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The Influence of Pet Fibers on the Properties of Fresh and Hardened Concrete

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Abstract

There is a worldwide interest in using fibers of different types in concrete mixtures. In this regard, as the use of PET fibers has gradually increased during the last decade, this study aims to investigate the effects of PET fibers on the mechanical properties of hardened concrete and the workability of fresh concrete. To this end, different contents of PET fibers (PC= %0, %0.5, %1 and %1.5) are added to a concrete mixture and the workability of fresh concrete samples are measured by the slump tests. Furthermore, the load-displacement behavior of the concrete samples is investigated in flexural and compression samples. Results of this study reveal that PET fibers can noticeably change the energy absorption of concrete samples, especially in flexural specimens.

Key Words: Fiber reinforced concrete, PET fiber, Concrete workability, Mechanical properties.

1. Introduction

The use of fiber reinforced concrete has increased in the last decade. Several types of fibers (e.g. steel, glass, and plastic fibers) are commonly used in the concrete reinforced fibers [1-4]. Since fibers can overcome the main disadvantages of the concrete such as low energy absorption and low ductility [5], the fiber reinforced concrete is widely used in shotcrete tunnel linings, pavements etc. In this regard, the application of Poly Ethylene Terephthalate (PET) fibers in the field of concrete technology has gradually developed. One of the most important advantages of using PET fibers is reducing environmental problems of PET bottle wastes [5-6]. Because of the major effects of PET fibers on the behavior of concrete and cement mortars, a number of studies have been conducted in the recent years in order to investigate the behavior of PET fiber reinforced concrete. For example, Betioli and Silva [6] evaluated the durability of PET fibers under different aggressive environments. Moreover, Silva et al. [7] investigated the degradation of recycled PET fibers in cement based mortars. Choi et al. [8] also studied the mechanical properties of concrete made of waste PET bottle aggregates.

This study is an attempt to investigate the mechanical properties of PET reinforced concrete. To this end, different contents of PET fibers of constant height were added to the concrete mixture. Then the effects of fiber size and content on the properties of the fresh concrete were studied and the load-displacement behavior of flexural and compression concrete samples were measured.

2. Methodology and Test Procedure

As mentioned before, this study aims to examine the impact of PET fibers content on the properties of fresh and hardened concrete. To accomplish this purpose, four different contents of PET fibers (PC=0, 0.5%, 1%, 1.5%) were added to fresh concrete mixtures. Afterwards, in order to study the effects of PET fibers on the properties of fresh concrete, slump tests were conducted on the fresh concrete samples. Furthermore, to investigate the effects of PET fibers on the mechanical properties of hardened concrete, the compressive and flexural behavior of the concrete samples were measured. Herein, cylindrical 300x150mm samples were used for evaluating the compression behavior and 100x100x500mm beam samples were used for measuring the flexural behavior of PET reinforced samples.

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2.1. Material properties and concrete mixture design

Ordinary Portland cement (Type I), whose chemical specifications are presented in Table 1, was used in the concrete samples. In order to investigate the effects of fiber length on the properties of fresh fiber, reinforced concrete fibers of the same width (3mm) and different lengths (2, 3, 4, 5mm) were used. Meanwhile, to measure the mechanical properties of the hardened concrete, PET fibers of 40±2 mm in length and 3 mm in width were used. The contents of the concrete samples are reported in Table 2.

Table 1. Chemical specifications of cement

Chemical analysis (%)	
Insoluble residue	0.38
SiO_2	20.03
Al_2O_3	5.53
Fe_2O_3	3.63
CaO	62.25
MgO	3.42
SO_3	2.23
Na_2O	0.3
K_2O	0.73
Loss of ignition	1.37
Physical properties	
Specific gravity (kg/m^3)	3150
Blain fineness (m^2/kg)	300
Initial setting time (min)	188
Final setting time (min)	240

