Iraqi journal of civil engineering (IJCE)
P-ISSN: 1992-7428 ; E-ISSN: 2706-686X

Vol. 17 , No. 2 (2023) , pp. 19 ~ 33
DOI: 10.37650/ijce.2023.170203

Iraqi Journal of Civil Engineering

Journal homepage: https://ijce.uoanbar.edu.iq/

The effect of waste polyethylene terephthalate fibers on the properties of self-compacting concrete using Iraqi local materials

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ARTICLE INFO

Article history
Received: 04 /07/2023
Revised: 06/10/2023
Accepted: 06/10/2023

Keywords:
Self-compacting concrete
Waste PET fibers
Fresh properties
Hardened properties
Mechanical Properties

ABSTRACT

This study was conducted to examine the impact of plastic fibers (WPFs) in an effort to improve some of the features of self-compacting concrete (SCC) using Iraqi raw materials. Waste polyethylene terephthalate fibers (waste PET fibers) from used beverage bottles were added. Some tests were carried out to determine the effects of adding WPFs on the fresh properties of new concrete, while additional tests examined the mechanical properties of hardened concrete. Because of this, self-compacting concrete blends were created with a constant water-to-binder ratio of 0.32 and a binder content of 525 kg/m3. The designated plastic fiber percentages contents were 0%, 0.5%, 0.75%, and 1% of mix volume. Self-compacting concrete mixtures' fresh characteristics were assessed for slump flow diameter, T50 slump flow concurrently, V-funnel flow concurrently, and L-box height ratio. The 28-day density, compressive strengths and flexural strength of self-compacting concretes were also measured. The use of plastic waste fibers had a slight effect on reducing the density of the produced concrete and a negative effect on the fresh properties. The compressive strengths were improved by using WPFs, with the maximum improvement equal to (11.065%) when compared to those made from the reference mix.

1. Introduction

Global production of solid trash is estimated to reach 2.2 billion tons by 2025 from the current 1.3 billion tons per year. The environmental impact of traditional plastic garbage disposal techniques is significant. For instance, the landfilling of these plastic wastes slows down plant growth. When plastic garbage is burned, harmful substances are released into the atmosphere. Plastic wastes that are dumped into water bodies float, spoil the ocean view, and endanger aquatic life(Alfahdawi, Osman, Hamid, & Al-Hadithi, 2018).Massive amounts of non-biodegradable waste, particularly waste plastics (WP), have demonstrated over the past few decades that they pose major environmental difficulties and are one of the most dangerous sources of pollution (Ismail, & Al-Hashmi, 2008; Al-Salem, Lettieri,& Baeyens, 2009; Guerrero, Maas, & Hogland, 2013; Iucolano, Liguori, Caputo, Colangelo, & Cioffi, 2013; Wu, Li, & Xu, 2013; Liguori, Iucolano, ,Capasso, Lavorgna, & Verdolotti,

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2014).Reusing plastic waste is crucial to the sustainable management of solid waste. Management of plastic waste lessens environmental pollution, conserves and recycles energy in manufacturing processes, and preserves nonrenewable natural resources (Ghernouti, Rabehi, Bouziani, Ghezraoui,& Makhloufi, 2015).New forms of sustainable concrete have been developed as a result of recent advancements in the production of concrete. When constructing a safe and dependable structure, several types of concrete are highly recommended.

Durable buildings that could withstand various loads. among them concrete is self-compacting concrete (SCC), which can decrease voids, boost durability, and reduce bleeding by improving adhesion with fibers. SCC has low viscosity and a high rate of flow, both of which are critical for concrete pumping, especially in tall buildings. The enhancement of ductility, resistance to impact load, and energy absorption capacity for SCC are thus worthwhile research issues. Fibers are now often used in a variety of improving the ductility, hardness, and energy absorption of concrete (Sahmaran, M, & Yaman, 2007; Meddah, & Bencheikh, 2009 ; Farnam, Mohammadi, & Shekarchi, 2010 ; Gencel, Brostow, Datashvili, & Thedford, 2011; Mastali, Dalvand, & Sattarifard, 2016 ; Picazo, Gálvez, Alberti, M. G,& Enfedaque, 2018).Aggregates, hydraulic cements, and discrete reinforcing fibers are the main components of fiber-reinforced concrete (FRC) (Wang, Liu, & Shen, 2008).

Numerous researchers have investigated the effect of adding various fibers types to self-compacted concrete properties (Lim, & Ozbakkaloglu, 2015).

The problem of the current study focuses on the weakness of self-compacting concrete to resist impact loads due to the brittleness that distinguishes it from ordinary concrete. It is known that concrete has a brittle nature, and extremely low tensile strength, because the concrete has numerous minuscule fissures that quickly expand when under load ,so the process of adding WPF is important in improving the properties of concrete in terms of bridging cracks, redistributing stresses, increasing tensile strength, increasing ductility and improving toughness, the most significant feature of it is that it significantly increases the durability of the concrete material and changes the concrete failure mechanism from sudden failure to ductile failure.

(Mastali and Dalvand 2017) evaluated the qualities of self-compacting concrete (SCC) reinforced with hybrid polypropylene (PP) and recycled steel fiber (RSF) with varied fiber fractions in their study (Mastali,& Dalvand, 2017).The results showed that adding Hybrid Recycled Steel -Polypropylene significantly enhanced the impact strength and mechanical properties of the concrete, comparing RSF to PP fibers, the compressive strength was dramatically increased. The study also found that increasing the amount of PP fiber lowered the effect of RSF on improving flexural strength. The fresh and hardened properties of the concrete were correlated using regression analysis.

