# MECHANICAL PROPERTIES FOR ORDINARY CONCRETE CONTAINING WASTE PLASTIC FIBERS

**Khalil Ibrahim Aziz** [1] **Huda Al Moqbel kuhair** [2]

(Received 11/10/2016; accepted 8/1/2017)

## Abstract

This study program has been conducted to investigate the influence of adding waste plastic fibers (WPF) resulting from manual cutting for bottles used in the conservation gassy beverage on different characteristics of ordinary concrete.

Cutting plastic waste by volumetric rates ranging between (0.5%) to (2%) was approved. Reference mix was produced for comparison. Tests were conducted on the models produced from waste plastic fiber concrete like compressive strength, flexural strength and splitting tensile strength. The analysis of the results showed that the use of plastic waste fibers (1%) has led to improve the properties of flexural strength and splitting tensile strength compared with reference concrete .When the( 0.75%)WPF ratio improved the compressive strength as compared with the control specimen . Compressive strength in (28 days) with fiber ratio (0.75%) WPF is higher than equal (5.1%) from compressive strength in (28 days) of reference concrete. Volumetric ratio (1%) WPF can be also observed that each of the flexural strength and splitting tensile strength increases equal (12.5 and 12.5%) respectively, from flexural strength and splitting tensile strength for the reference mix at(28day).

Key words: waste plastic fiber, mechanical properties, Compressive strength, tensile strength.

# الخصائص الميكانيكية للخرسانة الاعتيادية التي تحتوي على الفضلات البلاستيكية

هدى مقبل قهير د خليل ابراهيم عزيز

## الخلاصة

يتضمن هذا البحث دراسة الخصائص الميكانيكية للخرسانة الحاوية على فضلات بلاستيكية الناتجه من التقطيع اليدوي للقناني البلاستيكية المستخدمة في حفظ المشروبات الغازية ولقد تم اعتماد الياف الفضلات البلاستيكيه بنسب حجمية مختلفه تتراوح من(0.5%-2%)حيث ان.0.75% اعطت اعلى مقاومة انضغاط و1% اعطت اعلى مقاومة شد مع انتاج خرسانه اعتياديه مرجعيه لغرض المقارنة. وتم اجراء الفحوصات على النماذج المنتجة من الخرسانة الحاوية على فضلات الالياف البلاستيكية كفحوصات مقاومة الانضغاط ومقاومة الانثناء ومقاومة الشد بلانشطار ولقد اظهر تحليل النتائج ان استخدام الياف الفضلات البلاستيكة بنسبة (0.75%) ادى الى تحسين مقاومة الانضغاط بنسبة (5.1%) مقارنة مع الخلطة المرجعية بعمر 28 يوم.وكذلك يمكن ملاحظة بان كل من مقاومة الانثناء ومقاومة الشد بلانشطار تزداد بمقدار(12.5%)و(12.5%) على التوالي من مقاومة الانثناء والشد بالانشطار للخلطه المرجعية.

## 1. Introduction

Buildings made from reinforced concrete for all structural elements like slabs, beams, columns and shear walls still number one in the whole world because of safety, long life and fire resistance. In case of high rise buildings, the concrete structure not recommended because of the effects of wind and seismic loading and since concrete is a brittle material, so that become weak against these types of loading. The sources of waste plastic fiber classified in two types, first, due to production scrap and second after used plastic (post). The benefit of waste plastic fiber concrete not only enhanced

*1 Professor at the Department of civil Engineering, University of Anbar.* Khaleel_aziz@yahoo.com
*2 Student at the Department of civil Engineering , University of Anbar.*

