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Research Article

Effect of polyethylene terephthalate (PET) and polypropylene (PP) fibers on the shear behavior of RC deep beams

Ali Ramhormozy[1], Ehsan Kazeminezhad[2, *], Soroush Safakhah[3]

[1] Department of civil engineering, Ahvaz Branch, Islamic Azad University, Ahvaz (Iran); A.rmz5275@gmail.com
[2] Department of civil engineering, Ahvaz Branch, Islamic Azad University, Ahvaz (Iran); ehsan-kazeminezhad@iauahvaz.ac.ir
[3] Department of civil engineering, Semnan Branch, Islamic Azad University, Semnan (Iran); safakhah@semnaniau.ac.ir
*Correspondence: ehsan-kazeminezhad@iauahvaz.ac.ir

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Abstract: Today, environmental health needs more attention than in the past. Objects consisting of plastic materials such as bottles take many years to decompose. Therefore, in the recent years, a lot of research has been done to reuse them and one of which is use in the concrete mixes. In previous research, very low percentages of these materials (between 0.5% and 1.5%) has been used as fine aggregate substitutes in the concrete and evaluations have more focused on the flexural strength. In this research, Polyethylene terephthalate (PET) as a substitute for sand and Polypropylene fibers (PP) as an additive material are used in the concrete mixes. 14 concrete beams in both reinforced and unreinforced states have been evaluated. The replacement percentage of the PET is 10, 30 and 60% and additive percentage of the PP is 0.5, 1.5 and 3% of the total weight of concrete. The dimensions of the beams have been chosen in such a way to categorized in the deep beams. So, rectangular cross-section has been considered (width = 100mm and height = 400mm). Shear strength and ductility are two important parameters that have been evaluated in this research.

Keywords: Polyethylene terephthalate (PET), Polypropylene fibers (PP), deep beam, shear strength, ductility.

1. Introduction

Structural materials such as concrete have a vital role in the construction. Due to its low tensile strength and high specific weight engineers are always looking for alternatives such as recycled and lightweight materials instead of fine and coarse aggregate. Since environmental health is so important, effective recycled materials can contribute to this health cycle. Plastics have attracted the attention of engineers for use in the concrete because they take a long time to decompose and can damage to the environment. Polyethylene terephthalate belongs to the family of polyesters. It is extensively used in all places and is recyclable. PET is among those plastics which are an important part of our daily life. For all the applications demanding lightweight and impact-resistant material, PET is applicable. Polypropylene is a type of polyolefin which is slightly harder in comparison with polyethylene. It is a commodity plastic with low density and high heat resistance. In this research polyethylene terephthalate (PET) is used as alternative material instead of fine aggregate (sand) and polypropylene fiber (PP) is used as additive material in the concrete mixes. The PP fibers were added with percentages of 0.5, 1.5 and 3 of the total weight of the mixture. Polypropylene fibers are produced as an industrial process and are usually provided as straight strands in lengths of 6 and 12 mm. These materials have unique properties such as low specific weight and high tensile strength. The PP is more used in chemical industry, energy, clothing, environmental protection and construction. In the previous research, very low percentages of PET (between 0.5% and 1.5%) have been used as fine aggregate substitutes in concrete and have focused more on flexural strength. Polyethylene terephthalate is a white, stiff, and light-weight material that is extensively applied in industry. One existing method is applying polyethylene terephthalate as narrow fiber in civil engineering construction. It controls the formation of cracks and increases ductility for tensile concrete.

In this research, instead of using PET as fibers, we have considered it as an alternative fine aggregate in the concrete. In most research works, the flexural behavior of concrete beams has been studied, while in this study, the shear performance of deep beams has been studied. RC deep beams are used in many kinds of structures such as tall buildings, offshore and onshore structures and wall. The net span length of a deep beam is lower than four times of the beam depth and typically used in high rise building structures as shear walls and transfer girders (In this research the net span of the beams is 1000 mm while four times the beam depth is 1600 mm). Past works such as Foti (2011), Chung et al. (2013) and Al-Hadithi and Hilal (2019) have also investigated reinforced concrete beams, while in this research both reinforced concrete beams and non-reinforced concrete beams have been investigated. Ali et al. (2022) studied the flexural efficiency of polyethylene terephthalate fiber RC beams and evaluated ductility using the layered distribution.

Inclusion of 0.5% PET fibers to the normal concrete led to increased mechanical properties (compressive strength and elastic modulus). However, further increase in PET fibers content reduced the compressive strength and elastic modulus. Al-Hadithi and Hilal (2019) studied attributes of self-compacting concrete by adding plastic fibers and indicated that the plastic fibers have negative influence on the fresh properties of concrete and improvement by hardened properties. The addition of PET fibers at different volumes to SCC led to an enhancement in compressive strength at all ratios. Mohammed and Rahim (2020) analyzed performance of RC beams strengthened with polyethylene terephthalate fiber and decrease in compressive strength was showed. Cracking performance of the beam was enhanced, but PET fiber has no appreciable effect on the ultimate load capacity. Adnan and Dawood (2020) evaluated the performance of RC beam using recycle of polyethylene terephthalate as synthetic fibers and showed all RC beams with polyethylene terephthalate fibers had a few reduce in peak load in comparison with the control beam. Khan and Ayub (2020) analyzed the flexural and shear behavior of self-compacting RC beams with PET fibers and reported the effect of polyethylene terephthalate on the ductile behavior of reinforced concrete beams and maximum 13% increase was observed in the loading capacity for the beams with PET fibers and strips in the beams detailed for the flexural mode of failure.

Foti (2013) used recycled polyethylene terephthalate fibers to use in concrete and showed that more ductile behavior than typical concrete. Kim et al. (2010) evaluated structural efficiency of polyethylene terephthalate RC beams and showed that polyethylene terephthalate concrete experienced a little decrease in modulus of elasticity as the fiber dosage increased. Foti (2011) studied the concrete with PET and analyzed it effect on the ductility. Chung et al. (2013) evaluated the influence of fire on the slabs were constructed with polypropylene fiber concrete and confirmed that mixing RC with PP fiber can enhance residual load-carrying capacity after fire exposure. Murad and Abder-Jabbar (2022) investigated shear performance of reinforced concrete beams constructed with basalt and PP fibers and showed that the best proportion of basalt and polypropylene fibers that enhanced the shear behavior of RC beams were found at 2.5% and 0.6%, respectively. Ruslan et al. (2022) evaluated the effect of the PP fiber on rheological behavior of the concrete composition.

