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The Study of Characteristics of High-Performance Cement Base Material Reinforced with Dramix Steel Fiber

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ABSTRACT: Concrete can resist high tension stress. The low tensile strength and high fragility have made it unconsidered in designing Code. Using steel fiber in the concrete matrix decreases the fragility and brittleness of the material. Improvement of mechanical characteristics will cause the steel fiber reinforced with concrete matrix to be an efficient material for construction. In this paper, the mechanical properties of cement-based composites reinforced with various percentages of fiber (1 wt% and 2 wt%) have been studied. The matrix of cement-based, with DRAMIX fiber, in three types of 3D, 4D, and 5D, had compressive strength up to 64 MPa. In this study, to evaluate flexural strength, 4-point bending test was done on the reinforced flexural elements with various percentages of steel fiber. Flexural properties, including load-displacement graph, crack line, energy absorption, and bending tension stress have been evaluated and compared. The results show that in some specimens, strain-hardening behavior until before concentrating of cracks and failure and after strain-softening happens. Strain-hardening behavior improves the mechanical properties of the materials. In this case, failure occurred at various critical matrix cracks.

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1- Introduction

Steel fiber cement composites are a special group of fiber-cement composites that indirect tensile loading after the first crack, show strain hardening with various cracks before final failure and crack concentration [1]. Adding a low percentage of short fibers by random distribution into the cement matrix improves the mechanical behavior of the matrix which is typically known as fiber-reinforced cement composite. The performance of fiber-reinforced cement composites can be improved so much that flexural failure happens due to various cracks. Reinforced Fiber Composite Cementitious performance depends on many factors, such as mechanical characteristics of the fiber, including fiber strength, stiffness and Poisson's ratio, the geometry of fiber (flat, hooked, and curly), the volume ratio of fiber, qualities of the matrix (matrix strength, stiffness, Poisson's ratio) and properties of area of contact (viscosity, friction, and mechanical anchor). Every matrix depends on the type and volume of the fiber, and has different FRCC performance and related costs. In recent years, many studies have been done on fiber-reinforced matrice. In a study, Han et al. (2019) studied the effect of the steel fiber length and sizeable grading on the mechanical properties of the steel fiber reinforced concrete. Experimental findings show that by increasing the length of steel fiber, the utility of mixing, tensile strength, flexural strength, and loading failure also increases. Increasing the grading thickness to the maximum, slightly increases the compressive strength of mixing, tensile strength, flexural strength, and loading failure increase and then decrease [2]. Yoo et al. (2019) have studied the effect of the various types and percentages of fiber on the flexural behavior of the FRCC. In this study, we used four types of steel fiber, including wired, hooked, polyethylene, and 1.4% and 0.4% polyvinyl alcohol fibers. The results of which showed that the wired fiber-reinforced composites have the best utility in terms of loading tolerance, tension absorption, and various cracks [3]. Augusto Krahl et al. (2019) studied the cyclic behavior of 1%, 2%, and 3% steel fiber reinforced concretes and reviewed the different percentages and the effect of increasing steel fiber percentages on the concrete matrice. Finally, a structural model was presented for the super-powered composites [4].

2- Test Methodology

As shown in Figure 1, in order to measure the displacement of the middle of the beam's span, we used a metal mold. By using this mold, the transformations due to support settlements and specimen rotation when loading can be prevented. By pinning four screws, the mold in the middle of section height is connected to points A and B. Only two of these four screws are fixed and the other two allow the mold for horizontal displacement. Thus, when loading, the mold won't change its shape. The displacement of the middle of the span was measured by two Linear variable displacement transducers which are connected to both aspects of the

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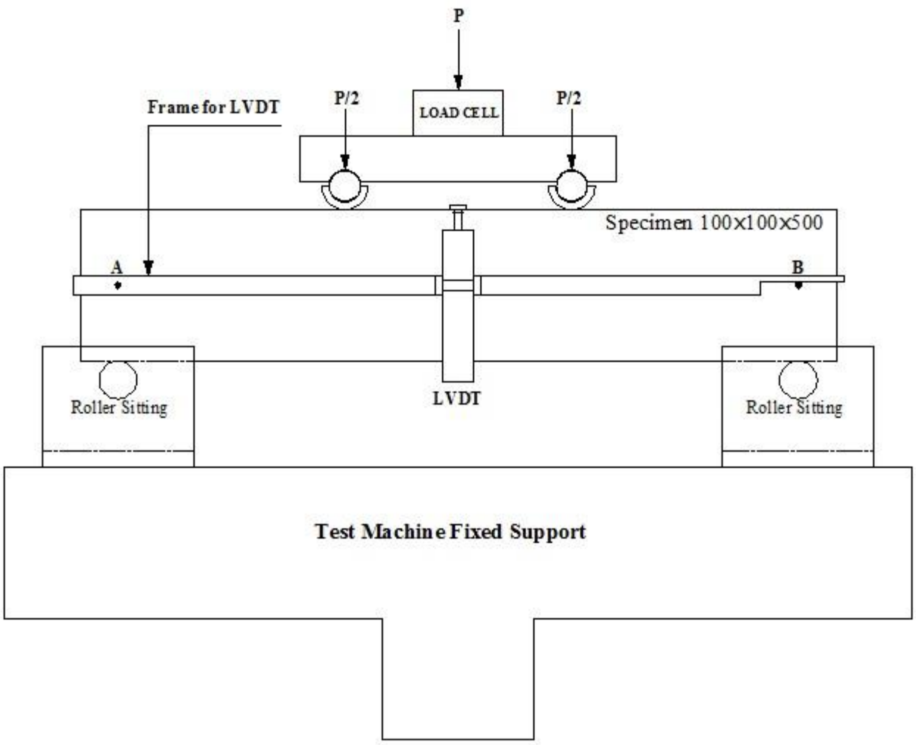

