International Journal of Engineering and Information Systems (IJEAIS)
ISSN: 2643-640X
Vol. 6 Issue 1, January - 2022, Pages:46-51

The Stress-Strain State of Fiber Reinforced Concrete Beams

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Abstract *- The article presents the results of laboratory research on the stress-strain state of fiber reinforced concrete beams dispersed with reinforced concrete and basalt fibers. At the same time, in the research work, fiber reinforced concrete beams were prepared by adding different amounts of 10 mm and 30 mm length fibers to the concrete. The results obtained show that the strength of reinforced beams with basalt fibers is higher than that of ordinary reinforced concrete beams*.

Keywords— reinforced concrete, beam, stress, strain, basalt fiber, flexure, strength, dispersed reinforcement.

1. INTRODUCTION

Basalt fiber is a complex of continuous basalt fibers of a certain length. Basalt fiber is derived from a variety of rocks, such as basalt, basanites, amphibolites, gabrodiabases, or mixtures thereof, which are chemically similar. The production of basalt fibers is based on the production of basalt solution (mixture) in smelting furnaces and its free flow through special devices. Melting point is 1450ºC. The advantages of basalt fiber for disperse reinforcement are that it has high strength as well as does not stretch under the influence of stresses, is resistant to chemical, corrosion and thermal effects of the external environment, changes in temperature and voltage direction, as well as cost not too expensive [1-4].

Certain theoretical and experimental studies have been conducted in many countries to study the actual operation of basalt fiber-based fiber concrete structures. For instance, K.L.Kudyakov studied the strength and cracking strength of flexible concrete structures made on the basis of composite glass reinforcement and basalt fibers under the influence of static and short-term dynamic loads. Fiber concrete made by adding basalt fibers in the amount of m_{bf}=0.5% using the technological method developed by the author, the compressive strength of the fiber increased to 51.2%, the tensile strength increased to 28.8 compared to concrete. Z. Yasmin, M. Hanen conducted experimental research to study the effects of basalt and metal fibers on flexible reinforced concrete beams.

In the research work, reinforced concrete beams with a cross-sectional area of 150x250x1200 mm were prepared. The beam is made by adding basalt and metal fibers in the amount of 2.5% and 15% of the weight of cement, respectively. The test results show that the load-bearing capacity of beams based on basalt fibers increased by up to 30% and the maximum bending by almost 2.4 times. In addition, the load-carrying capacity of metal fiber beams has increased by 47%. The maximum bending showed almost the same result as with normal beams. Basalt and metal fibers increased the flexibility of the beam. However, it delayed the formation and spread of cracks.

Julita Krassowska and Andrzej Lapko studied the properties of reinforced concrete beams made using basalt and metal fibers. Metal and basalt fibers with a length of 50 mm were used in the beams. The basalt fibers had a diameter of 16 μm and a modulus of elasticity of 90 GPa. To determine the tensile strength of concrete, the cross-sectional dimensions of 100x100x400 mm were tested in the laboratory by adding 1.5% metal fibers and basalt fibers in the amount of 20 kg/m^3 to concrete prisms. As a result of the test, the elongation strength increased by 62% in samples with basalt fibers and by 42% in samples with metal fibers compared to samples without fibers.

Shiping Li, Yibei Zhang, Wujun Chen conducted research to study the strength of flat bending reinforced concrete beams made with recycled fillers and basalt fibers. The cross-sectional dimensions of the sample beams were 210x300x4000 mm and the calculated length was 3800 mm. Concrete for beams is made of C40 class concrete. The length of the basalt fiber was 15 mm, diameter 15 μm, modulus of elasticity was 95-115 GPa, tensile strength was 3500–4500 MPa, density was 2.72 g/cm^3. The results show that the maximum bending moment increased by 69.08 kN·m in non-fiber beams, 78.94 kN·m in reinforced concrete beams with 0.2% addition of basalt fibers, ie by 14.3% compared to ordinary beams. In this research, the most effective amount is recommended to be 0.2-0.25% to increase the strength of structures, reduce crack expansion.

