

The Effects of Adding Waste Plastic Fibers (WPFs) on Some Properties of Self Compacting Concrete using Iraqi local Materials

Dr. Abdulkader I. Al-hadithi¹

Waseem Khairi Mosleh Frhaan²

(Received 30/10/2016; Accepted 1/2/2017)

Abstract

This study presents an experimental research of Self-Compacting Concrete (SCC) properties containing waste plastic fibers (WPF). Adding waste plastics which resulting from cutting PET bottles as fibers to SCC with aspect ratio (l/d) equal to (28). To illustrate the effects of WPFs on the SCC, the current study was divided into two parts, the first part shows the effect of adding plastic fibers on the properties of fresh SCC, which include the ability flow, spread, passing and resistance to segregation, and the second part to evaluate the properties of hardened (mechanical) destructive and non-destructive, which include compression strength, flexural strength and ultrasonic pulse velocity test.

One reference concrete mix was conducted and eight mixes contain WPF has been producing self-compacting concrete mixers containing a different volumetric ratio of plastic fibers (V_f) % percentages (0.25, 0.5, 0.75, 1, 1.25, 1.5, 1.75, 2) %. Three cubes samples were prepared for testing the compressive strength, three prisms were prepared for the test modules of rupture, one cylinder were prepared testing the modulus of elasticity.

The experiments show that adding plastic fibers to SCC leads to an increase in the compression strength and modulus of rupture at 28-day as follows (42.30)% and (73.12)% respectively for mix ratio (1.5)% in comparison with the reference mix, which represent the best ratio of fibers, as such the results of testing the fresh concrete containing waste fibers showed that adding these fibers led a reduction in workability for SCC.

Key Words: Self-compacting concrete; waste plastic; fiber reinforced concrete

تأثير اضافة الياف الفضلات البلاستيكية على خواص الخرسانة ذاتية الرص المصنعة من مواد محلية الصنع
د. عبدالقادر اسماعيل الحديثي وسيم خيري مصلح فرحان

الخلاصة

تقدم هذه الدراسة بحثاً عملياً لخواص الخرسانة ذاتية الرص المسلحة والمحتوية على ألياف الفضلات البلاستيكية. تم إضافة نواتج التقطيع اليدوي للقناني البلاستيكية (المستخدمة في حفظ المشروبات الغازية) حيث تم تقطيعها بنسبة باعية (الطول/العرض) (28). لتوضيح تأثير الألياف البلاستيكية على سلوك الخرسانة ذاتية الرص، تم تقسيم الدراسة الحالية إلى جزئين، الجزء الأول يوضح تأثير الألياف البلاستيكية على الخواص الطرية للخرسانة ذاتية الرص والتي تشمل قابلية الأنسياب، الانتشار، المرور ومقاومة الانعزال، في حين كان الجزء الثاني يشمل تقييم الخواص المتصلبة (الميكانيكية) الأتلافية وغير الأتلافية والتي تشمل مقاومة الأنضغاط، الأثناء (معامل الكسر) والموجات فوق الصوتية. تم تصميم خلطة مرجعية واحدة في هذا البحث والتي تم اعتمادها كأساس لتطوير الخلطات الأخرى، في حين تم صب (8) خلطات خرسانية ذاتية الرص محتوية على نسب حجمية مختلفة من الألياف البلاستيكية % (V_f)، حيث كانت تلك النسب (0.25، 0.5، 0.75، 1.0، 1.25، 1.5، 1.75 و 2) % لغرض المقارنة مع الخلطة المرجعية. تم صب ثلاث (3) مكعبات لفحص مقاومة الأنضغاط وثلاث (3) مواشير لفحص معايير الكسر و

¹ Professor at the Department of Dams & Water Resources Engineering , University of Anbar

² Student at the Department of civil Engineering , University of Anbar.

(1) أسطوانة لفحص معامل المرونة. أوضحت نتائج الفحوصات العملية للدراسة الحالية أن إضافة الألياف البلاستيكية إلى الخرسانة ذاتية الرص كان لها تأثير إيجابي في زيادة مقاومة الأنضغاط ومقاومة الأنثناء، حيث كان مقدار الزيادة بعمر (28) يوم يساوي (42.30%) و (73.12%) على التوالي عند نسبة المزج (1.5 %) بالمقارنة مع الخلطة المرجعية والتي تمثل أفضل نسبة حجمية للألياف، كما بينت نتائج الفحوصات الطرية للخلطات الخرسانية الحاوية على الألياف البلاستيكية بأن إضافة الألياف يؤدي إلى انخفاض في قابلية التشغيل للخرسانة ذاتية الرص.

1. Introduction

Concrete industry has developed in the recent period largely led to the production of a new type of building and construction of safe concrete facilities, so that they have the ability to withstand the impact loads inflicted on them, with the ease of pouring process and stack them high durability and increase productivity and reduce the manpower that is reliable during the implementation of these the new species are self-compaction concrete, Self-Compacting Concrete of modern concrete and high performance types. Among the most important developments in technology now concrete, is all the add-ons to improve the viscosity and additions of water reducer (superplasticizers) are two key elements for the production of self-compacted concrete [1].

Self-Compacting Concrete Have the ability to endurance as a result of operability and high density as well as it also has the ability to reduce the voids and reduce the phenomenon of maturity as it increases the strength of adhesion between the concrete and steel and characterized by their ability to free flow in the mold of air trapped and expel themselves and assemble their own without having to to use shakers [2,3,4], where tests showed that the Self-Compacting Concrete gives jowl higher (70-50%) compared with the normal concrete, in addition to the Self-Compacting Concrete is characterized by resistance to compressive and tensile strength and fracture criteria and the speed of the ultrasonic vibrations higher compared with normal concrete.

There are differences between normal concrete and Self-Compacting Concrete SCC. When using SCC will no concrete economic benefits as the most important feature is its high rate of flow of goods and low-viscosity and this leads to reduce the damage in the concrete pumping equipment in addition to reducing the casting process [5], with reduce in the cost of monitoring processes used in normal concrete because they have the ability to compaction itself under the influence of self-weight only. There is no need to vibrators for compacting and therefore reducing the noise emitted at the work site, and because of the SCC capability in the access to all aspects of the mold, they are easy to help designers on the possibility of completion of complex shapes and dense steel reinforcement with reducing the difficulty of using shakers in the case of ordinary concrete [5,6]. SCC provides a longer-handling in addition to reduce the chance of existing segregation, and help toward pumping of SCC, where it is used in high-rise buildings.

Reinforced concrete fiber represents one of the modern methods that improve durability and ductility and durability of concrete and reduce cracking susceptibility, it also gives a good correlation with the concrete and help to solve the problem of cracks to be early so they prevent (100-80)% of cracks in the plasticity stage of concrete (plastic state) and this lead to controlling most of the cracks. Another benefit of using fiber is to prevent fragmentation and reduce the vulnerability of concrete to explode when exposed to fire or high temperatures, because some types of fibers such as polypropylene fibers melt and allow the liberation of steam pressure in concrete. The high performance of fiber comes from its ability to provide a good performance for a long time, although various forms help to provide a good connect with the concrete [7]. The high tensile strength enjoyed by the fiber design provides for higher concrete durability and energy absorption and durability level, in addition to controlling the occurrence of cracks without fear of rust associated with the rebar problems [8].

Knowing the benefit and the effect of adding fibers to concrete helps to choose the appropriate quality of the concrete fiber mix, and whether it was intended to prevent shrinkage cracks early or to control the width of cracks. The effect of adding fibers can be classified into two phases: the fine cracks stage (Cracks Micro) and stage of large cracks (Cracks Macro) micro-cracks stage, and this will be start after the end of the flexible phase-linear, a short stage, where he established the small cracks and increasing the lengths of these cracks is to meet with each other to build up large cracks when increase Loads.

2. EXPERIMENTAL PROGRAM

2.1 Materials

2.1.1. Cement

Cement type I (ordinary Portland cement) of Kubaisa Factory for cement production was used in this study. Chemical compositions and physical analysis of this type are shown in Tables (1) and (2) respectively. The results indicated that the available cement conforms to the Iraqi specifications (IQS) No.5–84[9].

Table (1) Chemical composition and main compounds of cement.

Oxide composition	Content (percent)	Limit of Iraqi specification No.5/1984
CaO	63.19	---
SiO ₂	20.60	21% Max
AL ₂ O ₃	4.10	8% Max
Fe ₂ O ₃	4.48	5% Max
SO ₃	1.98	< 2.8%
MgO	2.28	≤ 5%
L.O.I	2.45	≤ 4%
I.R	0.47	≤1.5%
L.S.F	0.94	0.66-1.02
C ₃ S	57.11	---
C ₂ S	16.23	---
C ₃ A	8.39	> 5%

Table (2) Physical properties of cement.

Physical properties	Test Results	Limit of Iraqi specification No. 5/1984
Specific Surface area (Blaine Method , cm ² /gm)	3329	≥ 2300
Setting time (Vicats Method)		
Initial Setting time, hrs. : min	2:10	≥ 1:00
Final Setting time, hrs. : min	3:45	≤ 10:00
Compressive strength of mortar		
3- days, N / mm ²	32.4	≥ 15
7- days, N / mm ²	40.5	≥ 23

2.1.2.Fine Aggregates

The fine aggregate used is natural sand obtained from Al-Ukhaider region. It was clean, free of organic impurities and deleterious substances and relatively free of clay. The grading of sand is conforming to the requirements of the Iraqi Specification [IQS No. 45/1984] [10], as shown in Table (4).

