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Numerical Simulation of Fiber-Reinforced Concrete Beams Based on Steel Fibers Using Ansys Software

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Abstract: In this research work the strength, stress-strain state, and deflection of fiber-reinforced concrete beams dispersed with steel fibers were analyzed using the ABAQUS program. It was found that the strength of fiber reinforced concrete beams increased compared to ordinary reinforced concrete beams.

Keywords: reinforced concrete, beam, stress, strain, steel fiber, flexure, strength, dispersed reinforcement.

Introduction

Fiber concrete is a composite building material reinforced with fibers. Fiber concrete mainly consists of three components: fine and coarce aggragates, steel fibers and binding materials. Fiber concrete is a new building material, which is used in civil and industrial construction due to its high strength and durability. Also, the most important function of fiber concrete is to prevent the appearance of micro and macro cracks in concrete.

Many scientists have conducted scientific research on fiber concrete based on steel fibers. In particular, Y. Zheng et al. [2] studied the mechanical properties of steel fiber reinforced concrete using vibration mixing technology. Steel fibers with a length of 20 and 60 mm and a diameter of 0.3 and 1.2 mm were used in the preparation of samples. Samples were prepared by adding 39, 58.9, 78.9, 117 kg of steel fibers to concrete in amounts of 0, 0.5, 1.0, 1.5, 2.0% for 1 m3 of concrete, respectively. To determine the compressive strength of fiber concrete dispersed with steel fibers, standard cube samples with sides of 150x150x150 mm, prism samples with cross-sectional dimensions of 100x100x400 mm to determine bending strength, and cube samples with sides of 150 mm were prepared to determine the tensile strength of concrete when splitting.

D.S. Suman et al [3] studied the effect of steel fiber length on concrete strength. Cube samples with sides of 150x150x150 mm were prepared to determine the compressive strength of concrete, and cylindrical samples with sides of 150x300 mm were prepared to determine the tensile strength of concrete. The compressive strength of concrete at 7 days increased by 23%, 41.6%, 33.69% for fibers with a length of 30, 50, 75 mm, respectively, while the compressive strength at 28 days increased by 24%, 40%, 40.57% for fibers with a length of 30, 50, 75 mm, respectively.

A. Rana [4] conducted experimental studies on the bending strength of concrete based on steel fibers. In the scientific work, he used straight steel fibers with a hook at the end. The diameter of the steel fibers was 0.25-0.75 mm, and the length was 30 mm. To determine the bending strength of fiber concrete, prism samples with cross-sectional dimensions of 150x150x700 mm were prepared. According to the results of the authors' experiments, it was observed that the flexural strength of the fiber concrete prism samples dispersed reinforced with steel fibers increased by 20-40% compared to the samples without fiber addition.

In the Ansys program, the following tasks were defined in the modeling of reinforced concrete and fiber-reinforced concrete beams:

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1. Modeling of reinforced concrete and reinforced concrete beams.
2. Researching the state of stress-strain in beams and obtaining new scientific information.
3. Investigation of strain in concrete under load.
4. To study the development of deflection in samples under the influence of loads.
5. Study of strength indicators of fiber-reinforced concrete and reinforced concrete beams.

The dimensions of reinforced concrete beams made of fiber-reinforced concrete and ordinary concrete dispersed with steel fibers were modeled homogeneously with the dimensions of samples prepared in experimental tests. The cross-sectional dimensions of the sample beams were 0.1x0.2x1.2 m. An overview of the sample beam modeled using the software is shown in Figure 1. Steel fibers were also modeled by adding steel fibers to the beams in the sizes used in the experiment, i.e. 10, 20, 30 mm lengths and 1.0, 2.0, 3.0%. At the same time, the mechanical properties of concrete and fiber concrete were used in the modeling of materials in the ANSYS program based on the results determined through laboratory tests and using the Drucker-Prager method.