The influence of type and amount of investigated fiber on compression and bending strength, crack resistance and impact strength of fine-grained concrete obtained by activation of Portland cement in VLD was determined. It has been found that the greatest increase in bending strength is observed by introducing "Chelyabinka" metal fiber 36 mm long (up to 1.65 times), and polypropylene fiber 18 mm long – up to 1.4 times. Polypropylene fiber increases the crack resistance by 1.57 times, but metal fiber increases the impact. Akin et al. (2022) evaluated the influence of PP fibers on the reinforced concrete beams. Damage analysis indicated that cracks occur earlier in beams with insufficient lap splice length. For the beams with fiber additives, compared with the reference beam, cracks occur earlier in the PP-reinforced beam and later in the MS-reinforced beams. In addition, it has been observed that the addition of macro-synthetic fibers delays crack propagation in beams with insufficient lap splice. Hadi et al. (2022) studied the full-scale experimental evaluation of flexural strength and ductility of reinforced concrete beams strengthened with various FRP mechanisms and showed that the combination of FRP reinforcement and FRP sheet has the maximum increase in the flexural capacity of the concrete beams. In this research seven reinforced and seven unreinforced concrete beams are considered. The objective of this study is evaluating the effect of PP and PET materials on the shear strength and ductility of concrete beams. The dimensions of the beams have been chosen in such a way that they have similar performance to deep beams (width = 100mm and height = 400mm). In the first part typical reinforced concrete beam constructed with common material as control beam. Three reinforced concrete beams with 10, 30 and 60% PET instead of fine aggregate and three other reinforced concrete beams by adding 0.5, 1.5 and 3.0% of PP were constructed. In the second part, all previous beams reconstructed with the same combination but without longitudinal and transverse reinforcement. Finally, beams were subjected to three-point loading and the shear strength, yield point, cracks and ductility of them were compared with the the control samples.

2. Materials and methods

2.1. *Materials*

In this study, common type of cement (ordinary Portland cement) has been used to prepare the concrete mixes. The maximum size of fine and coarse aggregate is 4.75 and 10 mm, respectively. PET materials were sharded in such a way that they passed through the grade 4 sieve and remained on the grade 200 sieve (the holes of grade 4 sieve are 4.75 mm and the holes of grade 200 sieve are 0.075 mm) and PP material was used with 12 mm length. Figure 1 shows the PET and PP materials. Longitudinal and transverse reinforcement with 12 and 6 mm in diameter have been used, respectively. Mechanical properties of steel reinforcement of RC beams are presented in the Table 1. Two longitudinal steel reinforcement (Ø12mm) have been used at bottom of the beam and steel bars of Ø6mm have been used as transverse reinforcement and repeated every 100 mm.

(a) (b)

Figure 1. Materials. a) PET, b) PP.

Table 1. Mechanical properties of steel bars.

Yielding strength (MPa)	Diameter of longitudinal reinforcement (mm)	Diameter of transverse reinforcement (mm)
400	12	6

2.2 Concrete mix proportions

The concrete mix that used in the present research has been designed based on the American Concrete Institute (ACI 318). Seven various concrete mix is considered. Table 2 indicates the mixing properties. As showed in the Table 2, mixing plan number one is related to the concrete with ordinary materials, mixing plan number 2, 3 and 4 is related to the concrete with replacing 10, 30 and 60% PET instead of the fine aggregate (sand). Also, mixing plan number 5, 6 and 7 is related to the concrete with adding 0.5, 1.5 and 3% PP in the concrete mixes.

Table 2. Various concrete mixes (kg).

Mix	PET %	PP %	Cement	Coarse aggregate	Fine aggregate	Water	PET	PP
1	0	0			46.28		0	0
2	10	0			41.65		4.63	0
3	30	0			32.40		13.88	0
4	60	0	20.8	51.48	18.50	8.68	27.77	0
5	0	0.5			46.28		0	0.64
6	0	1.5			46.28		0	1.91
7	0	3.0			46.28		0	3.82

2.3 Preparation of samples

In this research, the experimental work has been done in two parts; in the first part, cubic samples (150 × 150 × 150 mm) were made for all the mixing design and compressive strength was determined. In the second part, fourteen beams were constructed by mixing plan No.1 to No.7 (seven beams are reinforced and other seven beams are unreinforced). Figure 2 shows the reinforced and unreinforced concrete beams. Table 3 describes the beams classification. Because the shear strength of the beams is the sum of the shear strength of concrete and reinforcements, in this research, it has been tried to investigate the effect of fibers (PET and PP) on the beam with and without reinforcements.

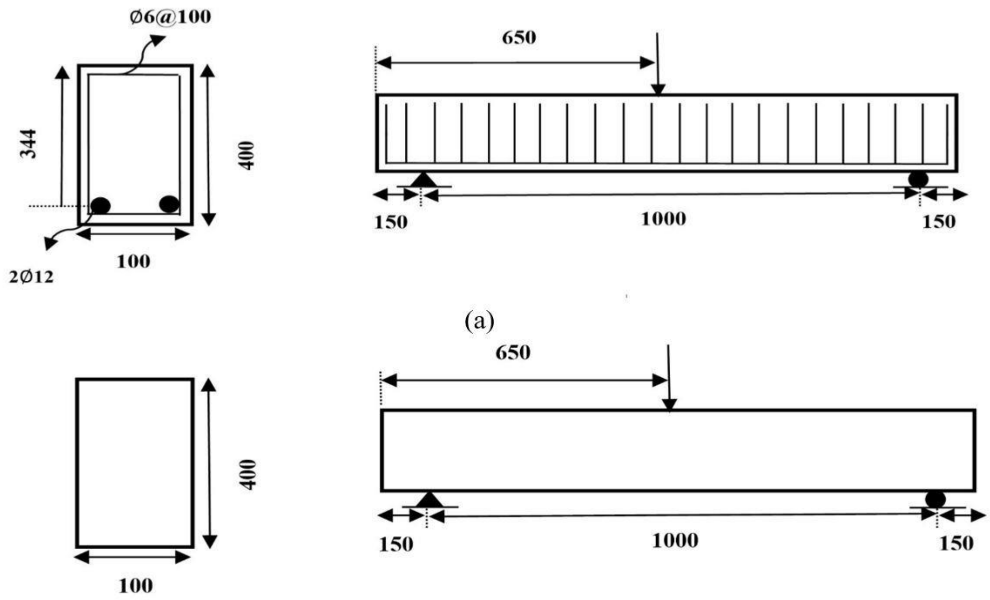


Figure 2. Concrete beams, a: Reinforced beams, b: Unreinforced beams (all dimensions are in mm)

Table 3. Beams classification.

Reinforced beams		Unreinforced beam		Mixing design
Beams	ID	Beams	ID	
Control beam(0%PET-0%PP)	CB-R	Control beam(0%PET-0%PP)	CB	1
10%PET replaced with fine aggregate	10%PET-R	10%PET replaced with fine aggregate	10%PET	2
30%PET replaced with fine aggregate	30%PET-R	30%PET replaced with fine aggregate	30%PET	3
60%PET replaced with fine aggregate	60%PET-R	60%PET replaced with fine aggregate	60%PET	4
0.5%PP add to mix	0.5%PP-R	0.5%PP add to mix	0.5%PP	5
1.5%PP add to mix	1.5%PP-R	1.5%PP add to mix	1.5%PP	6
3.0%PP add to mix	3.0%PP-R	3.0%PP add to mix	3.0%PP	7

2.4 Testing

2.4.1 Compressive strength

Compressive strength test was done based on the ASTM C39 for concrete mixes and three cubic samples with dimensions of 150 × 150 × 150mm was constructed and average of compressive strength is reported. Figure 3 shows a cubic concrete sample during the test. All tests were performed at 28 days of age of concrete. Table 4 indicates the results.

Figure 3. Details of compressive strength test apparatus and specimens.

Table 4. Compressive strength.

Mix	PET (%)	PP (%)	Average compressive strength (MPa)	Increase in compressive strength (%)
1	0	0	11.5	-
2	10	0	14.7	22
3	30	0	15.75	37
4	60	0	7.2	-38
5	0	0.5	25.65	123
6	0	1.5	19.7	71
7	0	3.0	6.37	-45

2.4.2 Shear test

The shear efficiency of the concrete beams in the present research has been evaluated by a hydraulic jack. The capacity of the jack is 500kN and velocity of loading (loading rate) is 1 mm/s. The loading setup includes two simple supports. The concentrate load is directly applied in the middle of the concrete beams. Figure 4 indicates the loading setup in the real and schematic view.

