Residual Compressive and Flexural Strength of Self Compacting Concrete Exposed to High Temperature

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Abstract

Self compacting concrete (SCC) can be classified as high performance concrete. As the name suggests, it does not require to be vibrated to achieve full compaction. This offers many benefits and advantages over conventional concrete.

This study aims to evaluate the fresh and hardened properties of SCC produced by using locally available materials. This study includes also the influence of different percentages of polypropylene fibers (PPF); added by about (0, 0.5 and 1) % by the total volume, on the same properties. To achieve these aims six different mixes of SCC (with and without fibers) are mixed, tested and evaluated.

Also, this study aims to identify the mechanical properties of SCC specimens (with and without fibers) at high temperature, including compressive and flexural strengths. The effect of different heating rates (25, 100, 400 and 700)^{0}C on the mechanical properties of SCC is studied. The difference of the mechanical properties between normal and high strength SCC is identified. The test results show that all the mixes have good consistency and workability from the filling ability and passing ability point of view. Also, the addition of PPF gives a homogeneous and cohesive mix with slight decrease in workability. However, the addition of PPF causes a slight reduction in compressive strength which increased as the percentage of PPF increased, while this addition causes a noticed increment in flexural strength.

Also, it is found that compressive and flexural strengths decreased as the heating temperature increased.

Keywords: Self compacting concrete, high temperature, strength, fiber.

الخلاصة :

تعرف الخرسانة ذاتية الرص بانها خرسانة عالية الاداء, وكما هو واضح من الاسم انها لا تحتاج الى رص ميكانيكي مما يجعلها مميزة ومفضلة عن الخرسانة التقليدية.

يهدف هذا البحث الى تقييم الخصائص الطرية والصلبة للخرسانة ذاتية الرص المنتجة باستخدام مواد محلية متوفرة, ايضا يهدف الى توضيح تاثير نسب مختلفة من الياف البولي بروبلين التي اضيفت بمقدار (0-0,5-1,0)% من الحجم الكلي للخرسانة على نفس الخصائص الطرية والصلبة. لتحقيق ذلك, 6 خلطات مختلفة من الخرسانة ذاتية الرص (مع او بدون الياف) تم تصميمها وخلطها وفحصها بالاضافة الى مناقشة النتائج.

كذلك يهدف البحث الى دراسة الخصائص الميكانيكية (مقاومة الانضغاط و مقاومة الانحناء) لنماذج الخرسانة ذاتية الرص (مع او بدون الياف)تحت تاثير الحرق فى درجات حرارة مختلفة. حيث تم دراسة تاثير التدرج الحرارى (100,400,700)^{0}س اضافة الى النماذج التى تم فحصها بدرجة حرارة الغرفة 25^{0}س ,إضافة الى دراسة الاختلاف فى الخصائص الميكانيكية بين الخلطات المختلفة للخرسانة ذاتية الرص ذات المقاومة الاعتيادية والمقاومة العالية.

ايضا وجد ان قابلية التشغيل جيدة كما ان اضافة الياف البولى بروبلين اكسبت خلطات الخرسانة ذاتية الرص قوام متجانس ومتماسك مع انخفاض قليل فى قابلية التشغيل. على اية حال، ان اضافة الياف البولى بروبلين سببت انخفاض قليل فى مقاومة الانضغاط وزيادة ملحوظة فى مقاومة الانحناء. كما وجد ان مقاومة الانضغاط والانحناء انخفضت بشكل واضح عند زيادة درجة حرارة الحرق.

1- Introduction:

The development of self compacting concrete started in Japan in the mid 80's with the aim to reduce durability problems in complicated and heavily reinforced concrete structures due to lack of skilled workers and a poor communication between designers and construction engineers [1].

This new concrete was deliberately designed to be able to fill every corner of the form and capsulate all reinforcement with maintained stability only under the influence of gravitational forces without segregation or bleeding. This makes SCC particularly useful wherever placing is difficult, such as in heavily reinforced concrete members or in complicated work forms [2,3].

In addition to the above advantages, adding fibers to SCC improves the structural properties of SCC like durability, post crack resistance, energy absorbing capacity, mechanical properties, etc [4]. Fiber reinforced SCC combines the benefits of SCC in fresh state and shows an improved performance in the hardened state due to addition of fibers.

Also, because SCC has a fine pore structure, exposure to high temperatures of SCC may lead to serious deterioration and explosive spalling [5].

Despite the serious uncertainties and despite the increasing use of SCC in many applications, the temperature behavior of SCC has not been investigated adequately and the processes involved are not fully understood.

In this study, the behavior of SCC under high temperatures is investigated.

2- Experimental Programme:

Six SCC mixes with different percentages of polypropylene fibers (PPF) were developed in the laboratory. The experimental programme consisted of casting and testing SCC and polypropylene fiber reinforced self compacting concrete PPFSCC elements. (12 and 8) specimens each for each mix of SCC and PPFSCC were cast for testing in compression and in flexure respectively.