(Youcef Ghernouti et al., 2015) studied the impact of waste plastic bag fibers on the properties of self-compacting concrete (SCC). The researchers found that incorporating 2 cm plastic bag waste fibers into SCC improved its performance, meeting SCC standards regardless of the fiber content. The addition of these fibers helped delay microcrack formation and enhance the tensile strength of the concrete. This suggests the potential use of plastic bag waste fibers in structural applications, offering both durability and mechanical benefits.

(Al-Hadithi, 2013) investigated adopting of waste plastic in gap graded concrete used with various proportions: 0.5%, 1%, and 1.5% of concrete volume, respectively. Results showed that adding waste plastic fibers to concrete at different percentages improved the compressive strength and splitting tensile strength of concrete. However, the improvement in splitting tensile strength was more pronounced.

(Ismail & Al-Hashmi, 2018) studied concrete mixture using waste plastic as a replacement for aggregate, 800 kg of concrete mixtures were mixed with 30 kg of waste plastic in fabiform forms to replace sand to varied degrees at 0%, 10%, 15%, and 20%. At ambient temperature, each concrete mixture was tested. These tests evaluated toughness, compressive strength, flexural strength, fresh density, dry density, and slump. For tests on compressive strength and dry density, 70 cubes were molded, and tests on flexural strength and toughness index required 54 prisms, which were cast. In this study, the curing times for the concrete mixtures were 3, 7, 14, and 28 days. The findings demonstrated that adding waste plastic in fabric-like structures to concrete mixtures stopped the spread of microcracks. This study confirms that recycling discarded plastic as a sand replacement aggregate in concrete provides a good method for lowering material costs and resolving some of the concerns with solid waste that plastics pose.

In the present study, an effort is made to take advantage of PETBWPFs by cutting them into fibers that can be used in the SCC to create sustainable concrete materials. Concrete that is brittle can be made more ductile by adding WPFS. The primary function of WPFS is to distribute stress across the crack and, hence, prevent crack initiation and spread. However, this form of addition has a negative impact on the new qualities of concrete mixtures, as seen by a decline in workability. One sort of cement composite that combines WPFS and SCC might open up new opportunities for structural and sustainability engineering.

Investigations into the impact resistance of SCC beams containing PET fibers, however, are almost non-existent. This study therefore discusses novel characteristics and mechanical strength. This investigation on the effects of WPF is a subset of the research around the behavior of self-compacting concrete beams under impact loads.

2. Experimental work

2.1. Materials

2.1.1. cement

All of the specimens, including cylinders and prisms, as well as reinforced concrete beams, were cast with Ordinary Portland cement (OPC - Type I)(Al-MASS Company), a type of cement widely used in Iraq. Table 1 describe its physical properties. Cement meets Iraqi specifications, according to test results (IQS No.5/2019) .

Table 1- physical characteristics of the cement used

Physical properties	Result	Limit No.5/2019
Fineness using the Blain method (m2/kg)	361	≥ 250 m2/kg
Time of initial setting (min.)	160	≥ 45 min
Time of Final setting (min.)	260	≤ 10 hr
Soundness (mm)	1	≤ 10 mm
Autoclave %	0.1	≤ 0.8%
The compressive strength of mortar		
2 days (MPa)	20	≥ 10 MPa
28 days (MPa)	37	≥ 32.5 MPa

2.1.2. fine aggregate

In this study, natural (river) sand was obtained locally Table 2 lists the physical qualities and grading of this sand according to Iraqi standards specification (I.Q.S) No.45/84.

2.1.3. Coarse Aggregate

Crushed stone with a nominal maximum aggregate size of 10 mm was employed as the coarse aggregate in mix design. Coarse aggregate grading which is complies with Iraqi Standard (I.Q.S) No.45/84.reviewed also in Table 2.

2.1.4. Silica Fume (SF)

Concrete mixes that self-compacted had a specific gravity of 2.2 were made with SF-Type Mega Add MS (D) as the CRM. The results of the pozzolanic effectiveness test and the chemical analysis of this type of silica fume are shown in Table 3, which is provided the requirements of ASTM C1240 (ASTM, 2011) .

Table 2- Grading of Course and Fine Aggregate

Sieve Size (mm)	Passing %	Iraqi specification No. 45/ 1984 Limit
	Coarse Aggregat	
20	100	100
14	100	90-100
10	82.9	50-85
5	8	0-10
Physical properties	**Tests results**	**Limits of Iraqi specification,No.45/1984**
Absorption	0.4 %	-
Specific gravity	2.62	-
Sulfate content SO3	0.04 %	
	Fine Aggregate	
10	100	100
4.75	97	90-100
2.36	81	75-100
1.18	68	55-90
0.6	43	35-55
0.3	9	8-30
0.15	2	0-10
Physical properties	**Tests results**	**Limits of Iraqi specification,No.45/1984**
Absorption %	0.81%	-
Specific gravity	2.6	-
Sulfate content SO3	0.11 %	0.5 % max
Fineness modulus%	2.75 %	

Table 3 -The characteristics of used silica fume

Physical properties	Results	Limits
Strength activity index with cement at 7 days period of control	105%	Min 105 %
Bulk density (kg /m^3)	500 kg/m^3	-
Appearance	Grey powder	-
Specific surface area	15 m²/gm	Min 15 m²/gm
Particles size	Less than 45 µm	-
Oxide composition	**Test Results**	**ASTM C1240- 05limits**
SiO2	94.2	Min 85%
Ai2O3	0.3	-
Fe2O3	0.82	-
Na2O	0.08	-
K2O	0.45	-
CaO	0.27	-
MgO	0.14	-
SO3	0.88	-
TiO2	0.02	-
Loss of ignition L.O.I	3.36	Max 6%

2.1.5. Super plasticizer (SP)

The EPSILONE I 21 solution was used as a water-reducing admixture with a high water-saving range to improve the strength and durability of all SCC blends and to obtain desired workability. It satisfies the superplasticizer requirements of ASTM-C-494 Types G and F. The physical properties of superplasticizer adopted in the present study is listed in table 4.