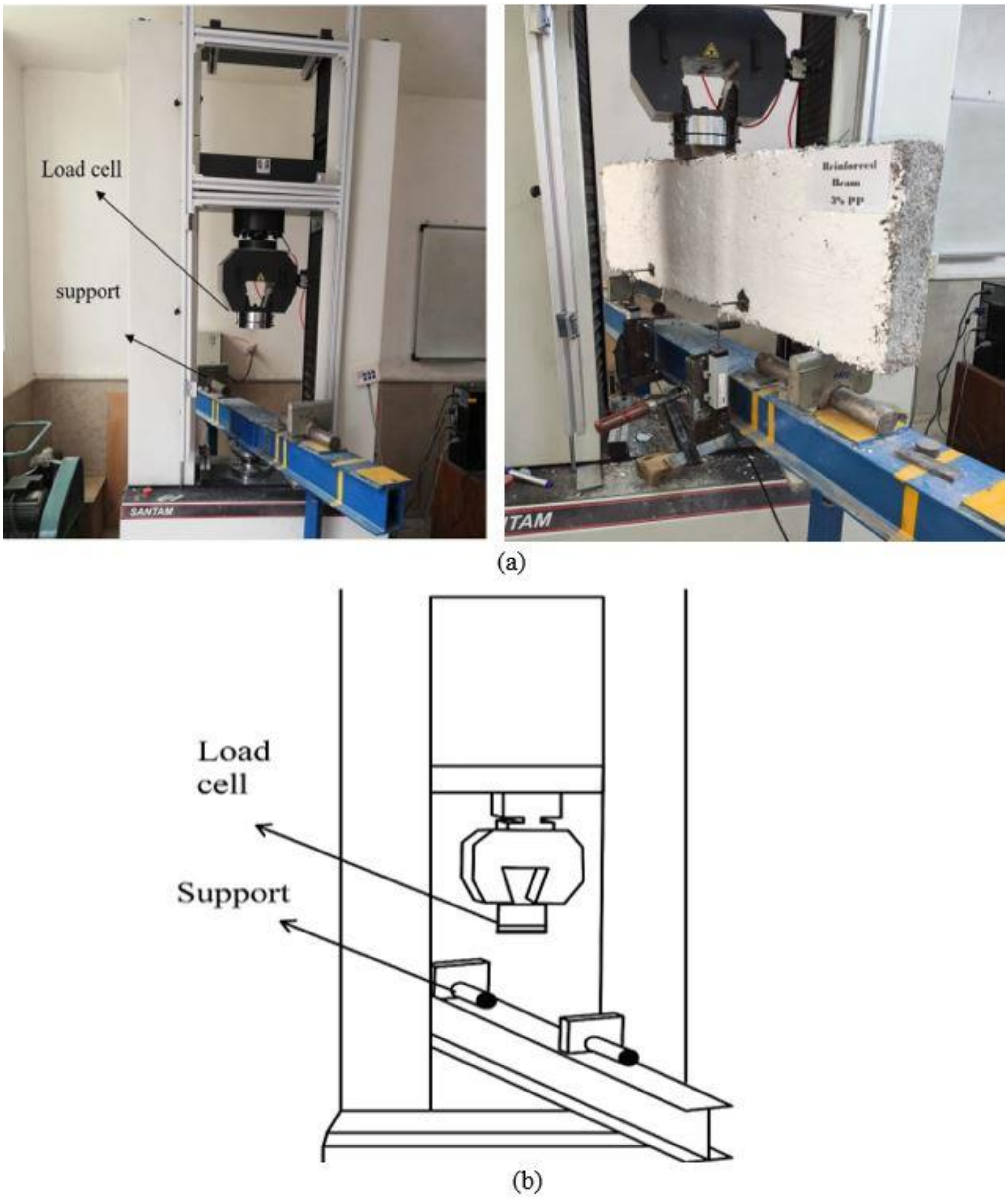


Figure 4. Loading setup; a) real view, b) schematic view.

The reinforced and unreinforced beams have been loaded at age of 28 days. The load – deflection of middle point of the beams (capacity curve) are achieved from the shear test. In this part, reinforced and unreinforced concrete beams with various percentage of PET and PP are investigated.

2.4.2.1 Reinforced concrete beam

In this part, seven RC beams due to evaluation the effect of PET and PP on the shear performance are performed. Control beam is prepared with mix No.1 and three other beams that contains PET are prepared with mix No.2 to No.4. PETs are used instead of a part of fine aggregate. Moreover, three other beams are containing 0.5, 1.5 and 3.0% polypropylene fiber that were added to concrete mixture (Polypropylene is used as a percentage of the total weight of the concrete) and prepared with mix No.5 to No.7. Figure 5 shows the loading procedure of the RC control beam (CB-R), 10 (10%PET-R), 30 (30%PET-R) and 60% PET RC beams (60%PET-R) and Figure 6 shows the cracks pattern.

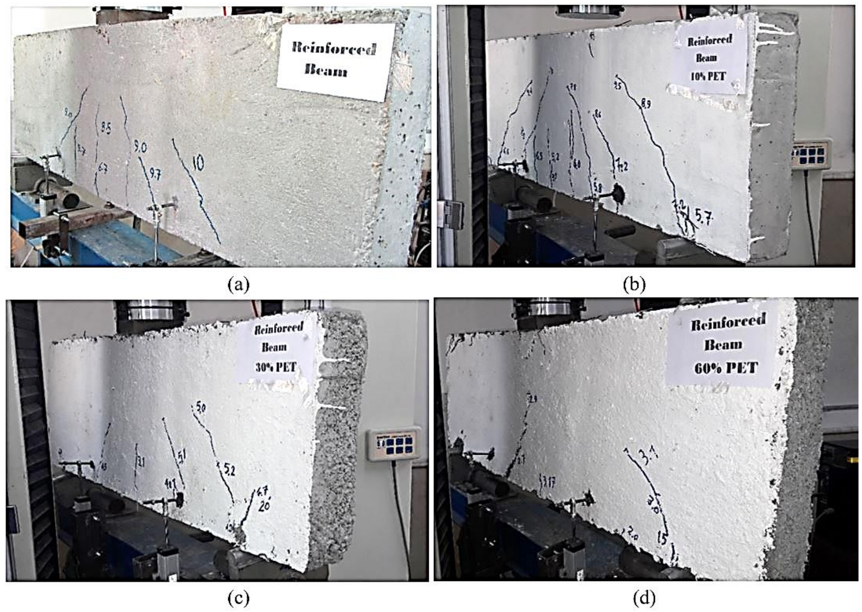


Figure 5. Loading procedure; a) control beam, b) 10%PET-R, c) 30%PET-R, d) 60%PET-R.