Table (3) Grading of fine aggregate.

Sieve size (mm)	Cumulative passing %	Cumulative passing % Limits of (I.O.S.) No.45/1984 Zone (3)
4.75	100	90-100
2.36	92	85-100
1.18	85	75-100
0.60	65	60-79
0.3	20	12-40
0.15	3	0-10
Fineness modulus = 2.42		

Table (4): Physical and Chemical properties of fine aggregate.

Properties	Test results	Limit of Specification
Specific gravity	2.60	-
Absorption %	0.75	-
Sulfate content as SO ₃ %	0.08	0.5 ≤

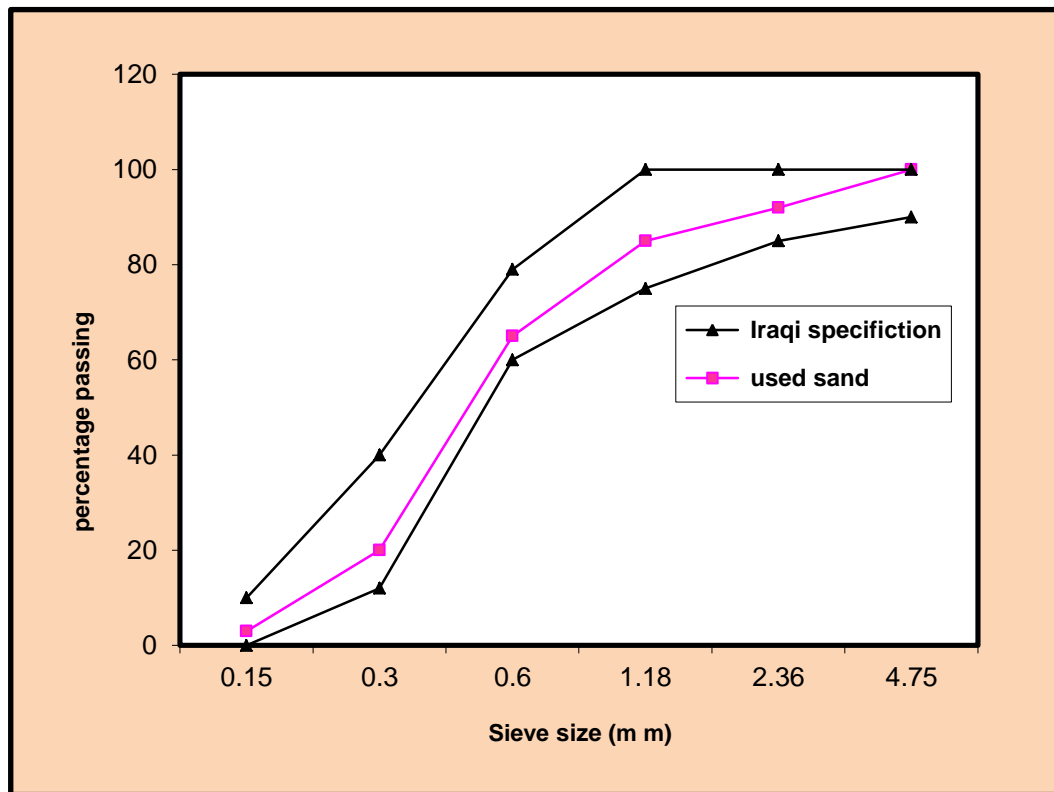


Figure 1. Sieve analysis of aggregates.

2.1.3 Coarse Aggregates

The coarse aggregate used in this work is a crushed gravel with a maximum size of 10 mm brought from Al-Nibae. Table (5) and Fig. (2) show the grading of this aggregate, which conforms to the Iraqi specification [IQS No. 45/1984] [10]. The specific gravity, sulfate content and absorption of coarse aggregate are illustrated in Table (6).

Table (5): Grading of coarse aggregate.

Sieve size Mm	Cumulative Passing %	Limit of Iraqi specification No. 45/1984
14	100	90-100
10	92	85-100
5	21	10-30
2.36	2.3	0-10

Table (6): Physical and Chemical properties of coarse aggregate.

Properties	Specification	Test Results	Limits of specification
Specific gravity	ASTM C128-01 [59]	2.60	---
Absorption	ASTM C128-01 [59]	0.69	---
Dry loose unit weight kg/m ³	ASTMC29/C29M/97 [60]	1593	---
Sulfate content (as SO ₃) %	(I.Q.S.) No. 45-84	0.08	0.5 ≤

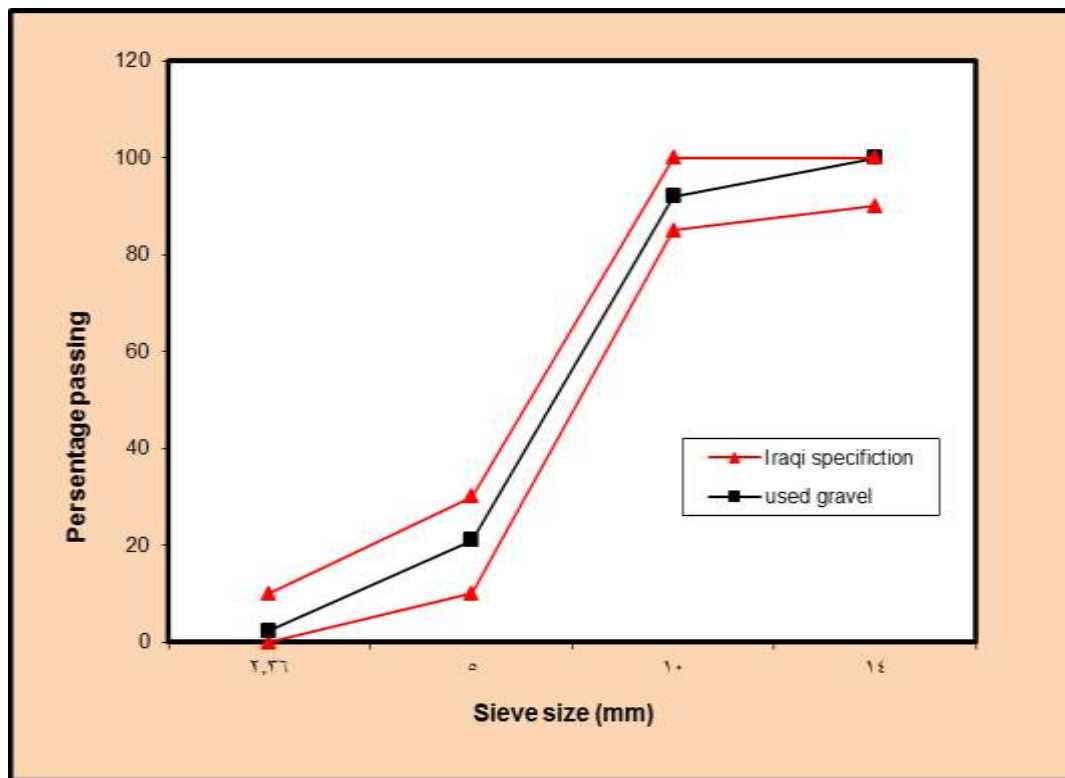


Figure 2. Sieve analysis of coarse aggregate.

2.1.4 Mix Water

Drinking tap water is used for mixing, and for curing the concrete.

2.1.5 Superplasticizer

High performance concrete superplasticizer which is known commercially as (GLENIUM 54) was used throughout this investigation as a high range water reducer agent (HRWRA). It is a third generation of superplasticizers and it complies with ASTM 494-05 Type F. GLENIUM 54 is based on unique carboxylic ether polymer with long lateral chains. This greatly improves cement dispersion at the start of the mixing process. Table (7) shows the main properties of the superplasticizer.

Table (7): Typical properties of Glenium 54.

Main Action	Concrete Super Plasticizer
anceAppear	Whitish to Straw Coloured Liquid
Relative Density	1.07kg/tr, at 20°C
pH Value	5.8
Chloride Content	Nil
Alkali Content	Typically less than 1.5 gm Na ₂ O Equivalent per Litre of Admixture

2.1.6 Silica Fume

Silica fume used in this investigation is commercially known as (MS610 @MEYCO) as shown in Figure (3), It complies with [ASTM C 1240-03] [11]. Table (8) shows the chemical analysis of this type of silica dust.

Table (8): Effective Buzolanah chemical analysis of the material (Microsilica).

Pozzolanic Activity	Limit if ASTM C1240-03	Chemical Decomposition		Limit of ASTM C1240-03
		Oxides	Resut%	
121.5%	105%	L.O.I	3.89	6% Max
		SiO ₂	91.03	85% Min
		Al ₂ O ₃	4.02	-
		Fe ₂ O ₃	0.32	-
		SO ₃	0.73	-

Figure 3. **lica usedMicrosi.**

2.1.7 Waste Plastic

The waste plastic fiber WPF used in this study resulting from the cutting of bottles available soft drinks in the domestic market, known as polyethylene Terephthalate (Polyethylene Terephthalate) length (30 mm) and width (4) mm and the thickness (0.3 mm), Show in Figure (4). Table (9) shows the results of the properties of plastic fibers examined according to the US standard (ASTMA D 1708-02a) [12].