Cubes of (150 mm) size were cast for testing in compression and prisms of (100*100*500) mm size were cast for testing in flexure.

3- Materials:

3-1 Cement:

Ordinary Portland cement (type 1) manufactured by Taasloja cement factory used throughout this study. The chemical and physical properties of this cement are shown in Tables (1) and (2), which comply with the Iraqi Standard Specification I.Q.S. No.5, 1984 requirements [6].

Table (1) Chemical Composition of Cement

Oxides		% #	IQS 5:1984 Limits
Calcium oxide	CaO	62.44	
Silicon oxide	SiO_2	20.25	
Aluminum oxide	Al_2O_3	4.73	
Ferric oxide	Fe_2O_3	4.32	
Magnesium oxide	MgO	2.19	5 max.
Sulphur trioxide	SO_3	1.88	2.8 max.
Loss on Ignition	L.O.I	3.5	4.00 max.
Insoluble residue	I.R	1.33	1.5 max
Lime saturated factor	L.S.F	0.66	0.66- 1.02
C3A		8.10	

Tests were made by National Center for Construction Laboratories and Research.

Table (2) Physical Properties of Cement

Physical properties	Test result#	IQS 5:1984 limits
Fineness: specific surface, Blaine cm²/gm	**3372**	**2300 min**
Setting time, Vicat's method:- **Initial (hrs: min.)** **Final (hrs :min)**	 **2:15** **2:70**	 **45 minutes min.** **10 hrs max.**
Compressive strength of cement mortar cubes (70.7mm) MPa **3 days** **7 days**	 **34.69** **40.9**	 **15 min.** **23 min.**

Tests were made by National Center for Construction Laboratories and Research.

3-2 Fine Aggregate:

Natural siliceous sand of Al-Ukhaider region with fineness modulus, specific gravity and absorption of 3.18, 2.7 and 1.5 % respectively is used in this work. Table (3) shows its grading test results conform I.Q.S. No.45, 1984 requirements for zone 2. Sulfate content (SO3 %) is 0.32%, while the maximum limit specified by I.Q.S. No.45, 1984 [7] is 0.5%.

Table (3) Grading of Fine Aggregate

Sieve size (mm)	% Passing by weight	IQS 45-84 limits zone-2-
10.0	**100**	**100**
4.75	**93.5**	**90-100**
2.360	**85.6**	**75-100**
1.180	**76.0**	**55-90**
0.600	**42.7**	**35-59**
0.300	**10.7**	**8-30**
0.15	**1.9**	**0-10**

Test was made by Laboratory of Materials in the Engineering College of Al-Mustansirya University

3-3 Coarse Aggregate:

Crushed gravel was used as a course aggregate, it was from Al-Niba'ee region with specific gravity and absorption of 2.64 and 0.57 %, respectively is used. Table (4) shows the grading of this aggregate. This table also gives the limits specified by I.Q.S. No.45, 1984 [7]. Sulfate content (SO3%) is 0.09%, while the maximum limit specified by I.Q.S. No.45, 1984. [7] is 0.1%.

Table (4) Grading of Coarse Aggregate

Sieve size (mm)	% Passing by weight#	IQS 45-84 limits
20	100	100
14	99	90-100
10	57	50-85
5	4.5	0-10
2.36	0	-------

The test was made in the Laboratory of Materials in the Engineering College of Al-Mustansirya University

A fine limestone powder (locally named as Al-Gubra) with fineness (3100cm²/gm) is used to avoid excessive heat generation, enhance fluidity and cohesiveness, improve segregation resistance and increase the amount of fine powder in the mix (cement and filler). The chemical composition of L.S.P. is listed in Table (5)

Table (5): Chemical Composition Properties of L.S.P.

Oxides		%
Calcium oxides	CaO	56.10
Silicon oxides	SiO_2	1.38
Aluminum oxides	Al_2O_3	0.72
Ferric oxides	Fe_2O_3	0.12
Magnesium oxides	MgO	0.13
Sulphur trioxides	SO_3	0.21
Loss on Ignition	L.O.I	40.56

Tests were made by Faluja Cement Factory.

3-5 Superplasticizer:

To produce self-compacting concrete, a superplasticizer known as (High Water Reducing Agent HWRA) based on polycarboxylic ether is used, it has the trade mark Glenium 51 [8] Glenium 51 is free from chlorides and complies with ASTM C494, types A and F. It is compatible with all Portland cements that meet recognized international standards. Table (6) shows the typical properties of Glenium 51.

Table (6): Typical Properties of Glenium 51.

Form	Viscous liquid
Colour	Light brown
Relative density	1.1@ 20 °C
pH	6.6
Viscosity	128±30 CPS @ 20 °C
Transport	Not classified as dangerous
Labeling	No hazard label required

Data from manufacture production report (Gulf International chemicals SAOG).

