

# Mechanical Properties And Flexural Behavior of reinforced Polymer Modified Concrete beams enhanced by Waste Plastic Fibers (WPF)

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## Abstract

This research include the study of flexural behavior of polymer modified concrete beams containing waste plastic fiber (WPF). Fifteen reinforced concrete beams are moulded of (100\*150\*1300) mm dimension with different steel reinforcement ratio ( $\rho$ ). These steel reinforcement ratio were (0.0038, 0.0207 & 0.0262). Styrene Butadine Rubber (SBR) was added as cement replacement by weight equal to (5%). Reinforced concrete beams classified in to five groups, each contains three beams with different ( $\rho$ ) value. The first group conducted of reference concrete mix , the second group made with SBR modified concrete, while the three remaining groups were make by PMC containing (WPF) with volumetric ratio equal to (0.75, 1.25 & 1.75)%. This study includes compressive and flexural tests for concrete which was used in this research, load deflection relationships, the moment at mid-span with deflection and ductility were established.

The results prove that, polymer modified concrete wich content waste plastic fiber has compressive and flexural strengths more than reference mixes as well as the PMC beams wich content waste plastic fiber have a stiffer response in terms of structural behaviour, more ductility and lower cracking deflection than those made by reference concretes and that refer to good role of styrene Butadiene Rubber (SBR) polymer and plastic fiber on the properties and behaviour of reinforced concrete beams.

Key word : Polymer modified concrete, waste plastic fibers ,PET, mechanical properties. Flexural behavior

الخواص الميكانيكية وسلوك الانحناء للخرسانة المحورة بالبوليمر والمعززة باللياف الفضلات البلاستيكية  
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## الخلاصة

يتضمن هذا البحث دراسة السلوك الانشائي للعتبات الخرسانية المطورة بالبوليمر والمزودة باللياف الفضلات البلاستيكية. حيث تم صب 15 عتبة خرسانية بابعاد (100\*150\*1300) ملم بنسب تسليح مختلفة ( $\rho$ ). وهذه النسب كانت (0.0038, 0.0207, 0.0262). تم اضافة بوليمر ستايرين بيوتادين ربر (SBR) بنسبة 5% من وزن الاسمنت. العتبات الخرسانية المسلحة قسمت الى خمس مجاميع, كل مجموعة تحتوي على ثلاث عتبات بتلات نسب تسليح مختلفة ( $\rho$ ). المجموعة الاولى تمثل الخلطة المرجعية, والمجموعة الثانية معدلة ببوليمر (SBR). بينما المجموع الثلاث المتبقية اعدت من الخرسانة المعدلة بالبوليمر وحاوية على اللياف بلاستيكية بنسب حجمية مساوية ل (0.75, 1.25, 1.75)%.

تضمنت الدراسة اجراء فحوصات مقاومة الانضغاط والانشاء للخرسانة موضوع البحث, فحص العتبات للانشاء ومن ثم ايجاد علاقات (الحمل- الأود), العلاقة ما بين العزم والأود في منتصف العتبة والمطيلية. أثبتت النتائج ان الخرسانة المعدلة بالبوليمر وحاوية على نسبة معينة من اللياف بلاستيكية ذات مقاومة انضغاط وانشاء اعلى مقارنة بالخرسانة المرجعية وأظهرت العتبات الخرسانية المسلحة المعدلة بالبوليمر وحاوية على اللياف بلاستيكية تصرفا أكثر صلابة , أكثر مطيلية

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وأقل أود من مثيلاتها المصنعة من الخرسانة المرجعية مما يدل على تأثير بوليمر الستايرين بيوتادين ربر (SBR) ودور الألياف المهم في تحسين خواص وسلوك العتبات الخرسانية المسلحة.

## 1. Introduction

The developing countries are trying their best to achieve rapid progress in the fields of industry and housing. Progress include large-scale construction activities. Cement concrete; hitherto has been one of the important materials of construction, despite its many drawbacks. The newly developed "Polymer Concrete" possessing many superior properties over conventional cement concrete, Makes itself as one of the most versatile construction materials. Polymer concrete in particular, is highly appropriate in case of pre-fabricated building industry, irrigation structures, marine structures, nuclear power production and desalination plants [1].

In addition to that, the addition of short, discontinuous fibers plays an important role in the improvements of the mechanical properties of concrete mix, decreases brittleness and controls crack initiation and its subsequent growth and propagation. Debonding and pulling out of the fibers require more energy absorption, resulting in a substantial increase in fracture resistance of the material to cyclic and dynamic loads and increase in the toughness [2].

### 1.1 Polymer modified concrete

Polymer resin is the name of organic material consisting of many high-molecular weight similar molecules one part of these molecules called monomer. The concrete resin it is the concrete are obtained by the especially treatment of ordinary concrete with polymer, which acts as a carnivore or a filler for the spaces between the aggregates [3].

Since 50 years or more began the development of the cement mortar and concrete by polymer and as a result became in 1970 polymer modified mortar and polymer modified concrete from the construction and industrial materials prevalent use in Japan and Europe, and also the case in the United States in 1980.

Today polymer modified mortar and polymer modified concrete is one of the commonly used materials in the field of building and construction [4].

### 1.2 Styrene-Butadiene Rubber

The (copolymer) of styrene-butadiene-known commercially under the name (SBR) of the most important types of flexible polymers in the world in terms of energy usability [5]. Styrene butadiene, an elastomeric polymer, is the copolymerized product of two monomers, butadiene and styrene. Latex is typically included in concrete in the form of a colloidal suspension polymer in water. Usually this polymer is a milky-white fluid. figure (1), shows the chemical structure of Styrene butadiene rubber latexes.

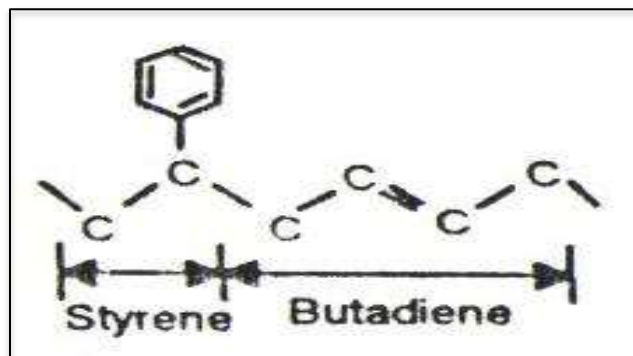


Figure 1. Chemical structures of SBR polymer latexes [5]

## 1.3 Recycled fibers

The amount and type of wastes being generated increasing with increasing grow the world population. Today domestic waste plastics caused considerable damage to the environment and it will remain for hundreds and perhaps thousands of years, the growing consumer population to creation of non-decaying waste materials, combined with a has resulted in a waste disposal crisis [6].

There are several methods used to dispose of plastic wastes, namely such as incineration, this method greatly harms the environment and human and causes many health problems. The burning of plastic to get rid of it leads to the emission of several toxic gases such as, dioxin compound, carbon dioxide (CO<sub>2</sub>), hydrogen chloride gas (HCL), and carbon monoxide, in addition to ash and the rise in temperature (more than 1000 C°) [7].

There one solution to this crisis lies in recycling wastes in to useful products is can be successfully used in concrete for improved some of the mechanical properties as in the case of the steel fibers [2].