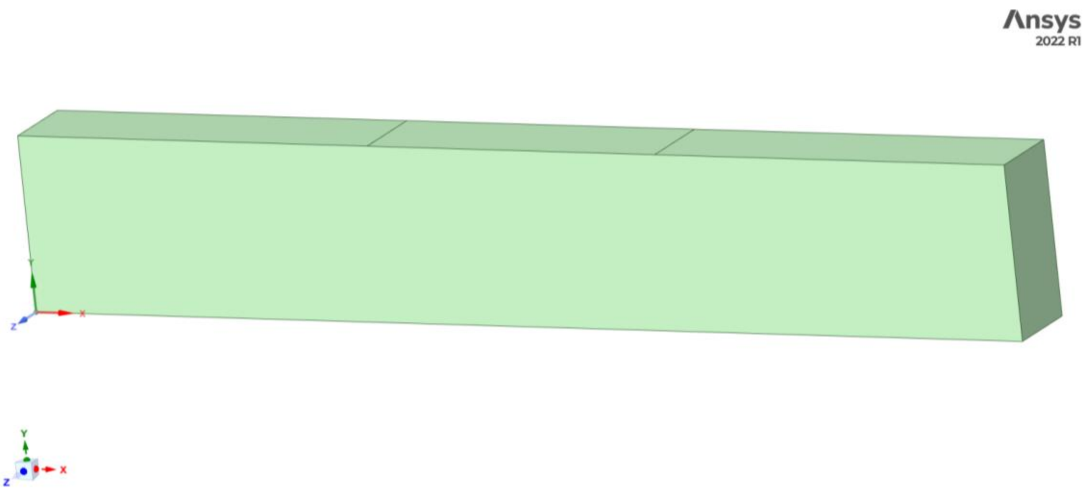

Figure 1. Model of the designed beam

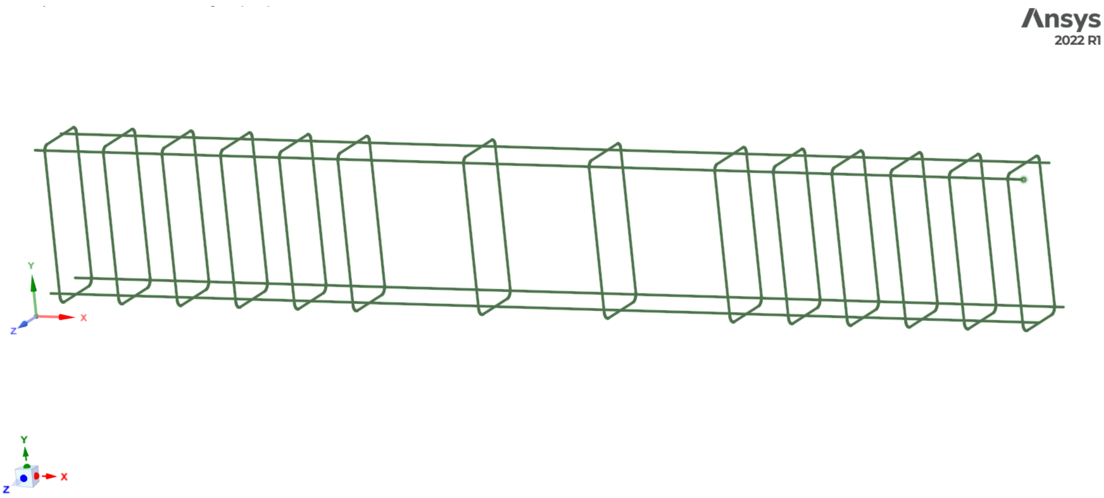

Figure 2. Designed beam reinforcement model

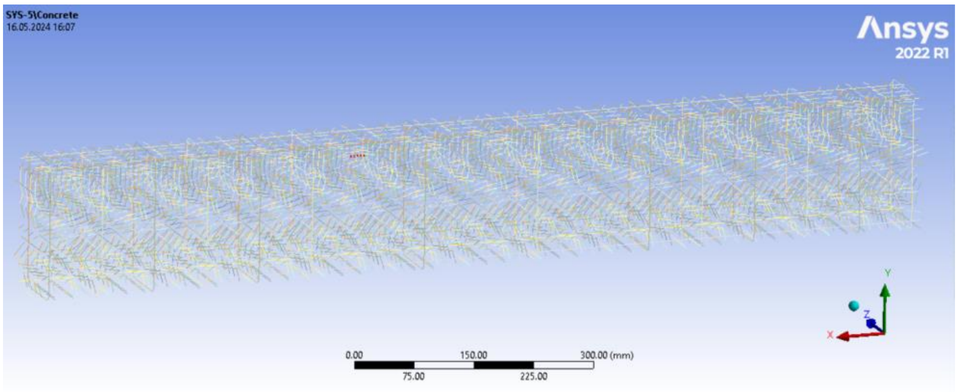

Figure 3. Model of steel fibers in a designed fiber-reinforced concrete beam

Through the modularization of reinforced concrete and fiber-reinforced concrete samples in the ANSYS program, new scientific information was obtained on the stress-strain states of concrete and rebars, stresses in beams, deflection and strength at different stages of loading.

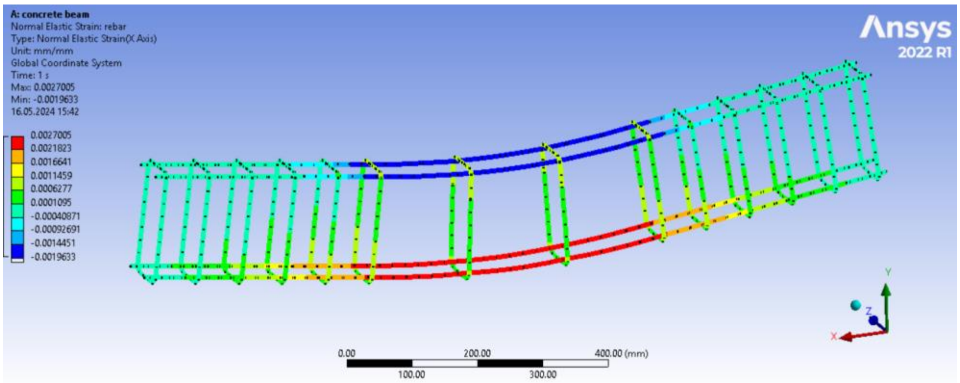

Figure 4. Strain of rebar in reinforced concrete beam