Table 4- Physical properties of EPSILONE I 21 super plasticizers

CHARACTERISTICS	
Form	Liquid (Light Yellow)
Specific gravity at 25 °C	1.08 ± 0.02
Chloride content(BS 5075/EN 934-2)	NIL

2.1.6. Waste Plastic Fibers

Waste plastic fiber in a rectangular form manufactured from polyethylene terephthalate (PET) was used in the present study. The specimen having equal size: 30 mm total length, 3 mm width and a thickness of 0.3 mm. As shown in Figure 1 the waste fibers were manufactured manually by chopping plastic beverage bottles. The main physical properties of the plastic fibers are listed in Table (5).

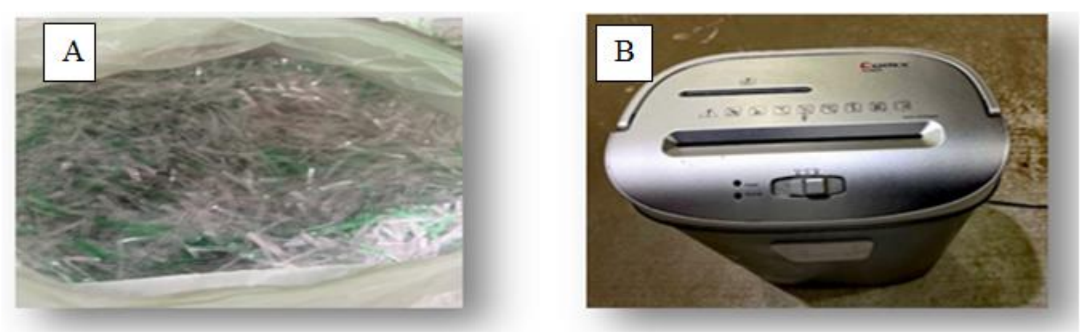

Fig. 1 [A] Waste plastic fibre, [B] Paper shredder machine

Table 5- Physical properties of WPF

Property	Description
Aspect Ratio	28.025
Tensile Strength (MPa)	105
Density (kg/m3)	1.1
Water absorption	0.00

2.2. Mix Design

The specifics of the experimental mixtures are presented in Table 6 including the amount of coarse aggregates, plasticizers, and fillers according to the limitations indicated in the specification (EFNARC,2002).

2.3. Fresh concrete properties

Tests have been done in order to detect the physical properties of SCC fresh mix. These tests are: slump flow test, V-funnel test , and L-box test.

Table 6- Mix proportions for self-compacting concrete (kg/m^3).

Mix	Fiber Content%	Cement	Sand	Coarse aggregate	Water	Silica fume	Superplasticizers
MO*	0	475	950	700	169	50	13
MA*	0.5	475	950	700	169	50	13
MB*	0.75	475	950	700	169	50	13
MC*	1	475	950	700	169	50	13

**MO (Mix class 0 with 0% fiber content), *MA (Mix class A with 0.5% fiber content), * MB (Mix class B with 0.75% fiber content), *MC (Mix class C with 1% fiber content).*

2.3.1. T_{50} cm Test and Slump Flow Test

Tests were used to calculate the flow and cohesion of self-compacting concrete, and this test is one of them. The test measures the time elapsed for self-compacting concrete to reach flowability of (50) centimeters on the test base Flow tests for self-compacting concrete are illustrated in Figures 2 (A)and (B), which show the conventional slump cone and the spreading diameter, respectively.

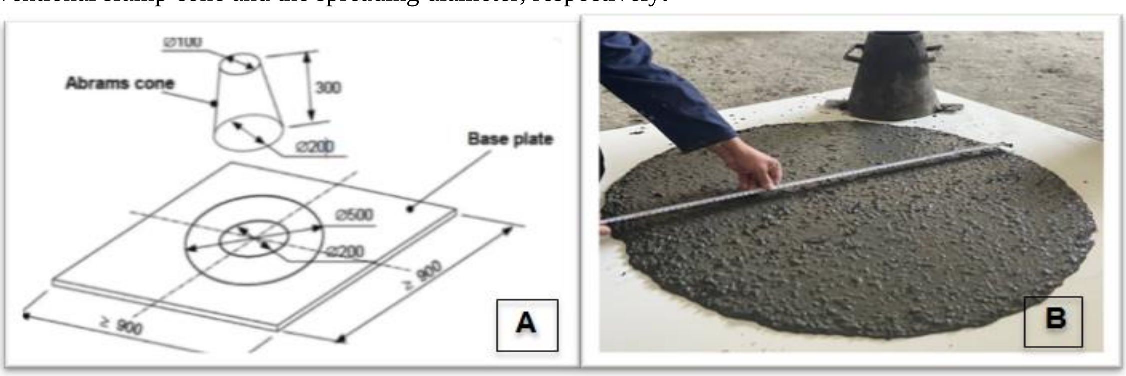

Fig. 2 conventional slump cone. [A] Standard slump cone for SCC slump test, [B] Diameter of spread of self-compacting concrete

2.3.2. V- Funnel and L-box tests

V-funnel and L-box checks are used to measure the influx of concrete mixtures without segregation. The assay used in this study complies with the requirements of EFNARC (EFNARC,2002). Figure 3 (A) and (B) show the dimensions of the steel mold used and its shape in the funnel test on the form of (V), respectively. Figure 4 shows the device used to carry out the L-Box test.

