Studying the Compressive Strength and Crack Growth Pattern in Samples Reinforced with Polymer and Macrosynthetic Fibers

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Abstract

Concrete is widely used in construction. Plasticity and energy absorption capacity are two main specifications of structures resistant against earthquake. On the other hand, plain concrete has low tensile strength, low energy absorption and trivial resistance to cracks.In this research, samples reinforced with polymer and macrosynthetic fibers in 150*150 and 500*100*100 mm sizes were prepared and tested after being processed. The results show decrease in compressive strength of fiber-reinforced samples. On the other hand, the use of fibers reduces the distance, width and depth of cracks in samples under loading and bending, which is indicative of increase in concrete flexibility.

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Key words: polymer fiber; macrosynthetic fiber; compressive strength; crack; bending

1. Introduction

This Concrete is basically made up of cement, aggregate and water, thus is widely used in construction industry since all its constituents are commonly available and cheap. Concrete under loading has much high strength, whereas its tensile strength is low. In order to improve the tensile strength, steel is often used in concretes. In addition to traditional steel, different fibers are mainly used to increase the tensile strength of concretes. Generally, four types of fiber are used to reinforce concretes: steel fiber, glass fiber, natural fiber and artificial fiber [1].

Cracking is an important factor in the final life of a concrete. Cracks allow harmful substances to enter the concrete, which in turn causes structural failure. In recent years, fiber-reinforced concrete has been welcomed as a preventive action to reduce cracks [2]. In order to have a more resistant and economical concrete, synthesis of fiber and common concrete-reinforcing steels can be a suitable solution [3]. Fibers increase the concrete flexibility [4]. Regarding concretes under bending, tensile cracks have lesser width and are placed at closer distances [5]. Given the width and distance of cracks, crack pattern prediction is a turning point for correct definition of the amount of steel in reinforced concretes [6].

2. Experimental program

2.1. Concrete samples

Samples are constructed using 150*150 cm metal molds. The water used in preparing concretes is drinking water and its temperature is 20 ± 2 according to NFP 18-404 Standard.

2.2.Macrosynthetic fibers

These fibers consist of different synthetic materials made up of 100% pure copolymer or Polypropylene. The materials are made from very thin, twisted and entangled strings with high durability, increase in structural properties and control of a web of stranded fibers. Fig.1(a) shows the macrosynthetic fibers.

2.3. Polymer fibers

This is another type of Polypropylene-based fiber. Fig.1(b) shows the polymer fibers used in this research.

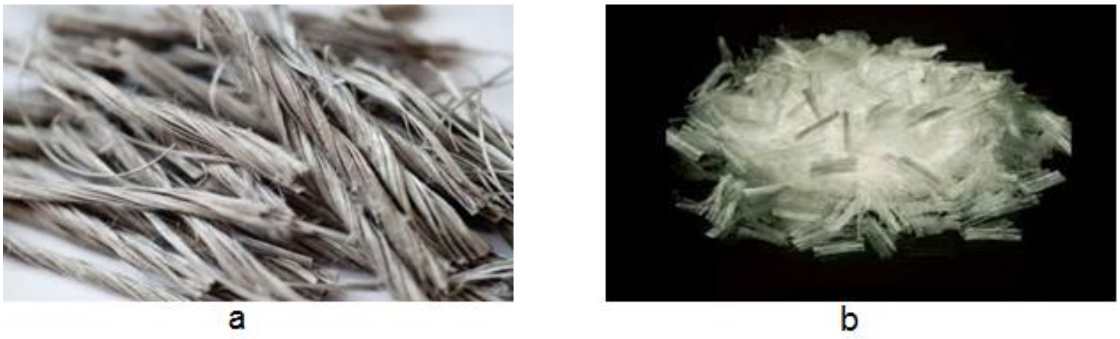

Fig.1: Polymer and macrosynthetic fibers

2.4. Preparation of samples

Samples are prepared based on the mixture patterns presented in Table1. In order to better consider the effect of fibers on compressive strength, different values are used in preparation of samples. Moreover, a control group has been considered for each group.

Table1: Mixture patterns of prepared samples

Group	No. of sample	Type of cement	Polymer fiber (g)	Macrosynthetic fiber (g)
A	1	Bojnurd, Type 2	0	150
	2	Bojnurd, Type 2	0	250
B	3	Bojnurd, Type 5	350	0
	4	Bojnurd, Type 5	500	0
	5	Bojnurd, Type 5	600	0

2.5. Conducting the compression test

After being processed, control concretes and fiber-reinforced concretes were taken out of water after 28 days and their compressive strengths were evaluated. Servo Control device with a capacity of 200 tons was used to conduct the test.