Padmanabhan Iyer (2014) studied the compressive, elongation, and bending strengths of basalt fiber-based concrete. Concrete of M35 class and fibers of length 12, 36, 50 mm and basalt content of 4 kg/m^3 3.8 kg/m 3.12 kg/m^3 were used in the preparation of the beams. The cross-sectional dimensions of the beams were 150x250x2100 mm. When basalt fibers were used at lengths of 50 mm and 8 kg/m^3, bending strength increased by 21%, compressive strength by 38%, and elongation strength by 14%. When basalt fibers were used with a length of 36 mm and an amount of 8 kg/m^3, bending strength increased by 23%, compressive strength by 24%, and tensile strength by 4%.

Research and analysis of scientific studies show that flexible fiber-reinforced concrete structures based on basalt fibers have not been sufficiently studied. Therefore, it is advisable to conduct experimental studies on the stress-strain state of flexible fiber reinforced concrete beams with basalt fibers [5-21].

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2. Research methodology

Reinforced concrete beams for dispersed reinforcement have a density of 2650 kg / cm3, fiber diameter 17 μm, fiber length 10; 30 mm basalt fibers were used. An overview of the fibers used in the study is shown in Figure 1.

Fig. 1. *Basalt fibers*

Six series of beams were prepared and laboratory tests were performed to study the stress-strain state of fiber reinforced concrete beams. The first series of reinforced concrete beams are made of concrete without basalt fibers. The rest of the series of fiber-reinforced concrete beams are made of basalt fibers of different sizes and lengths.

In measuring the amount of basalt fibers, high-precision Kern PBJ scales were used. The process of measuring basalt fibers is shown in Figure 2.3.

Fig. 2. An overview of the basalt fiber measurement process.

The cross-section dimensions of reinforced concrete and fiber-reinforced concrete beams, as well as the diameters and lengths of the reinforcement used, are shown in Figure 2.

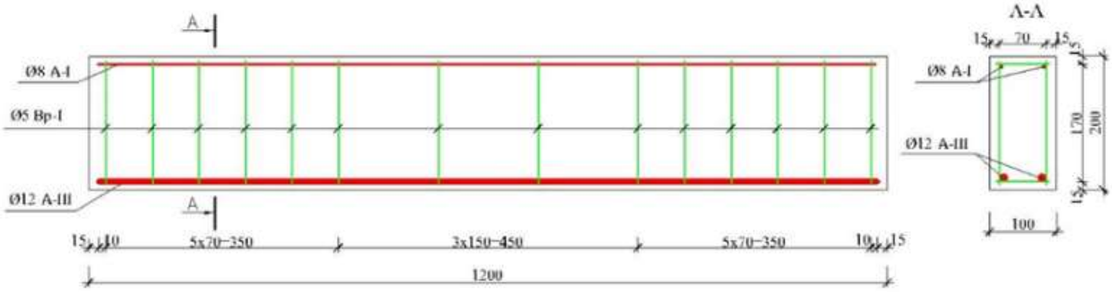

Fig. 3. *An overview of sample beam reinforcement.*

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Dispersed reinforced concrete beams with reinforced concrete and basalt fibers were formed using a hydraulic press of OKS-1671M brand, modernized by the authors, with a load capacity of 400 kN. The layout of the samples on the test device is shown in Figure 3.

