(3.9) .The results indicated to the effect of polypropylene fiber on flexural tensile strength of the SCCs was very clearly ,and they showed the benefit of polypropylene fibers to improve of flexural strength, This improvement in flexural strength increases with the increase in polypropylene fiber volume up to 0.15% The flexural strength indicated significant increase in strength due to the inclusion of polypropylene fibers. The percentages of increase in flexural tensile strength for all mixes are summarized in Table (3.5) and illustrated in Figure (3.9). The flexural strength increases, due to the superior performance in flexural strength for specimens with polypropylene fibers arises from the improved fiber - matrix.

Table (3.5): Results of Flexural strength test of scc

Mix	**Flexural strength (Mpa)**	**Change in Flexural strength with respect to reference Mix (SP1)%**
	28day	**28day**
PF1	8.4	-
PF2	8.6	2.38
PF3	9.1	8.33
PF4	9.52	13.33

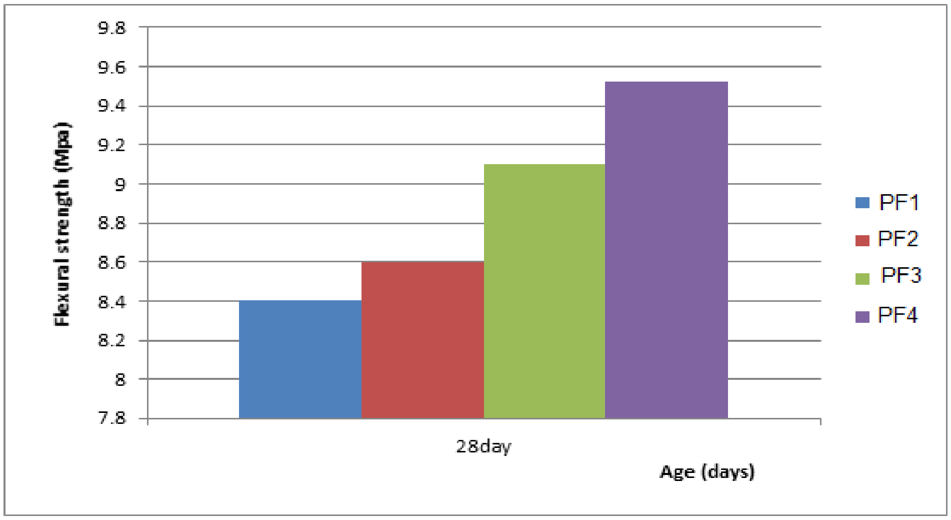


Figure 3.9: *Development of Flexural tensile strength with age for different PF content in SCC*