some mechanical properties of concrete up to specific percentage, but also, make the environmental very fresh and clear because of removing all waste that make air pollutions. In 2013, R. N. Nibudey et al [1], studied the performance of concrete in presence of WPF. The experimental works that adopted included tests of cube and cylinder specimens. The WPF that added to the concrete was ranged from( 0 to 0.3 %).The specimens was cured at twenty eight days and after that tested to investigate compressive and tensile strength. The results indicated that at (1%) of WPF there was improved the mechanical properties of concrete as compared with control specimen. In 2013, Al-Hadithi Abdulkader Ismail and Shilan[2], investigated the effects of presence waste plastic chips on the mechanical properties of the new concrete. Various percentages by volume was adopted as (1.6 and 3.25 %), with Styrene Butadiene Rubber SBR polymer (10 %) from cement weight to the mix. The tests result indicated that there was improved in mechanical properties of new concrete with increasing of fibers. The increasing in c strength was (4.1 %) and modulus of rupture (24.4 %). In 2014, Al-Rawi [3], investigated the flexural behavior of reinforced concrete beams contained waste plastic fiber. The ratio of (WPF) that looked out was (0,0.5,1,1.5 and 2 %) by volume According to **tests result**, the conclusions as follow, there was reduced in deflection when the percentage of WPF increased, and up to (1%) of WPF the compressive strength increased. In 2014, Alani Mahmood Fawzi [4], studied the possible way to use waste plastic material as fine aggregate in structural elements by evaluate the mechanical properties of concrete. Various ratio of waste plastic was considered (2.5%,5% and 7.5% ) by volume with ten percent of silica fume. Tests result indicated that the presence of waste plastic reduce concrete workability and decreased in compressive strength and modulus of elasticity compared with fresh concrete. In 2015, P. Ganesh et al[5],investigated the increasing in compressive strength of concrete by replace percentage of fine aggregate by waste plastic. Total of twenty seven specimens included cube and cylinder tests and compared with the reference specimen without replacements. The ratio used in the work was (0. 5,1 and 1. 5 %) of waste plastic by volume. The results indicated that the ratio of waste plastic one percent give good result for compressive and tensile strength. In 2016, J. M. Irwan and Mohd Haziman[6], investigated the effects of ring shaped of waste plastic bottle on the flexural toughness. The width that looked out was (5mm and 10 mm) with applied loading at the third point of specimen. By tested results, there was increased in the toughness around (23%) in case of (5 mm) width and (40%) in case of (10 mm )width.

# 2. Materials

## 2.1 Cement

Ordinary Portland Cement (OPC - Type I) produced by Al-Mass company was used to cast all specimens as cubes, cylinders, prism and RC slabs. Its physical properties and chemical composition are given in Tables (1) and (2), respectively. Test results indicate that the adopted cement conforms to the **Iraqi specifications (IQS No.5/ 1984)[7].**

Table 1. Physical properties of cement

| Physical properties | Test result | Limits of Iraqi specifications No.5/1984 |
|---|---|---|
| Specific surface area, Blaine Method, ($m^2$/kg). | 300 | > 230 |
| Setting time :<br>-Initial setting (min.)<br>-Final setting (min.) | <br>90 min<br>225 | <br>≥ 45 min.<br>≤ 600min. |
| Compressive strength of mortar (MPa):<br>3-days<br>7-days | <br>21<br>27 | <br>≥ 15<br>≥ 23 |
| Soundness % (Autoclave) | 0.02 | ≤ 0.8 |

Table 2. Chemical properties of cement

| Oxide composition | Abbreviation | by weight% | Limits of Iraqi specifications No.5/1984 |
|---|---|---|---|
| Lime | CaO | 61 | - |
| Silica | SiO2 | 19.84 | - |
| Alumina | Al2O3 | 5.28 | - |
| Iron oxide | Fe2O3 | 4.2 | - |
| Sulphate | SO3 | 2.49 | $\leq$ 5% |
| Magnesia | MgO | 2.48 | $\leq$ 2.8% |
| Loss on Ignition | L.O.I. | 3.8 | $\leq$ 4% |
| Lime saturation Factor | L.S.F. | 0.92 | 0.66-1.02 |
| Insoluble residue | I.R. | 1.13 | $\leq$ 1.5% |

## 2.2Fine aggregates

Natural fine aggregate that used in present work from local Al_ Akhadir area has properties as free of organic, clay and deleterious, so it clean. Table(3) listed sieve analysis and Figure(1) show the full sieve analysis behavior with lower and upper limits. Table(4) show the physical properties of fine aggregate .

Table 3. Sieve analysis of fine aggregate

| Sieve size(mm) | % passing | Limits of the Iraqi specifications No. 45/1984- % passing Zone |
|---|---|---|
| 10 | 100 | 100 |
| 4.75 | 91 | 90-100 |
| 2.36 | 79 | 75-100 |
| 1.18 | 67 | 55-90 |
| 0.6 | 48 | 35-59 |
| 0.3 | 15 | 8-30 |
| 0.15 | 2 | 0-10 |

Table 4. Physical and chemical properties of the used fine aggregate

| Physical properties | Test result | Limits of Iraqi Specification No.45/1984 |
|---|---|---|
| Specific gravity | 2.60 | - |
| Sulfate content (SO3%) | 0.42% | 0.5% (max) |
| Absorption% | 0.75% | - |
| Fineness modulus | 2.97 | - |