Table (9): Properties of the plastic fibers.

Fiber type	Length (mm)	Width (mm)	Thickness (mm)	Density (kg/m ³)	Aspect ratio (l/d)	Tensile strength Mpa	Modulus of elasticity Gpa
Plastic Fiber	35	4	0.30	1100	28	101	0.19

Figure 4: **Plastic fibers used**

2.2. Mixture Design

The selection of materials and the design of concrete mix for producing SCC requires high accuracy with conducting experimental mixtures to change the amount of cement, the amount of fine and coarse aggregates, as well as the proportion of plasticizers, fillers, according to the parameters mentioned in the specification (EFNARC) [1], the details of the experimental mixtures are shown in the table (9).

2.3. Properties of SCC Fresh Tests

Testing of concrete in its fresh state is one of the major aims of this study. The primary performance attributes of self compacting concrete (SCC) are filling ability, passing ability and stability. These can be measured by a combination of tests that give an indication of the quality of the SCC. Many different test methods have been developed in attempts to characterize the properties of SCC. In this work three tests were used slump flow test, L-box test and V-funnel test.

2.3.1 Slump Flow Test and T50 cm Test

Slump flow value, which is used for the description of the fluidity of a fresh concrete in unconfined conditions, is a sensitive test. It is the primary check for the fresh concrete consistence to meet the specification. Thus, it can normally be specified for all self-compacting concretes. The values of D represent the maximum spread (slump flow final diameter), while the values of T_{50} represent the time required for the concrete flow to reach a circle with 50cm diameter. Moreover, additional information about segregation resistance and uniformity of concrete can be achieved from the visual observations during the test and/or measurement of the T_{50} time that is the measured time for flowing of concrete to a diameter of 500 mm. Figure (5) and (6) describe the apparatus used for the tests above.

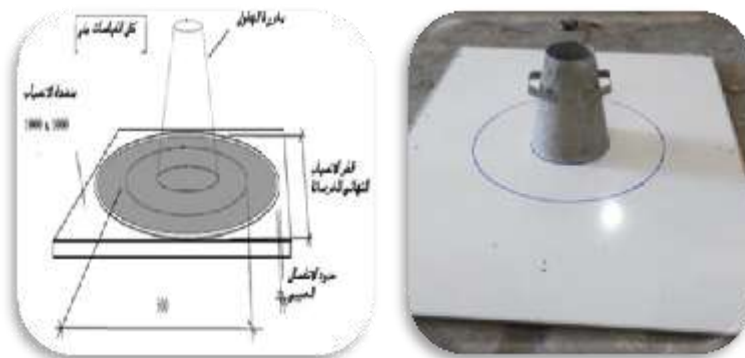


Figure 5: f SCC Sketch of test apparatus used for measuring the standard slump test



Figure 6: diameter diffusion of SCC

2.3.2 V-funnel Test

V-shaped funnel is used to measure the V-funnel flow time, it is filled with fresh concrete and then it is allowed to flow out from the funnel, the elapsed time of fully flowing is recorded as the V-funnel flow time. The used apparatus and test procedure which was used in this test complies with (EFNARC) [1], Figure (7) shows the device which used to conducting this test.

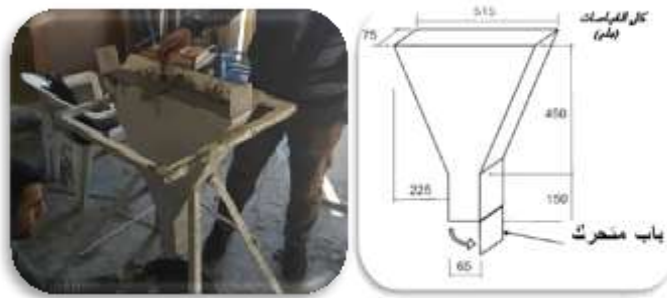


Figure 7: .funnel-ng of VThe dimensions and shape of the iron mold used in the testi

2.3.3 L-box Test

The passing ability of the fresh concrete mix to flow through confined spaces and narrow opening such as areas of congested reinforcement without segregation, loss of uniformity or causing blocking can be measured in terms of L-box test. A measured volume of fresh concrete is allowed to flow horizontally through the gaps between vertical, smooth reinforcing bars and the height of the concrete beyond the reinforcement is measured. The test was done according to (EFNARC) [1] Figure (8) shows the user's machine in the test test in the form of the box (L).

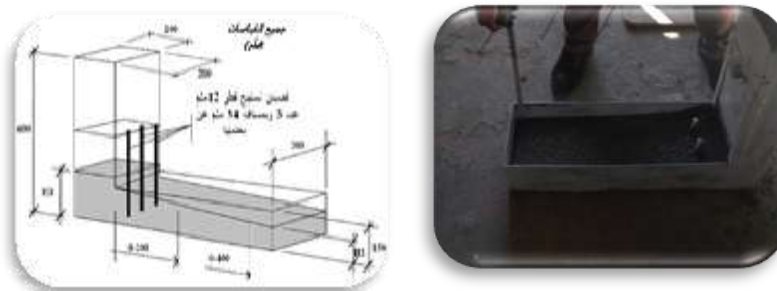


Figure 8 :The dimensions and shape of the iron mold used in the L test-box

2.4 Mechanical Properties of Hardened Concrete

2.4 .1 Compressive Strength

Compression test of self-compacting concrete sample was carried out with respect to (BS 1881: Part 116: 1989) [11]. The results for compressive strength of self-compacting concrete were given as the average of three concrete cube of (150 × 150 × 150) mm dimensions. An electrical compression machine with a capacity of (1900) kN was used for this test as shown in Figure (9).



Figure 9:Compressive strength testing machine.

2.4 .2 Flexural Strength

Flexural strength test of self-compacting concrete sample was carried out with respect to ASTM C78 [12]. The results for flexural strength of self-compacting concrete were given as the average of three concrete prisms of (100 × 100 × 500) mm dimensions. (Universal Testing machine SANS) with a capacity of 150 kN and a rate of loading equal to (1MPa / min) was used to measure the modulus of rupture as seen in Figure (10).



Figure 10: modulus of rupture testing machine.

2.4 .3 Modulus of Elasticity Test

The static modulus of elasticity (the chord-modulus method) was performed according to the (ASTM C469-02) [13]. The test method provides a stress-strain curve for a hardened concrete at whatever age and curing conditions may be designated. The test was carried out at the age of (28) days using cylinders of (150×300) mm, as shown in Figure (11); the cylinder specimens were grinding top surface to be smooth and level. The average value of three cylinders was calculated at each resulted.



Figure 11: **test modulus of elasticity.**

2.4 .4 Ultrasonic Pulse Velocity Test

The ultrasonic pulse velocity (UPV) test was performed according to American Standard (ASTMC78-02) [14]. PUNDIT device as shown in Figure (12) was used in the testing of (150 × 150 × 150) mm cubes at the age of (28) days.

The method of measuring (UPV) depended on the time (T) needed for the waves to pass a distance (L) in concrete. In order to ensure stable transit time, grease and pressure were applied between the test object and the contact faces of the transducers. The ultrasonic pulse velocity was calculated from the following relationship :

$$V = L/T \quad (1)$$

Where:

V: ultrasonic pulse velocity, (km/sec);

L: average length of specimen, (mm);

T: transit time, (microsecond).



Figure 12: UPV testing machine

3. Results and Discussion

3.1. Fresh Concrete Properties

Adding of WPFs to SCC mixes leads to decrease the workability with an increasing in the volumetric ratio of WPF. To decrease this negative effect silica dust had been used to increase the adhesion between the fibers and components of concrete mix, and because of softness by superparticles and silica dust, this will lead to the production of an SCC mix with the thick cement paste and it is closely interconnected with WPFs.

3.1.1. Slump Flow and T50 Slump Flow Time Tests

WPFs work to reduce the diameter of diffusion and increase the time, which concrete takes to reach a diameter (T_{50}) cm, where the value of checking the flow of the slump and the access time of diameter (T_{50}) cm for reference mix is (780) mm and 2.9 mm, respectively. Adding WPFs to SCC leads to reduce the flow of the slump and the access time of diameter (T_{50}) cm. Some of SCC mixes became outside the boundaries of the specifications of SCC. The results of the test mentioned above are shown in the Table (10) and Figs. (13) and (14).

Table (10): The results of subjective tests of concrete compaction soft empty container on fiber.