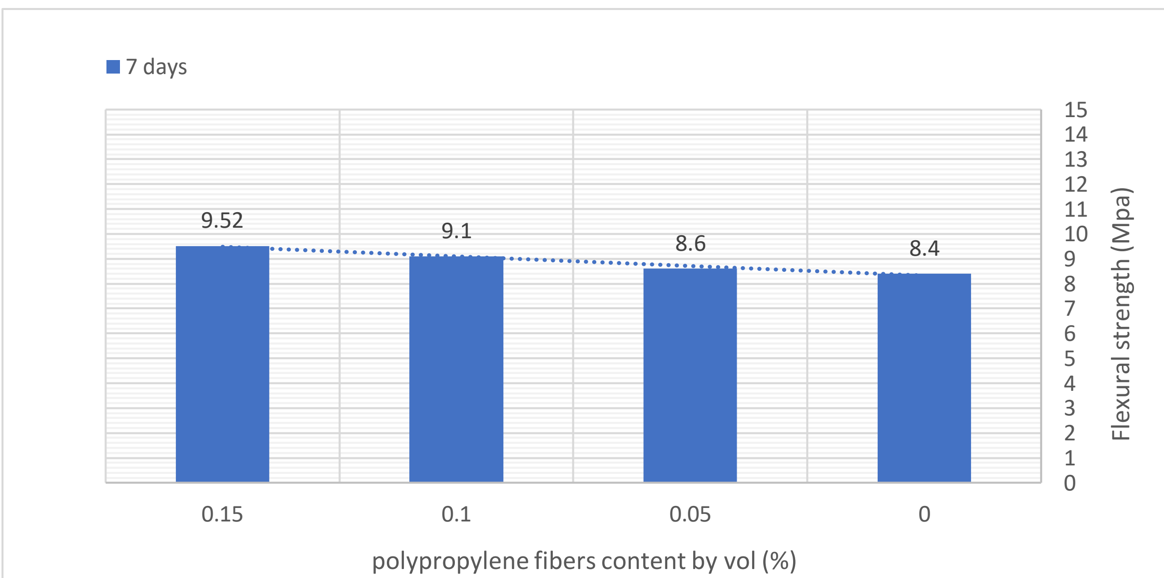


Fig (10): *Effect of* Polypropylene Fiber *content on Flexural tensile strength in SCC at age (7,28) days*

4. Conclusions and recommendation

Based on the tests results of the fresh and hardened state of self-compacting concrete added with polypropylene fiber, the following conclusions can be drawn**:**

1. Overall, slump flow diameter (flowability) and L-Box blocking ratios (passing ability) decrease with the increase in polypropylene fiber content of the concrete mixtures with respect to plain SCC mixtures. However, all mixes are satisfied to SCC requirements.

2. Slump flow time and V-funnel flow time increase with the increase in polypropylene fiber content of the concrete mixtures with respect to SCC plain mixtures.

3.The compressive strength of self-compacting concrete is increasing by adding polypropylene fiber at age 28 days but at age 7 days, polypropylene fibers had a marginal increment in compressive strength compared to the increments in the other mechanical properties.

4. All polypropylene fiber mixes demonstrated a higher splitting tensile strength and flexural strength relative to SCC plain mixes at all curing ages. The tensile strength increased as the fiber content increased, however, the increments in flexural strength were higher than splitting tensile strength with more than 13.33% increments having been recorded.

5. The highest polypropylene fiber content 0.15 (% by Vol.) had, in general, best effect on hardened properties but the worst on fresh properties of SCC.

6. As well, (0.15) % polypropylene fiber content were sufficient for achieving satisfying (optimum) performance in fresh and hardened properties of SCC.

References

[1]. ACI 237R-07 Self-Consolidating Concrete Reported by ACI Committee 237

[2]. H. Okamura and M. Ouchi, Self-compacting concrete, *J. Adv. Concr. Technol.* 1, 5–15 (2003).

[3]. المواصفة القياسية الليبية رقم 340 \1997 الاسمنت البورتلاندي العادي

[4]. ACI 237R-07, (2007), Self-Consolidating Concrete, American Concrete Institute, Michigan.

[5]. ASTM, (2009), ASTM C1621 / C1621M - 09b Standard Test Method for Passing Ability of Self- onsolidating Concrete by J-Ring, ASTM International.

[6] M. Prasad, R. Chandak and R. Grover, "A Comparative Study of Polypropylene Fiber Reinforced Silica Fume Concrete with Plain Cement Concrete", *International Journal of Engineering Research and Science & Technology*, ISSN 2319-5991, Vol. 2, No. 4, pp 127-136, 2013.

[7] R. Kolli, "Strength Properties of Polypropylene Fiber Reinforced Concrete", *International Journal of Innovative Research in Science Engineering and Technology,* ISSN 2319-8753, Vol. 2, Issue 8, pp 3409-3412, 2013

[8] P. A. Patel, A. K. Desai and J. A. Desai, "Evaluation of Engineering Properties for Polypropylene Fiber Reinforced Concrete", *International Journal of Advanced Engineering Technology*, Vol. 3, Issue 1, pp. 42-45, 2012

[9]. V. K. Singh, "Effect of Polypropylene Fiber on Properties of Concrete", *International Journals of Engineering Sciences and Research Technology*, ISSN: 2277-9655, Vol. 3, Issue 12, pp 312-317,2014.

[10] Alkan G. Investigation of mechanical properties of polypropylene fiber concrete [master's thesis] Istanbul Technical University Institute of Science and Technology, _Istanbul, 2004. (In Turkish)

[11] V. K. Singh, "Effect of Polypropylene Fiber on Properties of Concrete", *International Journals of Engineering Sciences and Research Technology*, ISSN: 2277-9655, Vol. 3, Issue 12, pp 312-317, 2014.