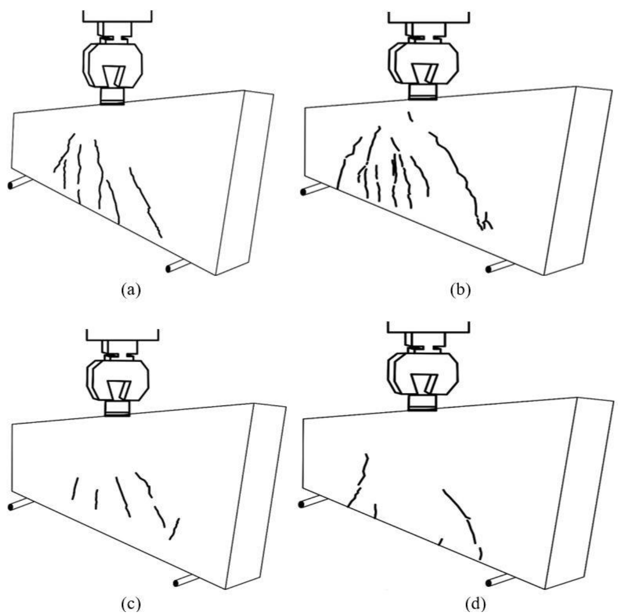


Figure 6. Cracks pattern; a) control beam, b) 10%PET-R, c) 30%PET-R, d) 60%PET-R.

Load – deflection curve of the middle point of the beams are compared with control beam. Figure 7 shows comparison between CB-R and 10, 30 and 60% PET-R, respectively.

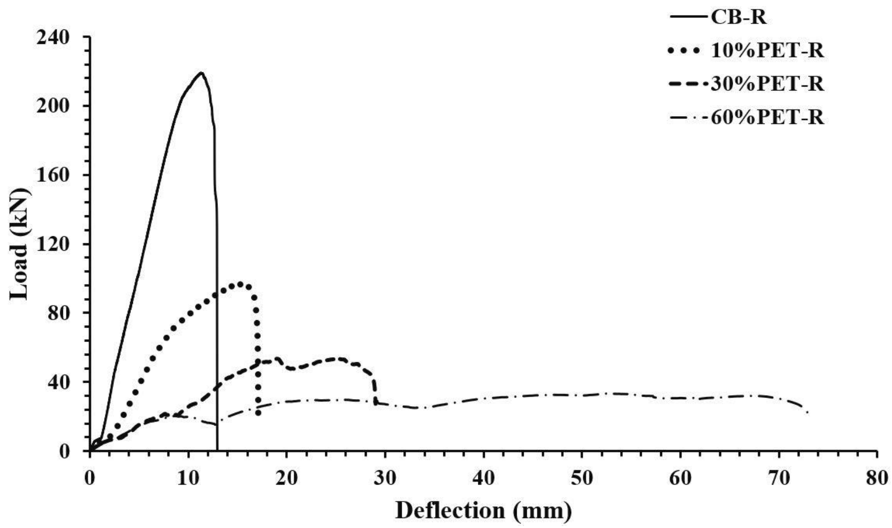


Figure 7. Comparing capacity curve of CB-R, 10%PET-R, 30%PET-R and 60%PET-R beams.

As showed in Figure 7, the shear strength is decreased significantly while the displacement corresponding to the failure point is increased. Three other beams that contains PP are constructed with mix No. 5 to No.7. The PP fibers are added to the concrete mix as a percentage of total concrete weight (0.5, 1.5 and 3.0%). Figure 8 shows the loading procedure of the RC control beam (CB-R), 0.5 (0.5%PP-R), 1.5 (1.5%PP-R) and 3.0% PP RC beam (3.0%PP-R) and Figure 9 shows the cracks pattern.

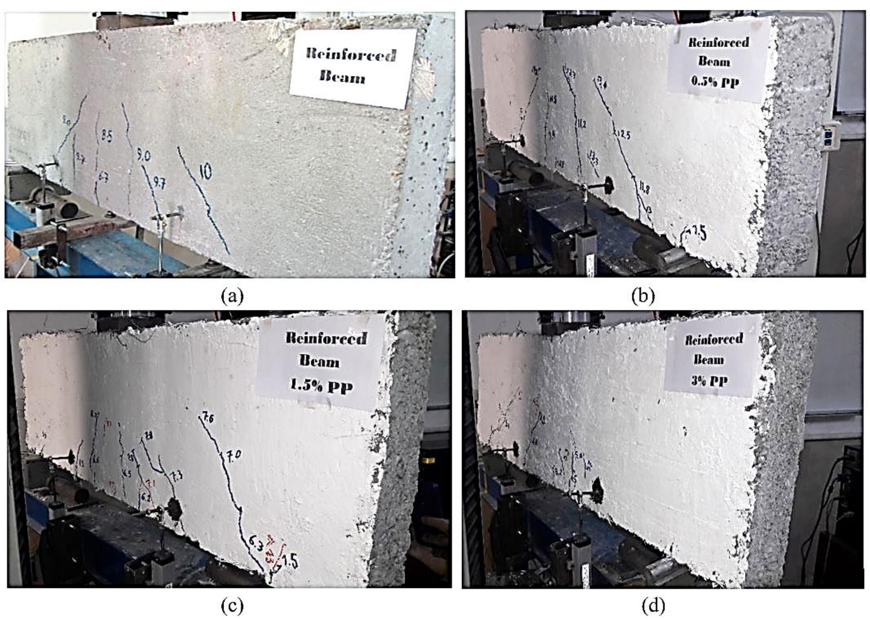


Figure 8. Loading procedure; a) control beam, b) 0.5%PP-R, c) 1.5%PP-R, d) 3.0%PP-R.

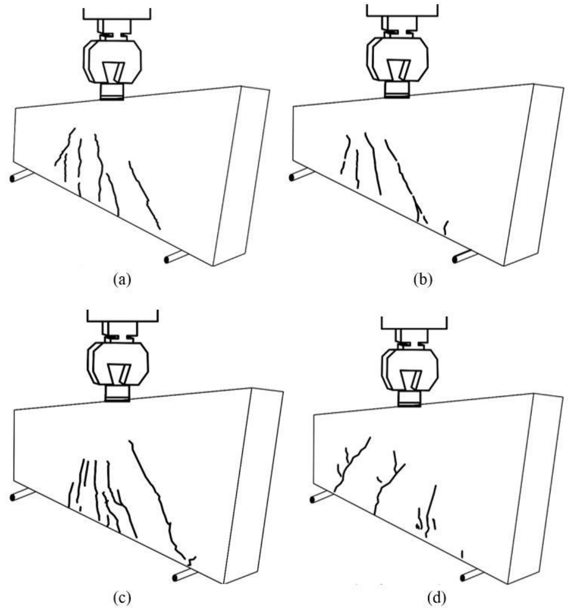


Figure 9. Crack pattern; a) control beam, b) 0.5%PP-R, c) 1.5%PP-R, d) 3.0%PP-R.

Load – deflection curve of the middle point of the beams are compared with control beam. Figure10 shows comparison between CB-R and 0.5, 1.5 and 3.0% PP-R, respectively.