## 1.4 Polyethylene terephthalate (PET)

This type of plastic is from the polyester family. It is a thermoplastic type composed of ethylene glycol and terephthalic acid his chemical name is polyethylene terephthalate or "PET". The molecular formula of PET plastic is (C<sub>10</sub>H<sub>8</sub>O<sub>4</sub>)<sub>n</sub> and it is unique among the major polymers for its high oxygen content. its can amorphous or crystalline thermoplastic material which melts at 256-264° C. The densities of amorphous and crystalline PET are about 1330 and 1450 kg/m<sup>3</sup> respectively. Figure (2) shows the chemical formula of PET plastic. This type of plastic has a high oxygen content so it make it impervious to gas diffusion, which is crucial to keep carbonated soft drinks fresh. Also, PET is used extensively in the formation of synthetic fibers as a member of the polymer family. In 2009, national association of PET container resources found that the overall amount of recyclable PET in the United States was about 2.34\*10<sup>9</sup> kg in one year, whereas the recycled quantity was just about 6.52\*10<sup>8</sup> kg which is 28% of the existing amount [8].

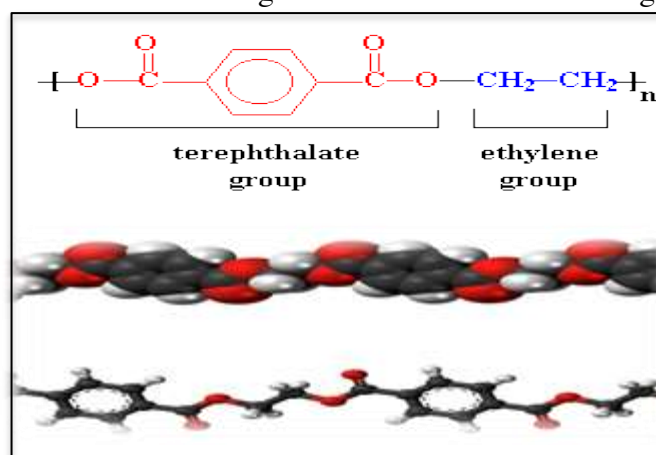


Figure 2. Molecular formula of polyethylene terephthalate- (C<sub>10</sub>H<sub>8</sub>O<sub>4</sub>)<sub>n</sub> [8]

## 2. Experimental Work

### 2.1 Materials

#### 2.1.1 Cement

Iraqi Ordinary Portland Cement (OPC) manufactured in the north of Iraq with trade mark of (Al-mass) was used throughout the investigation. The physical properties and chemical composition

are given in table(1). Test results indicate that the adopted cement conforms to the Iraqi specifications (IQS No.5/ 1984) [9].

Table (1-a): Physical properties of cement used throughout this work

Physical properties	Test result	Limits of Iraqi spec. No.5/1984
Fineness using Blain air permeability apparatus (cm/gm)	2983	≥ 2300
Setting time using Vicat's instrument		
Initial (min.)	2:30	≥ 00 : 45
Final (min.)	3:40	≤ 10 : 00
Compressive strength for cement paste		
3 days age (N/mm)	19.8	≥ 15
7 days age (N/mm)	24.6	≥ 23

Table (1-b) Chemical composition and main compounds of ordinary portland cement

No.	Oxide composition	Abbreviation	by weight%	Limits of Iraqi spec. No.5/1984
	Lime	CaO	62.77	-
2	Silica	SiO <sub>2</sub>	20.88	-
3	Alumina	Al <sub>2</sub> O <sub>3</sub>	5.22	-
4	Iron oxide	Fe <sub>2</sub> O <sub>3</sub>	3.42	-
5	Sulfate	SO <sub>3</sub>	3.46	≤ 5%
6	Magnesia	MgO	2.55	≤ 2.8%
7	Loss on Ignition	L.O.I.	1.2	≤ 4%
8	Lime saturation Factor	L.S.F.	0.91	0.66-1.02
9	Insoluble residue	I.R.	0.67	≤ 1.5%
Main compounds (Bogues eq.)			by weight of cement%	
1	Tricalcium silicate (C <sub>3</sub> S)		46.95	
2	Dicalcium silicate (C <sub>2</sub> S)		24.52	
3	Tricalcium aluminate (C <sub>3</sub> A)		8.05	
4	Tetracalcium aluminoferrite (C <sub>4</sub> AF)		10.39	

## 2.1.2 Fine Aggregate

Al-Ukhaider natural aggregate was used for concrete mixes of this work. Results of sieve analysis of this sand are shown in table (2). It is shown that the sand confirms to the requirements of the Iraqi specification (IQS) No. 45-1984, zone [10].

Specific gravity and materials finer than 75µm% of the used sand were calculated according to (IQS) No. 45-1984 [10]. And they were equal to 2.64 and 2.98 respectively. The sulfate content was equal to 0.35%.

Table (2): Shows the grading and physical properties of fine aggregate

No.	Sieve Size (mm)	Percent Passing	
		Fine Aggregates	Limits of the Iraqi specification <sup>(2)</sup> No. 45/1984 Zone (2)
1	10	100	100
2	4.75	91	90 – 100
3	2.36	79	75 – 100
4	1.18	67	55 – 90
5	0.6	48	35 – 59
6	0.3	15	8 – 30
7	0.15	2	0 – 10

## 2.1.3 Coarse Aggregate

Crushed gravel from AL-Nibaey region was used with a maximum size of 10 mm was used for all concrete mixes in this study. The aggregates was conform to the requirements of the Iraqi specification (IQS) No. 45-1984 [10].

As shown in table (3) which gives the sieve analysis results of the coarse aggregate. Specific gravity was equal to 2.58 and sulfate content was equal to 0.05%.

Table (3): Grading and physical properties of coarse aggregate

No.	Sieve size (mm)	Passing%	Limits of Iraqi spec. No.45/1984
1	12.5	100	100
2	9.5	94	85 - 100
3	4.75	3	0 - 25
4	2.36	1	0 - 5
5	1.18	0	0

## 2.1.4 Mixing Water

Ordinary tap water was used in this work for all concrete mixes and curing of specimens.

## 2.1.5 Polymer

In this study styrene butadiene rubber (SBR) is used as polymer modifier. The SBI Company, United Arab Emirates, manufactured this polymer and the properties of SBR polymer is shown in table (4). The polymer (SBR) was used as a ratio by weight of cement of 5%.

Table (4): Typical properties of polymer #

No.	Property	Description
1	Appearance	Milky white change to transparent when dry
2	Min. Application temperature	+5 C°
3	pH value	8 - 9
4	Temperature resistant	-20 up to +90 C°
5	Solid Content	36-38 %
6	Flammability	Non-flammable
7	Density kg/ m <sup>3</sup>	1,050

# Properties obtained from product catalogue <sup>[11]</sup>.

## 2.1.6 Admixture

Admixtures are chemicals, added to mix of concrete at the mixing stage to modify some of the properties of the mix. A superplasticizer is one of class of admixtures called water reducers that are used to lower the mix water requirement of concrete [12]. . The optimum dosage is found to be 0.5% of the weight of cement It meets the requirements for super plasticizer (SP) according to ASTM-C- 494, Its properties are listed in table (5).