3.Experimental results

3.1. Considering the crack growth pattern

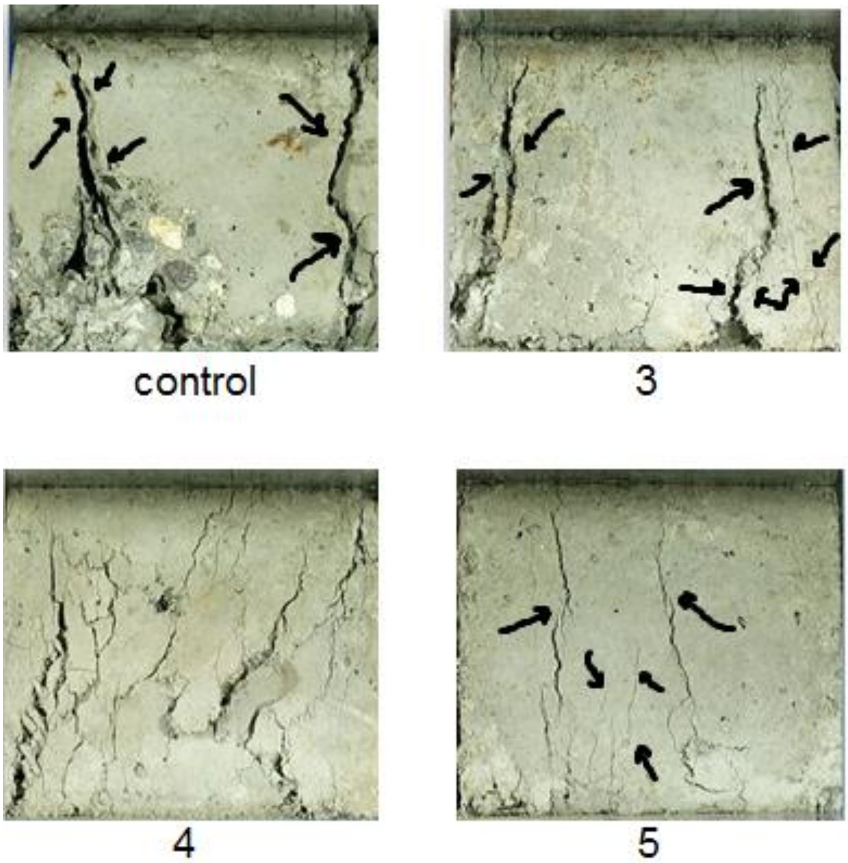

Fig.2: Polymer-reinforced fibers after loading

The effect of polymer fibers on cracks' behavioural pattern after loading is shown in Fig.2. The control group having no fiber has undergone cracks from both sides. The crack range is 5% of the sample's length from both sides. The crack has also grown throughout the sample (150 mm length). The openness and depth of the cracks can be observed in this figure.

In Sample 3 (with the lowest amount of fiber), two relatively deep cracks can be observed in 5% range from both sides, as well as some cracks with little openness and length. Longitudinal cracks have grown in 90% of the sample's height. In Sample 4, the number of cracks has gradually increased and their openness and depth have decreased. Length of the cracks varies and the longest crack is 80% of the sample's height. Cracking area includes the whole sample surface. In Sample 5 (with the highest amount of fiber), cracks have grown in the middle area of the sample. These cracks include two cracks; one with a length equal to the sample's height, and one with several shorter cracks with a length equal to 1.2 of the sample's height. The openness of all cracks is at their lowest amount compared with other samples.