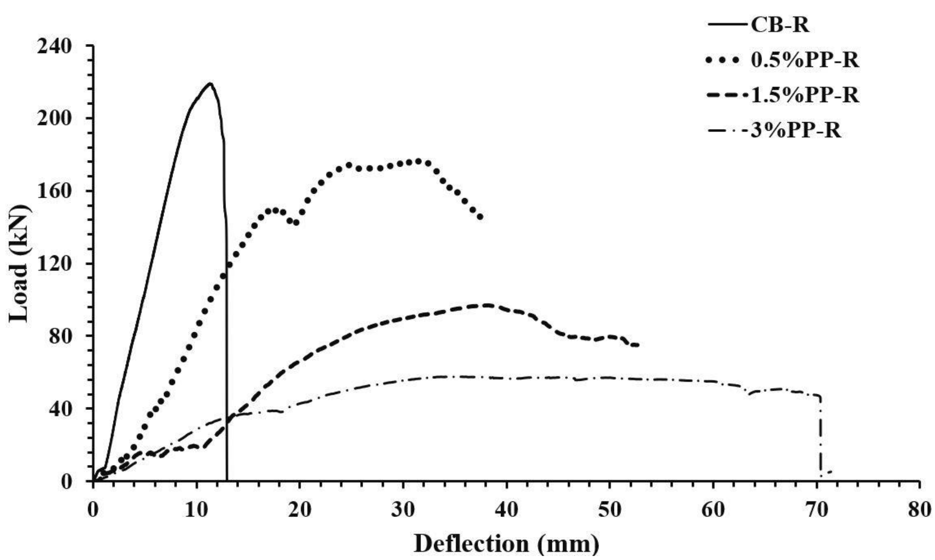


Figure 10. Comparing capacity curve of CB-R, 0.5%PP-R, 1.5%PP-R and 3.0%PP-R beams.

As showed in Figure10, the shear strength is decreased while the displacement corresponding to the failure point is increased.

2.4.2.1 Un-reinforced concrete beam

In this part seven unreinforced concrete beams due to evaluation effect of PET and PP on the shear performance are constructed. The control beam is prepared with mix No.1 and three other beams that contains PET are constructed with mix No. 2 to No.4. PETs are used instead of a part of fine aggregate. Figure 11 shows the loading procedure of the control beam (CB), 10 (10%PET), 30 (30%PET) and 60% PET RC beam (60%PET) and Figure 12 shows the cracks pattern.

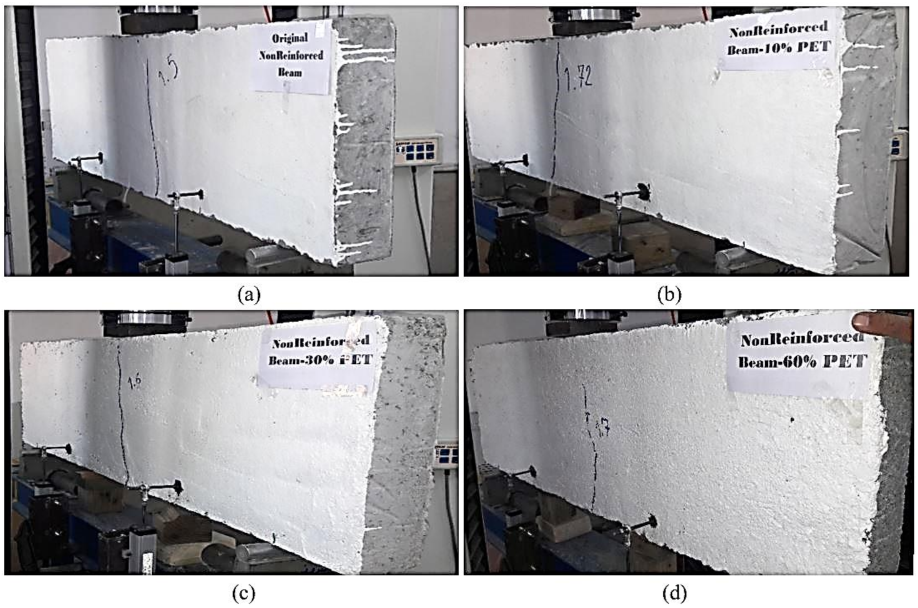


Figure 11. Loading procedure; a) control beam, b) 10 %PET, c) 30%PET, d) 60%PET.

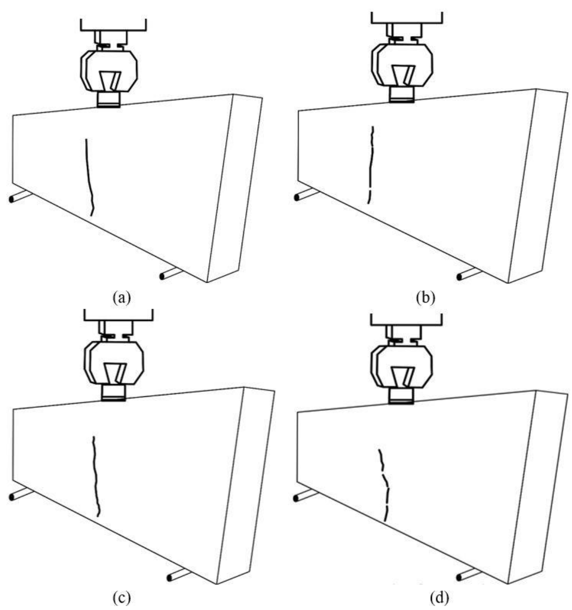


Figure 12. Cracks pattern; a) control beam, b) 10 %PET, c) 30%PET, d) 60%PET.

Load – deflection curve of middle point of beams are compared with the control beam. Figure 13 shows the comparison between CB and 10, 30 and 60% PET, respectively.

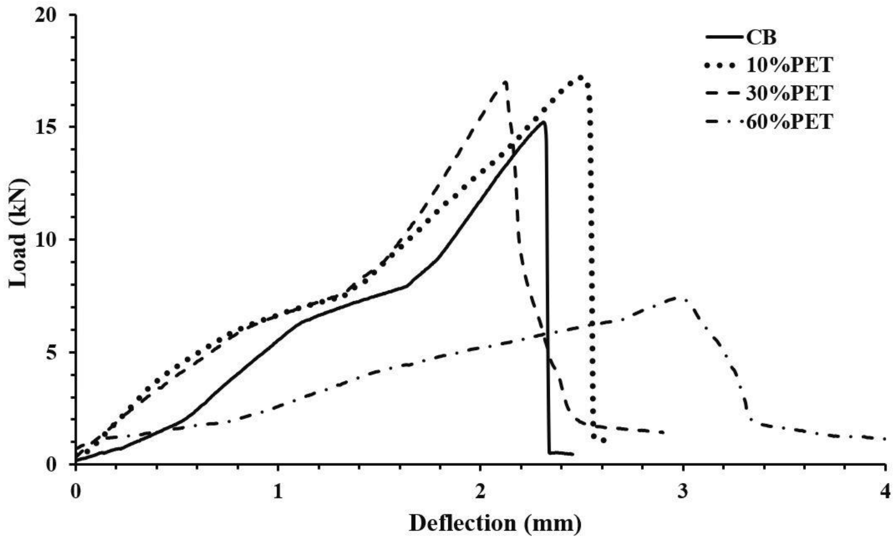


Figure 13. Comparing capacity curve of CB, 10%PET, 30%PET and 60%PET beams.

In the unreinforced beams with 10 and 30% PET material, the shear strength is increased and in the 60% of PET is decreased. In the beams with 10% and 60% PET the maximum displacement is increased and in the beam with 30% PET it's decreased.

Three other beams that contains PP are constructed with mix No. 5 to No.7. The PP fibers are added to the concrete mix as a percentage of total concrete weight (0.5, 1.5 and 3.0%). Figure 14 shows the loading procedure of control beam (CB), 0.5 (0.5%PP), 1.5 (1.5%PP) and 3.0% PP concrete beam (3.0%PP) and Figure 15 shows the cracks pattern.