Mix No.	Fiber Content (V)%	Flow (mm)	Time Flow 50cm (Sec)	V-Funnel (Sec)	V-funnel Time (50Sec)	L-box
SCC	0	780	2.9	6.5	8	0.94
SCC1	0.25	760	3	7	9	0.88
SCC2	0.5	750	3.5	8	9	0.85
SCC3	0.75	740	5	9	10	0.83
SCC4	1	720	6.5	9.5	11	0.81
SCC5	1.25	700	7.5	11	13	0.80
SCC6	1.5	690	8	12.5	14	0.79
SCC7	1.75	670	9	14	17	0.78
SCC8	2	650	11	16	19	0.75

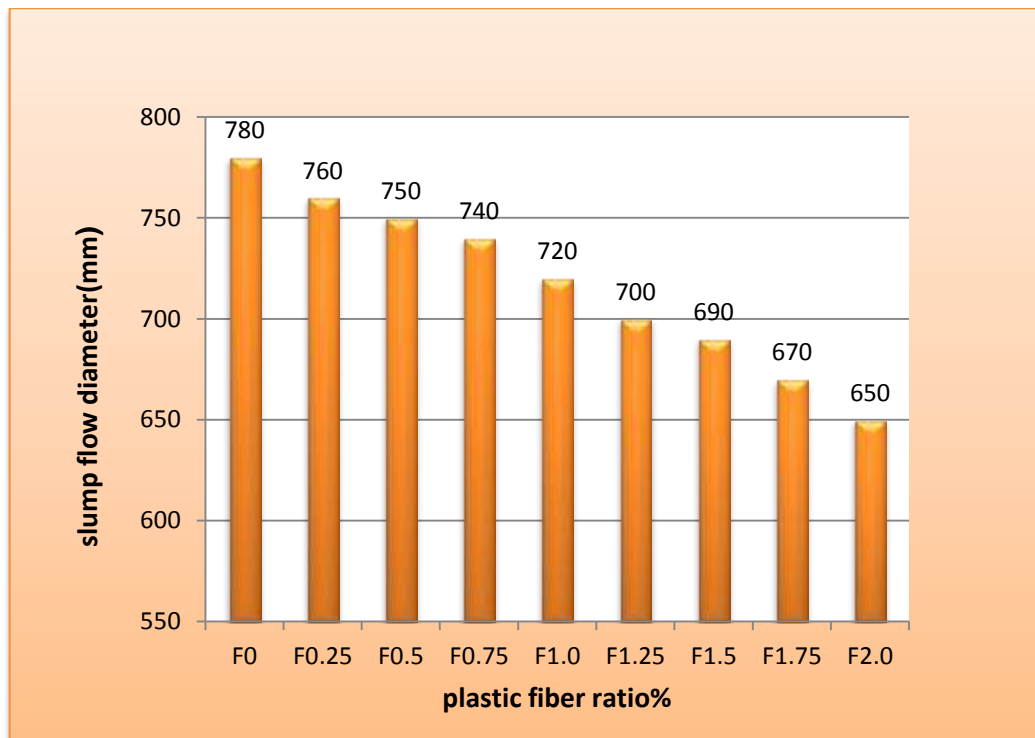


Figure 13 : The relationship between Slump Flow value and (WPF%) for SCC mixe

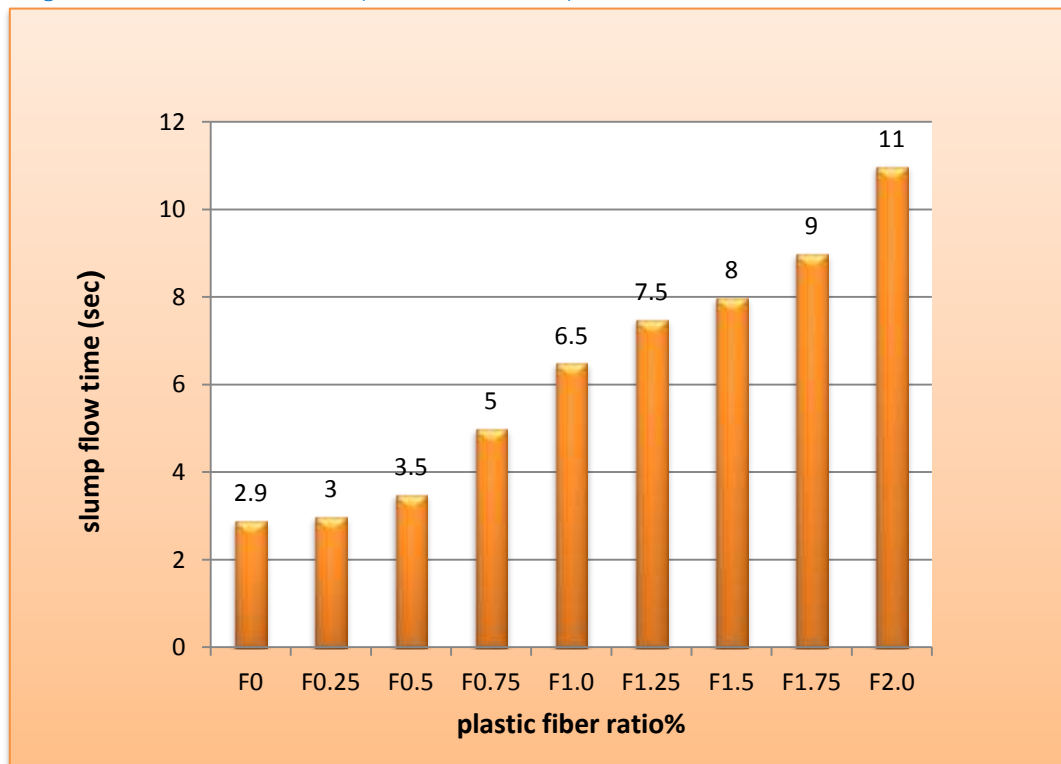


Figure 14 : The relationship between (T50 cm) value and WPF% for SCC mixes.

3.1.2. V-funnel time tests

The addition of WPFs to SCC leads to an increase in the time of (V-Funnel) and (Time50Sec V-Funnel) test. The reason of this increment is the decrease in the thickness of the surrounding aggregate layer (cement paste) and the establishment of these fibers to block the flow

by increasing the friction between the fibers and aggregates which leads to a reduction in the velocity of flow and an increase in the viscosity of the mixture, and this in turn leads to an increment in the test time. Test results are shown in Table (10) , Figures (15) and (16).

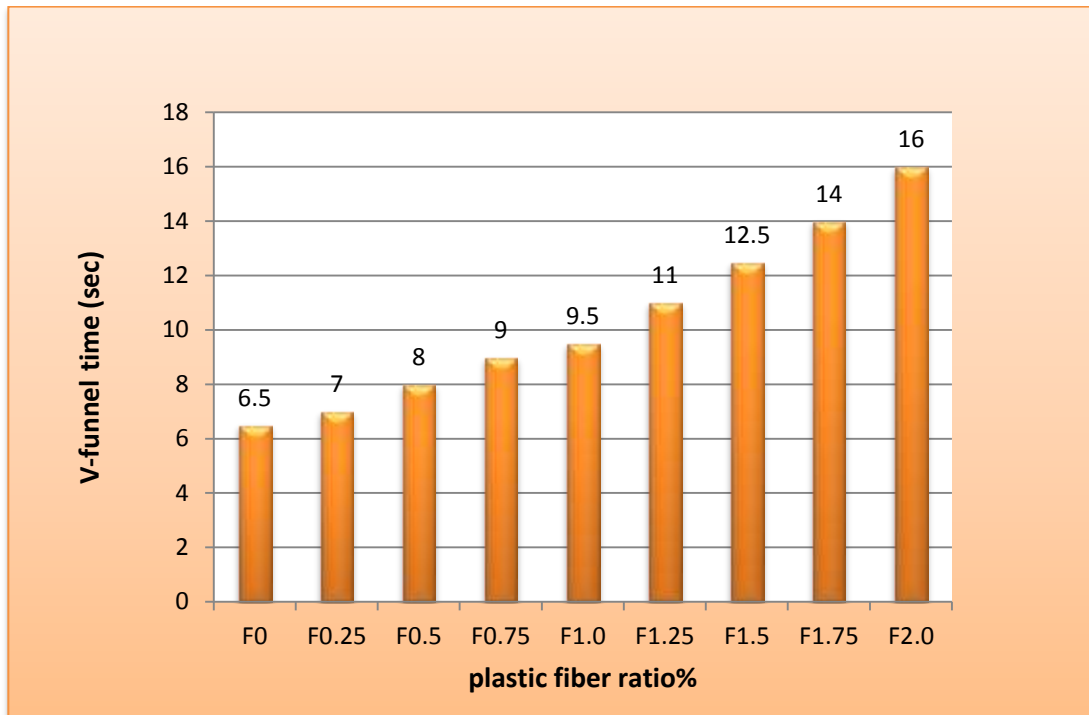


Figure 15 : The relationship between (V-funnel) value and (WPF%) for SCC mixes.