3-6 Polypropylene Fiber (PPF):

High performance short 19 mm polypropylene fibers were used in this study, Table (7) indicates the physical properties of PPF used throughout this work.

Table (7): Physical Properties of Polypropylene Fibers (PPF) .

Specific gravity	0.91
Alkali content	Nil
Sulfate content	Nil
Chloride content	Nil
Air entrainment	Air content of concrete will not be significantly increased
Fiber thickness	(18 and 30) microns
Young modulus	(5500-7000) MPa
Tensile strength	350 MPa
Melting point	160 ^{o}C
Fiber length	19 mm

Data from manufacture production report **(**FosRoc Company**).**

3-7 Water:

Tap water from Baghdad water supply is used for both mixing and curing of concrete.

4- Mix Design:

A number of attempts was made in the laboratory to get optimum dosages of mineral and chemical admixtures in order to produce mixes of SCC and PPFSCC without segregation or bleeding with satisfying the properties both in fresh and hardened states. From these trials six mixes described in Table (8) and shown in Table (9) were selected for this investigation.

Table (8) Descriptions of Mixes.

Mix notation	Description of Mix
S30/0	Mix with compressive strength of (30)MPa and 0%PPF by the total volume
S30/0.5	Mix with compressive strength of (30)MPa and 0.5%PPF by the total volume
S30/1	Mix with compressive strength of (30)MPa and 1%PPF by the total volume
S70/0	Mix with compressive strength of (70)MPa and 0%PPF by the total volume
S70/0.5	Mix with compressive strength of (70)MPa and 0.5%PPF by the total volume
S70/1	Mix with compressive strength of (70)MPa and 1%PPF by the total volume

Table (9) Mix Proportions of SCC and PPFSCC Concrete Mixes by Weight.

Mix notation	Cement Kg/m^3	LSP Kg/m^3	Sand Kg/m^3	Gravel Kg/m^3	Water L/m^3	Superplasti-cizer L/m^3	Polypropylene Fibers (% by the total volume)
S30/0	367	195	841	791	183	4	0.0
S30/0.5	367	195	841	791	183	7.5	0.5
S30/1	367	195	841	791	183	12	1.0
S70/0	535	64	863	784	155	10	0.0
S70/0.5	535	64	863	784	155	14	0.5
S70/1	535	64	863	784	155	18	1.0

5- Mixing Procedure:

A standard mixer of rotating drum was used for mixing the mixtures. To begin with, all the dry materials (fine aggregate, coarse aggregate, cement and limestone powder) were mixed for about two minutes. The superplasticizer was thoroughly mixed with water and the liquid component was added to the dry material mixture. This wet composition was allowed to mix for another four minutes. During the process, PPF (if any) was sprinkled uniformly in the wet mixture. Care has been taken in allowing all the materials to get mixed up uniformly avoiding the materials to get stuck up to the walls of the mixer. After the mixing was completed, tests were conducted on fresh concrete to determine setting time, mini slump flow diameter.

Segregation and bleeding were visually checked during the slump flow test and were not observed.

6- Tests on SCC and PPFSCC in Fresh State:

In this investigation, with first by trial and error, different mix designs of SCC were cast and tested to find out the fresh properties:

6-1 Slump Flow:

The slump flow was used to assess the horizontal free flow and the ability of SCC and PPFSCC mixed in the absence of obstructions. It is recommended to maintain slump flow diameter value as 610 mm to 680 mm. While T50 ranged from 5.5 sec. to 10.23 sec.

6-2 L-Box Test:

This test assesses the flow of the concrete in the presence of reinforced obstructions. This test was done for all mixes and the values of blocking ratio ranged from 0.8 to 0.97, while T20 ranges from (2.9 to 6.5) sec. and T40 ranges from (4.5 to 8.1) sec.

7- Specimen preparation

After testing the SCC and PPFRSCC in fresh state, the concrete was poured in steel moulds of cubes (150) mm size and prisms of (100*100*500) mm size. After the concrete has set in moulds, the specimens were capped with plastic nylon.

After 24 hours of casting, the specimens were de-moulded and placed in water for curing. After 28 days of curing the specimens were taken out from water to allow the surfaces to dry. For each SCC and PPFSCC mix, 12 cubes and 8 prisms were cast. Then, four levels of temperature (25,100,400 and 700)^{0}C were subjected to the specimens in order to find the residual (compressive and flexural) strengths. The specimens were heated using an electric furnace. Its temperature capacity is 1200 ^{0}C. The furnace temperature was controlled by an electronic thermostat controller. The temperatures were continuously recorded by two thermometers positioned at the mid height side and mid top of the furnace. The furnace was heated gradually, after reaching the selected temperature the specimens were still at that temperature for one hour.

For the cooling regime, the furnace was switched off at the end of the exposure time and the specimens were allowed to cool in the half open furnace for twenty four hours, after which they were removed to cool in air for twenty four hours and then tested.