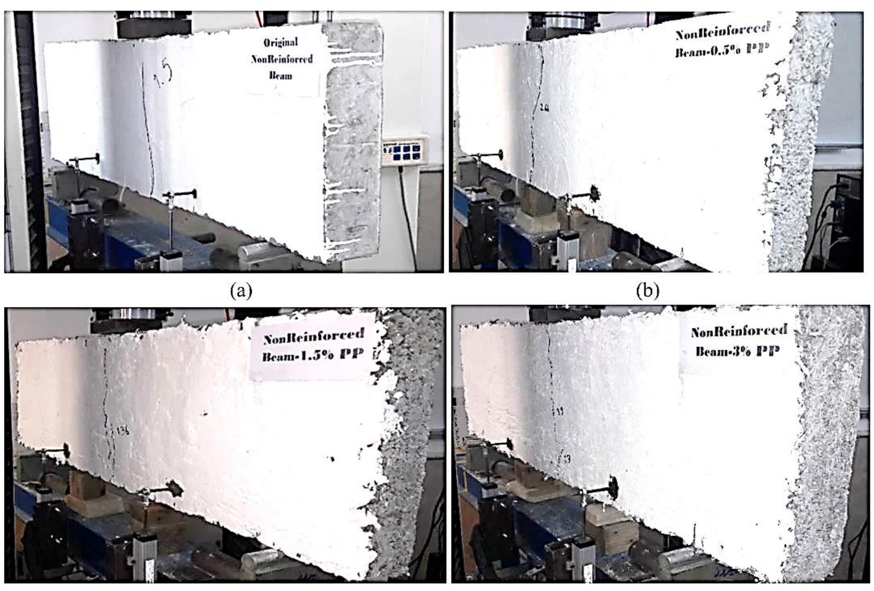


Figure 14. Loading procedure; a) control beam, b) 0.5 %PP, c) 1.5%PP, d) 3.0%PP.

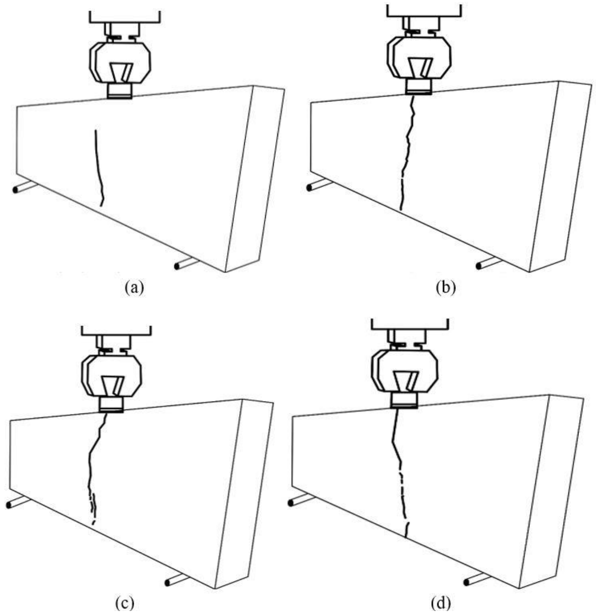


Figure 15. Cracks pattern; a) control beam, b) 0.5 %PP, c) 1.5%PP, d) 3.0%PP.

Load – deflection curve of the middle point of the beams are compared with the control beam. Figure 16 shows the comparison between CB and 0.5, 1.5 and 3.0% PP, respectively.

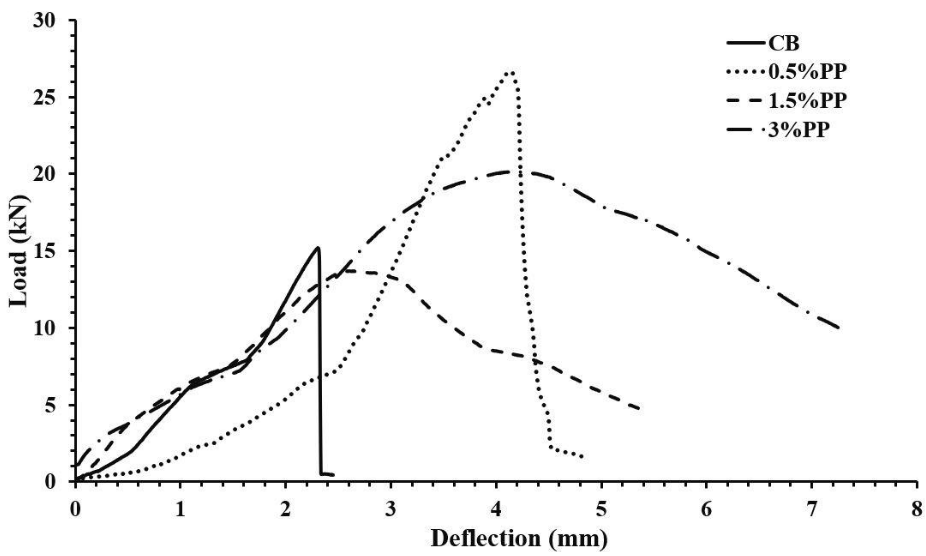


Figure 16. Comparing capacity curve of CB, 0.5%PP, 1.5%PP and 3.0%PP beams.

As showed in Figure 16, in the beams with 0.5% and 3% PP, the shear strength is significantly increased and in the beam with 1.5% PP it's decreased. In all the PP dosage the failure displacement significantly is increased.

3. Experimental results and analysis

3.1. Compressive standard test

The results achieved from compressive tests was showed in the Table 4. As indicated in the Figure 17 the inclusion of polyethylene terephthalate instead of a part of fine aggregate led to increase for 10 and 30% and decrease for 60% in the compressive strength. Also, the inclusion of the PP as a percentage of total concrete weight led to increase for 0.5 and 1.5% and decrease for 3.0% in the compressive strength.

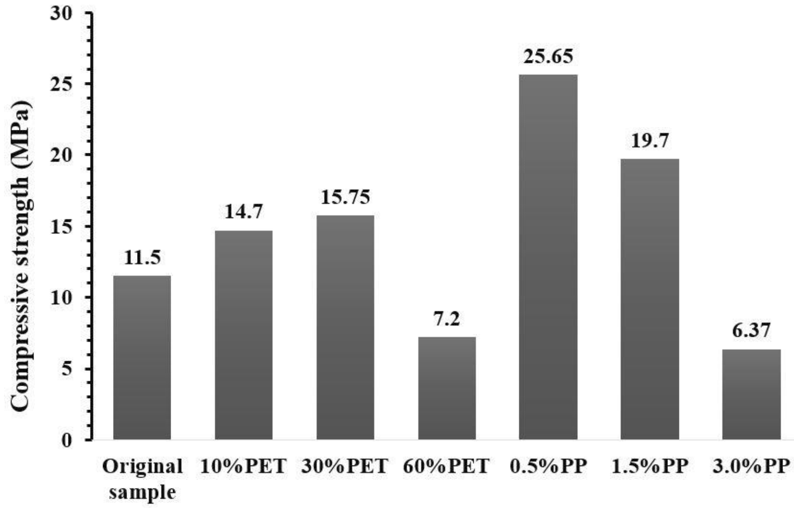


Figure 17. Influence of the PET and PP on the compressive strength.