Figure 4 shows the strain of the rebar under the load on a simple reinforced concrete beam. The maximum tension of the rebar in the tension part of the reinforced concrete beam was equal to $\varepsilon_c = 270.05 \cdot 10^{-5}$.

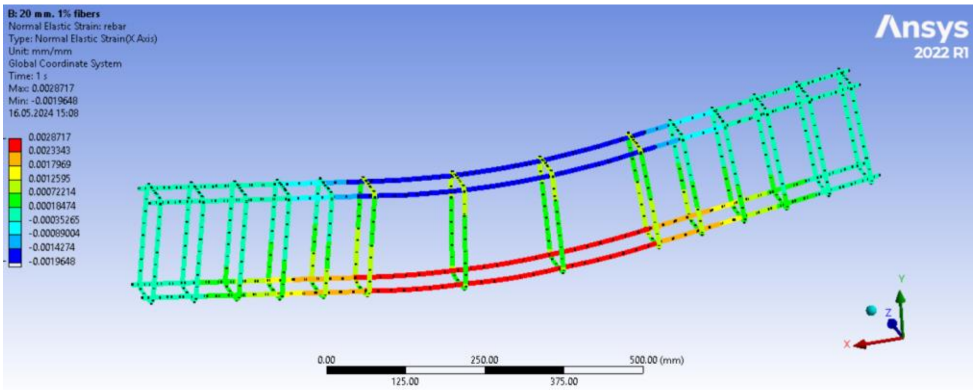

Figure 5. Strain of rebar in fiber reinforced concrete beam

When steel fibers with a length of 10 mm are dispersed reinforced by adding 1% to concrete and the amount of destructive load acting on the fiber-reinforced concrete beam reaches 80-90%, the strain in the rebars is $\varepsilon_c = 287.17 \cdot 10^{-5}$, the strain in the rebars of the samples reinforced with 2% is $\varepsilon_c = 279.12 \cdot 10^{-5}$, and the samples reinforced with dispersed reinforcement are the strain in the rebars was $\varepsilon_c = 263.10 \cdot 10^{-5}$ (Fig. 5).