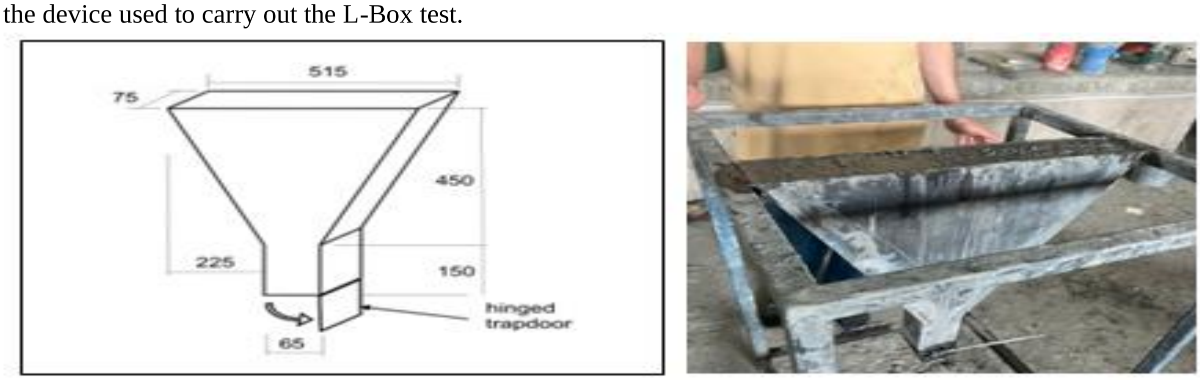

Fig. 3 V- funnel test equipment.[A] Dimensions of the steel mold used, [B] its shape in the funnel test on the form of (V).

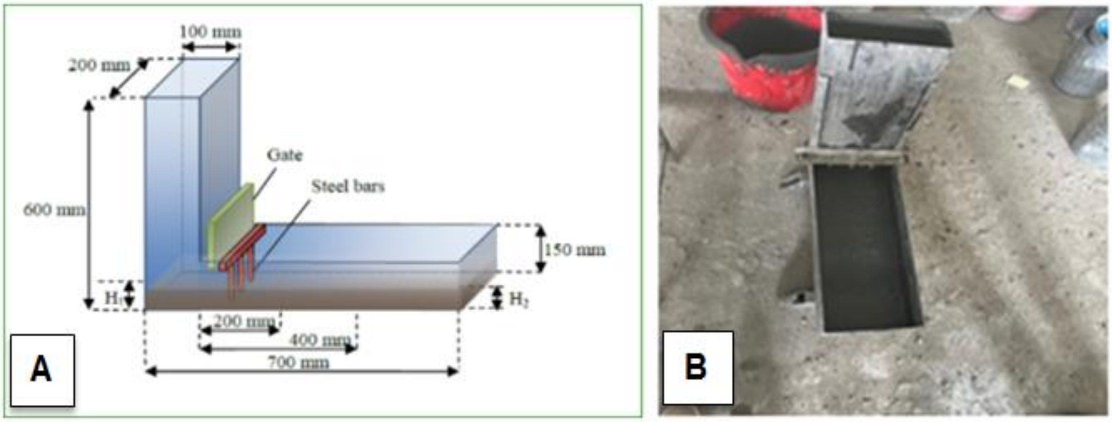

Fig. 4 L-Box test equipment. [A] Dimensions of the steel mold used, [B] its shape in checking the test L-Box.

2.4. Hardened Concrete's Mechanical Properties

2.4.1. Dry Density (Unit Weight)

The density of concrete samples was determined at 28 days using ASTM C642-13(ASTM, 2013).For each blend, the average of three readings was calculated using Equation (1).

$$\rho = \frac{M}{V} \quad \ldots (1)$$

Where :-

ρ; bulk density (kg/m^3), M; mass of concrete (kg), V; volume of concrete (m^3).

2.4.2. Compressive Strength

Three standard cylindrical specimens with dimensions of 150 mm diameter x300 mm height, were used to detect compressive strength. At a rate of 5.30 kN/s, the specimens were tested and this test was confirmed to ASTM C39-05 (ASTM 2005).

The average strength of three samples from each mixture was determined using the ELE-Digital testing compression machine, which has a max capacity of 2000 kN. The prepared test samples are shown in Figure 5.

Fig 5. Compressive testing of specimens [A] The ELE-Digital testing compression machine, [B] The test sample.

2.4.3. Flexural Strength Test

The concrete bending strength of the prepared mixtures was calculated also. The specimens were tested under four-point loading with distance between two concentrated loads equal to 100 mm from each support using the ASTM standard (ASTM, 2016). A hydraulic fracture machine with a capacity of 200 kN was used to measure the flexural strength or modulus of rupture. The dimensions of prismatic specimens are (100×100×500) mm. The 300 mm distance between the supports was divided into three equal parts, and two point loads were applied to the sides of the middle section, as shown in Figure 6. After determining the machine's fracture load, the flexural strength was determined using equation (2) (ASTM 2016).

$$fr = \frac{P\,L}{b\,d^2} \quad \dots (2)$$

Where:-

fr : Modulus of rupture (MPa), P : Maximum Load (N), L : Length of clear span (mm), b : Width of Prism (mm), d : Depth of Prism (mm).