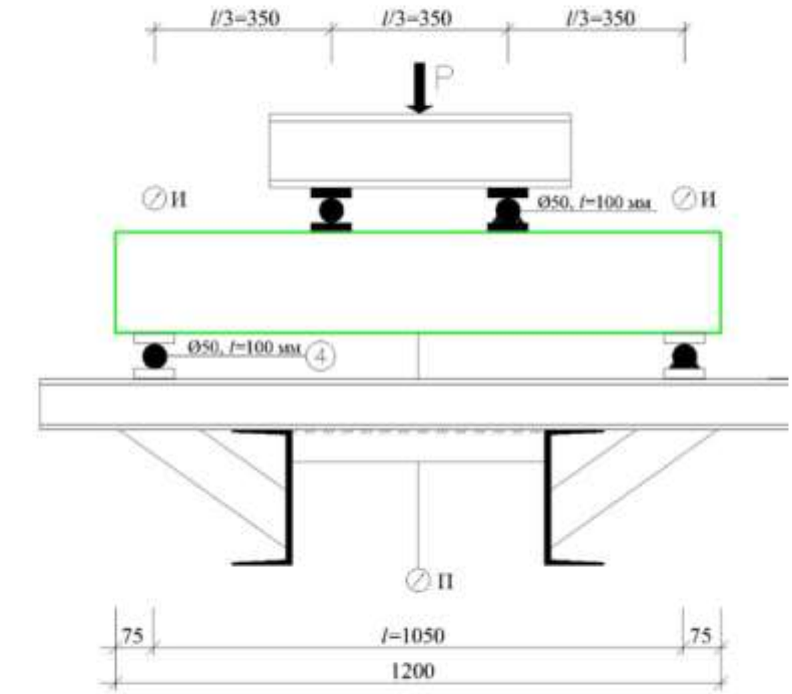

Fig. 4. *View of the sample on the test device.*

In order to measure the deformation of the beams, specially prepared metal pins were attached to the compressible and elongated parts of the beams. Holes were made in the metal studs. One of the bars has a clock-type indicator and the other has a messura.

To determine the stress-strain state of the concrete, the cross-sections of the side beams were measured using a portable messura (Figure 4) using clockwise indicators with an accuracy of 0.01 mm at a base of 300 mm.

Fig. 5. *view of the messura.*

3. Analysis and results

Longitudinal elongation and compressive deformations of concrete do not have large values at the initial loads, and their variation increases almost in a straight line. Elongation deformations of concrete ε_{fb}=(32-45)·10^{-5} and compressive deformations of concrete reached ε_{fbt}=(17-23)·10^{-5} when the force reached 30 kN on reinforced concrete beams of series I. Elongation deformations of concrete ε_{fb}=(12-20)·10^{-5} and compression deformations of concrete reached ε_{fbt}=(8-12)·10^{-5} values when the force reaches 30 kN in sample II reinforced concrete beams.

Elongation deformations of concrete have reached ε_{fb}=(150-160)·10^{-5} and compressive deformations of concrete ε_{fbt}=(47-50)·10^{-5} when the amount of load have reached F_{ult}(0,8-0,9). Elongation deformations of concrete in series II reinforced concrete beams ε_{fb}=(130-145)·10^{-5} compressive deformations of concrete up to ε_{fbt}=(28-45)·10^{-5}.

When the amount of breaking force in the series III sample fiber-reinforced concrete beams reached F_{ult}=(0.2-0.3), the elongation deformations of concrete reached ε_{fb}=(13-28)·10^{-5} compressive deformations of concrete ε_{fbt}=(8-14)·10^{-5}. Elongation deformations of

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concrete ε_{fb}=(14-20)·10^{-5} Compression deformations of concrete ε_{fbt}=(10-17)·10^{-5} in the IV series sample fiber-reinforced concrete beams (Figures 5-8).

Elongation deformations of concrete in series III samples reached ε_{fb}=(130-140)·10^{-5} compressive deformations of concrete ε_{fbt}=(28-32)·10^{-5} as the loading stages approached the destructive force. Elongation deformations of concrete ε_{fb}=(115-132)·10^{-5} compression deformations of concrete up to ε_{fbt}=(31-35)·10^{-5} were found in the IV series sample fiber-reinforced concrete beams.

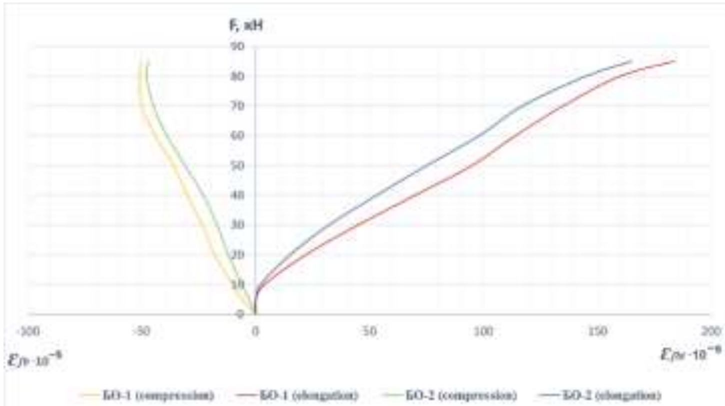

Fig. 6. *Average relative compressive and elongation deformations of concrete in series I ordinary reinforced concrete beams*