In the cubic samples with 10 and 30% polyethylene terephthalate (PET) the compressive strength is increased as 22% and 37% in comparison with the control sample, respectively and in the sample with 60% polyethylene terephthalate (PET) sample led to decreased as 38%.

In the cubic samples with 0.5 and 1.5% polypropylene (PP) fiber the compressive strength is increased as 123 and 71% in comparison with the control sample, respectively and in 3% polyethylene terephthalate (PET) sample led to decrease as 45%.

3.2. Beams evaluation

The evaluation that has been done in this part of the research assigned for investigating the influence of the polyethylene terephthalate (PET) and polypropylene fibers (PP) on the shear efficiency of reinforced concrete beams and unreinforced concrete beams. The beams were loaded and results that were achieved are such as initial crack, yield load, peak load, ultimate load, deflection, and ductility. The peak point is related to the maximum load. The ultimate point was defined as the after maximum load dropped to 85% of the peak load. Pcr, Py, Pp, and Pu denote the first crack, yielding, peak, and ultimate load, respectively. Δcr, Δy, Δp, and Δu are the displacement of beams at the initial crack, yielding, maximum, and ultimate point, respectively.

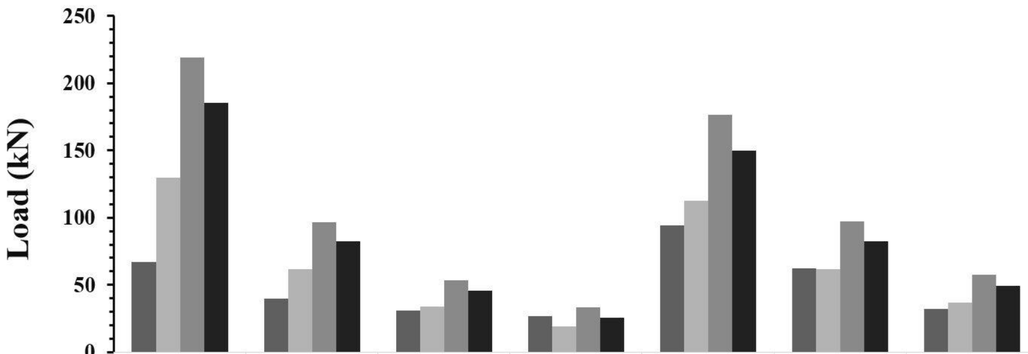
3.2.1 Reinforced beams

The test results are presented in the Table 5. Figure 18 indicates the initial cracks, yield load, peak capacity and ultimate load of the beams. Moreover, the ductility results are showed in Figure 19.

Table 5. Reinforced beam behavior.

Specimen	First crack		Yielding		Peak		Ultimate		Ductility
	P_{cr}	Δ_{cr}	P_y	Δ_y	P_p	Δ_p	P_u	Δ_u	$\mu = \frac{\Delta_{max}}{\Delta_y}$
CB-R	67	3.4	130	6.4	219.14	11.3	185.4	12.6	1.97
10%PET-R	40	5.16	61.71	7.33	96.8	14.97	82.28	16.9	2.31
30%PET-R	31	11.7	34.12	12.37	53.53	19.03	45.5	28.03	2.27
60%PET-R	27	18.6	19.2	7.7	33.41	52.74	25.6	72.3	9.39
0.5%PP-R	94	10.8	112.4	12.51	176.33	31.47	149.9	43.21	3.45
1.5%PP-R	62	18.7	61.81	18.75	96.96	38.2	82.42	44.82	2.39
3.0%PP-R	32	11.9	36.75	14.2	57.67	35.24	49	63.82	4.49

Force: kN Displacement: mm



	CB-R	10%PET-R	30%PET-R	60%PET-R	0.5%PP-R	1.5%PP-R	3.0%PP-R
First crack load	67	40	31	27	94	62	32
Yield load	130	61.71	34.12	19.2	112.4	61.81	36.75
Peak load	219.14	96.8	53.53	33.41	176.33	96.96	57.67
Ultimate load	185.4	82.28	45.5	25.6	149.9	82.42	49

Figure 18. Influence of the PET and PP on the RC beams strength.

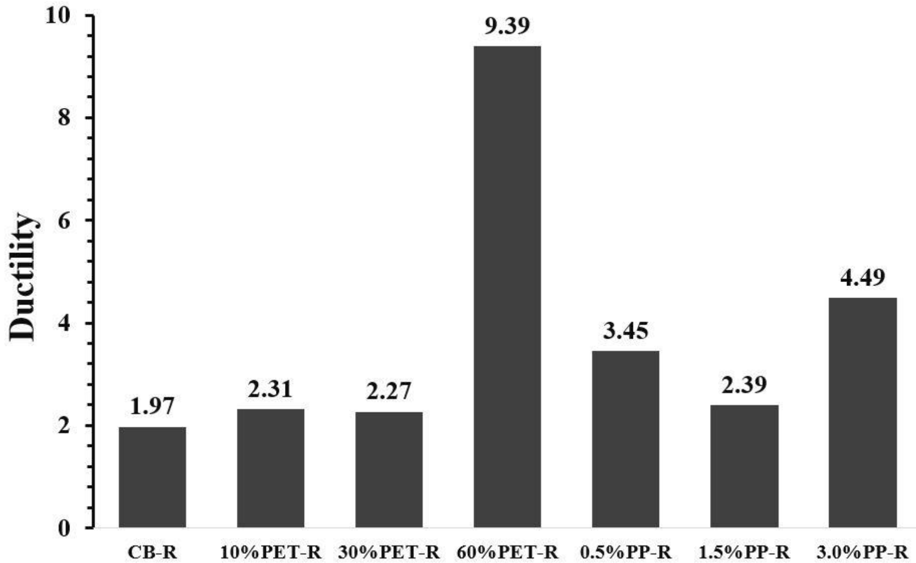


Figure 19. Ductility of the RC beams.

As showed in the Table 5, the ductility has increased in all percentages of the polyethylene terephthalate (PET) and polypropylene (PP) in comparison with the control beam. Also, shear strength in all percentages of the PET and PP has decreased in comparison with the control beam. The first crack occurs in the control beam at a deflection of 3.4 mm, while in beams with 10, 30 and 60% PET occurs at the deflection of 5.16, 11.7 and 18.6 mm, respectively. The yield deflection in beams with polyethylene terephthalate (PET) and polypropylene (PP) has been increased in comparison with the control beam and indicates that they were reached to the yielding point later.

- In the reinforced concrete beams included 10, 30 and 60% polyethylene terephthalate (PET), shear strength is decreased as 55.8, 75.6 and 84.8% in comparison with the control beam, respectively.
- In the reinforced concrete beams were included 0.5, 1.5 and 3% polypropylene (PP) fiber, the shear strength is decreased as 19.5, 55.7 and 73.7% in comparison with the control beam, respectively.
- In the reinforced concrete beams were included 10, 30 and 60% polyethylene terephthalate (PET), ductility is increased as 17.3, 15.2 and 376.6% in comparison with the control beam, respectively. In the reinforced concrete beams were included 0.5, 1.5 and 3% polypropylene (PP) fiber, ductility is increased as 75.1, 21.3 and 128% in comparison with the control beam, respectively.