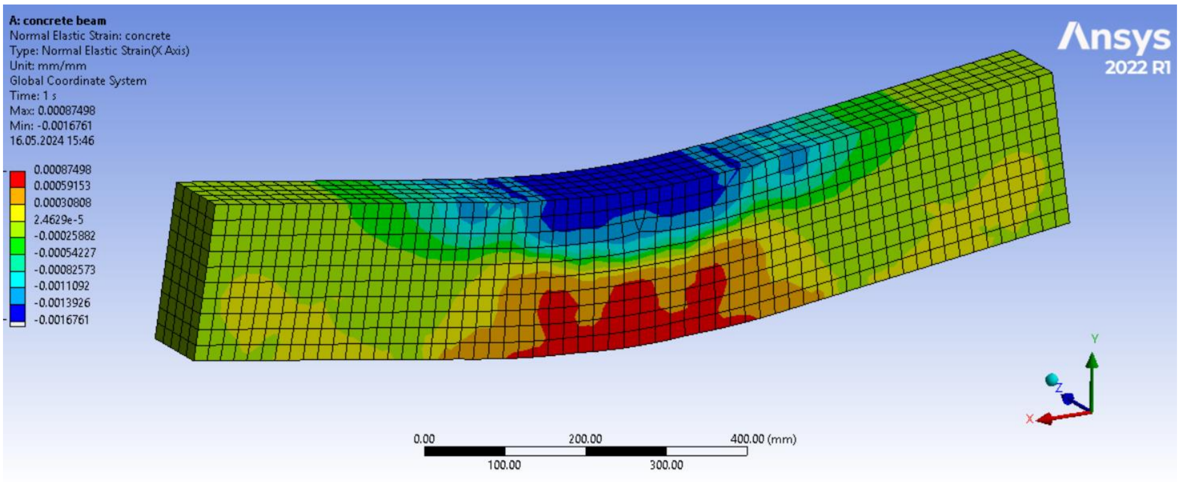

Figure 6. Strain in concrete.

Figure 6 shows the strain in concrete under load on a simple reinforced concrete beam. The maximum strain of concrete in the tensile part of the reinforced concrete beam was $\varepsilon_{fbt} = 87.5 \cdot 10^{-5}$, and the maximum strain of concrete in the compressive part of the fiber-reinforced concrete beam were $\varepsilon_{fb} = 16.5 \cdot 10^{-5}$.