Table (5): Properties of the superplasticizer #

No.	Properties	Description
1	Main action	Concrete superplasticizer
2	Subsidiary effect	Aqueous solution of modified Polycarboxylate
3	Appearance	Turbid liquid
4	Density	1.095 g/cm <sup>3</sup>
5	Chloride content	None
6	Sugar content	None
7	Toxicity	Non-Toxic under relevant health and safety codes.
8	Storage life	Shelf life at least 12 months from date of production.

# Properties are obtained from the product catalogue <sup>[13]</sup>

## 2.1.7 Fibre

A rectangular shape of waste plastic fiber were added to the mixes as a ratio by volume of mixture of 0.75%, 1.25% and 1.75%. Table (6) shows the characteristics of short fiber was use in this study.

Table (6): Characteristics of plastic fibre

Fiber type	Length (mm)	Width (mm)	Thickness (mm)	Density (Kg/m3)	Aspect ratio (l/d)
Waste Plastic	34	4	0.3	1100	28

## 2.1.8 Reinforcement

Ukraine steel bars have been used for all types of steel reinforcement as a shear, flexural reinforcement for all length of beam. The steel bars are tested according to ASTM A 615/A 615M – 03a.[14] .The properties of the tested reinforcing bars are shown in table (7).

Table (7): Properties of the reinforcing steel bars\*

Nominal Diameter (mm)	Fy (MPa)	Fu (MPa)
8	424	691
10	583	672
12	610	696

\* Test conducted at the Laboratory of Civil Engineering Department Al- Nahrain University

## 2.1.9 Reinforced concrete beam specimens for structural behavior

Specimen details are shown in fig.(2). All beams were (100 mm) wide and (150 mm) deep and spans (1100mm). 8 mm bar have been used as shear reinforcement (The stirrups). Three levels of steel reinforcement ratios were used.

The approximately minimum ratio ( $\rho=0.0038$ ) and maximum ratio ( $\rho=0.0262$ ), in addition to a third level was ( $\rho=0.0207$ ) were used in order to investigate the behaviour of PMC with waste plastic fibre. Beams covering the code allowable levels of reinforcement. Cubes of (150X150X150) mm for compressive strength were used with beam specimens to determine the compressive strength of these beams.

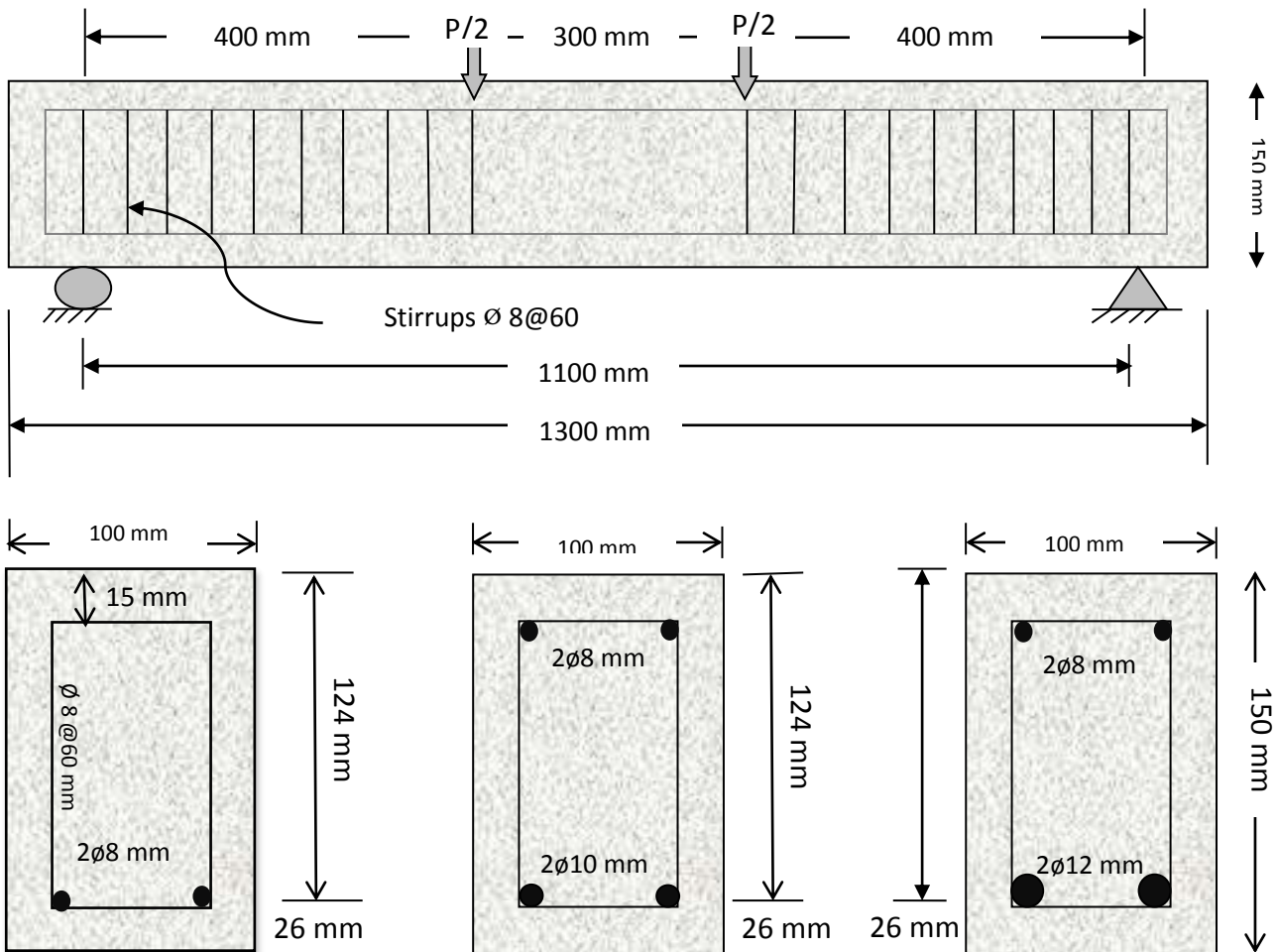


Figure 3. Loading and reinforced beam specimens details

## 2.1.10 Preparation of Concrete Specimens

A horizontal rotaty mixer of 0.1m<sup>3</sup> capacity is used for preparing the concrete mix. First of all aggregates and sand were added firstly then fibers were slowly added as separated filaments by hand spraying, while the mixer is rotating, before adding the cement seconds to obtain a homogenous mix.

After adding the cement, the materials were well mixed for about 90 seconds then, (SBR) polymer dispersion is added after appropriate dilution with water, and mixing continued for two minutes resulting in a uniform matrix.

Finally, water and polymer with superplasticizer is gradually added, stirring constantly for a period of not less than 60 seconds until uniformity is ensured through visual inspection. All material mix with each other the mixing time was ranging between (1-3) minutes; this increase in the time of mixing was necessary to get a uniform mix without segregation.

## 2.1.11 Mix Proportions

Several trial mixes were done to indicate the suitable mix proportion for obtaining the required concrete compressive strength. table (8) shows the mix proportions of materials used in this work.