8- Tests on SCC and PPFSCC in Hardened State:

8-1 Compressive Strength:

The compressive strength test was carried out according to BS 1881: part 116: 1983, for all (150 mm) cubes. Three cubes were used to determine the compressive strength for each mix at each level of heating.

8-2 Flexural Strength:

The flexural strength tests were carried out on prisms of size (100*100*500) mm on flexural testing machine of 50 kN capacity.

In all the specimens, the fracture initiates in the tension surface within the middle third of the span length using the following relation:

$R=PL/bd^2$

9- Results and Discussion:

9-1- Characteristics of SCC and PPFSCC Mixes in the Fresh State.

Properties such as filling ability, passing ability of the SCC and PPFSCC mixes in the fresh state are shown in Figures (1 to 4):

In the Figures (1 to 4), the values of (D) represent the maximum spread (slump flow final diameter), while T50 values represent the time required for the concrete flow to reach a circle with 50 cm diameter. Values of (H2/H1) represent blocking ratio, the values of T20 and T40 represent the time required for the concrete flow to reach distance of 20 and 40 cm respectively in L-Box.

D and (H2/H1) are plotted in a decreasing manner in Figures (1and 3), while Figures (2 and 4) represent the increasing manner of T50, (T40 and T20) respectively.

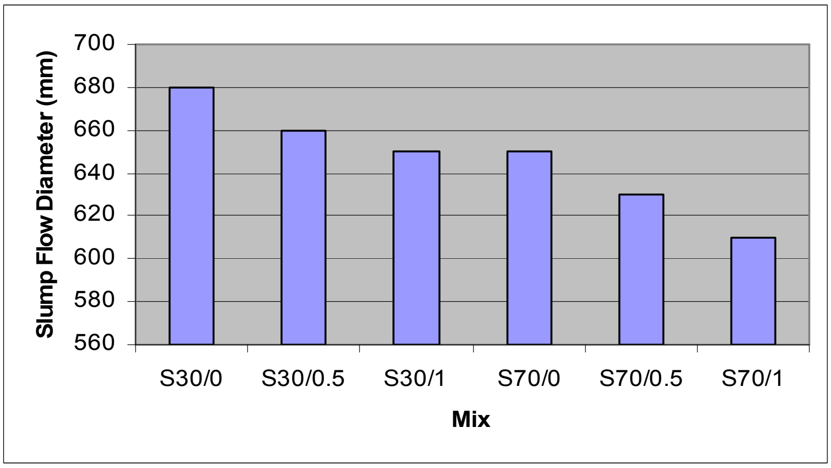

Figure (1): Slump Flow Diameter (mm)

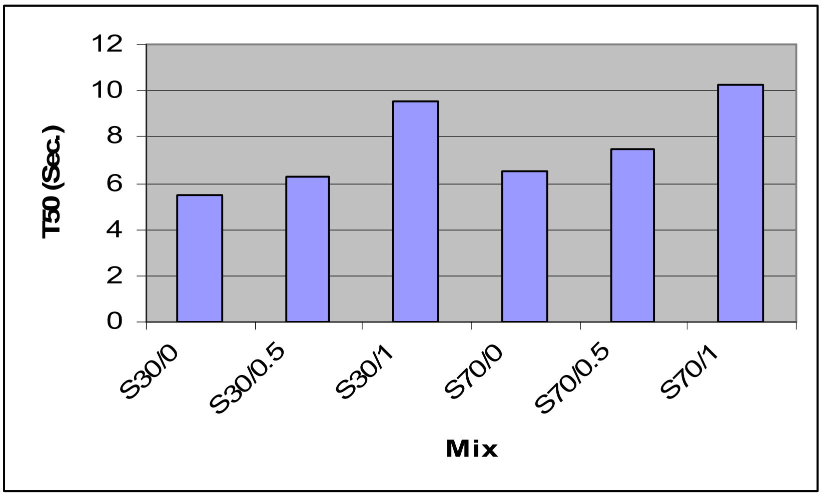

Figure (2): Time Required Passing (50 cm Dia.) Circle (T50)