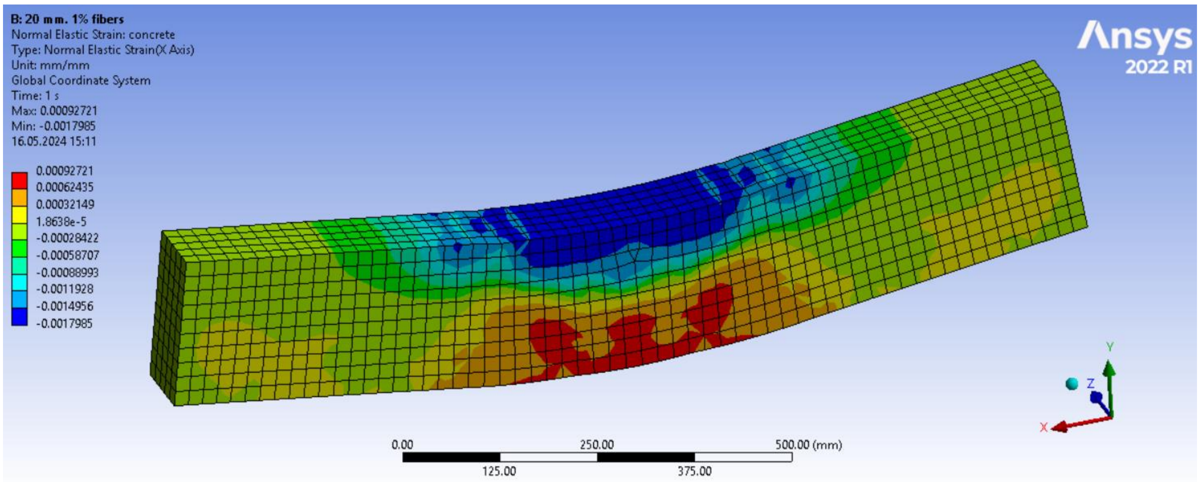

Figure 7. Strain in fiber concrete.

The strain of concrete in the tensile part of the fiber-reinforced concrete beam reinforced by adding 1% of steel fibers with a length of 10 mm to the concrete was $\varepsilon_{fbt} = 99.3 \cdot 10^{-5}$ when the amount of destructive load affected by the strain reached 80-90%, and the maximum strain of concrete in the compressive part of the fiber-reinforced concrete beam was $\varepsilon_{fb} = 18.2 \cdot 10^{-5}$. The maximum strain of concrete in the tensile part of the fiber-reinforced concrete beam reinforced with 2% addition of steel fibers to concrete was $\varepsilon_{fbt} = 98.0 \cdot 10^{-5}$, and the maximum strain of concrete in the compressive part of the fiber-reinforced concrete beam was $\varepsilon_{fb} = 17.4 \cdot 10^{-5}$. The maximum strain of concrete in the tensile part of the fiber-reinforced concrete beam reinforced with 3% addition of steel fibers to concrete was $\varepsilon_{fbt} = 89.0 \cdot 10^{-5}$, and the maximum strain of concrete in the compressive part of the fiber-reinforced concrete beam was $\varepsilon_{fb} = 16.8 \cdot 10^{-5}$.

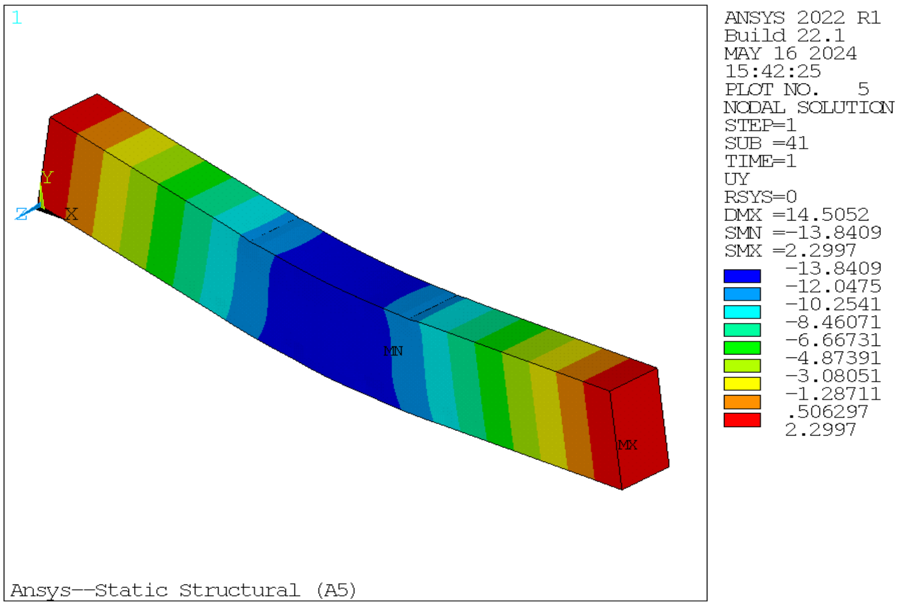

Figure 8. General view of the deflection of the reinforced concrete beam

In the specimen beams, the deflection loads increased linearly in the initial stages, while the deflection values increased sharply when the reinforcement in the tensile zone reached yielding.

The deflection was 0.85 mm at 30% of the breaking force of the ordinary reinforced concrete beam, and at the maximum breaking force (103.45 kN) it was 14.51 mm (Fig. 8).