Table (8): The details of the mix proportions for normal concrete

Mix. Ratio	Cement (kg/m <sup>3</sup> )	Sand (Kg/m <sup>3</sup> )	Gravel (Kg/m <sup>3</sup> )	S.P %	W/C	Slump (mm)	FC Mpa
1:1.94:2.56	370	720	950	0.55	0.42	85	40

## 2.1.12 Casting, Compacting and Curing

The moulds were coated with mineral oil before use, according to ASTM C192-88 [15], concrete casting was carried out in two layers. Each layer was compacted by using needle vibrator until no air bubbles emerged from the surface of concrete and the concrete is levelled top of moulds smoothly. Then the specimens were kept in the laboratory for about (24) hrs. After that the specimens remoulded carefully for two days immersed in water for polymer modified concrete specimens, whereas the control specimens immersed in water for (28) days.

## 2.1.13 Compressive Strength Test

Compressive strength was determined using (150\*150\*150) mm cubes according to B.S.1881 part 116 [16]. Machine with a capacity of (1900) kN was used for that test. The average compressive strength of three cubes was recorded for 28 days age.

## 2.1.14 Flexural Strength Test

(100\*100\*400)mm concrete prisms were prepared according to ASTM C192-88 [17]. Two point load test was carried out according to ASTM C78-94 [18]. Using machine with a capacity of (190) kN capacity machine. Average modulus of rupture of two prisms was recorded for 28 days age.

## 2.1.15 Load Measurement

A flexural machine with a (190)kN hydraulic testing machine is used for testing the beam specimens at two point load arrangement over simply supported span of (1100) mm as shown in fig.(3) and Plate (1).



Plate 1. Set-Up of beam specimen test

### 3. Results and Discussion

The results of the tests of reinforced beams are presented. Effects of waste plastic, moment-deflection relationship, reinforcement ratio on deflection, member's ductility and crack patterns are investigated and discussed.

These beams were tried at (28) day age. The details of all beams are mentioned in section (2-1-9).

#### 3.1 Concrete Compressive Strength "f<sub>cu</sub>"

The compressive strength test results obtained for the average of three 150 mm cubes for each mix made in this study are given in table (8). We can notice that the addition of polymer did not effect in compressive strength [19].

It can be noticed that an improvement in the compressive strength with the increased of waste plastic fibres, until (1.25%) after that, there will be a decrease in compressive strength. These results confirm similar predictions made by **Al Hadith et al** [20], **AL-Kubaysi Gassan** [21]. The improvement of the compressive strength results is due to the ability of the fibres to elongate the crack path and the reason of compressive strength decreasing after (1.25%) might be due to the forming of segregate on mix. This led to form stiff bond around these bulks. Therefore, the existence of waste plastic fibres increased the porous inside the mix structure and allows the absorption of water inside the porous (4).

Table (8) Properties of Polymer Concrete in Test Beams

The Mix	Polymer:cement Ratio %	Compressive Strength "f <sub>cu</sub> " (At 28 days) MPa	Flexural Strength "f <sub>r</sub> " (At 28 days) MPa
R	-	40	6.43
RP	5	39.7	6.58
V <sub>f</sub> =0%	5	42	6.98
V <sub>f</sub> =1.25	5	41	7.2
V <sub>f</sub> =1.75	5	37	6.85

#### 3.2 Flexural Strength "f<sub>r</sub>"

The results of flexural strength at 28 days age are given in table (8). From the resulted we can see that the addition of waste plastic fiber to the polymer modified concrete improves flexural strength.



This improvement is might be due to the use of SBR polymer which leads to form a continuous three-dimensional network of polymer molecules throughout cement which increases the binder system due to good bond characteristics of SBR polymer [22]. These results confirm similar predictions made by **Bing Chen et al** [23], **Al-Dolaimi Mohammed** [24].

Also the flexural strength increased with the increase in fibers volume after percentage (1.25%) there will be a decrease in flexural strength this happens for the same reasons mentioned for the concrete compressive strength. These results confirm similar predictions made by **Karim et al** [25], **Al Rawi Mohammed** [26].

### 3.3 Load-Deflection Behaviour

Table (9) shows properties, maximum load and deflections of the tested beams. Fig. (4-7) show load-deflection at mid spans for the fifteen beams with different reinforcement ratios, different waste plastic fibre.

In the pre-cracking stage, the deflection with load increases linearly. This is expected since the strains in the steel and concrete are small relatively and both materials are in the elastic portion of their respective response. The beam with higher value of reinforcement ratio has stiffer responses to loading in general due to a higher moment of inertia as shown in Fig.(4-7).

In the post-cracking stage, there is a change of slope in the load-deflection curve due to the cracking, which reduces the effective moment of inertia of the beams cross section. After cracking, deflection again increases linearly with the load up to the point just after yielding of all tensile steel. The results inducted that the response of the beams in this regain is function of both the reinforced ratio and concrete compressive strength.

In the post-yielding stage due to the yielding of the tensile steel all of the load-deflection curves exhibit changes in slope. The deflection immediately increases after yielding due to redaction of neutral axis depth, each exhibits different post-yield, load-deflection responses depending upon the amount of tensile steel reinforcement and the concrete strength.

Table (9) Properties, deflection and ductility of reinforced concrete beams

Beam No.	$A_s$ (mm <sup>2</sup> )	Polymer %	WPF %	$P_u$ (kN)	$\Delta_u$ (mm)	$M_u$ (KN.m)	$\Delta_y$ (mm)	Ductility ( $\mu d$ ) $\Delta(\Delta u/y)$
B1	0.0262	0	0	85.4	21.1	18.50	11.56	1.83
B2	0.0207	0	0	72.5	22.3	15.71	10.34	2.16
B3	0.0038	0	0	70	24.6	15.17	7.64	3.22
B4	0.0262	5	0	86.3	19.6	18.70	10.3	1.90
B5	0.0207	5	0	73.4	21.2	15.90	9.6	2.21
B6	0.0038	5	0	71	23.4	15.38	7.2	3.25
B7	0.0262	5	0.75	106.4	17.3	23.05	8.84	1.96
B8	0.0207	5	0.75	95.6	19.21	20.71	7.78	2.47
B9	0.0038	5	0.75	85.2	21.2	18.46	6.45	3.29
B10	0.0262	5	1.25	95.6	18.2	20.71	9.45	1.93
B11	0.0207	5	1.25	80.4	20.8	17.42	8.5	2.45
B12	0.003	5	1.25	75.1	21.62	16.27	8	2.70
B13	0.0262	5	1.75	60.5	22.3	13.11	15.67	1.42
B14	0.0207	5	1.75	50.4	23.8	10.92	10.62	2.24
B15	0.0038	5	1.75	42	24.2	9.10	8.8	2.75