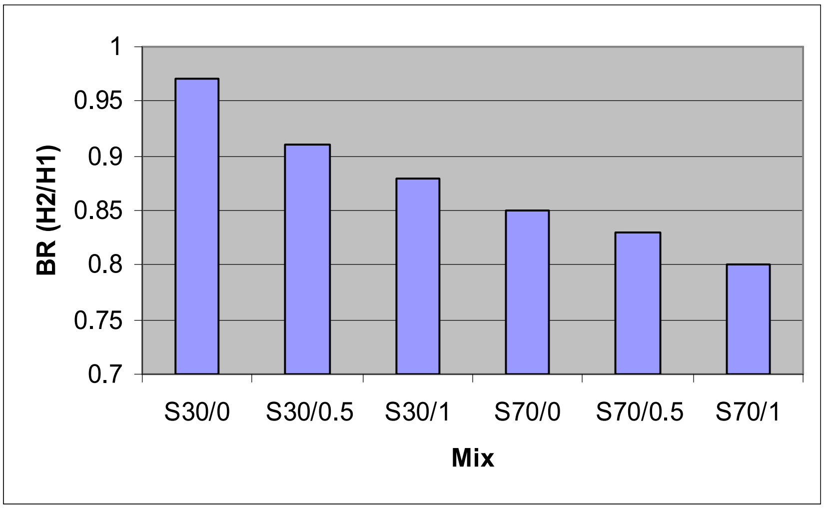

Figure (3): Results of H2IH1

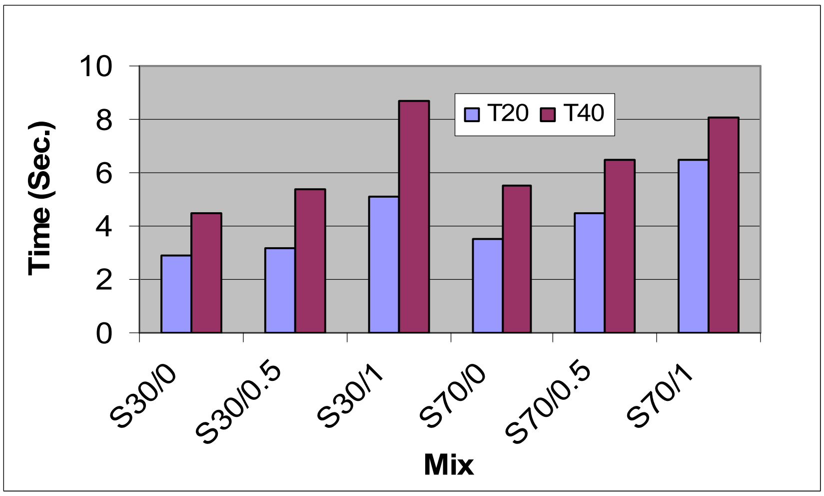

Figure (4): Results of T20 & T40

From Figures (1 to 4), it is clear that:

1- All of the mixes satisfy the requirements of SCC illustrated in EFNARC specifications [9]. Thus all the mixes are assumed to have good consistency and workability from the filling ability and passing ability point of view.

2- As water/ (cement+LSP) ratios decrease and superplasticiser dosage increases, the value of T50 increases by about (18.2) % while slump flow decreases by about (4) %. These results are in agreement with those obtained by other researchers [10, 11 and 12].

3- It is evident that the mix with nominal compressive strength of 30MPa can be described as concrete with low viscosity and mix with nominal compressive strength of 70MPa can be described as concrete with high viscosity.

4- During flowing and after stoppage of the flow neither segregation nor bleeding occurs.

5- In mixes containing PPF by about 0.5% by the total volume, it is observed that T50 increases by about (14.5-15.4)% while a marginal decrement is observed in slump flow diameter by about (2.9-3.1)% compared with reference mixes without fibers. Also, by adding PPF by about 1.0% by the total volume, it is observed that T50 increment (57-73)% is higher than that in mixes containing 0.5% PPF, while the decrement in slump flow diameter ranges between (4.4-6)% compared with reference mixes without fibers. This may be due to the reduction in workability which increases with increased percentages of fibers. Therefore, these mixes contain high dosages of superplasticizer to maintain the workability. These results are in agreement with those obtained by other researchers |12, 13 and 14|.

6- The value of blocking ratio decreased by about 12.3% and values of T20 and T40 increased by about (3.7, 2.2)% respectively as compressive strength increased by about 133.3%. This behavior may be due to the slow flow because of the lower W/C ratios and higher viscosity (increase of superplasticizer dosage).

7- It is noticed that blocking ratio decreased by about (2.3-6.1)% and values of T20 and T40 increased by about (10.3-12.5, 18.1-20)% respectively in mixes containing PPF by about 0.5% by the total volume, compared with reference mixes without fibers. While blocking ratio reduction is about (5.9-9.7)% and values of T20 and T40 increment are about (62.5-75.9, 47-93)% respectively in mixes containing PPF by about 1.0% by the total volume, compared with reference mixes without fibers. This may be due to the cohesive mixes and decrease in workability, these results are in agreement with those obtained by other researchers |12, 13and 14|.

9-2- Characteristics of SCC and PPFSCC Specimens in Hardened State

9-2-1 Compressive Strength:

The compressive strength values obtained by testing standard cubes (150mm)size made with different SCC and PPFSCC mixes are tabulated in Table (10). All the mixes show strengths ranging between (30-70)MPa, which is the required strength. While Figures (5 and 6) shows different relations.