Table 2. Specifications of the samples

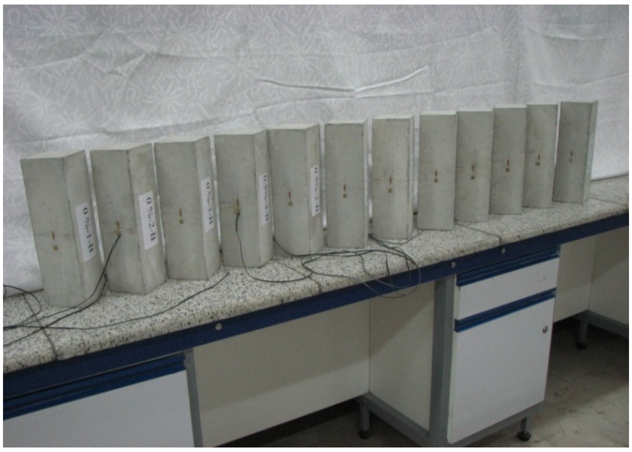
% fiber (PC)	Cylindrical Specimen	Beam Specimen	Cement (Kg/m^3)	Fine Aggregate (Kg/m^3)	Coarse Aggregate (Kg/m^3)
0	0-1-C	0-1-B	500	734	896
	0-2-C	0-2-B	500	734	896
	0-3-C	0-3-B	500	734	896
	0-4-C	NA	500	734	896
	0-5-C	NA	500	734	896
	0-6-C	NA	500	734	896
0.5	0.5-1-C	0.5-1-B	500	734	896
	0.5-2-C	0.5-2-B	500	734	896
	0.5-3-C	0.5-3-B	500	734	896
	0.5-4-C	NA	500	734	896
	0.5-5-C	NA	500	734	896
	0.5-6-C	NA	500	734	896
1	1-1-C	1-1-B	500	734	896
	1-2-C	1-2-B	500	734	896
	1-3-C	1-3-B	500	734	896
	1-4-C	NA	500	734	896
	1-5-C	NA	500	734	896
	1-6-C	NA	500	734	896
1.5	1.5-1-C	1.5-1-B	500	734	896
	1.5-2-C	1.5-2-B	500	734	896
	1.5-3-C	1.5-3-B	500	734	896
	1.5-4-C	NA	500	734	896
	1.5-5-C	NA	500	734	896
	1.5-6-C	NA	500	734	896

Some points are worthy to mention here. In all of the specimens, the water to cement ratio was 0.5. Moreover, the maximum aggregate size was 12mm. The PET fiber content (PC) is the ratio of the weight of the fibers to the weight of the cement. For the specimens that did not have any fiber, the content of super plasticizer was basically considered to be 0%. In order to produce workable mixtures in the fiber reinforced samples, additional super plasticizers of 0.15%, 0.35% and 0.5% were required for the samples with 0.5%, 1% and 1.5% PC, respectively. All of the specimens were cured in water at a temperature of 20°C± 2°C for 28 days.

2.2. Test Procedures

In the second main phase of the study, the slump tests were conducted according to ASTM C143 [9]. In order to investigate the mechanical properties of the hardened concrete samples, the load-deformation relations of cylindrical and beam specimens were measured. To do so, strain gauges were attached to the concrete samples as shown in Figure 1. The test setup of flexural tests is depicted in Figure 2.

(a)



(b)

Figure 1. The location of strain gauges in the samples
(a) Cylindrical samples (b) Beam samples