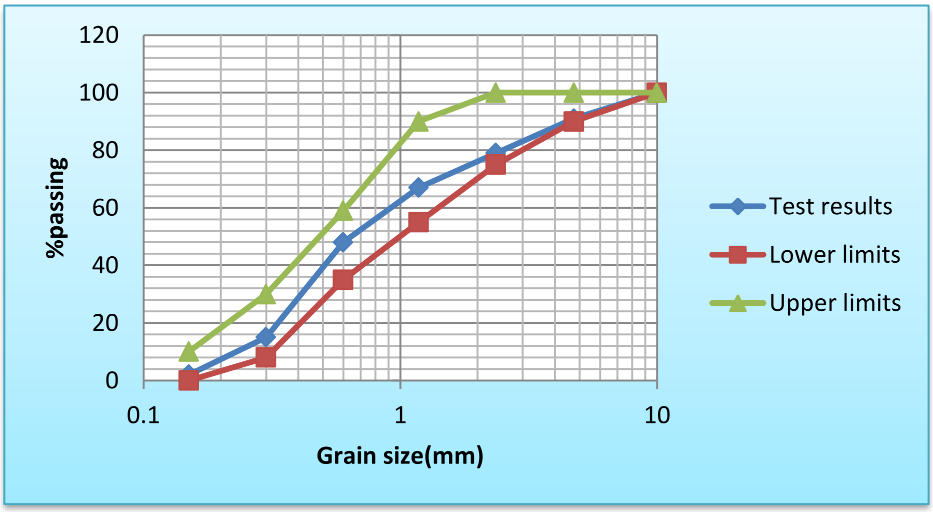



Figure 1. Sieve analysis for used Fine aggregate

## 2.3 Coarse aggregate

The maximum size of coarse aggregate is (10 mm), Crushed gravel from AL- Nibaey zone was washed and submerged in to water for about two hours and dry in air to get saturated surface dry (SSD). Table (5) and (6) listed the sieve analysis of coarse aggregate, and the physical and chemical properties of coarse aggregate respectively and the limit specified by **Iraqi Specification No 45 / 1984** )[8]**.** Figure (2) show the full sieve analysis behavior with lower and upper limits.

Table 5. Sieve analysis of coarse aggregate

| Sieve Size (mm) | % Passing | Limits oflraqi specifications No. 45/1984 |
|---|---|---|
| 12.5 | 100 | 100 |
| 9.5 | 86 | 85-100 |
| 4.75 | 5.5 | 0-25 |
| 2.36 | 1 | 0-5 |

Table 6. Physical and chemical properties of coarse aggregate

| Properties | Test results | Limits oflraqi specifications No. 45/1984 |
|---|---|---|
| Specific gravity | 2.65 | - |
| Sulfate content | 0.09 | ≤0.1 |
| Absorption % | 0.52% | - |

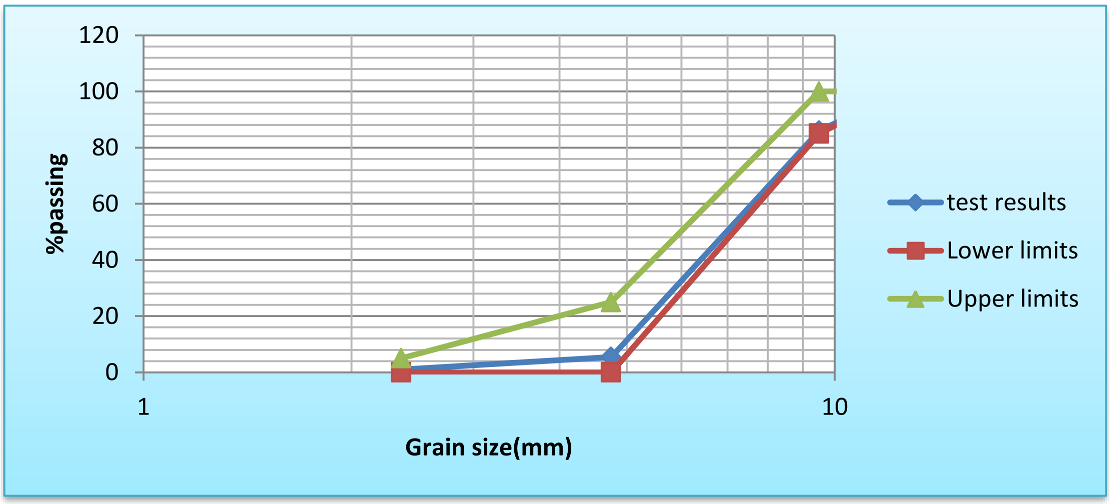



Figure 2. Sieve analysis for used coarse aggregate

## 2.4 Waste plastic Fibers

This type of plastic fiber used is conforming to(**ASTM –A 820, 2002**)[9]**.** The geometrical characteristics of plastic fibers throughout the experimental work are illustrated in Table(7) and resulting from cutting by hand. Fibers were added to the mixes as a ratio by volume of mixture of (0.5, 0.75, 1.00, 1.25, 1.50, 1.75 and 2%) respectively show plate(1) plastic waste cutting.