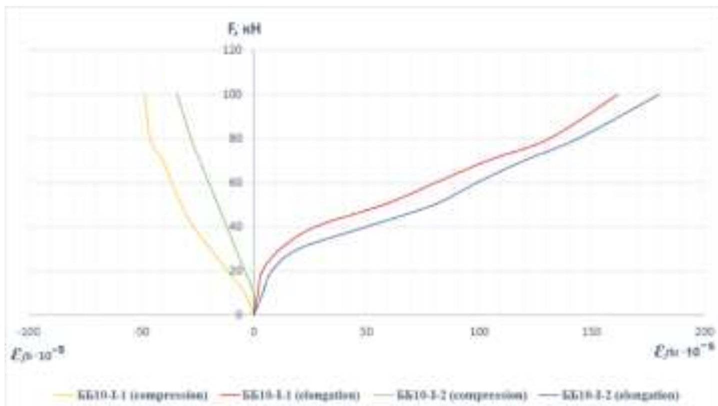

Fig. 7. *Average relative compressive and elongation deformations of concrete in series II fiber reinforced concrete beams*

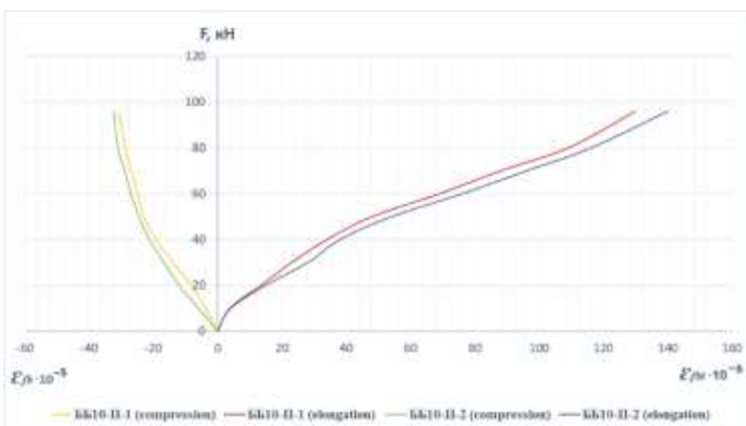

Fig. 8. *Average relative compressive and elongation deformations of concrete in series III fiber reinforced concrete beams*

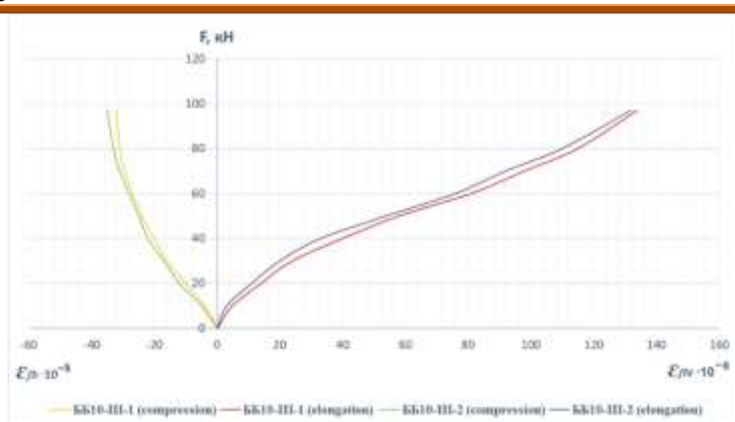

Fig. 9. *Average relative compressive and elongation deformations of concrete in series IV fiber reinforced concrete beams*

4. Conclusion

Experimental studies of sample beams have provided new data on the nature of the stress-strain state of fiber reinforced concrete beams and the strength of normal sections. Basic fiber-reinforced concrete beams have shown high strength, high load-bearing capacity, high tensile strength, and stiffness compared to ordinary reinforced concrete beams.

The addition of basalt fibers to concrete in the range of 0.1-0.3% allows more efficient use of regular reinforcement. It also has the effect of increasing the load-bearing capacity of fiber reinforced concrete beams, which are subject to bending and increasing it by an average of 10-19% compared to control samples.

5. Acknowledgment

The authors would like to thank the laboratory staff of Bunyodkor-3 LLC for their close assistance in conducting this research.

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