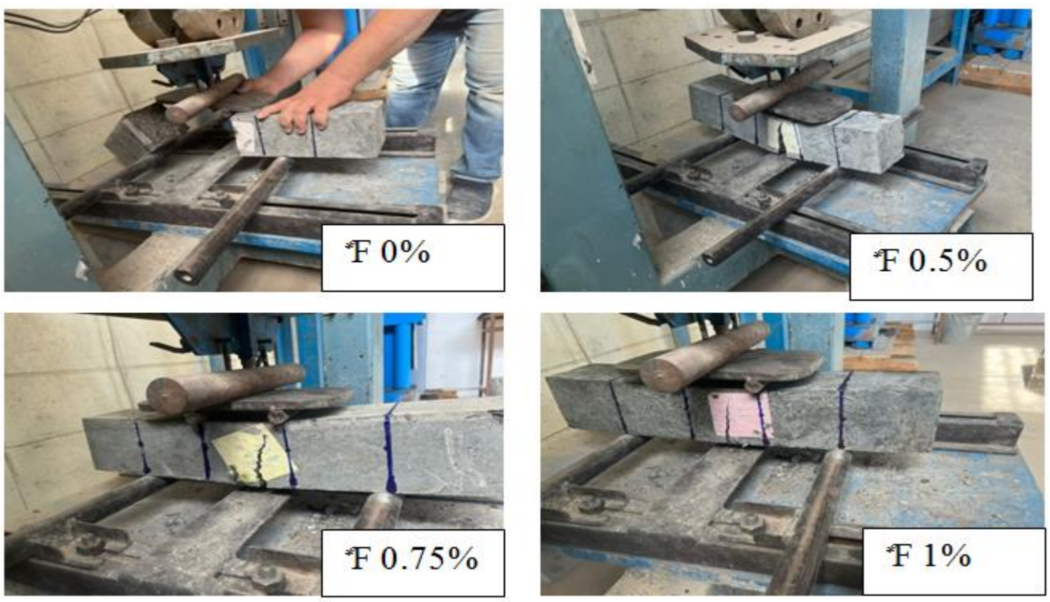

Fig 6. Hydraulic fracture machine with flexural strength

** F 0% (control mix), * F 0.5% (Fiber content 0.5%), * F 0.75% (Fiber content 0.75%), * F 1% (Fiber content 1%).*

2.4.4. Ultrasonic Pulse Velocity (UPV)

This test was carried out using cylindrical samples (150×300mm) in accordance with ASTM C597-09[28]. The UPV of the samples was measured using ultrasonic non-destructive digital equipment with a precision of 0.1 µs. A transducer with a vibration frequency of 60 kHz was used (ASTM, 2016).The time token for a pulse to traveling through a sample of concrete was then measured in second (T). Equation (3) was used to convert this time to propagation pulse velocity.

$$V = L/T \quad \dots. (3)$$

Where,

V = Ultra-Pulse velocity, (km/s), T = transit time (µs), L = Pulse length (mm)

3.Results and Discussions

3.1. Fresh Concrete Properties

Table 7 displays the test results conducted on concrete mixtures.

3.1.1. Slump of flow test

The addition of PWF to the SCC resulted in a decrease in rheological properties. This is due to the fact that the fibers increase the cohesion of the concrete mix and then the internal resistance to the fluidity increases as a result of the decrease in the thickness of the layer surrounding the aggregate (cement paste) to coat the surface of the fibers and thus obstruct the sliding of concrete and increase friction interior between the aggregate, as well as the friction between the aggregate and the fibers, as the fibers reduce the spreading diameter and lengthen the time it takes for concrete to reach the diameter (T_{50}) cm (Mosleh,2022).These fibers have a propensity to tangle and cluster in the flow's center spread, threaded the fluidity of the concrete. It is clear that mixes with low WPF content flow more easily than mixes with high WPF content. This can be accredited to these fibers' large specific surface area (Almusawee, 2012). The addition of 1% of the fibers in the SCC mixture reduced the slump flow diameter from 790 mm for the reference mixture to 730 mm for the fiber-containing mixture. The Table 7 shows the results of the tests, indicating that plastic waste has a negative effect on the slump flow value of SCC compared to the reference mix.

Table 7- Results of tests for fresh with and without PET fibers SCC

Mix	Fiber Content %	Flow (mm)	Time Flow 50cm (Sec)	V-Funnel (Sec)	L-box
MO	0	790	2.5	6.2	0.95
MA	0.5	780	3	6.9	0.89
MB	0.75	765	3.7	7.8	0.84
MC	1	730	4.9	9.1	0.81

3.1.2. V-Funnel test

The addition of WPF to the SCC caused the V-Funnel test time (T_0) to increase. The reason is due to the reduction in the layer thickness encasing the aggregate (cement paste), which causes the fibers to prohibit the concrete flow due to high friction between the fibers and aggregates. This behavior, in turn, decreases the velocity of flow due to an increase in the viscosity of mix, which leads finally to extend the test duration. Testing results are listed shown in Table 7, and explained by Figure 7.

3.1.3. L-Box test

Fibers were added to the reference mix decreased the blocking ratio (H2/H1), due to the high viscosity developed after adding of plastic fibers. In this test, the blockage ratio (0.8-1) increases due to an increase in viscosity, which causes the fibers to hinder the flow of the mix. Table 7 list the results and Figure 8 explains the test effect.