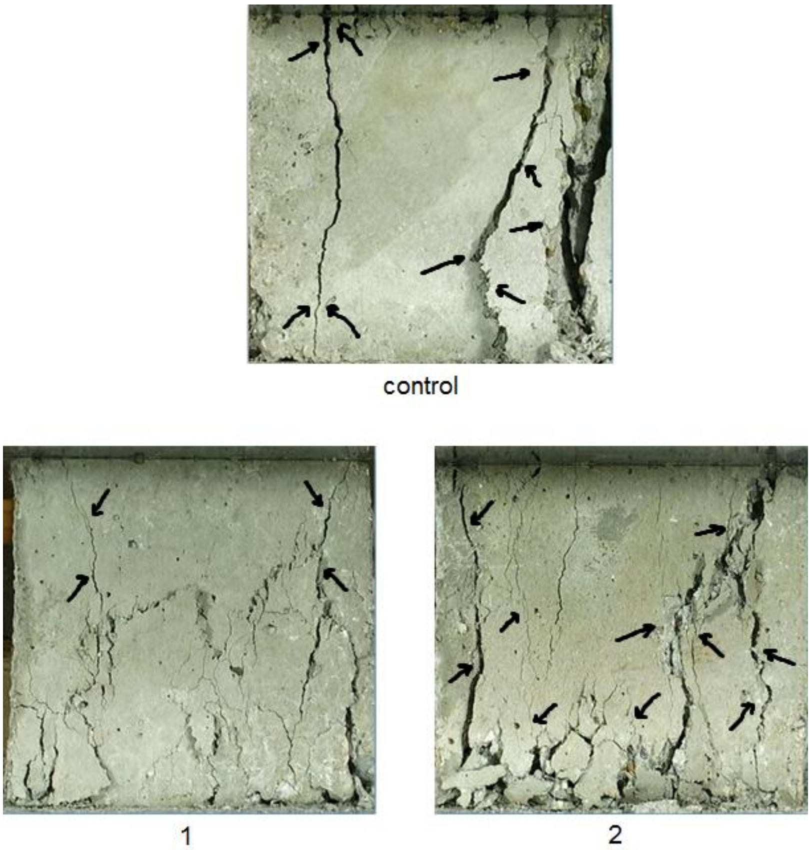

Fig.3: Samples reinforced with macrosynthetic fiber after loading

Crack pattern in macrosynthetic-fiber-reinforced samples is shown in Fig.3. The control group has undergone cracking from both sides after loading. The cracks are deep, have much openness and have grown in the whole sample's height.

In Sample 1, it can be observed that cracks have spread throughout the sample, which has caused decrease in their length, openness of their opening, and their depth. These cracks have grown in the form of a capillary to 1.2 of the sample's height. The cracking area in Sample 2 has close relationship with the control sample; however, lesser values are observed in terms of openness and depth of the cracks. The number of cracks has also increased. Fibers are able to control cracking [7]. Moreover, the use of appropriate amount of fibers has positive effect on the emergence of the first crack and prevention of sudden matrices of cracking [8]. Width and distance between cracks have decreased after failure [9].

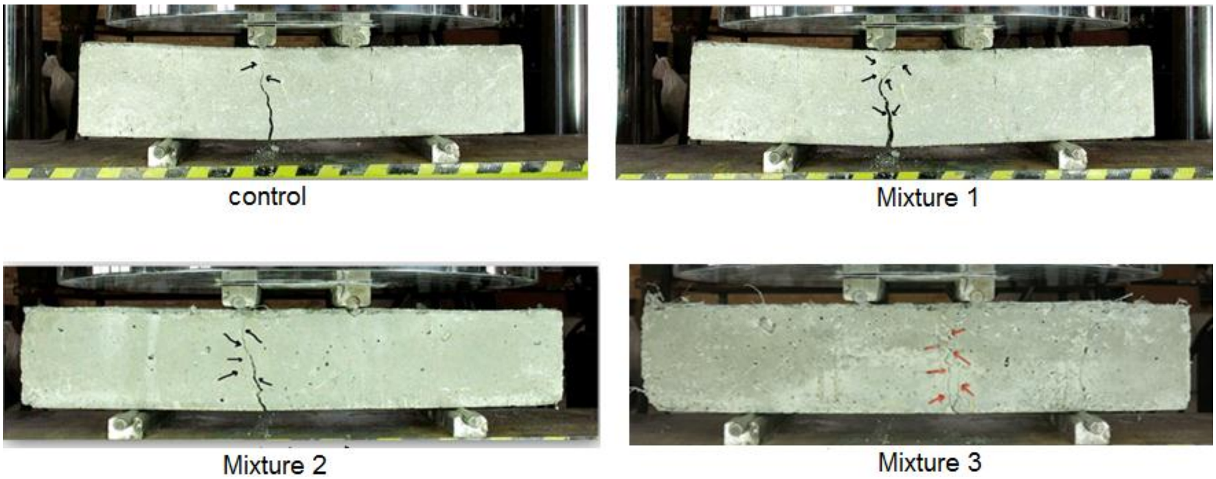

Fig.4: Considering the crack pattern in samples reinforced with fibers under bending

Fig.4 shows the cracking pattern in samples under bending. In the image of Mixture 1 (the sample reinforced with 350-polymer fiber), we observe a decrease in stress focus on the crack tip, which finally causes a wide crack to be changed into finer cracks. In the image of Mixture 2 (the sample reinforced with 150-macrosynthetic fiber), two longitudinal cracks with different widths have grown on the sample, in which, compared to Mixture 1, the number of cracks has increased and the cracks' width has decreased. In Mixture 3 (the sample reinforced with 250-macrosynthetic fiber), fibers have better effect on the sample's cracking, so that the number of cracks has increased and their depth and width have decreased; this is indicative of increase in plasticity. In comparison with the fibers used in concrete samples under bending, macrosynthetic fibers have better effect on samples' cracking pattern and increase of plasticity.