Fig. 1. Setup of flexural strength test

Table 1. 1% Fiber Reinforced Specimen

Fiber type	Cracking Force (kN)	Correspondent displacement (μm)	Maximum Force (kN)	Correspondent displacement (μm)
3D	10.88	1	21.77	215
4D	11.57	1	22.10	358
5D	10.70	2	21.42	281

mold. The mid-values of these Linear variable displacement transducers were considered as net displacement of the span's mid-point. The load on the specimen was measured with the load cell connected to the moving arm of the transducer. In order to record the data from the load cell and Linear variable displacement transducers, we used a data logger. For uploading the specimen, we used a hydraulic arm that is able to load by displacement control. The loading speed of the specimen was 0.1 mm/m. The dimensions of the specimen are 100 × 100 × 500 mm3 and the net span of loading is 450 mm. For implementing the test, we used ASTM C1609. In order to test, we used a device with No. model STM-250 built by Santam Co. The tests have been done in the New Research Center of civil engineering of the Islamic Azad University of Arak.

3- Bending behavior of the specimen

Bending behavior of 1% and 2% 3D, 4D, and 5D steel fiber reinforced specimen is described and interpreted in tables and graphs of the load-displacement curve.

According to Table 1 and Table 2, all the 1% 3D fiber-reinforced specimens with increased loading capacity showed limited hardening behavior in displacement and then softening in displacement. However, in the case of 2% 3D fiber-reinforced specimen, this behavior improved and with increased loading capacity, the hardening of the displacement happened. In 1% and 2% 4D and 5D fiber-reinforced specimens, due to increased mechanical anchor, with increased loading capacity, hardening behavior of the displacement happens. According to Table 1 and Table 2, displacement such as cracks, is not dependent on the percentage of fiber. However, the displacement, such as maximum tension, is dependent on the materials' behavior,

Table 2. 2% Fiber Reinforced Specimen

Fiber Type	Cracking Force (kN)	Correspondent Displacement (µm)	Maximum Force (kN)	Correspondent Displacement (µm)
3D	16.82	1.5	21.77	455
4D	18.36	1.5	22.10	536
5D	13.83	2	21.42	617

so with the emergence of the hardening behavior after initial cracks associated with increased loading capacity, the capacity for displacement increases, too.

4- Conclusion

In the present paper, the mechanical characteristics of steel fiber reinforced cement-based composites have been studied. The applied 3D, 4D and 5D steel fibers with different percentages (1% and 2%) have been added to the cement matrix. When the initial cracks in 1% 3D fiber-reinforced specimen happen, due to the hardening behavior resulting in increased loading capacity of materials, because of limited hardening behavior, the specimen fails. In 2% 3D fiber-reinforced specimen, and 1% and 2% 4D and 5D fiber-reinforced specimen, due to hardening behavior after the initial cracks, various other cracks formed, too, and the loading capacity has increased, then with increased tension, formed crackles unite and after forming the big crack, specimen fails. With the increased percentage of the fiber, due to the increased crack bridging in the concrete matrix after the cracking, tension absorption also increases, so much that the mean tension absorption in 2% 3D fiber-reinforced specimen is higher than the one in 1% 3D fiber-reinforced specimen and the mean tension absorption in 2% 4D fiber-reinforced specimen increases more than the mean tension absorption in 1% 4D fiber-reinforced ones. The mean tension absorption in 2% 5D fiber-reinforced specimen increases more than that of 1% 5D fiber-reinforced specimen. As the rate of fiber effectiveness depends on the percentage volume of the fiber, and the increased percentage of fiber before cracking does not increase the loading capacity of the specimen, and after cracking, due to the increased percentage of steel fiber, loading capacity also increases, we observed that: 1) loading capacity of 2% 3D fiber-reinforced specimen has increased 42% more than the 1% 3D fiber-reinforced specimen, 2) loading capacity of 2% 4D fiber-reinforced specimen has increased about 34% more than the 1% 4D fiber-reinforced specimen, and 3) loading capacity of the 2% 5D fiber-reinforced specimen has increased about 21% more than the capacity of the 1% 5D fiber-reinforced specimen.

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