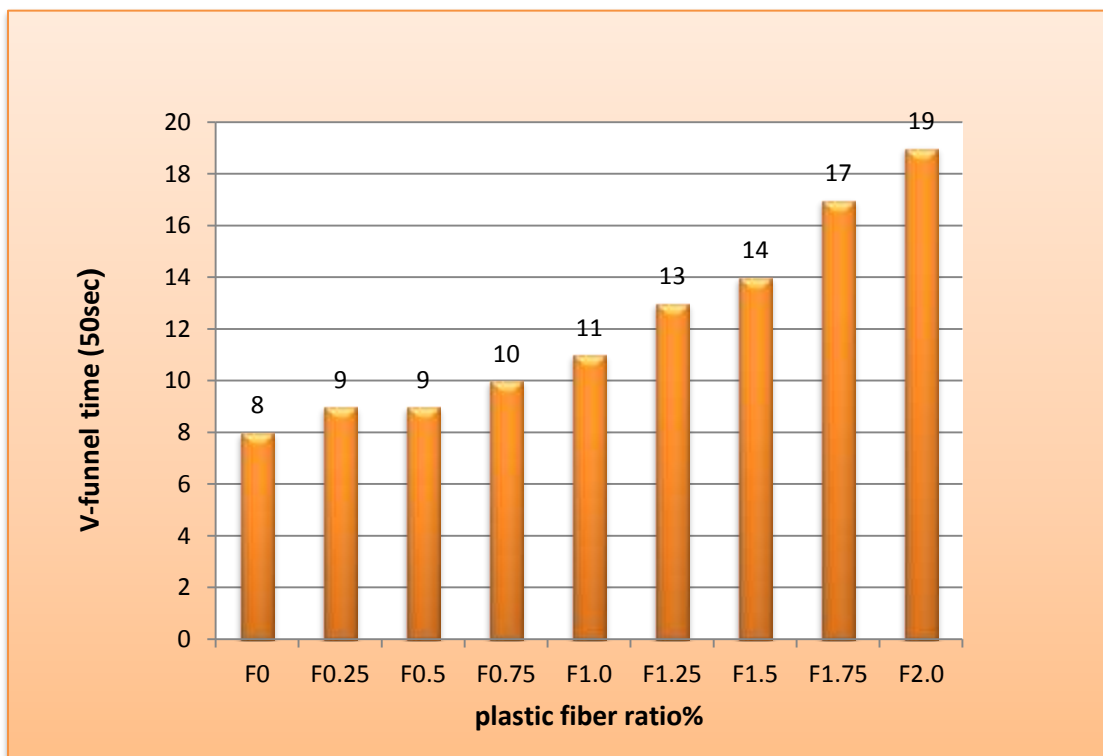


Figure 16: The relationship between (V-funnel time(50 sec)) value and (WPF%) for SCC mixes.

3.1.3. L-box ratio tests

The addition of WPFs to the SCC mixes leads to decrease the percentage of (H_2 / H_1), with low

flow velocity and this is due to the high viscosity of mixtures containing WPFs as a result of the impedance the flow by WPFs, there by increasing internal friction between the particles of aggregates, the friction among the aggregates and with low flow velocity, and the friction between the aggregates and WPFs with steel reinforcement, the test results are shown in Table (10) and Fig. (17).

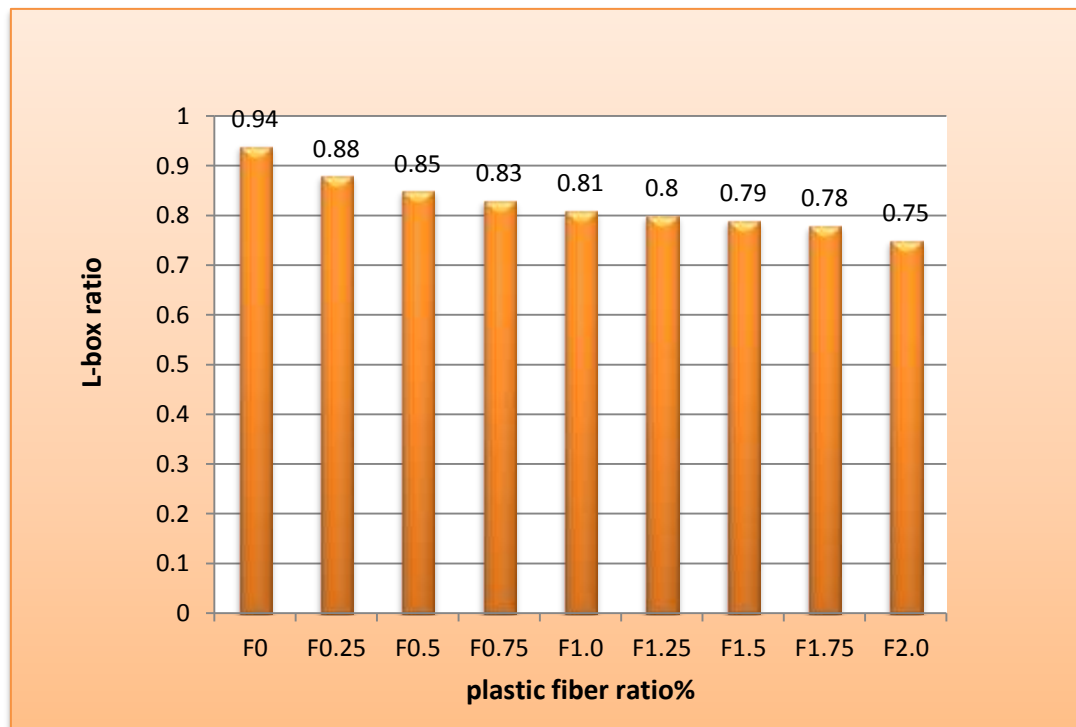


Figure 17: The relationship between (H1/H2) value and (WPF%) for SCC mixes.

4.2 Hardened Concrete Properties

4.2 .1 Compressive Strength Test

The results of the compressive strength at the ages of (7) days and (28) days for all SCC mixes are shown in Tables (11-a), Figures (18) and (19). The addition of WPF in different volumetric proportions has a positive effect on increasing the compressive strength. All SCC mixes containing WPFs have a compressive strength greater than reference mix. The compressive strength increased significantly when WPFs were added by V_f equal to (1.5-0.25%). This increment can be attributed to that, the WPFs are regularly distributed inside the structure of the concrete mixture and this leads to increases the homogeneity and decrease the voids amount within the concrete body and makes it more cohesive and more hardness. When micro-cracks begin to evolve inside the matrix, WPFs try to arrest the propagation of these kind of cracks in the neighboring region development and limiting this propagation. As a result this leads to winding the path of propagation of cracking, and thus need to a more energy for the continued of crack propagation, and therefore this operation needs to get to high stresses for the existence of failures [15]. Results showed an increase in compressive strength as a result of an increasing of WPF. When the volumetric ratio of WPF is equal to (1.75, 2)%, the decreasing in compressive strength will began, but the compressive of concretes containing WPFs still higher than that of the reference mix. This decreasing can be attributed to an increasing of WPF volumetric percentages leads to irregularly distributed of WPF into the mixture, thus, a concrete fiber collected and roll and hence leads to a decrease homogeneity and adhesion between the cement paste and the surface of the fiber and be air spaces under plastic fiber.

Table (11-a): Compressive strength for all concrete admixtures old rate (7) days.

Mix No.	Fiber Content (%)	Compressive Strength f_{cu} (MPa), 7-day	Increasing %I
SCC	0	46	-
SCC1	0.25	48	4.34
SCC2	0.5	51	10.86
SCC3	0.75	54	17.39
SCC4	1	56	21.73
SCC5	1.25	56	21.73
SCC6	1.5	59	28.26
SCC7	1.75	50	8.69
SCC8	2	47	2.17

Table (11-b): Compressive strength for all concrete admixtures old rate (28) days.

Mix No.	Fiber Content (%)	Compressive Strength f_{cu} (MPa), 28-day	Increasing %I
SCC	0	52	-
SCC1	0.25	59	13.46
SCC2	0.5	64	23
SCC3	0.75	69	32.69
SCC4	1	71	36.53
SCC5	1.25	72	38.46
SCC6	1.5	74	42.30
SCC7	1.75	69	32.69
SCC8	2	58	11.53