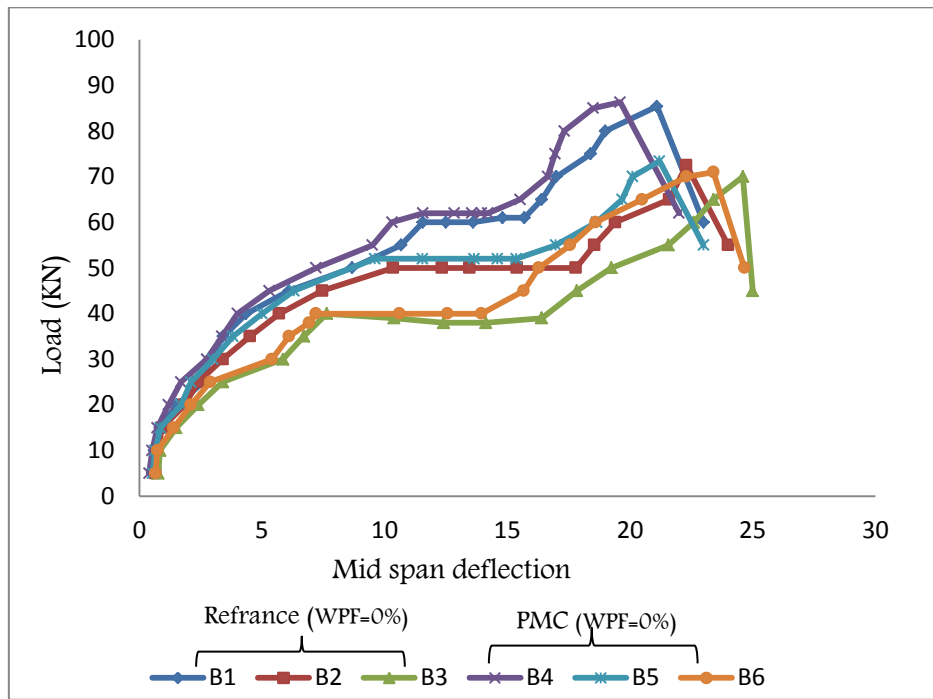


Figure 4. Load - deflection curve for with reference beams and (PMC) beams (WPF=0%)