Table 7. Characteristics of plastic fibers

| Properties | Length(mm) | Width(mm) | Thickness(mm) | Specific gravity (gm/cm3) |
|---|---|---|---|---|
| Plastic fibres | 35 | 4 | 0.30 | 1.1 |

Plate 1. plastic waste cutting

## 2.5 Water

Fresh water was used to produce concrete without any admixture.

# 3. Concrete Mixes

Six trail mixes was used in present experimental work by using normal concrete mixing different proportions, upon to arrival the required compressive strength. Seven ratios from (%WPF) and add them to the mixture volumetric ratios as (0.5, 0.75, 1, 1.25, 1.5%, 1.75 and 2%) then selected three percentage that gives higher compressive and tensile strength (0.5, 0.75 and1%). The trail mixes with waste plastic fiber at (0.75%) give increased in compressive strength and at (1%) give enhanced in tensile strength. The variation of compressive and tensile strength of concrete with (%WPF) at 28 days as shown in Figure (3a) and (3b), respectively.

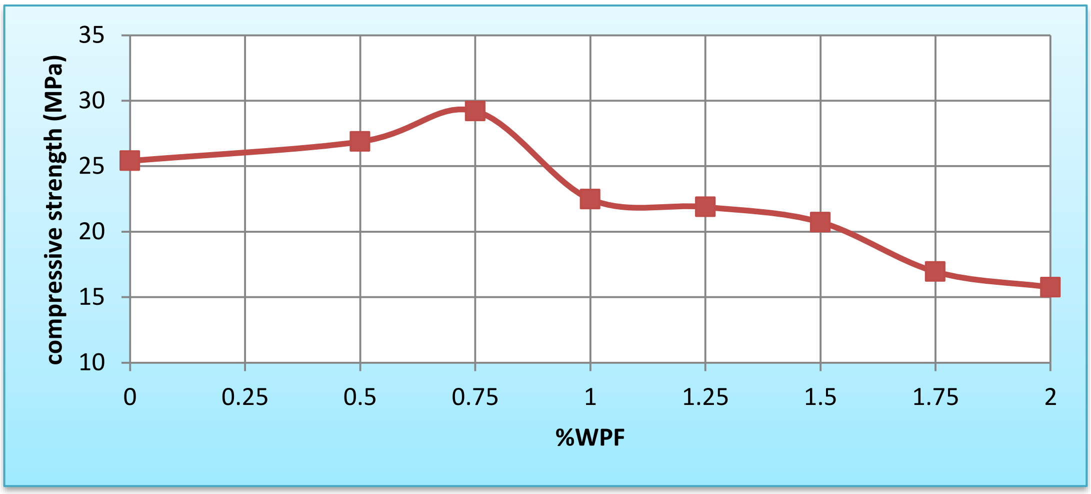



Figure3.a Relationship between compressive strength and %WPF at 28 day

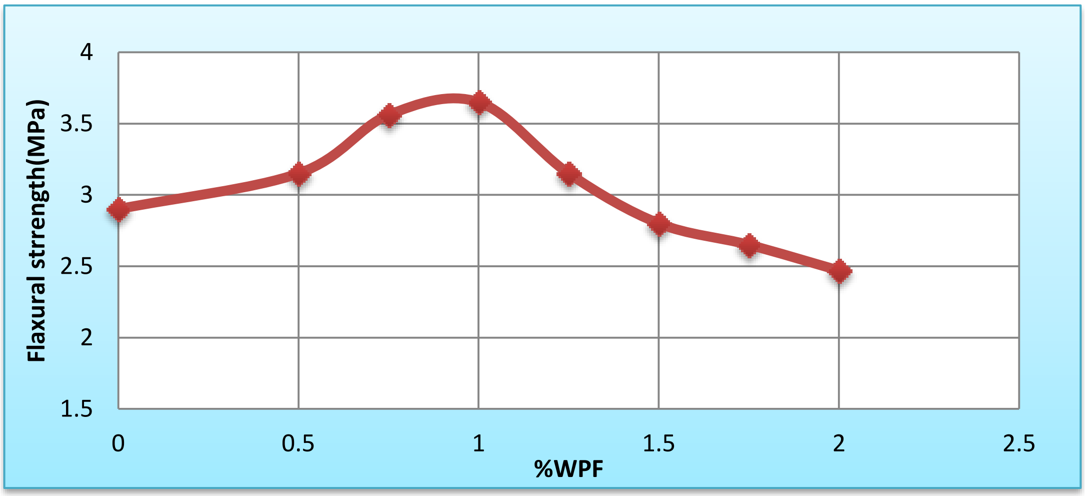



Figure3.b Relationship between flexural strength and %WPF at 28days

# 4. Normal weight concrete

The normal weight mix was prepared and then mixed mechanically and steering until all components becomes uniform. In case of presence waste plastic material to produce waste plastic concrete (WPC), the waste plastic was added to the dry mix and put all materials in the mixer and then turned on without water until the mixing become uniform and then the water required that calculated before was added and then remixed all components together. Table (8) shows the mix proportions of materials used for normal weight concrete .