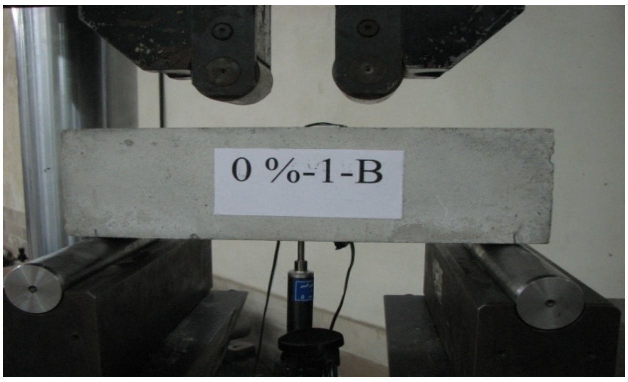


Figure 2. Setup of the flexural test

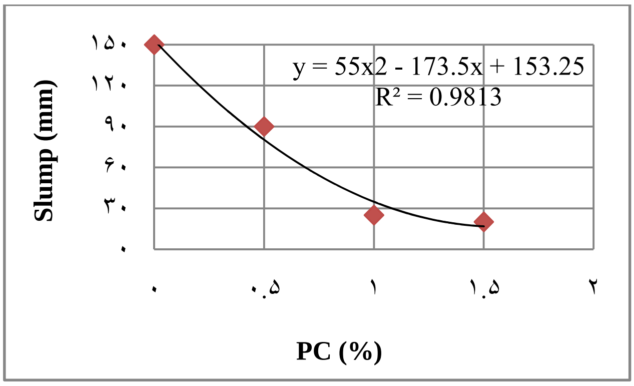


Figure 3. Effects of the PC on the workability of the fresh concrete

3. Results

3.1. Properties of the fresh concrete

Having completed the processes mentioned above, the researcher investigated the stability and workability of the fresh concrete samples. In order to study the size effect of the fibers on the stability of concrete samples, different PCs of 0, 0.5%, 1.0% and 1.5%, and different fiber lengths (40, 50 and 60mm) were included in the study. The width of all fibers was 3mm. Table 3 indicates the stability and workability of the fresh concrete with different fiber lengths and PCs.

The results of slump tests illustrated in Figure 3 show that by increasing the PC, the workability of the fresh concrete decreases noticeably. Thus, in order to produce a workable mixture, a superplasticizer was used. The comparison of the slumps of fresh concrete samples before and after adding the superplasticizer to the concrete mixture (S1 and S2 respectively) is depicted in Figure 4. Then Figure 5 indicates the required superplasticizer for each concrete sample in comparison with the slump ratio (SR) of the sample. Herein, SR is the ratio of the slump of the fibered reinforced concrete to the slump of the concrete without fibers. It should be pointed out that the instability of the fresh concrete was not observed in any of the samples.

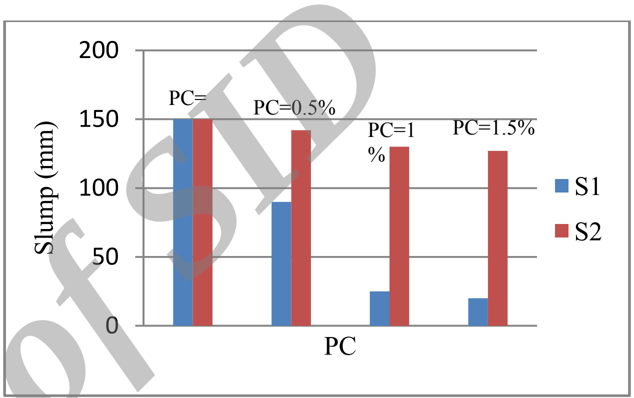


Figure 4. The comparison of the slump of samples before and after adding the superplasticizer

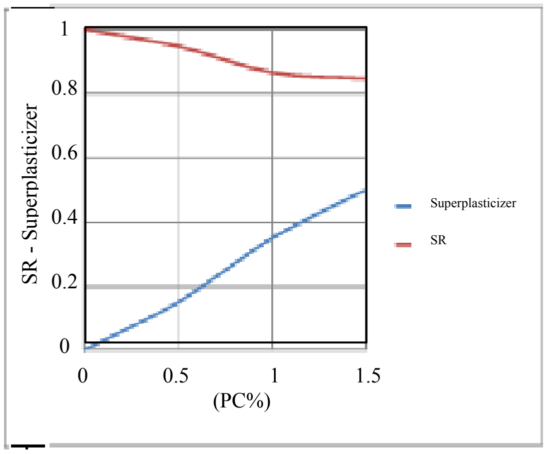


Figure 5. Effects of the content of the superplasticizer on the SR

Table 3. The stability and workability of the fresh samples

Length of the fiber (mm)	PC (%)	Description
40	0.5	Stable- low workability
40	1	Stable- not workable
40	1.5	Stable- not workable
50	0.5	Unstable
50	1	Unstable
50	1.5	Unstable
60	0.5	Unstable
60	1	Unstable
60	1.5	Unstable
NA	0	Stable- Workable