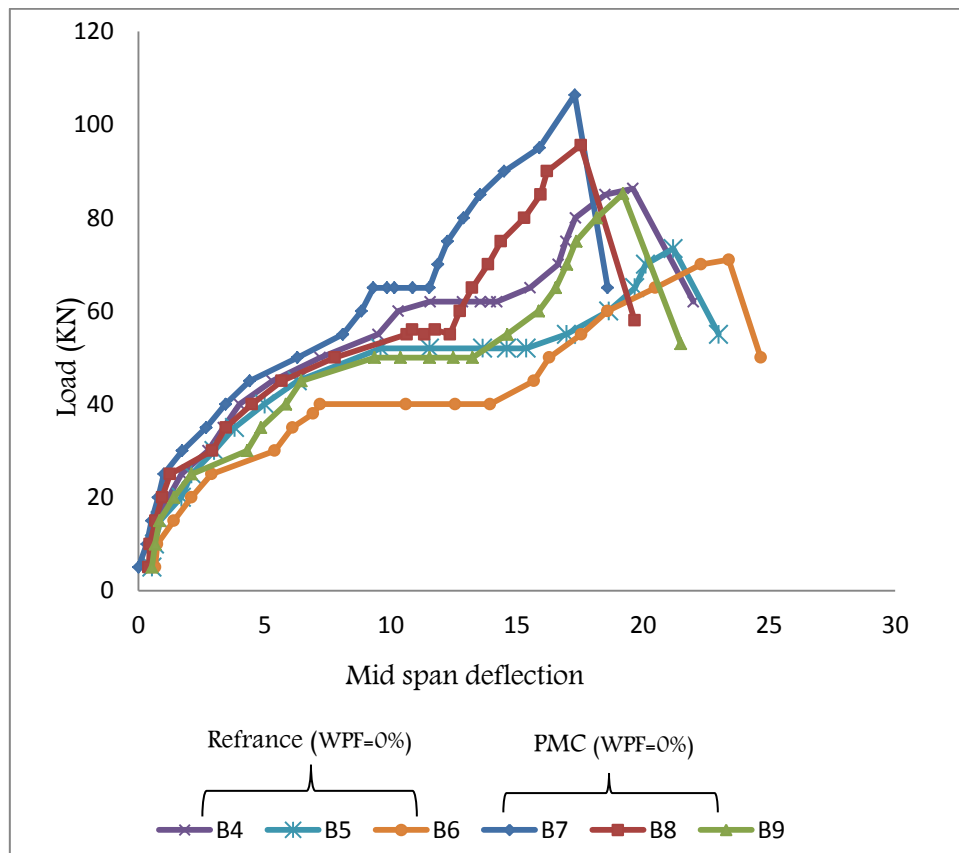


Figure 5. Load - deflection curve for (PMC) beams with (WPF) (0 and 0.75)%

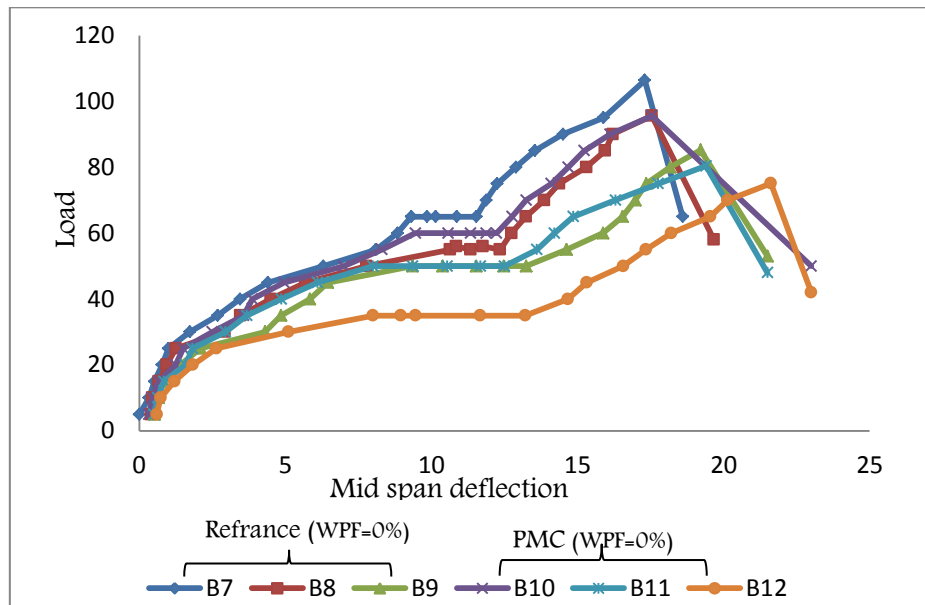


Figure 6. Load - deflection curve for (PMC) beams with (WPF) (0.75 and 1.25)%

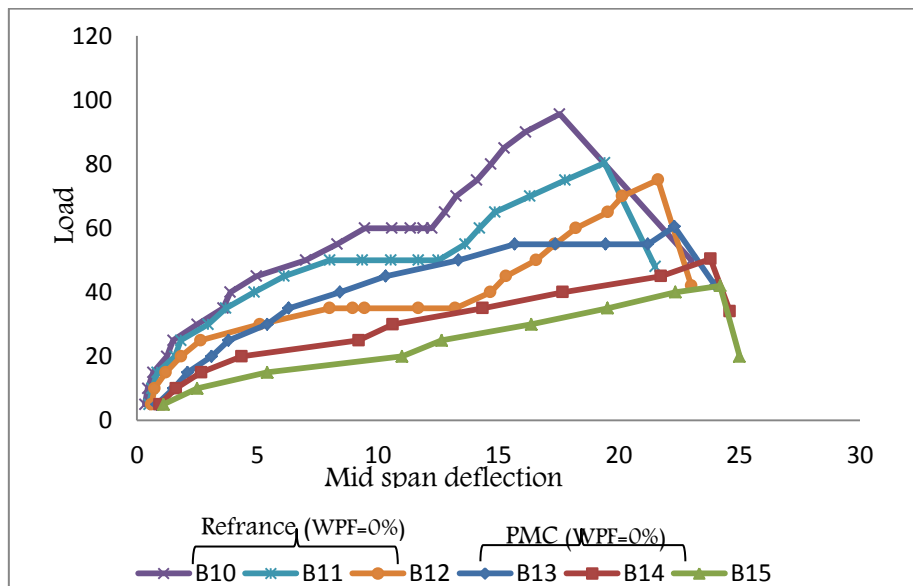


Figure 7. Load - deflection curve for (PMC) beams with (WPF) (1.25 and 1.75)%

### 3.5 Effect of the amount of tension reinforcement

From table (9) for the (PMC) beams which has the same waste plastic ratio, but different amounts of reinforcement ratio. Up to yielding, it can be seen that the beam with the higher steel contents has a stiffer response in terms of load-deflection behaviour, due to the larger effective moment of inertia resulting from higher amount of tensile reinforcement.

In post-yielding stage, the specimens with higher steel content experiences less deflection. From fig. (8) we can notice that the increase in load capacity and rigidity in the post-yielding stage it depending on the increasing in steel content for the same compressive strength.

These results confirm similar predictions made by **Al-Al wani Asmaa** [27], **Al Rawi Mohammed** [26].

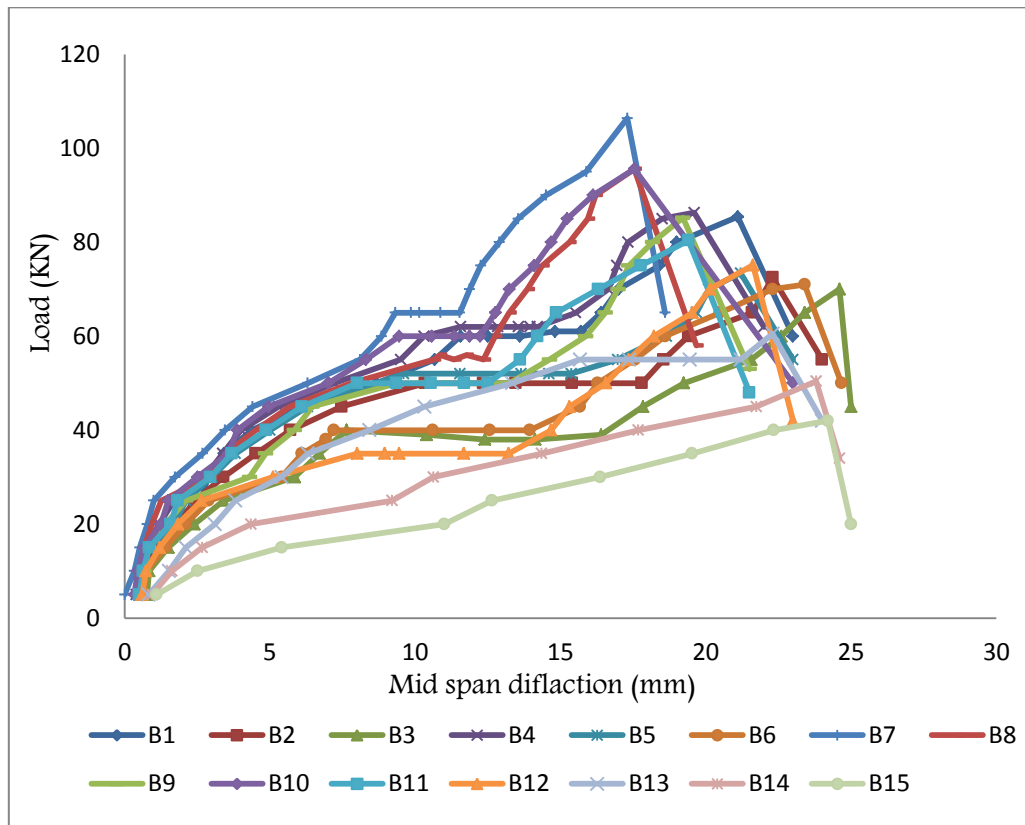


Figure 8. Load - deflection curve for all beams

## 2.6 Moment-Deflection Relationship

Figure (9) shows the moment-deflection curves for fifteen beams. In pre-cracking stage, deflection increases linearly with moment. The crack moment increases with the increase in concrete compressive strength and longitudinal reinforcement amount.

This means that deflection is reduced with an increase in compressive strength of concrete. But  $M/M_{cr}$  is reduced with the reduction in amount of longitudinal reinforcement due to the reduction in beam capacity.

Table (10) Deflection of cracking and moment of cracking of reinforced concrete beams

Beam No.	As (mm <sup>2</sup> )	Polymer %	WPF %	$\Delta_{cr}$ (mm)	$\Delta_u$ (mm)	$\Delta_u/\Delta_{cr}$	Mcr (KN.m)	Mu (KN.m)	Mu/Mcr
B1	0.0262	0	0	2.1	21.1	10.05	5.2	18.50	3.56
B2	0.0207	0	0	1.4	22.3	15.93	3.9	15.71	4.03
B3	0.0038	0	0	1.3	24.6	18.92	3.03	15.17	5.01
B4	0.0262	5	0	1.5	19.6	13.07	5.42	18.70	3.45
B5	0.0207	5	0	1.7	21.2	12.47	4.33	15.90	3.67
B6	0.0038	5	0	1.5	23.4	15.60	3.47	15.38	4.43
B7	0.0262	5	0.75	1.65	17.3	10.48	6.5	23.05	3.55
B8	0.0207	5	0.75	1.1	19.21	17.46	5.2	20.71	3.98
B9	0.0038	5	0.75	1.1	21.2	19.27	3.9	18.46	4.73
B10	0.0262	5	1.25	1.35	18.2	13.48	5.85	20.71	3.54
B11	0.0207	5	1.25	1.67	20.8	12.46	4.33	17.42	4.02
B12	0.003	5	1.25	1.42	21.62	15.23	3.68	16.27	4.42
B13	0.0262	5	1.75	2.4	22.3	9.29	4.33	13.11	3.03
B14	0.0207	5	1.75	2.3	23.8	10.35	3.03	10.92	3.60
B15	0.0038	5	1.75	3.4	24.2	7.12	2.38	9.10	3.82