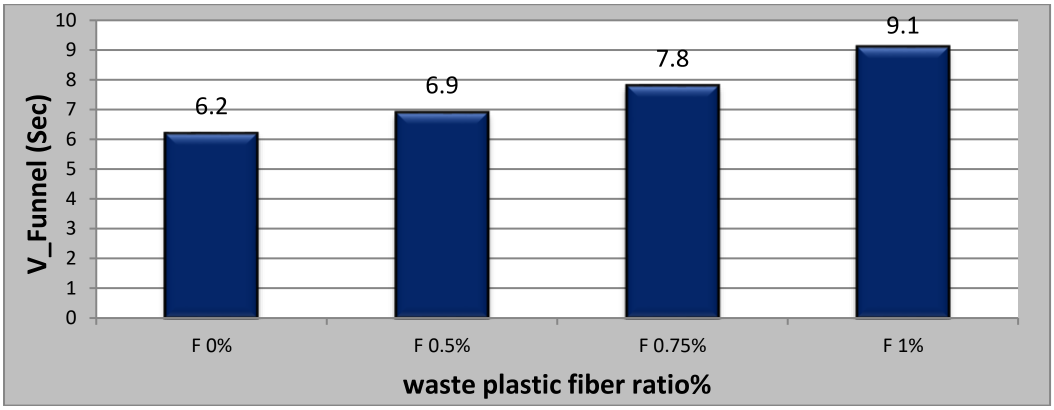

Fig. 7 Relationship of time for flow time (V-Funnel) with volumetric ratio of WPF for all concrete mixes

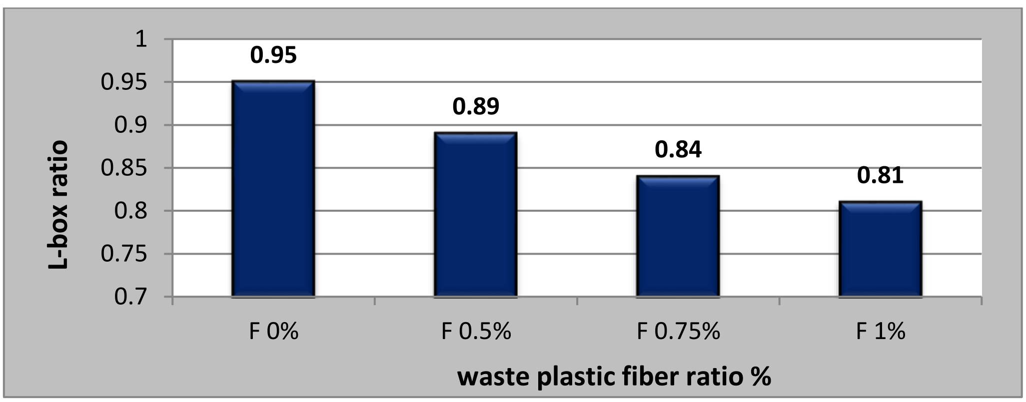

Fig .8 Relationship between blocking ratio (H2 / H1) and volumetric ratio of WPF for all concrete mixes

3.2. Hardened and Mechanical Properties Tests

The hardened and mechanical properties of the specimens were tested at the University of Anbar College of Engineering's labs after a 28-day wet curing period.

3.2.1. Dry Density (Unit Weight)

The dry density values from the three-sample average density for each mix type are shown in Figure 9. When PET fibers were inserted, the density value dropped to 1.622% at 1% WPF content. This is consistent with what the researchers found in their study (Daud, Desa, Wahidudin, & Mohamed, 2012 ; Al-Obaidi, 2013 ; Daud, Selamat, & Rivai, 2013 ; Aziz, Hama, & Kuhair, 2019; Chyad, 2021). Because PET fibers have a lower density than concrete, they have been used to replace some of the other components of the reduction. As a result, the overall density decreased. The elevated WPF content could have prevented a dense concrete matrix from being formed by preventing the cement paste and fibers from mixing properly. As a result, the mixture's density may have decreased as more air may have leaked out as a result. By increasing the porosity of the concrete and decreasing the mass of the specimen, more water will be absorbed when the porosities are filled with water. Because density equals mass/volume, the density reduced as the mass decreased (Albano, Camacho, Hernandez, Matheus, & Gutierrez, 2009 ; Araghi, Nikbin, Reskati, Rahmani, Allahyari, & Materials, 2015; Al-Hadithi, & Abbas, 2018a).

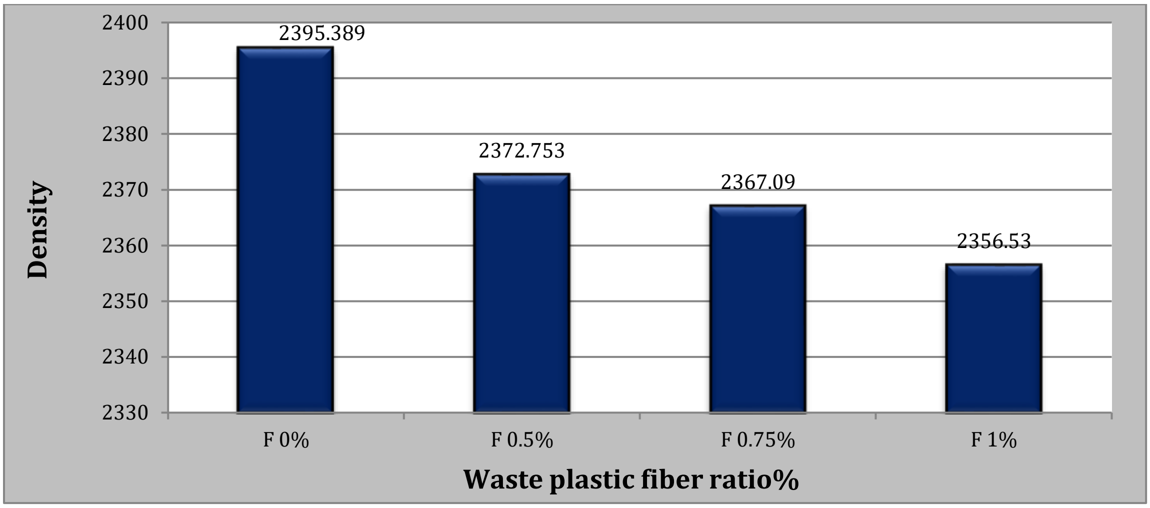

Fig. 9 Effect of adding fiber on Dry Density values.