Table 8. Mix properties of materials

| Materials | Cement(kg) | coarse aggregate(kg) | Fine aggregate(kg) | % w/c | fcu(MPa) | fc′(MPa) |
|---|---|---|---|---|---|---|
| Mix1 | 400 | 1050 | 750 | 0.45 | 33 | 28 |
| Mix2 | 370 | 1050 | 750 | 0.5 | 29 | 25 |
| Mix3 | 400 | 1050 | 400 | 0.55 | 27 | 33 |
| Mix3 | 400 | 1260 | 600 | 0.43 | 40.1 | 34 |
| Mix5 | 420 | 1000 | 720 | 0.5 | 28.3 | 24 |
| Mix6 | **420** | **950** | **720** | **0.5** | **25.6** | **21.7** |

# 5. Curing

All specimens before tested was cured under ideal conditions in water tank that contained fresh water and keep the specimens to the specific and required time to make the concrete complete the hydration processes, see plate (2). The temperature degrees for the water about 20±5 C°

Plate 2. curing the specimens

# 6. Experimental works

## 6.1 Slump Test

The slump tests was adopted before any other tests like compressive strength, tensile strength and modulus of elasticity to ensure the adequacy of concrete that used in tests. Slump test different in values based on the percentages of waste plastic fiber that added to the concrete according to **ASTM C143 / C143M - 5a** [(10)] Plate (3) show the slump test method and Table (9) show slump values decries with increase the (WPF) percentage.

Table 9. Slump Test Results

| Symbols | H(0%) | H(0.5%) | H(0.75%) | H(1%) | H(1.25%) | H(1.5%) | H(1.25%) | H(2%) |
|---|---|---|---|---|---|---|---|---|
| Slump(mm) | 95 | 80 | 70 | 61 | 50 | 33 | 15 | 0 |

Plate 3. Slump test

## 6.2 Compressive strength

Two kind of molds were used to determine the compressive strength and these molds were cube (150x150x150 mm) according to **BS 1881 – 119 – 2011** [11], and cylinder (300 mm) in height and (150 mm) in diameter according to **ASTM C39 / C39M-14** [12]. The machine used in tests by BESMAK, have capacity (2000 KN) for compression, as shown in plate (4a). Three specimens were tested for each type of mix for cube and cylinder. All test results was listed in Table (9).

## 6.3 Splitting tensile strength

Splitting tensile strength tested by traditional testing method according to **C 496 – 96** [13]**,** that cast standard cylinder. The loads applied gradually and continuously without shock and after that record the breaking load. Plate (4c) show the specimen rest on the machine test. Three specimens were tested for each type of mix .All test results was listed in Table(10).

## 6.4 Flexural strength(modulus of rupture)

Flexural strength or modules of rupture test define the stress in a concrete before yield in flexure this test was conducted according to **ASTM C 293**[14] (center-point loading). The dimension of prism is (400x100x100 mm) and the machine used in tests by BESMAK, have capacity (200 KN) was used to determine the flexural strength of concrete in different percentages of WPF and normal concrete with different ages. Plate (4b) show the specimens which were testing. Three specimens were tested for each type of mix the flexural strength. All test results was listed in Table (11). (Modulus of rupture) is calculated using the formula:

$$fr = 3PL/2bd^2 \qquad (1)$$

Where:

***fr*** : flexural strength, (MPa);

***P***: maximum applied load indicated by tested machine, (N);

***L***: Span length of specimen, (mm);

***b*** : average width of specimen, mm

a) The specimen during compressive strength test
b) The specimen during Flexural strength test
c) The specimen during Splitting Strength

Plate 4. specimen the tests

# 7. Results and Discussions

## 7.1 Compressive strength tests

Test results listed in Table (10) at ages (7, 14 and 28) days for (0, 0.5, 0.75 and 1%) from (WPF) by total volume. The compressive strength increased as compared with the reference mix without (WPF) up to (0.75%) because of the ductility and elongation of (WPF) through cracks Also, the compressive strength increased with age because of with age the concrete become stiffer and strength due to complete of hydration processes and reduces in porosity and after that there was dropped in result, the increased percentages (5.1 %) and (2.9%) for (0.75 and 0. 5%) respectively. Plate (5) shows the specimens after and before tests.