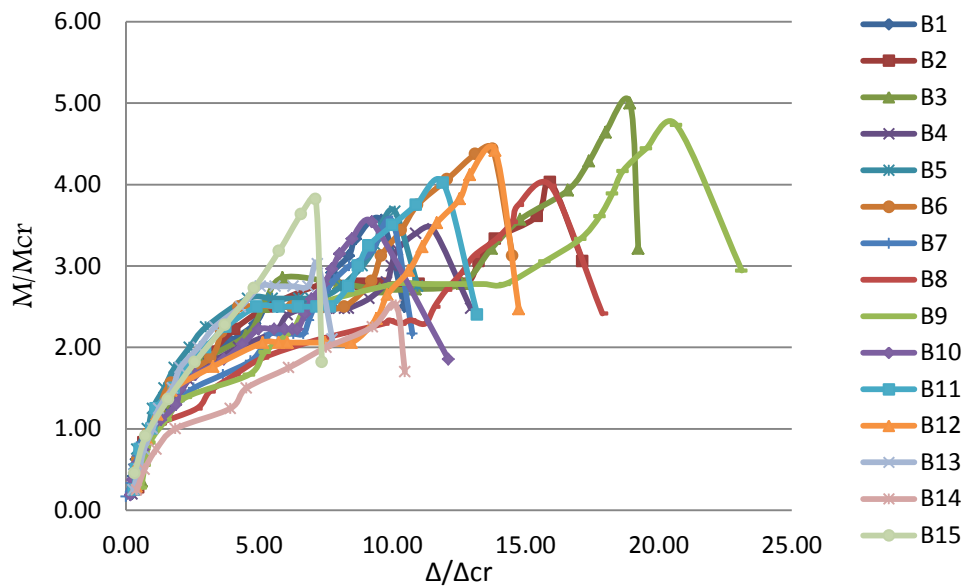


Figure 9. Moment versus mid-span deflection relationship for all beams

Crack patterns of the tested beams at failure are shown in plate (2). Cracking in the flexural span consists of predominately of vertical cracks. This is expectant since the concrete, which cracks perpendicular to the direction of maximum main stress, is subjected to longitudinal tensile stresses that are induced by the pure moment.

First crack prevalence outside the pure moment region is similar to flexural cracking. However, inclined cracking then, began due to the existence of increasing shear stresses as the load is increased. The joining of the inclined crack to a flexural crack outcome in a flexural shear crack. That means failure in these beams is flexural-shear failure. Failure occur to due to the propagation of these cracks toward the proximity of the point load at the compressive beams face .

For the beams with lower reinforcement in this study, (B3, B6, B9, B12, B15) the crack propagation is inside the pure moment and it is similar to flexural crack. These flexural cracks grow upward with an increase of the applied load until failure. The failure in these beams is fundamentally flexural failure. Number of cracks and length of crack growth in beams made by polymer modified concrete with waste plastic fiber are greater than that of references beam as shown in plate (2). In general cracks of beams made of polymer.

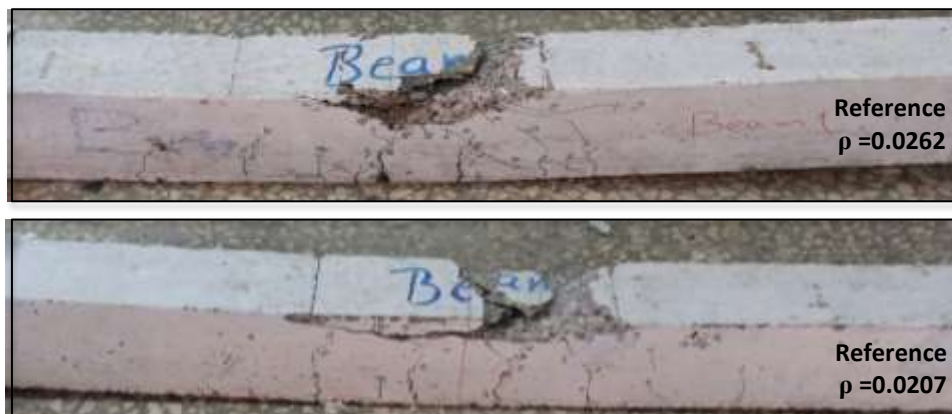






Plate 2. Failure mode of reinforced concrete beams made by polymer modified concrete with waste plastic fibre

### 3.7 Ductility

Member ductility is better expressed in terms of deflection. Deflection-ductility is defined as the ratio of deflection at eventual to the deflection at the yielding of the tensile steel. Ultimate stage is defined as the stage beyond which it was felt through the testing that the beam would not be able to sustain additional deformation at the same load intensity [28].

Results of ductility index ( $\mu_d$ ) are listed in table (9).

With the decrease in tensile reinforcement ratio ( $\rho$ ) the ( $\mu_d$ ) will increase as the results shown in fig.(10), for example for beams (B1,  $\rho=0.0262$ ), (B2,  $\rho=0.0207$ ) and (B3,  $\rho=0.0038$ ) the ductility index ( $\mu_d$ ) was (1.83, 2.16 and 3.22).

From the table (9) and fig.(11) we can see that for the same amount of reinforcement the  $\rho$  decrease with the proportion of fibre additives fairly certain percentage and then begin less again.

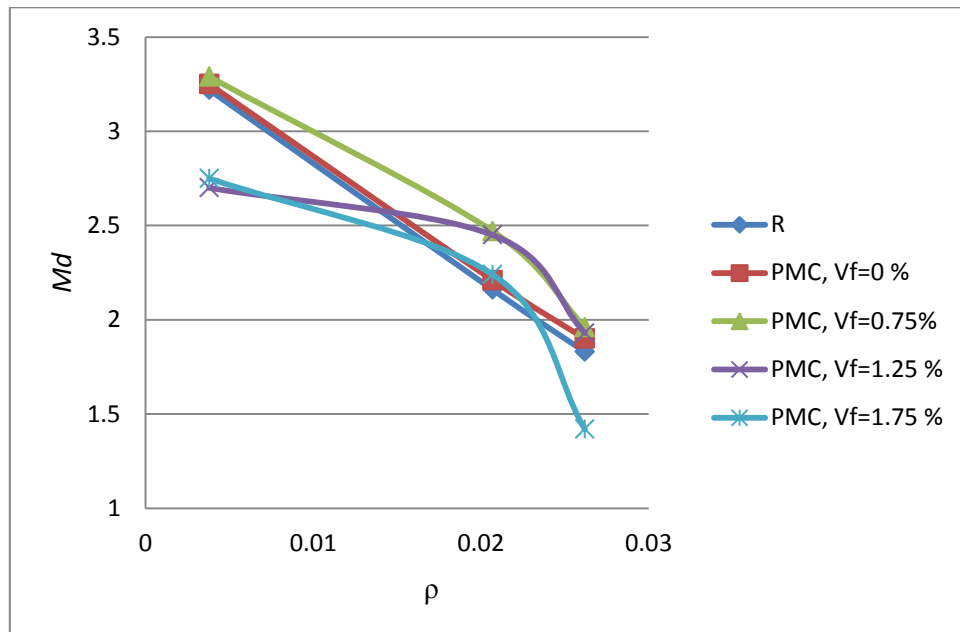


Figure 10. Effect of reinforcement ratio ( $\rho$ ) on ductility index ( $\mu_d$ ).