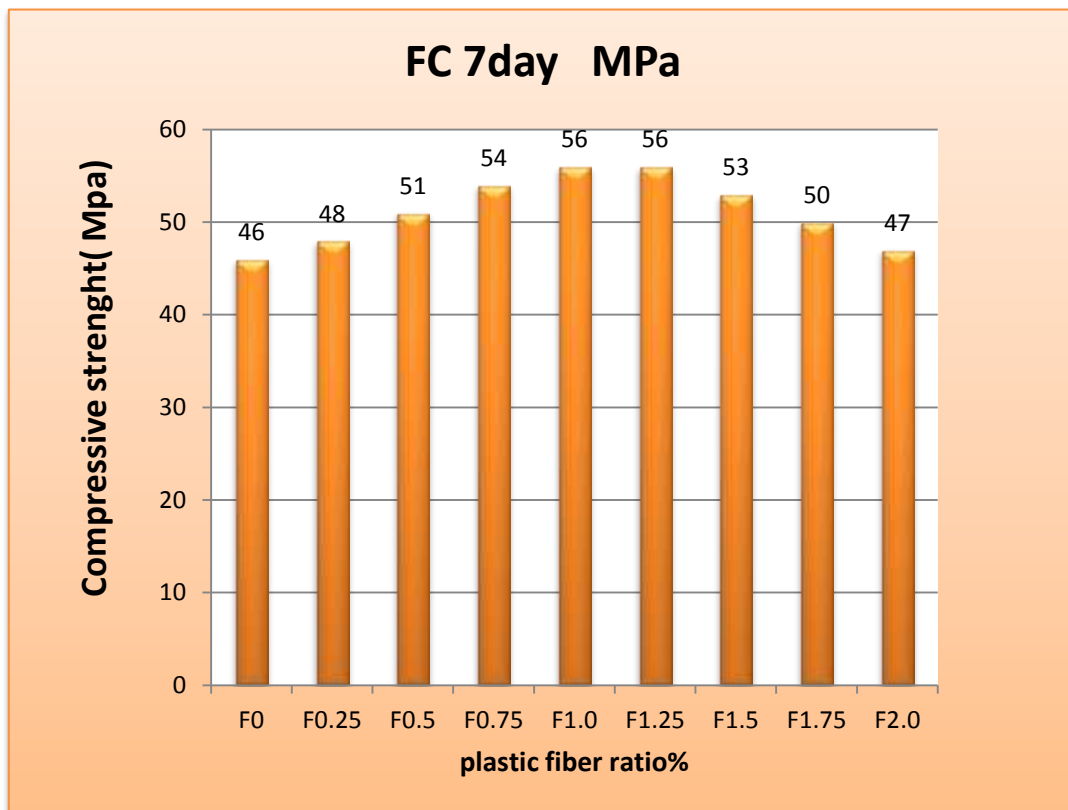


Figure 18: The relationship between compressive strength (MPa) variation and (WPF%) for SCC mixes at (7 day) age.

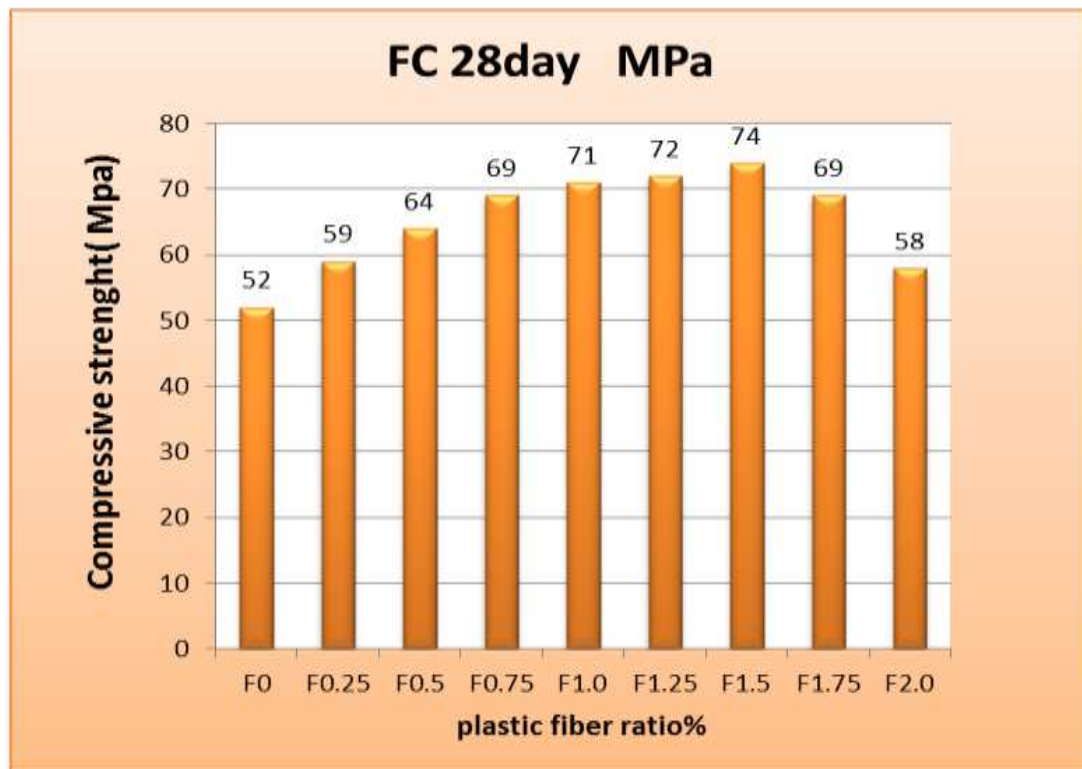


Figure 19: The relationship between compressive strength (MPa) variation and (WPF%) for SCC mixes at (28 day) age.

4.2.2 Flexural Strength Test

The prisms made from non-fibrous mix exhibited brittle failure mechanism, while the fibrous concrete prisms were quite ductile. In the flexural strength test, WPFs bridged the cracks and failed in bond. The addition of WPFs in different volumetric proportions to SCC has had a positive effect on the value of modulus of rupture if compared to RCC reference mix. The addition of WPFs was significantly appear when adding of these kind of fibers with V_f equal to (0.25-1.5%). This can be attributed to: 1-the increasing of the homogeneity, 2-decreasing in voids, 3-the increment of the bond strength between the WPF and the other components of concrete mixture as a result of the lack of convergence and the spacing of the fibers. 4-the fibers resist the generation of cracks and bridging of these cracks, and hence resist tensile stresses.

Test results showed that, the increasing of flexural strength with the increased of WPF content up to the volumetric ratio reached (1.75) %, after this V_f the modulus of rupture decreased, but it's still greater than that of of reference mixture. The reason for this is the irregular distribution of fibers when increasing the volumetric ratios of fiber and this leads to roll and increase air voids under the lamellar body of the waste plastic fibers and hence decrease the flexural strength, as well as the modulus of elasticity of WPFs will be less than that of concrete in the later ages. Tables (12-a) , (12-b) and figures (20) , (21) represent the test results of modulus of ruptures at (7 and 28) days age of tests for all SCC mixes.

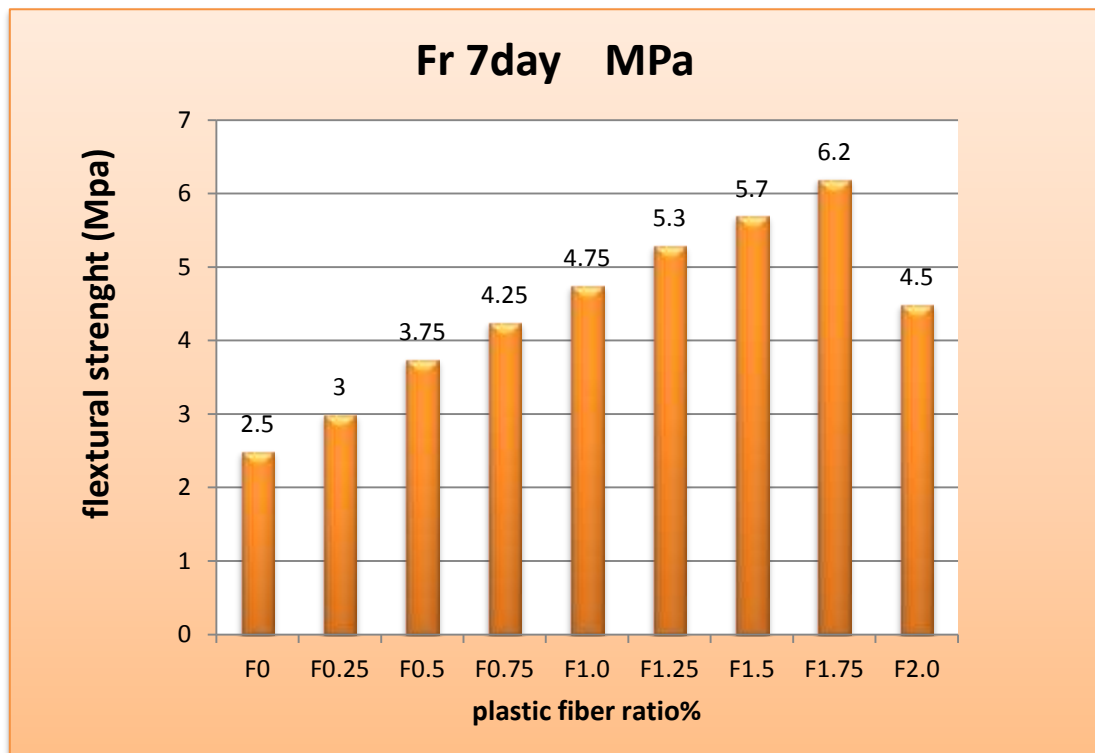


Figure 20: The relationship between modulus of rupture (MPa) variation and (WPF%) for SCC mixes at (7 day) age.