## 7.2 Flexural strength and splitting strength tests

All test results for flexural and splitting tensile strength of concrete with (%WPF) listed in Tables ( 11) and (12) respectively and plotted in Figures (5) and (6) respectively at (7, 14 and 28 days) for (0, 0.5, 0.75 and 1%) from (WPF) by total volume. Flexural and splitting tensile strength increased when (%WPF) increased and also increased with time, that is mean there was enhancement in tensile strength of concrete due to the presence of (WPF) because the presence of (WPF) make tight the microscopic coracles to propagate and reinforced the concrete matrix. The percentages increasing of flexural as compared with the reference specimen was (6%), (10.3%), (12.5%), respectively. Plate (6and7) shows the specimens after and before tests.

# 8. Conclusions

Based on the experimental work and results obtained in this study, the following conclusions can be presented:

1. Addition of waste fiber with different ratios (0.5% and0.75%) increases the compressive strength at ages 28 compared with the original mix. The value of increasing is about (2.9% and 5%) respectively for 28 days.
2. Addition of waste fiber with different ratios increases the flexural and splitting strength at ages 28, and compared with the original mix. The max. value of increasing is (12.5%) and (12.5%) respectively for 28 days for the mix with (1%) (waste fiber to concrete) percentages.
3. Take advantage of the industrial waste of plastic used in the empty bottled water bottles of soft drink and turn them into plastic fibers after manual cutting appropriate and added to concrete as well environmental effect good at cleaning up the environment from the waste.

Table 10. listed result of compressive strength test for cylinder( fc' )

| % WPF | compressive strength(MPa) at different ages (days) | | | Change in compressive strength with respect to reference mix at 28 days |
|---|---|---|---|---|
| | 7 days | 14 days | 28 days | |
| 0(REF) | 15.5 | 17.4 | 21.4 | - |
| 0.5 | 16.42 | 18.18 | 22.02 | 2.9 |
| 0.75 | 16.79 | 18.75 | 22.49 | 5.1 |
| 1 | 14.1 | 15.64 | 18.78 | -12.2 |

Table 11. listed result of flexural strength test

| % WPF | flexural strength(MPa) at different ages (days) | | | Change in flexural strength with respect to reference mix at 28 days |
|---|---|---|---|---|
| | 7 days | 14 days | 28 days | |
| 0(REF) | 2.4 | 2.49 | 2.8 | - |
| 0.5 | 2.5 | 2.61 | 2.97 | 6 |
| 0.75 | 2.56 | 2.68 | 3.09 | 10.3 |
| 1 | 2.56 | 2.71 | 3.15 | 12.5 |

Table 12. listed result of splitting strength test

| % WPF | splitting strength(MPa) at different ages (days) | | | Change in splitting strength with respect to reference mix at 28 days |
|---|---|---|---|---|
| | 7 days | 14 days | 28 days | |
| 0(REF) | 2.1 | 2.4 | 2.55 | - |
| 0.5 | 2.18 | 2.53 | 3.71 | 6.3 |
| 0.75 | 2.25 | 2.59 | 3.81 | 10.2 |
| 1 | 2.27 | 2.61 | 3.87 | 12.5 |