Table 10: Values of Compressive Strength for all Mixes after 28Days of Curing (MPa)

Heating Temperature	S30/0	S30/0.5	S30/1	S70/0	S70/0.5	S70/1
25^0C	35.60	33.65	31.50	74.45	70.20	61.01
100^0C	32.85	30.63	29.70	70.20	61.10	55.20
400^0C	25.15	23.30	21.30	59.45	50.20	48.60
700^0C	20.25	18.10	17.80	49.30	45.50	40.40

** Each value of compressive strength represents an average of three specimens.

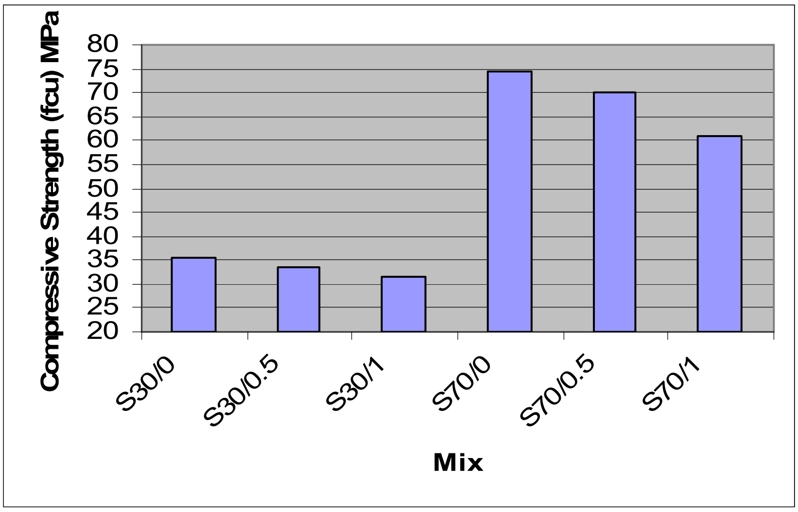

Figure (5): Effect of Volume Fraction of PPF on the Compressive Strength for Different Types of SCC Mixes.

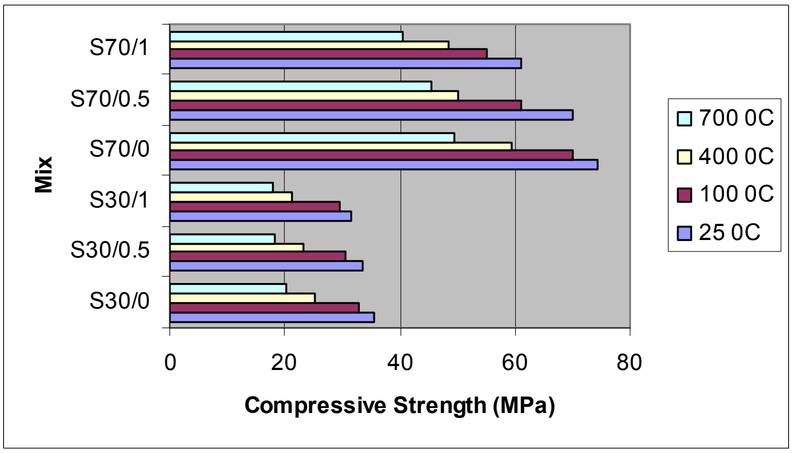

Figure (6): Results of Compressive Strength of Different SCC Mixes after High Temperature Exposure

From the test results illustrated in Table (10) and in Figures (5 and 6) the following points may be observed:

1- The compressive strength decreased in the specimens containing PPF. The reduction in strength is about (5.4-5.7) %, compared with reference mixes without fibers, by using PPF by about 0.5% by the total volume. While this reduction is about (11.5-18.05) %, compared with reference mixes without fibers, by using PPF by about 1.0% by the total volume. This may be due to the high air content and large volume of voids percentage in the mixes in adding a high volume fraction of PPF. These results are different from those obtained by other researchers [12, 13, 15 and 16].

2- In specimens containing PPF, it is observed that the failure occurred gradually and PPF tied the segments together. While, the failure in specimens without fibers occurs suddenly and the cube separated into several segments. Figure (7) illustrates the shape of failure.

Specimen without fiber Specimen with fiber

Figure (7) Modes of Failure

3- A decrement in compressive strength was observed in specimens subjected to high temperatures. It is noticed that as the temperature increased, the strength decreased. When the temperature of the furnace is (100,400 and 700) ^{0}C, the decrement in compressive strength in SCC specimens (without fibers) is about (5.7-7.7, 20.1-29.3, 33.78- 43.1) %compared with specimens still at room temperature. The decrease in compressive strength of concrete is attributed to the breakdown of interfacial bond due to incompatible volume changes between cement paste and aggregate during heating and cooling [17]. Also, dehydration of calcium hydroxide occurs when temperature exceeds about (400 $^\circ$C) and causes shrinkage of the cement paste. Various quartz like aggregates undergo a crystalline transformation at about (577 $^\circ$C) which causes a large expansion and cracking of the concrete [18].