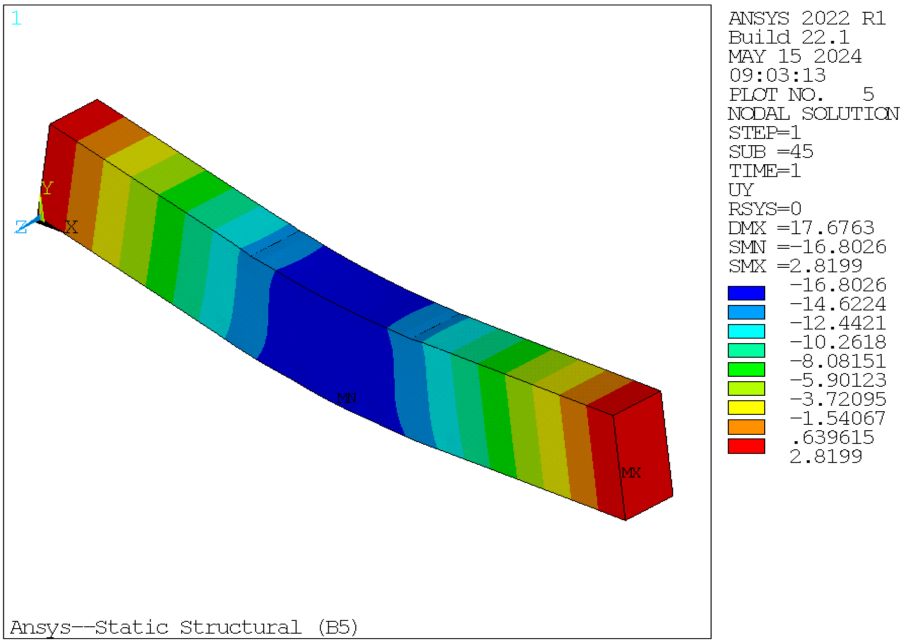

Figure 9. General view of the deflection of the fiber-reinforced concrete beam

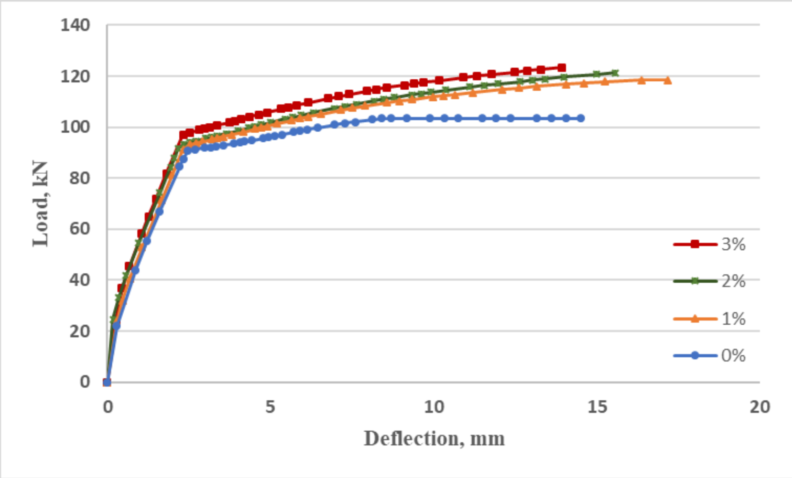

Fig. 10. Deflection of samples based on steel fibers with a length of 10 mm

At the failure stage load of a simple reinforced concrete beam, i.e. at 103.45 kN, the deflection was 14.51 mm. At the same loading, when steel fibers with a length of 10 mm were added to concrete with 1.0% of dispersion reinforcement, the deflection was 5.99 mm, when dispersion reinforcement was added with 2.0%, the deflection was 5.78 mm, and when dispersion reinforcement was added with 3.0%, the deflection was 5.64 mm. At the value of the maximum breaking force, i.e. at 118.46 kN, the maximum sag is 17.16 mm in the dispersed reinforced samples with 1.0%, at the maximum breaking force value of the samples with 2.0% in concrete, that is, at 124.57 kN, the maximum sag is 15.57 mm, in the samples with 3.0% in the concrete at the force value, that is, at 129.49 kN, the maximum deflection was 18.02 mm.