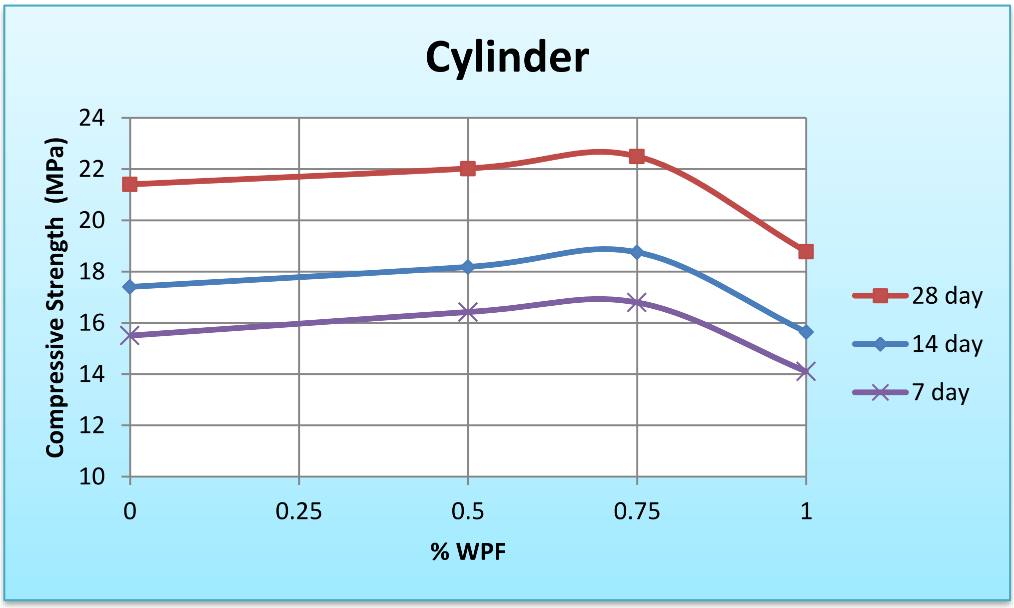



Figure 4. Relationship between compressive strength of RC mixes with %WPF

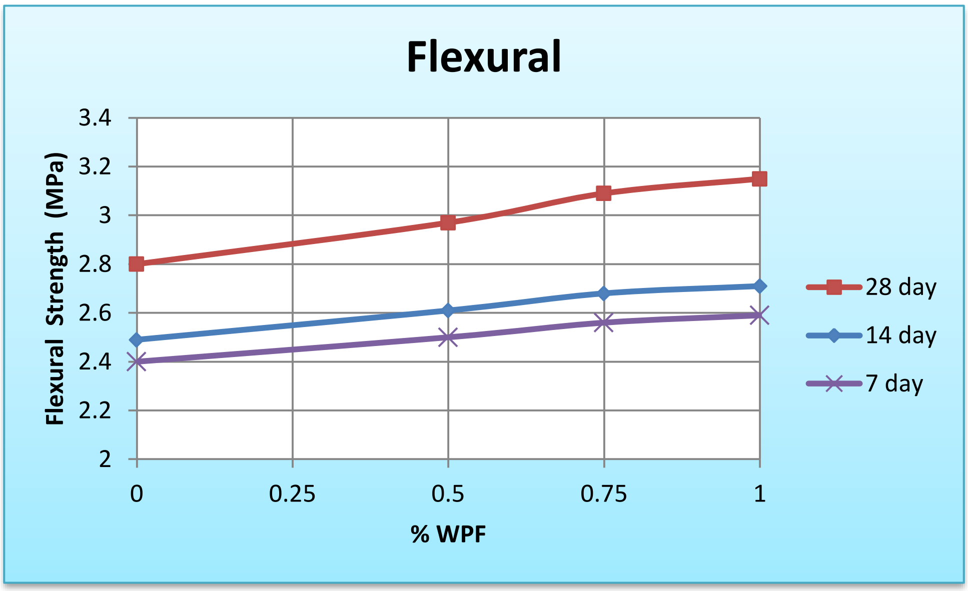



Figure 5. Relationship between flexural strength of RC mixes with %WPF

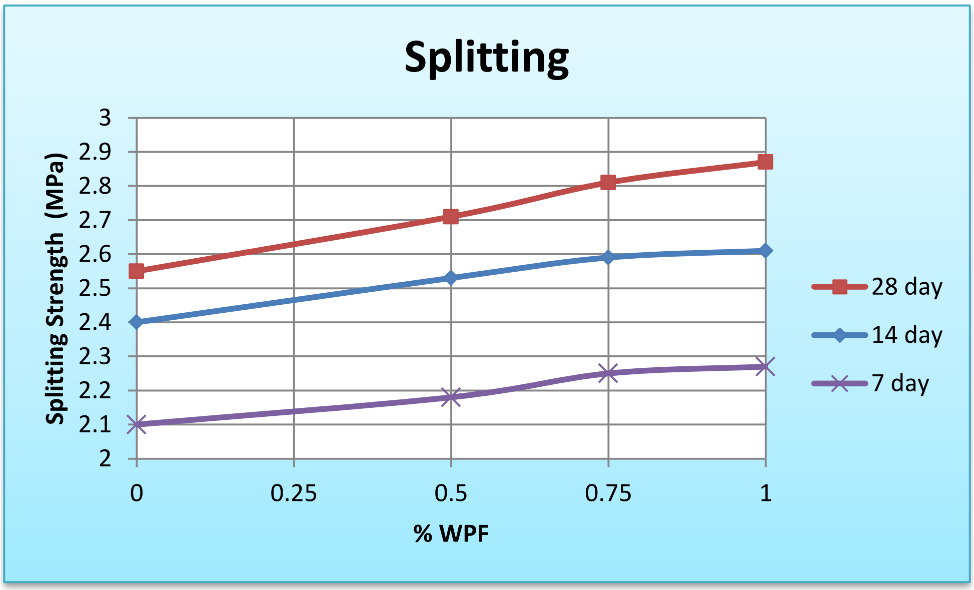



Figure 6. Relationship between splitting tensile strength of RC mixes with %WPF

| Mix type | Specimen before test | Specimen after test |
|---|---|---|
| Without WPF |  |  |
| With WPF |  |  |