3.2. Properties of the hardened concrete

The load-deformation relationships of axially compressed cylinders are indicated in Figure 6. According to this figure, the ductility and energy absorption of the concrete samples increases by adding the fiber to the concrete mixture. In other words, the sample with PC=0 has the lowest ductility, energy absorption and axial strength. The largest axial compressive strength belongs to the sample with PC=0.5% but the highest ductility belongs to the sample with PC=1.5%. The axial compressive capacity of the samples with PC=1% and PC=1.5% are almost the same but the ductility and energy absorption of the latter is noticeably higher than the former. Figure 7 illustrates the variation of the bending strength of the concrete samples with different fibers contents. As indicated in this figure, PET fibers do not increase the ductility of the banding specimens. This phenomenon may be explained with the insufficient bondage of PET fibers and the concrete. In this regard, it is worth mentioning that the number of examined flexural samples is not sufficient to draw firm conclusions.

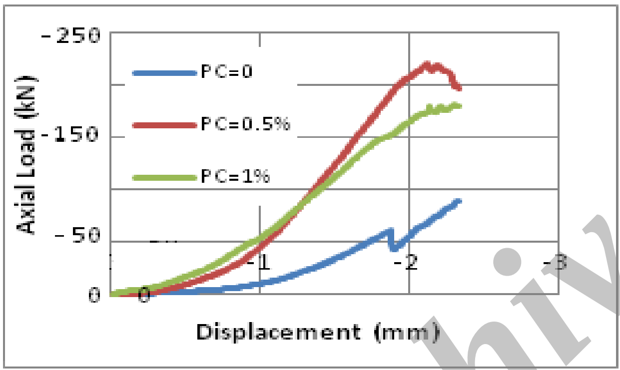


Figure 6. Load-deformation relationship of the axially compressed cylinders

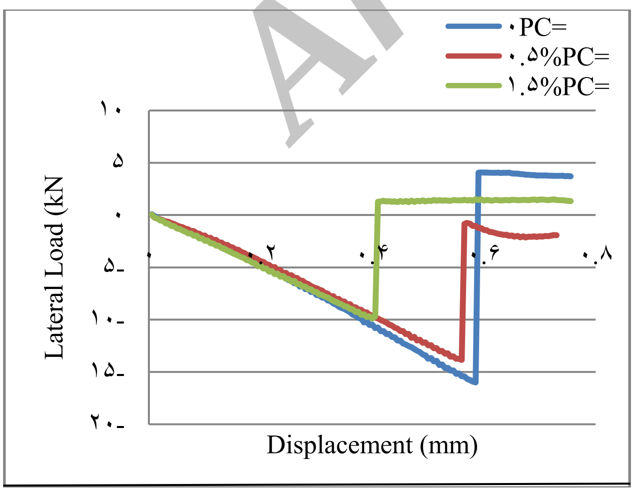


Figure 7. Load-deformation relationship of the beam specimens

4. Conclusions

In the present study, the effects of PET fibers on the properties of the fresh concrete and on the mechanical properties of the hardened concrete were investigated. In doing so, different contents of PET fibers were added to the concrete mixture. The findings of the study reveal that:

- PET fibers may decrease the workability of fresh concrete mixture. Using long fibers may lead to unstable fresh concrete. The best stability of fresh concrete was observed in the samples with fibers 40mm in length.
- PET fibers in the concrete showed a slight decrease in the compressive strength. The best workability in the fiber reinforced concrete samples belonged to the specimens with PC=0.5%.
- PET fibers can increase the compressive strength of the concrete. The highest compressive strength belonged to the specimens with PC=0.5%.
- PET fibers increased both ductility and energy absorption of the axially compressed concrete samples. The highest ductility belonged to the specimens with PC=1.5%. However, the ductility and energy capacity decreases as the fiber increases.

The interesting findings of this study are preliminary. Thus, in order to arrive at more detailed conclusions about the effects of PET fibers on the bending behavior of concrete samples, further studies are needed.

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