3.2.2. Compressive Strength Test

When WPF is added to SCC at various volumetric ratios, the compressive strength of all fiber-containing concrete mixes is significantly enhanced when compared to the reference mix The highest achievable compressive strength was identified when the volume ratio of plastic fibers was between 0.5 and 0.75%. This improvement can be attributed to the ability of WPF_S to lessen these tensions, bear the stresses, and bridge the cracks. When microscopic cracks develop in the bonding material (matrix), the fibers in the area around the cracks work to hinder the development of the cracks and prevent from spreading. This causes the cracks to move in a zigzag pattern, requiring more energy to keep spreading and high pressures to collapse with a different fiber content (Barros, Pereira, & Santos, 2007 ; Ochi, Okubo, &Fukui, 2007 ; Al-Hadithi, 2008).The results also detected a rise in the compressive strength due to the increase in fibers; however, at a certain limit, when the plastic fiber volume ratio is 1%, the compressive strength was decreased but remains more than the reference mix. The increase in WPF volume ratios is to blame for this decrease since it led to an uneven distribution of fibers in the concrete mix, which in turn led to the fibers gathering and clumping together. Air gaps build up beneath the PF as a result of the cement paste's declining homogeneity and adhesion to fiber surfaces (Sharma, & Bansal, 2016).Figure 10 display results for all SCC mixes' compressive strength at age (28) days.

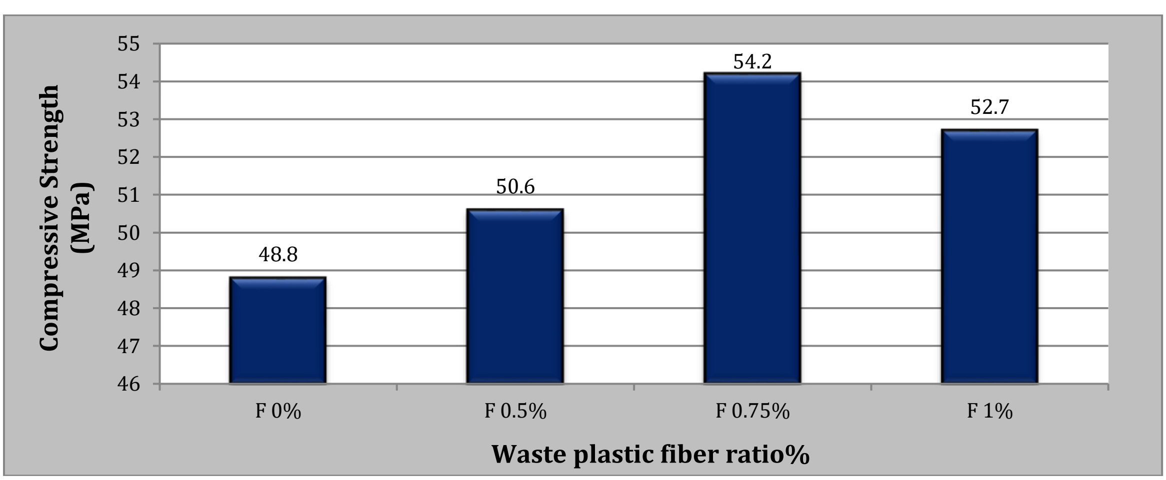

Fig. 10 Effect of fiber addition on compressive strength at (28) day age

3.2.3. Flexural Strength(fr)Results

Prisms were made of non-fibrous mix showed brittle failure mechanisms, but fibrous concrete prisms were very ductile. WPFs failed to bridge the bonding gaps in the flexural strength test. The results of flexural strength for each mix are shown in Figure 11. It has been shown that adding WPF with different ratios to SCC has a significant effect , and the fibers have a higher capacity to withstand stresses than concrete, which leads to an increase in flexural strength. This increase in flexural strength is due to the following factors:

The plastic fibers have an important role in controlling the cracks resulting from the excess of the internal stresses in the concrete, the tensile stress in the concrete, by restricting the expansion and impeding the expansion of the cracks and redistributing the stresses by transferring the stresses on both sides of the crack. Plastic fibers also have high flexibility, which means that when the stresses increase, the fibers will contribute to the expansion of the crack and limit its spread due to this restriction. This bridging effect increases the effective crack length, which results in increased energy absorption and resistance to crack propagation. The fibers act as barriers to crack growth, delaying or inhibiting the failure of the material.

Waste plastic fibers resists the propagation of cracks, which is leads to the strengthening of the internal tensile stresses (Al-Obaidi, 2013 ; Al-Hadithi, & Hilal, 2016).The largest increase in flexural strength of concrete prisms due to the use of WPFs was (36.17%) when compared to those made from the reference mix. The results of the tests conducted to determine flexural strength revealed that SCC with 0.75% WPFs offers the best flexural strength performance.

When the percentage of fibers exceeds the optimum percentage (0.75), there will be more gaps, and more free water around the particles will weaken the interface of plastic paste, resulting in a least dense zone with big voids and a relatively poor adhesion. Since the fibers are lamellar in shape, the bond between them and the paste of cement will decrease, and the bending strength will decrease (Al-Hadithi, & Hilal, 2016).