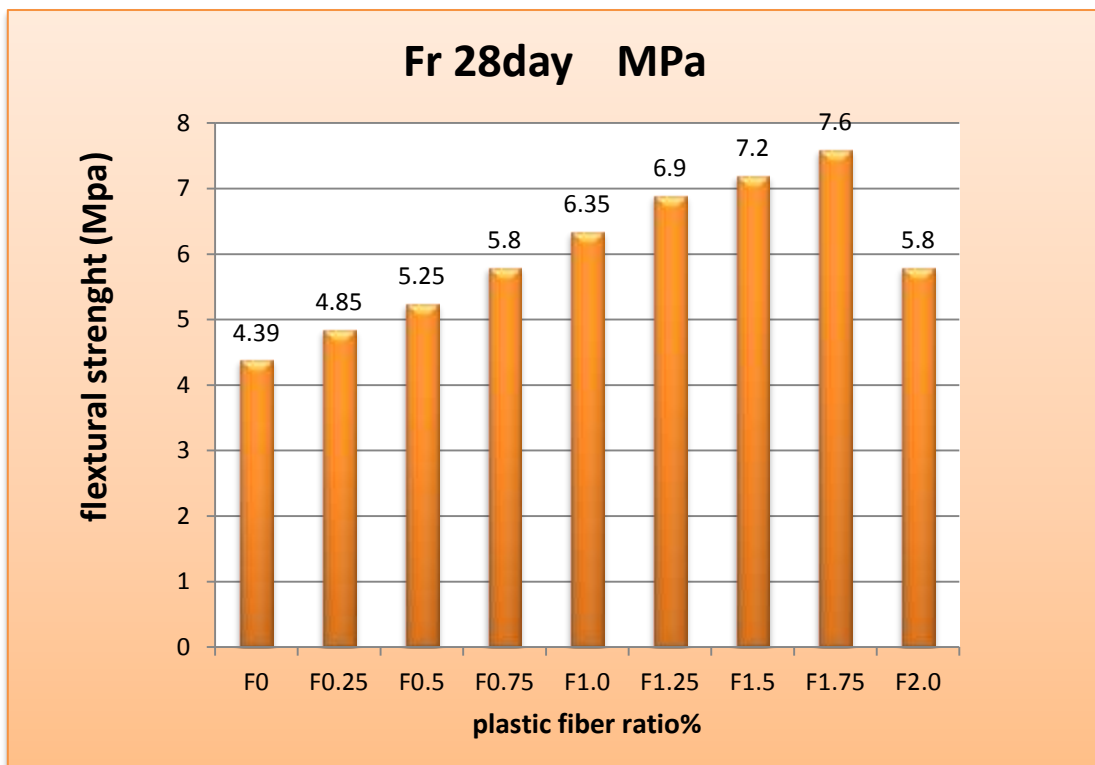


Figure 21: The relationship between modulus of rupture (MPa) variation and (WPF%) for SCC mixes at (28 day) age.

4.2.3 Modulus of Elasticity Test

The results of the test of the modulus of elasticity for the cylinders at the age of (28) days for all concrete mixtures used are described in the table (13) and figure (22). Adding WPFs at different volumetric rates to SCC leads to an increment in the modulus of elasticity for all SCC mixtures containing fibers compared to reference SCC. The amount of these percentages of increment was (11.29, 13.85, 17.02, 15.39, 13.61, 10.2, 6.81, 3.13) % for the volumetric ratios of WPFs equal to (0.25, 0.5, 0.75, 1, 1.25, 1.5, 1.75, 2)% respectively. The results also showed that, the increase of the modulus of elasticity value result of increased fiber with the increased of WPF content until the volumetric ratio reached (1.75) %, after this V_f the modulus of rupture decreased, but it still greater than that of the reference mixture. This behavior can be attributed to the same reasons mentioned in paragraph (4.2.2).

Table (12-a): Resistance to bending for all concrete admixtures rateAge (7) days.

Mix No.	Fiber Content (%)	Flexural Strength fr (MPa), 7-day	Increasing %I
SCC	0	2.5	-
SCC1	0.25	3	20
SCC2	0.5	3.75	50
SCC3	0.75	4.25	70
SCC4	1	4.75	90
SCC5	1.25	5.3	112
SCC6	1.5	6.2	148
SCC7	1.75	5.7	128
8SCC	2	4.5	80

Table (12-b): Resistance to bending for all concrete admixtures at (28) days age.

Mix No.	Fiber Content (%)	Flexural Strength fr (MPa), 28-day	Increasing %
SCC	0	4.39	-
SCC1	0.25	4.85	10.47
SCC2	0.5	5.25	19.58
SCC3	0.75	5.8	32.11
SCC4	1	6.35	44.64
SCC5	1.25	6.9	57.17
SCC6	1.5	7.6	73.12
SCC7	1.75	7.2	64
SCC8	2	5.8	32.11

Table (13): Modulus of elasticity for all concrete mixes at (28) days age.

Mix No.	WPF (%) by volume	Modulus of elasticity (MPa)	Increasing %
SCC	0	40250	-
SCC1	0.25	41511	3.13
SCC2	0.5	42992	6.81
SCC3	0.75	44356	10.2
SCC4	1	45732	13.61
SCC5	1.25	46445	15.39
SCC6	1.5	47102	17.02
SCC7	1.75	45825	13.85
SCC8	2	44798	11.29

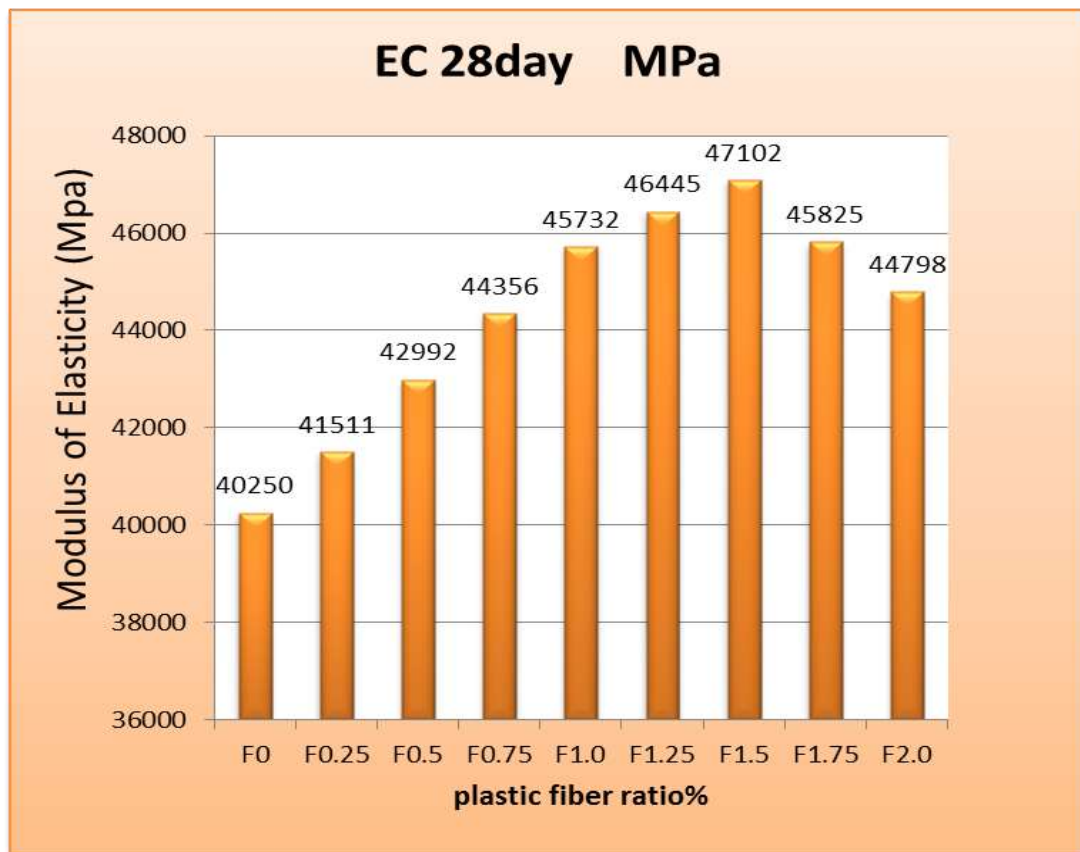


Figure 22: .Variation in modulus of elasticity with (WPFs%) of all SCCs mixes at(28).day age

4.2.4 Ultrasonic Pulse Velocity Test (UPV)

The values of ultrasonic pulse velocity of various types of SCC mixes at (28) days are shown in Table (14) and Figure (23). The results indicated that all SCC mixes containing WPFs had an ultrasonic pulse velocity slightly lower than that of reference mix. This can be attributed to the fact, that the ultrasonic pulse velocity value depends on the density of the material and the pores inside this material. Adding of WPFs leads to increase the amount of spaces inside the SCC, and that cause a reduction in the velocity of ultrasonic pulse, because the ultrasonic wave will pass through several layers consisting of a mixture of concrete and plastic fiber and air voids which forms under WPFs body [16].

Table (14): results of ultrasounic velocity for all concrete mixes at (28) days.