4- In specimens containing PPF, it is noticed that the reduction in compressive strength is higher than that in SCC specimens (without fibers). This reduction is about (8.9-12.9, 28.5-30.7, 35.1-46.2), when the furnace temperature is (100,400 and 700)^{0}C respectively, in specimens containing 0.5% PPF by the total volume, compared with specimens still at room temperature. While, in specimens containing 1.0% PPF by the total volume, the reduction is about (9.5-12.1, 20.3-32.3, 33.78-43.5)% when the furnace temperature is (100,400 and 700)^{0}C respectively. This is may be due to the combined effect of the high temperature which affects the structure of concrete, as illustrated in point 3, and because of PPF reaching its melting point (especially at 400 and 700^{0}C) which results in large amounts of weak points between ingredients of concrete. These results are in agreement with those obtained by other researchers [19].

9-2-2 Flexural Strength:

The flexural strength expressed by modulus of rupture is obtained by testing standard prisms of (100*100*500)mm size made with different SCC and PPFSCC mixes. The results are listed in Table (11). While Figures (8 and 9) show different relations.

Table 11: Values of Modulus of Rupture for all Mixes after 28Day of Curing (MPa)

Heating Temperature	S30/0	S30/0.5	S30/1	S70/0	S70/0.5	S70/1
25^0C	5.10	5.50	5.80	6.50	7.30	8.00
100^0C	4.65	5.00	5.10	6.35	7.10	7.70
400^0C	4.04	3.8	3.80	5.10	5.10	6.00
700^0C	3.69	2.91	2.80	4.50	4.60	5.01

** Each value of modulus of rupture represents an average of two prisms

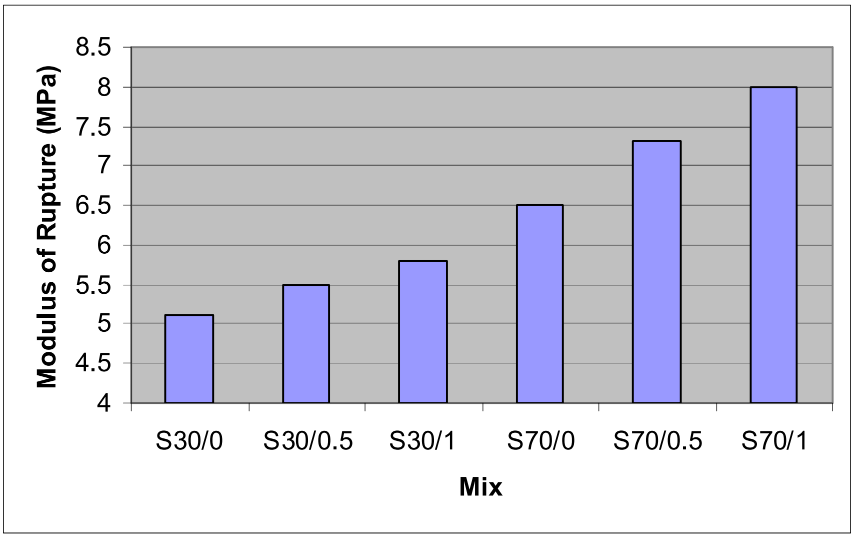

Figure (8): Values of Modulus of Rupture for all Mixes (MPa)

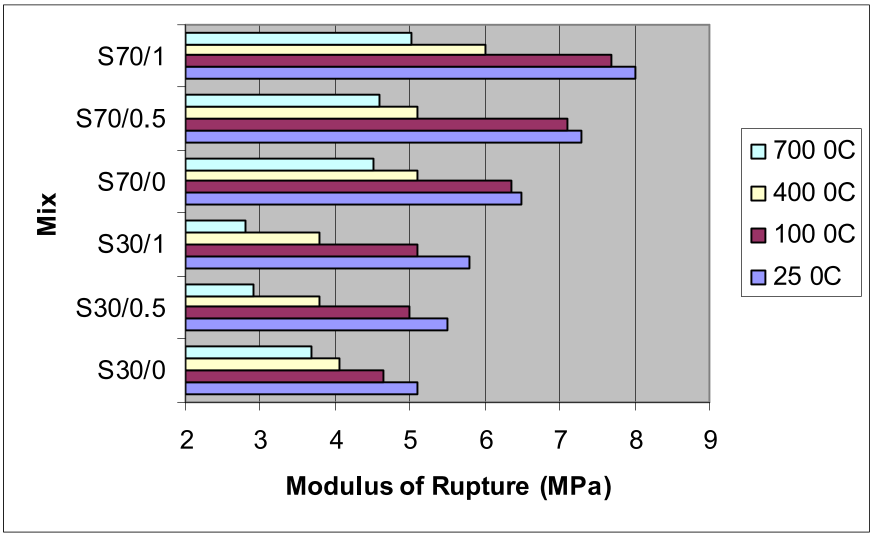

Figure (9): Values of Modulus of Rupture for all Mixes (MPa) at Different Temperatures

From the above results, the following points are observed:

1- The flexural strength increased by about 27.5% when compressive strength increased by 133.3%.