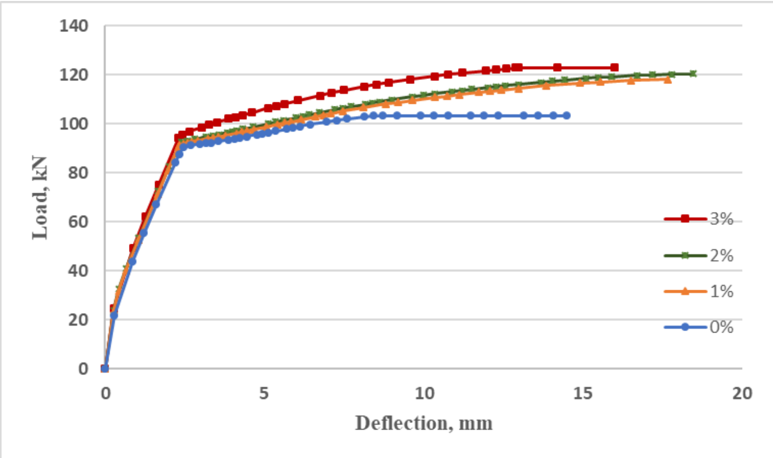

Fig. 11. Deflection of samples based on steel fibers with a length of 20 mm

When 20 mm length steel fibers added 1% to concrete and reinforced fiber reinforced concrete beam was 30% of the breaking force amount, the deflection was 0.65 mm, and at the maximum breaking force amount (119.21 kN) it was 17.68 mm. An overview of the deflection in the fiber-reinforced concrete beam is shown in Figure 5.3. When steel fibers with a length of 20 mm were added to concrete with 1.0% dispersion reinforcement, the maximum deflection was 17.68 mm, when dispersion reinforcement was added with 2.0%, the maximum deflection was 18.47 mm, when dispersion reinforcement was added with 3.0%, the deflection was 16.0 mm.

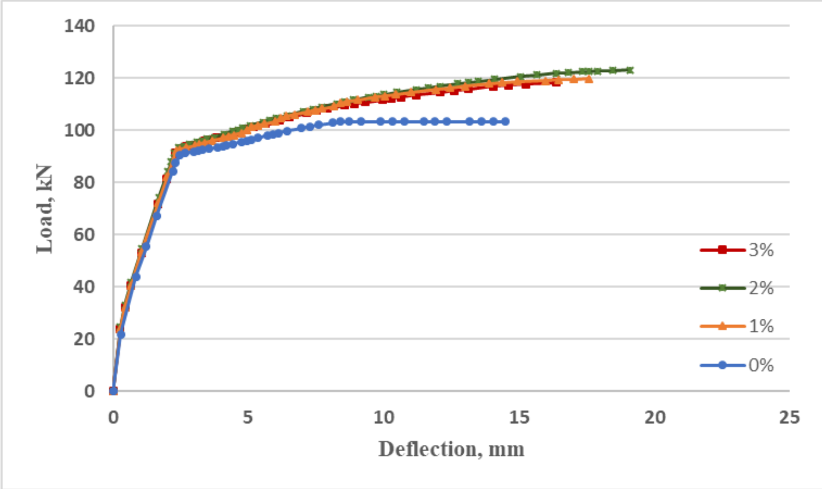

Fig. 12. Deflection of samples based on steel fibers with a length of 30 mm

When steel fibers with a length of 30 mm were added to concrete with 1.0% dispersion reinforcement, the maximum deflection was 17.61 mm, when dispersion reinforcement was added with 2.0%, the maximum deflection was 19.10 mm, when dispersion reinforcement was added with 3.0%, the deflection was 17.16 mm. It was found that the deflection of samples reinforced with steel fibers reduced compared to the coolness of ordinary reinforced concrete samples.

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