Mix No.	Fiber Content (%)	UPV Km/s 28-day	Decreasing %
SCC	0	4.70	-
SCC1	0.25	4.68	0.42
SCC2	0.5	4.64	1.27
SCC3	0.75	4.61	1.91
SCC4	1	4.57	2.76
SCC5	1.25	4.54	3.40
SCC6	1.5	4.50	4.25
SCC7	1.75	4.45	5.31
SCC8	2	4.39	6.59

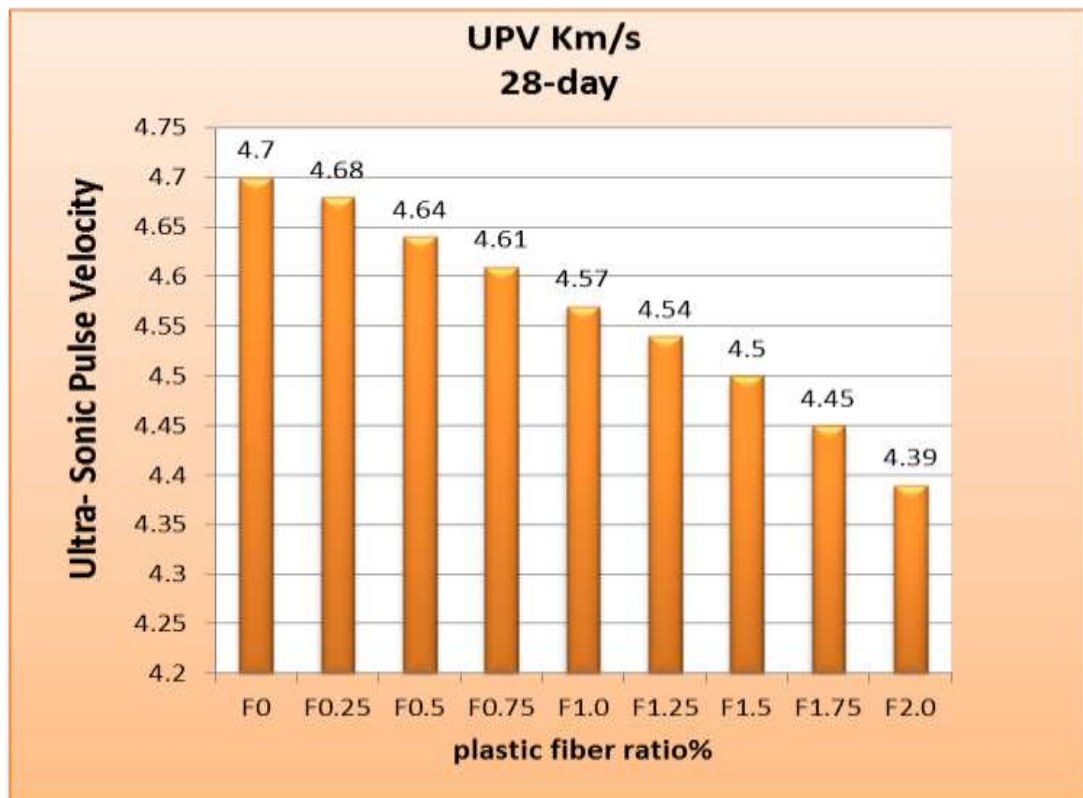


Figure 23: The relationship between Ultra Sonic Velocity and (WPF%) for SCC mixes at (28 day) age.

5 .Conclusions

5.1 Fresh Properties of Self-Compacting Concrete

- 1- Adding WPFs significantly influence the properties of fresh SCC, and this addition leads to decrease the value of the slump flow and slump flow comparing to reference mix, which had the values of slump flow equal to (780)mm and (T_{50}) equal to (2.9) Sec, while the higher decrease in the slump flow value and (T_{50}) were for the SCC with V_f equal to (2%), and the results were equal to (650)mm and (11) Sec respectively.
- 2- The addition of WPFs to SCC leads to an increase in the time of test of (V-Funnel) and ($Time_{50}$ Sec V-Funnel) test. The test results for reference mix were (6.5)Sec and (8)Sec, respectively, while the largest increase at the time of test of (V-Funnel) and ($Time_{50}$ Sec V-Funnel) test when the content of the WPF = (2%), and the results were Sec (16)Sec and (19) Sec.
- 3- The study showed that, when comparing reference mix and SCCs containing WPFs , a difference in time between the (T_0) and (T_{50}) This means that the SCC lose workability with the passage of time, where there was a difference in time between (T_0) and (T_{50}) for each mixture concrete between (3-1.5) seconds.
- 4- adding plastic fiber led to a decrease the proportion of disability and all concrete admixtures, and the lowest percentage of disability when the content of the plastic fibers (0.25%).

5.2 Mechanical Properties of Self-Compacting

- 1- Adding WPFs with different volumetric rates to SCC leads to a significant improvement in compressive strength. The maximum increment in compressive strength when WPFs were added by volumetric ratio varied between (0.25%) and (1.5%) compared to reference mix, and the

- highest percentage of increment was equal to (42.30%) at the rate of adding of WPF equal to (1.5%) for (SCC6 mix)
- 2- Adding WPFs at different volumetric rates to SCC leads to an increase in modulus of rupture of SCC reinforced with this kind of fibers compared to the reference mix. The highest rate of increase compared with the reference mixture is (73.12%) at the rate of adding WPF equal to (1.5%) (SCC6 mix), but when the volumetric ratio arise to value equal to, or more than ($V_f = 1.75\%$) there will be decreasing in flexural strength, but it still greater than that of reference mix.
 - 3- Adding WPFs with different volumetric rates to SCC leads to an increase in the modulus of elasticity of SCC reinforced with this kind of fibers compared to the reference mixture. The highest rate of increment compared with the reference mixture is (17.02%) at the rate of adding of WPFs equal to (1.5%) (mixture (SCC6)) , but when the volumetric ratio equal to (2 and 1.75)%, the increment in the value of elastic modulus will be decreased and the value of the decrement will became equal to (13.85 and 11.29)%, respectively, but it still higher than the reference mixture.
 - 4- Adding WPFs at different volumetric rates to SCC lead to a reduction in the ultrasonic pulse velocity of SCC containing these kind of fibers compared with the reference mixture. The highest rate of decrease compared to the reference mixture is equal to (6.59%) for the $V_f = 2\%$ mixture (SCC8).

Rferences

- [1] EFNARC: Specification and guidelines for self-compacting concrete «February 2002 .
- [2] Al-Qaisy, w. , " **Steel Fiber Reinforced Ultra High Performance Self – Compacting Concrete** " , Ph . Thesis , Submitted to Department of Building and Construction Engineering , University of Technology 2006.
- [3] Hadhrati , H. , " **Mechanical Properties of Self – Compacting High Performance Structural Lightweight Aggregate Concrete** " , M. Sc. Thesis , Submitted to Department of Building and Construction Engineering , University of Technology 2006.
- [4] Kbaleel , O. " **The Effect of Coarse Aggregate Properties on the Behavior Of Self - Compacting Concrete** " , M. Sc. Thesis , Submitted to Department of Building and Construction Engineering , University of Technology 2007.
- [5] Horta A. , " **Evaluation of Self – Consolidating Concrete for Bridge Structure Applications** " , M. Sc. Thesis , Georgia Institute of Technology, 2005 .
- [6] Bouzoubaa N. , and Lachemi M. , " **Self - Compacting Concrete Incorporating High – Volumes of class F fly Ash : Preliminary Result** " , Cement and Concrete Research , Vol. 31 , No. 3 , Mar. 2001 , pp. 413 – 420 .
- [7] AL-Rahamy, A.S., (2002). " **Properties and durability of admixed steel fiber concrete exposed to oil products** ", M.Sc. Thesis, University of technology. Barchip, E.P.C. (2008). Elasto-plastic, "Synthetic Reinforcing Fiber", copyright elasto plastic concrete Inc., pp.5.
- [8] Takemoto, K., Hasaba S. and Kiozumi, T., (1984). " **Resistibility against impact load in polymer and steel (hybrid) reinforced concrete.** ", International Symposium on Fiber Reinforced Concrete, pp.187-196 .
- [9] 1984 ، بغداد، "المواصفة القياسية العراقية رقم (5)، " **السمنت البورتلاندي** "، الجهاز المركزي للتقييس والسيطرة النوعية، بغداد، 1984
- [10] 1984 ، بغداد، "المواصفة القياسية العراقية رقم (45)، " **ركام المصادر الطبيعية المستعمل في الخرسانة والبناء** " الجهاز المركزي للتقييس والسيطرة النوعية، بغداد، 1984
- [11] ASTM C1240-03 , " **Standard Specification for Use of Silica Fume as a Mineral Admixture in Hydraulic-Cement Concrete «Mortar «and Grout** " .
- [12] ASTM D1708-02a " **Standard Test Method for Tensile Properties of Plastics By Use of Microtensile Specimens** " , Annual Book of ASTM Standard , Vol. 08.01 2002.
- [13] ASTM C469-02 " **Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression** " , Annual book of ASTM standards, vol. 04.02, pp-1-5, 2004.
- [14] ASTM 597-02 " **Standard Test Method for pulse velocity through concrete** " , 2002.
- [15] Barros, Joaquim ; Pereira, Eduardo and Santos, Simão , " **Lightweight Panels of Steel Fiber-Reinforced Self-Compacting Concrete** ", Journal of Materials in Civil Engineering, Vol. 19, No. 4, April 1, 2007.
- [16] Khalaf , Jumaa khalaf (2015) " **Studying the Utilization of Polymeric Wastes to Produce Sustainable Concrete** " , M.SC. thesis , Building Construction Engineering department , University of Techonology , Baghdad , Iraq.