2- The flexural strength of the specimens containing PPF increased by about (7.8-12.3) %, compared with reference mixes without fibers, by using PPF by about 0.5% by the total volume. While this increment is about (13.7-23.1) %, by using PPF by about 1.0% by the total volume. These results are in agreement with those obtained by other researchers |5, 13, 15 and 16|.

3- In specimens containing PPF, it is observed that PPF helps to hold the prism elements together after reaching failure, preserving the whole member and integrity of the connection. Figure (10) illustrates the shape of failure.

Specimen with fiber Specimen without fiber

Figure (10) modes of failures

4- A decrement in flexural strength is observed in specimens subjected to high temperatures. When the temperature of the furnace is (100,400 and 700) ^{0}C, the decrement in flexural strength in SCC specimens (without fibers) is about (2.3-8.8, 21.5-29.4, 30.7-43.1) %compared with specimens still at room temperature. This may be due to the effect of the high temperature which affects the structure of concrete. Also, dehydration of calcium hydroxide occurs when temperature exceeds about (400°C) and causes shrinkage of the cement paste.

5- In specimens containing PPF, it is noticed that the reduction in flexural strength is higher than that in SCC specimens (without fibers). This reduction is about (2.7-9, 30.1-30.9, 36.98-47.1), when the furnace temperature is (100,400 and 700)^{0}C respectively, in specimens containing 0.5% PPF by the total volume, compared with specimens still at room temperature. While, in specimens containing 1.0% PPF by the total volume, the reduction is about (3.75-12.1, 25-34.5, 37.3-51.7)% when the furnace temperature is (100,400 and 700)^{0}C respectively. This may be due to the combined effect of the high temperature which affects the structure of concrete, and because of reaching PPF its melting point (especially at 400 and 700^{0}C) which results in large amounts of weak points between ingredients of concrete. These results are in agreement with those obtained by other researchers |19|.

10- Conclusions:

The following conclusions can be drawn based on the results of this work:

1- By examining slump flow and L-Box tests, it is concluded that, all of the mixes satisfy the requirements of SCC illustrated in EFNARC specifications. Thus all the mixes are assumed to have good consistency and workability from the filling ability and passing ability point of view.

2- The employment of PPF in SCC is possible and the properties of PPFSCC are within the acceptance criteria limits. Also, the addition of PPF gives a homogeneous and cohesive mix with marginal decrease in workability

3- As water/ powder ratios decrease and superplasticiser dosage increases, the T50 increase by about (18.2) % while slump flow decreases by about (4) %.

4- During flowing and after stoppage of the flow neither segregation nor bleeding occurs.

5- In mixes containing PPF, it is observed that T50 increases by about (14.5-73) % while a slight decrement is observed in slump flow diameter by about (2.9-6) % compared with reference mixes without fibers. Therefore, these mixes contain high dosages of superplasticizer to maintain the workability.

6- Blocking Ratio decreased by about 12.3% and values of T20 and T40 increased by about (3.7, 2.2) % respectively as compressive strength increases by about 133.3%.

7- It is noticed that blocking ratio decreased by about (2.3-9.7)% and values of T20 and T40 increase by about (10.3-75.9, 18.1-93)% respectively in mixes containing PPF, compared with reference mixes without fibers.

8- In specimens containing PPF, it is observed that the failure occurred gradually and PPF tied the segments together. While, the failure in specimens without fibers occurs suddenly and the specimen separated into several segments. This indicates that PPF is capable to hold the segments together.

9- The compressive strength decreased in the specimens containing PPF. The reduction in strength is about (5.4-18.05) %, compared with reference mixes without fibers.

10- A decrement in compressive strength is observed in specimens subjected to high temperatures. It is noticed that as the temperature increased, the strength decreased. When the temperature of the furnace is (100,400 and 700) ^{0}C, the decrement in compressive strength in SCC specimens (without fibers) is about (5.7-7.7, 20.1-29.3, 33.78- 43.1) %compared with specimens still at room temperature.

11- In specimens containing PPF, it is noticed that the reduction in compressive strength is higher than that in SCC specimens (without fibers). This reduction is about (8.9-12.9, 20.3-32.3, 33.78-46.2)%, when the furnace temperature is (100,400 and 700)^{0}C respectively.

12- The influence of PPF on the flexural strength is better than that on the compressive strength. The flexural strength increased in the specimens containing PPF. This increment is about (7.8-23.1) %, compared with reference mixes without fibers. Also, a decrement in flexural strength is observed in specimens subjected to high temperatures. When the temperature of the furnace is (100,400 and 700) ^{0}C, the decrement in flexural strength in SCC specimens (without fibers) is about (2.3-8.8, 21.5-29.4, 30.7-43.1) %compared with specimens still at room temperature.

13- In specimens containing PPF, it is noticed that the reduction in flexural strength is higher than that in SCC specimens (without fibers). This reduction is about (2.7-12.1, 25-34.5, 36.98-51.7)%, when the furnace temperature is (100,400 and 700)^{0}C respectively.

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