3.2.2 Un-Reinforced beams

In this part, the effect of the polyethylene terephthalate (PET) and polypropylene (PP) on the key parameters of unreinforced concrete beams are evaluated. As the first crack occurred simultaneously with peak point, the crack properties are not mentioned. The test results are presented in the Table 6. Figure 20 indicates the yield, peak and ultimate loads of the tested beams. Also, the ductility results are showed in the Figure 21.

Table 6. Un-Reinforced beam behavior.

Specimen	Yielding		Peak		Ultimate		Ductility
	P_y	Δ_y	P_p	Δ_p	P_u	Δ_u	$\mu = \frac{\Delta_{max}}{\Delta_y}$
CB	11.41	1.97	15.21	2.31	15.21	2.31	1.17
10%PET	12.91	2.0	17.21	2.5	17.21	2.5	1.25
30%PET	12.76	1.81	17	2.12	17	2.12	1.17
60%PET	5.56	2.2	7.43	2.97	7.43	2.97	1.35
0.5%PP	19.98	3.4	26.65	4.1	26.65	4.1	1.21
1.5%PP	8.73	1.68	13.69	2.6	11.64	3.31	1.42
3.0%PP	12.86	2.4	20.16	4.17	17.14	5.36	2.24

Force: kN   Displacement: mm

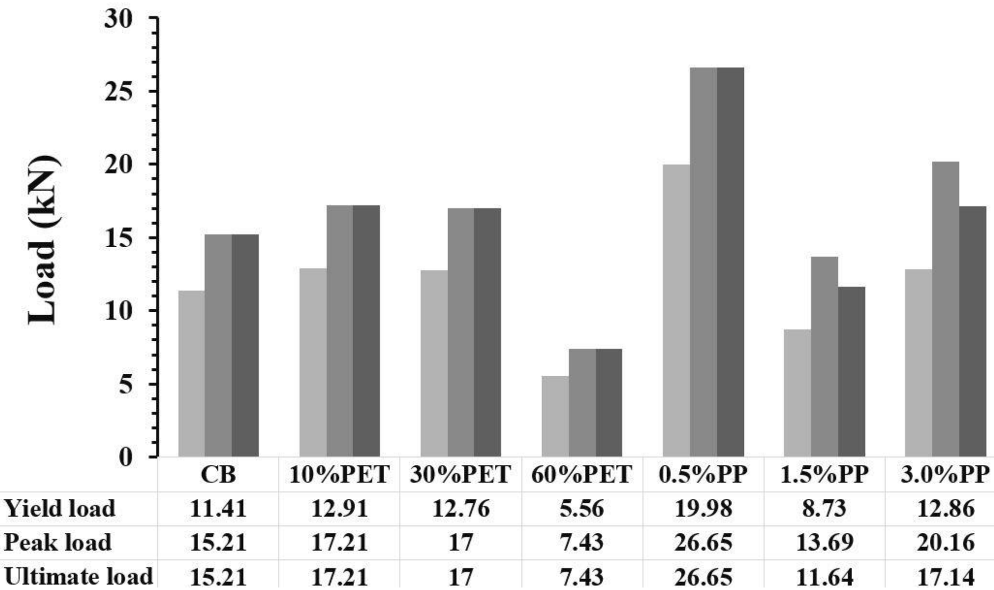


Figure 20. Influence of PET and PP on the unreinforced beams behavior.

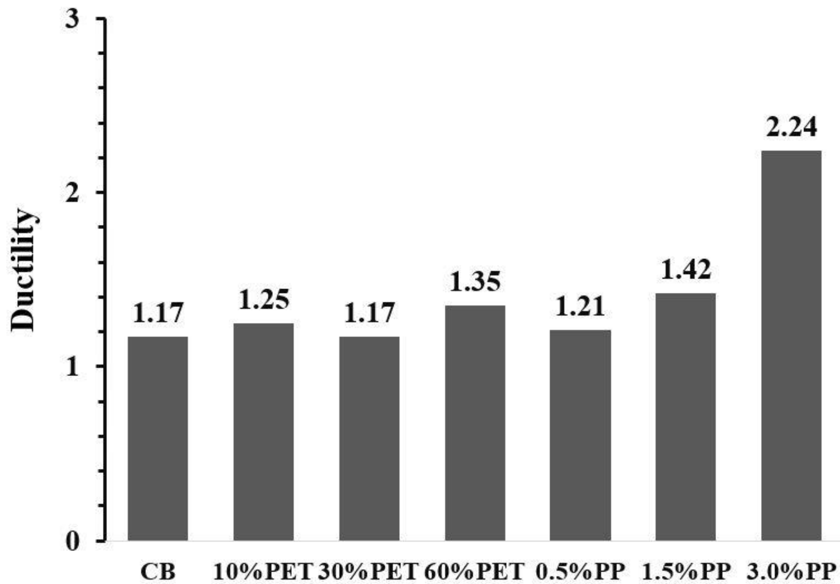


Figure 21. Ductility of concrete beams.

As showed in Table 6, ductility has been increased in the all percentages of polyethylene terephthalate (PET) and polypropylene (PP) in comparison with the control beam (only in beam with 30% PET ductility is equal to the control beam). In the beams with 10 and 30% polyethylene terephthalate (PET) and 0.5 and 3% polypropylene (PP), the shear strength is increased in comparison with control beam but in 60% polyethylene terephthalate (PET) and 1.5% polypropylene (PP) beams the shear strength is decreased.

- In the unreinforced beams were included 10, 30 and 60% polyethylene terephthalate (PET) led to 13.1 and 11.8% increase and 51.2% decrease in shear strength in comparison with the control beam, respectively.
- In the unreinforced beams were included 0.5, 1.5 and 3% polypropylene (PP) fiber led to 75.2% increase, 10% decrease and 32.5% increase in the shear strength in comparison with the control beam, respectively. In the unreinforced beams were included 10, 30 and 60% polyethylene terephthalate (PET) led to 6.8, 0 and 15.4% increase in ductility in comparison with the control beam, respectively. In the unreinforced beams were included 0.5, 1.5 and 3% polypropylene (PP) fiber led to 3.4, 21.4 and 91.4% increase in ductility in comparison with the control beam, respectively.

4. Conclusions and comments

In the present research, polyethylene terephthalate (PET) has been used instead of the fine aggregate and polypropylene (PP) has been used as an additive to the concrete mixture. Seven reinforced and seven unreinforced concrete beams are considered. In the first part the control reinforced concrete beam with common material, three reinforced concrete beams with 10, 30 and 60% polyethylene terephthalate (PET) instead of the fine aggregate and three other reinforced concrete beams by adding 0.5, 1.5 and 3.0% of polypropylene (PP) were constructed. In the second part, the same construction combination was used for beams without reinforcement. For each mixing design, the compressive strength of the standard cubic sample was calculated then the beams were subjected to the three-point loading and the results were achieved as follows:

1. Use of PET instead of the fine aggregate led to increase in ductility in both reinforced and un reinforced beams.
2. By adding 0.5% of PP fibers in reinforced concrete beams, the ductility can be increased, while the reduction in strength is negligible.
3. One of the interesting points of this research is that adding PP fibers increases strength and ductility in the unreinforced beams.

4. By replacing 10 and 30% PET fibers instead of fine aggregate, the shear strength of the unreinforced beams has increased.
5. In the end, it is suggested to use PET in high-strength concrete beams to increase the ductility, or to use metal fibers simultaneously to compensate for the decrease in the strength.

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