3.2.Considering the compressive strength

Samples reinforced with polymer fibers were compressively tested. The results are presented in Fig.5. Increasing the amount of polymer fibers has significant effect on decreasing the compressive strength of samples. A difference of 20 units between fiber-free sample and the one with the lowest amount of fiber is significant.

Fig.6 shows the compressive strength of samples constructed with macrosynthetic fibers. The obtained strengths are similar to those of polymer fibers. The use of fiber decreases the compressive strength of samples. Compared to plain concrete, the use of polymer and macrosynthetic fibers does not increase the compressive strength [10].

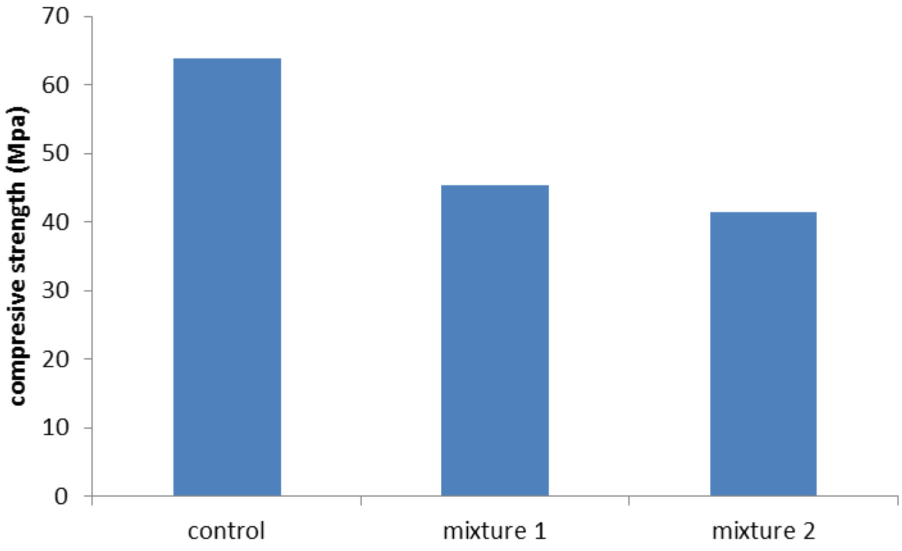

Fig.5: Considering the compressive strength of samples reinforced with polymer fiber

High volumes of fibers decrease compressive strength due to the aggregation of fibers and formation of holes in fiber-reinforced concretes [11]. In fact, replacing part of the aggregates with fibers and increasing the porosity are the causes of decrease in compressive strength.

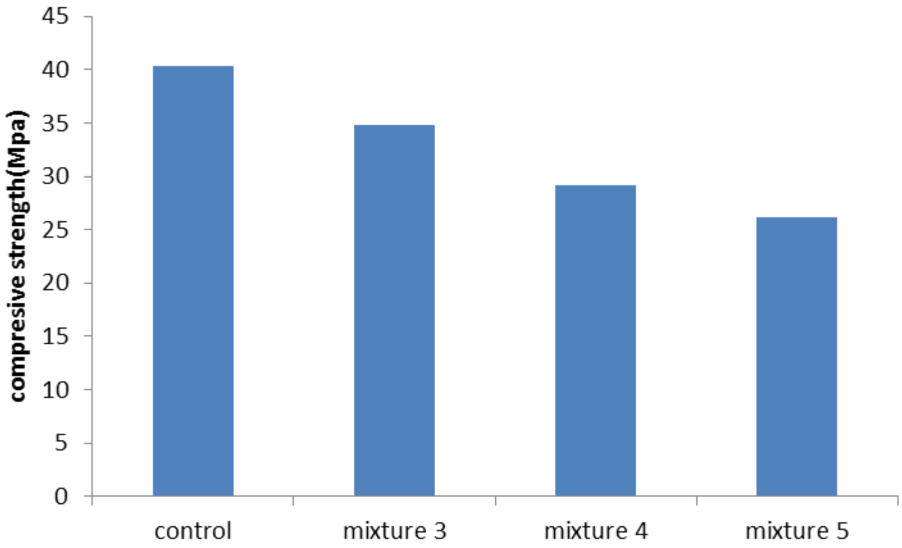

Fig.6: Considering the compressive strength of samples reinforced with macrosynthetic fibers

4. Conclusions

1. Fibers show desirable results in concrete samples in controlling and delaying the spread of cracks and in decreasing the focus of stress on crack tip.
2. Fibers play an essential role in preventing brittle failures and changing them into soft failures.

3. Compared to the control group, in all samples reinforced with fibers, we witnessed decrease in compressive strength, and this decrease has direct relationship with increase in the amount of fibers.
4. Given the application of concrete in different structures, the positive effect of fibers on plasticity as well as the intended compressive strength can be used.

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