Plate 5. The 150x150 mm concrete cubes tested for compressive strength

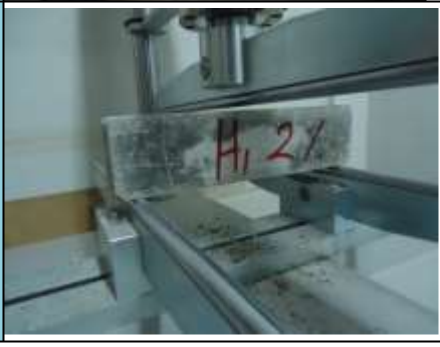
| Mix type | Specimen before test | Specimen after test |
|---|---|---|
| Without WPF |  |  |
| With WPF |  |  |

Plate 6. The 100x100x400 mm concrete prisms tested for modulus of rupture

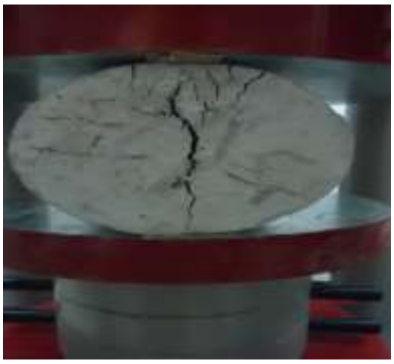
| Mix type | Specimen before test | Specimen after test |
|---|---|---|
| Without WPF |  |  |
| With WPF |  |  |

Plate 7. The 150x300 mm concrete cylinders tested for splitting tensile strength

# References


[1] R. N. Nibudey, Dr. P. B. Nagarnaik, Dr. D. K. Parbat, Dr. A. M. Pande "Strengths Prediction of Plastic fiber Reinforced concrete M3" International Journal of Engineering Research and Applications Vol. 3, Issue 1 ,2013, pp.1818-1825 .

[2] الحديثي، عبدالقادر اسماعيل عبدالوهاب," بعض الخواص الميكانيكية للخرسانة البوليميرية المعززة بألياف الفضلات البلاستيكية ." المجلة العراقية للهندسة الميكانيكية وهندسة المواد، طبعة خاصة، 2012، 653- 664.

[3] Al-Rawi Mohammed ,"Flexura Behavior of Reinforced Concrete Beams enhancement with Waste Plastic Fiber. " " M . Sc. Thesis , Dep . of Civil Eng ., Univ . of Tikrit , 2015.

[4] Al-Ani Mahmood Fawzi ," Behavior of High Perf romance Concrete by Using waste plastic as Aggregate." " M . Sc. Thesis , Dep . of Civil Eng ., Uni v . of Baghdad, 2015

[5] p.Ganesh Prabhu,C.Arun Kumar, R. Pandiyaraj, P. rajesh& I. sasi kumar" Study on Utilization of Waste pet Bottle Fiber in Concrete" International Journal of Research in Engineering & Technology ,Vol. 2, Issue 5, May 2014, PP.233-240

[6] J. M. Irwan and Mohd Haziman,"Flexural Toughness of Ring-Shaped Waste Bottle Fiber Concrete", ResearchGate , January2016,(Internet Paper).

[7] المواصفات العراقية ، المواصفة القياسية رقم 5 "السمنت البورتلاندي"، الجهاز المركزي للتقييس والسيطرة النوعية، بغداد، 1984

[8] المواصفات العراقية ، المواصفة القياسية رقم 45 "ركام المصادر الطبيعية المستعملة في الخرسانة والبناء"، الجهاز المركزي للتقييس والسيطرة النوعية، بغداد، 1984

[9] ASTM –A 820, "Standard Specification for Steel Fibers for Fiber-Reinforced Concrete" steel structural, Vol(01.04),2002.

[10] ASTM C143 / C143M –05. , "Standard Test Method for Slump of Hydraulic-cement concrete.ASTM .International, West Conshohocken, PA, 2005

[11] B.S.1881, Part 116, "Method for Determination of Compressive Strength of Concrete Cubes", British Standard Institution, 1989,p.3.

[12] ASTM C39/C39M-01, "Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens", Vol. 04.03), West Conshohocken, PA., 2003

[13] ASTM-C496-96, "Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens", Annual Book of ASTM Standards, Vol. (04.03), West Conshohocken, PA., 2003.

[14] ASTM C293, "Standard Test Method for Flexural Strength of Concrete (Using Simple Beam With Center-Point Loading) ", Annual Book of ASTM Standards, Vol. (04.02), West Conshohocken, PA., 2002.