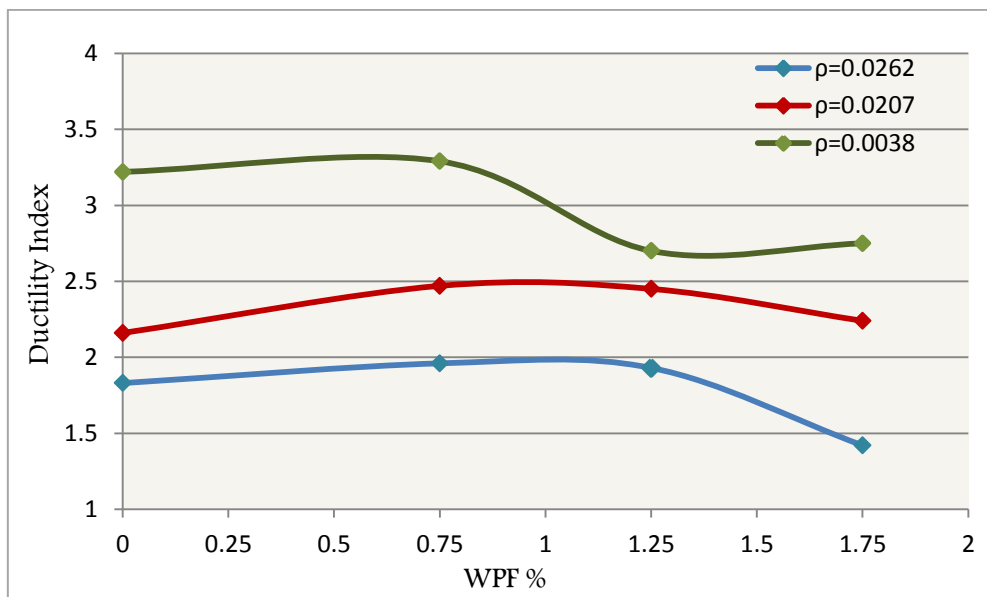


Figure 11. Effect of WPF on ductility index ( $\mu_d$ ).

## 4. Conclusions

Based on the research works, the following conclusions can be drawn:

- The maximum applied load on the beam increased extensive to gather fiber ratio until (ratio 1.25%) after then, it is decreased after ratio (1.25%).
- Addition waste plastic fiber to (PMC) reduces the value of deflection for all beams until percentage (1.75%).
- The presence of (PMC) with waste plastic fiber had transformed the mod of failure of the tested beams into a more ductile one.



- An improvement in compressive strength is significantly noticed with an increase of WPF volume up to ( $V_f 0.75\%$ ), and at that volumetric percentage the value of the increment in compressive strength at 28 day age of test was equal to (5%).
- An improvement in flexural strength is significantly noticed with an increase of WPF volume up to ( $V_f 1.25\%$ ), and at that volumetric percentage the value of the increment in flexural strength at 28 day age of test was equal to (11.97%).

## References

- Shetty, M., S., and Sikand, Dinesh, "Application of Polymer Concrete in Developing Countries", Int. Symposium, Sp-58, ACI, Detroit, 1978, pp. 205-214.
- Al-Obaidi Zayd, "The Possibility of Enhancing The Impact Strength Property of Ferro Cement Panels by Using Waste Plastic Fibers", M.Sc. Thesis, Dep. of Civil Eng., Univ. of Al Anbar, 2013.
- د. محمود احمد امام , "الخرسانة", الجزء الاول , جامعة المنصورة  
4.الحديثي عبدالقادر اسماعيل, خالد بتال نجم و طارق علي ذاكر, " سلوك العتبات المصنعة من الخرسانة المحورة بالبوليمر والخالية من الركام الناعم". جماد الاول, 2007.
- Mc Crum, N. G., Buckley, C. P., and Bucknafi, C. B, "Principles of Polymer Engineering", Oxford University Press, 2Ed, 1997, 447 pp.
- B.V.Kiran Kumar and P.Prakash, "Use of Waste Plastics Cement Content Pavemente", pp.12
- Zainab Z. Ismail and Enas A. AL-Hashmi, " Use of Waste Plastic in Concrete Mixture as Aggregate Replacement", Waste Management, 28, 2008, pp. 2041–2047
- Khalaf Jumaa, "A Study on the Utility of Waste Materials to Produce Green Concrete", M.Sc. Thesis, Dep. of Civil Eng., Univ. of Mustansiriyah, 2013.
- المواصفات العراقية / 5 ، " السمنت البورتلاندي " ، الجهاز المركزي للتقييس و السيطرة النوعية، بغداد 1999 ، صفحة 8 و 10 . المواصفات العراقية ، المواصفة القياسية رقم 45 "ركام المصادر الطبيعية المستعملة في الخرسانة والبناء"، الجهاز المركزي للتقييس والسيطرة النوعية، بغداد، 1984.
- SBI manual, "Speciality Building Industries", United Arab Emirates, [www.sbi-me.com](http://www.sbi-me.com).
- Khalid B. N., "Using high Performance Steel Fiber Concrete to Improve The Impact Strength Property", M.Sc. Thesis, Dep. of Civil Eng., Univ. of Technology, 1997.
- ASTM-C- 494, Types G and F and BS, EN 934, part 2, 2001.
- ASTM, "Standard Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement," A 615M/A 615-03, 2003.
- ASTM C-192, "Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory", 1988.
- B.S.1881, Part 116, "Method for Determination of Compressive Strength of Concrete Cubes", British Standard Institution, 1989,p.3.
- ASTM C-192, "Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory", 1988.
- ASTM C293-86, "Standard Test Method for Flexural Strength of Concrete Using Simple Beam with Two Points Loading", Annual Book of ASTM Standard, Vol. 04.02, 1989, pp. 194-196.
- Ohama , Y. " Polymer-based Admixtures". Cement and Concrete Composites J.1998, 20:189-212.
- Al-Hadithi Abdulkader Ismail, Al-Ejbari Ahmed Tareq and Ghassan Sbhee, "Behaviour of Waste Plastic Fiber Concrete Slabs Under Low Velocity Impact", Iraqi Journal of civil engineering Vol. 9(1), pp. 135-148.
- AL-Kubaysi Gassan Subhi, "Mechanical and Some Thermal Properties of Fiber Concrete Containing Acrylic Polymer", M.Sc. Thesis, Dep. of Civil Eng., Univ. of Al Anbar, 2008.
- Al-Hadithi Abdulkader Ismail and Shelaan Mahmood, " Some Properties of Polymer Modified Concrete Containing (PET) Plastic Fiber" The Iraqi Journal For Mechanical And Material Engineering, pp. 653-664.
- Bing Chen and Juanyu Liu, " Mechanical properties of polymer-modified concretes containing expanded polystyrene beads", construction and building materials, Univ. Shanghai Jiaotong and Texas, August 2005, pp.5
- Al-Dulaimi Mohammed Tarrad, "Impact and Mechanical properties For Ferro-Cement Slabs Modified By polymer", M.Sc. Thesis, Dep. of Civil Eng., Univ. of Al Anbar, 2009.
- Karim S. Rebeiz, David and Donald R. PauP, " Recycling Plastics In Polymer Concrete For Construction Applications" Vol. 5, No. 2, May, 1993.
- Al-Rawi Mohammed Issa, "Flexural Behavior Of Reinforced Concrete Beams Enhancement With Waste Plastic Fibers", M.Sc. Thesis, Dep. of Civil Eng., Univ. of Tikrit, 2011.
- Al-alwani assmaa khalaf, "Flexural rigidity of reinforced local porcelinite lightweight aggregate concrete beams", M.Sc. Thesis, Dep. of Civil Eng., Univ. of Al Anbar, 2011.
- Magda I. Mousa, " Flexural behaviour and ductility of high strength concrete (HSC) beams with tension lap splice", Alexandria Engineering Journal, No. 54, 2015, pp. 551–563