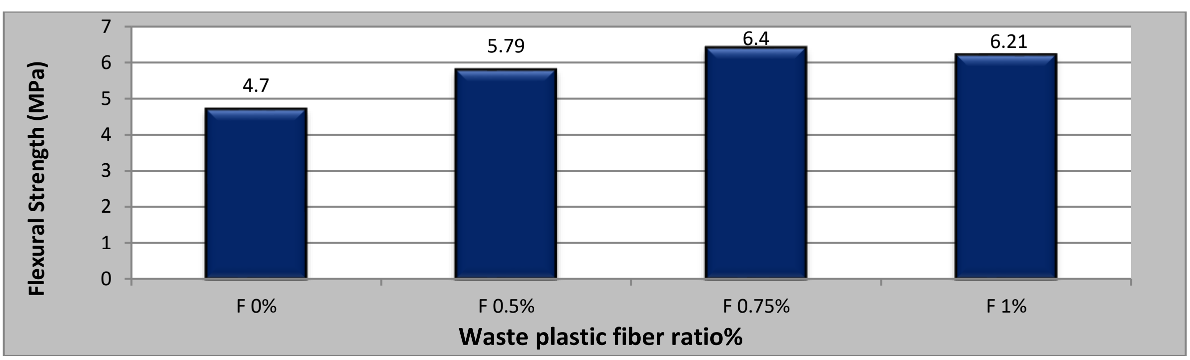

Fig .11 The impact of fiber addition on rupture modules.

3.2.4. Ultrasonic Pulse Velocity (UPV)

Figure 12 display the results of tests on ultrasonic velocities for various types of self-compacting concrete (with and without fiber) during a 28-day period, which is one of the nondestructive tests of concrete. According to the results, all concrete composition contain fibers, compared to the reference concrete, the ultrasonic arrival velocity was somewhat lower, and this can be partially attributed to the presence of fibers. With increasing PET particle load in the mixture, the ultrasonic pulse velocity decreases. This is because of two reasons: The first is that the addition of PET fiber can make the concrete porous because the ultrasonic waves must pass through multiple layers of the concrete mixture, plastic fibers, and air holes that occur under the fibers. The addition of plastic fibers results in more voids, which lengthens the time it takes for ultrasound to arrive (Rahmani, Dehestani, Beygi, Allahyari, & Nikbin, 2013 ; Khalaf, & Khalil, 2015).The transmission of ultrasonic waves in the reference concrete components is faster than that of concrete that contains fibers because each of the cement paste, gravel, and sand has a higher density than plastic fibers, and thus the wave transmission is faster. When adding fibers, the wave speed will decrease due to the low density of the fibers. The existence of porosity in concrete explains this drop in pulse velocity. As it travels through the porous concrete, the pulse is dispersed. As a result, the real wave travel path is greater than the distance between the transducers, and the pulse travel time is higher because the pulse cannot go through the porosity (Al-Hadithi, & Abbas, 2018a).

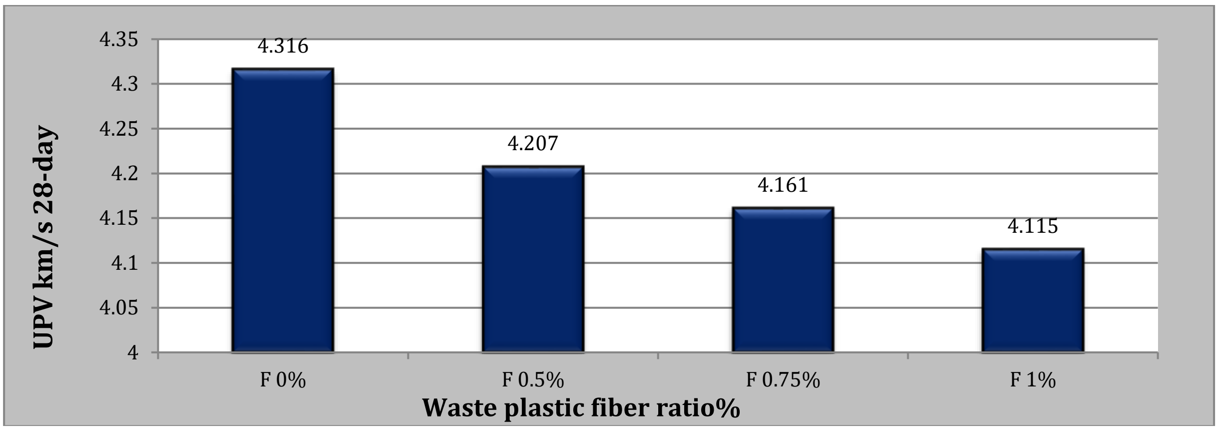

Fig.12 Effect of adding fibers on ultrasound velocity at age of (28) days

4. Conclusions

1. The addition of WP fibers of different ratio to the SCC led to a decrease in the properties of fresh concrete and a decrease in workability. This addition causes the slump flow and T50 to be lower than they would be in a reference mix with slump flow equal to 790 mm and 2.5 sec, respectively. As for the mixture containing the highest fiber content (1%), with results equal to (730) mm and (4.9) sec, correspondingly, the slump flow value and T50 decreased.
2. The time it takes to test the V-Funnel increases when WPFs are added to SCC. Testing results for the reference mix were (6.2) sec; however, the highest increase occurred during the V-Funnel test when the WPF content was (1%), and the results were (9.1) sec.
3. The use of WPF also has an impact on the L-box height ratio because adding more WPF results in a steady decline in the L-box height ratio.
4. The use of WPF had an effect on reduction the density of concrete, and 1.622% was the biggest reduction percentage.
5. Compressive strength is increased by incorporating WPFs for various volumetric rates. The biggest percentage increase, equivalent to (11.065%) at the rate of adding WPF equal to (0.75%) for the mix, occurred when WPFs were added by volumetric ratio, which ranged from (0.5%) to (0.75%) as compared to the reference mix.
6. The rupture modulus of SCC enhanced with plastic fibers increases in comparison to the reference mix.
7. The ultrasonic pulse velocity of SCC containing plastic fibers decreased relative to the reference mixture.

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