STRENGHT OF FIBER CONCRETE DEPENDING ON SYNTHETIC FIBER CONCENTRATION

ŠĶIEDRBETONA STIPRĪBA ATKARĪBĀ NO SINTĒTISKO ŠĶIEDRU KONCENTRĀCIJAS

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Abstract. *Concrete is one of base materials for nowadays constructions and it is important to understand its capabilities to ensure safety and longevity of construction. To enhance the properties of concrete, fibers are used. These fibers increase both tensile strength and durability, prevents cracking and extends lifespan of concrete. In this paper we will look at concrete tensile strength using scrap polymer fibers from sailing rope manufacturer.*

Keywords: *Synthetic fiber, Reinforced concrete, tensile strength, three-point bending.*

Introduction

Concrete is a fundamental building material thanks to its valuable properties. Heat resistance, affordability and ability to withstand compression makes this material very popular and useful in many constructions all over the world. The main weaknesses of concrete is brittleness, weak tensile strength and low crack resistance leading to a drop in the fracture strength once cracking has started [1].

Fiber Reinforced Concrete (FRC) is a concrete containing fibrous material which increases its structural integrity. It contains short discrete fibers that are uniformly distributed and randomly oriented [2]. FRC, in general, offer improved tensile strength, flexural toughness, impact strength, energy absorption, and crack control compared to plain concrete [3].

The material of choice for reinforcement has been and remains to be steel [4]. But it has some downsides, like corrosion when it meets with aggressive environment [5]. On the other hand, synthetic fibers are immune to corrosion and have low thermal conductivity [6].

This research will investigate how much concentration of synthetic fibers in concrete mixture affects its tensile strength.

Materials and methods

Fibers dimensions: thickness of 0.4 mm, 1 mm wide and 42mm long. Plastic fibers were taken from scrap sailing rope string. These are Polypropylene/Polymethyl blend fibers, where 75% is polypropylene (PP) and 25% Polymethyl (PM).

“Sakret BE” concrete mixture was chosen due to its simplicity of work and good repeatability of sample making. To make concrete using this mixture, only water and fibers should be added.

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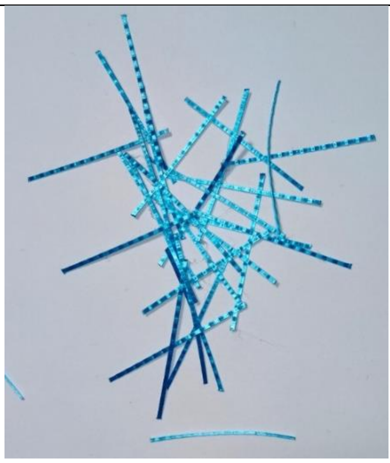	
Fig. 1 **Plastic Fibers**	*Fig. 2* **Concrete mixture**

The most important parameter for this study is concentration of fibers.

Dimensions of mold is 60 (W) x 60 (H) x 270 (L) mm and knowing desired amount of fibers measured by kg/m^3 it is possible to calculate the mass of fibers which should be added to sample. For calculations is used following formula:

$$Fiber\ mass\ (kg) = fiber\ concentration\ \left(\frac{kg}{m^3}\right) \times mold\ volume\ (m^3) \tag{1}$$

If desired fiber concentration is 2 kg/m^3 and mold volume is 0,000972 m^3, then in this case, added fiber mass should be 1,94 grams.

Desired concentrations and fiber weight per sample is shown in Table 1.

Table 1.

Fiber mass for desired concentration

concentration (kg/m^3)	**Fiber mass (g)**
2	1,94
5	4,86
8	7,78

This experiment consists of 4 fiber concentrations which is: plain concrete without fibers, 2 kg/m^3, 5 kg/m^3 and 8 kg/m^3. For each of them will be made and measured 3 samples.

Sample preperation

This section will detail the process of preparing samples used for testing strength of fiber concrete.

1. Prepare fibers.
2. Using scale with accuracy of 0,01mm to measure weight of fibers for each sample group.
3. Measure Empty Mold Weight.
4. Mix Concrete with Water.
5. Fill Molds and Weigh.
6. Calculate Plain Concrete Weight for One Sample.

- *Subtract the weight of the empty mold (step 3) from the weight of the filled mold (step 5). This difference represents the weight of the plain concrete for one sample.*

7. Measure Concrete for Fiber-Reinforced Mix.
   - *Weigh out three times the amount of plain concrete weight calculated in step 6 and pour it in separate container for mixing.*
8. Add Fibers While Mixing.
   - *While mixing the concrete, gradually add the pre-measured fibers for one sample group. This makes better dispersion and minimizes fiber clumping.*
9. Pour Fiber-Reinforced Concrete into molds and lightly tap it on the ground to let air bubbles leave concrete.
10. Clean mixing container and repeat from step 7 for rest of sample groups.

Fig. 3. **Samples ready to cure**

After concrete has been cured for 48h, it could be freed from mold and continue curing for next 8 days.

Results

The testing is performed on “Zwick/Roell Z150” material testing machine which can provide 150 kN of force applied to test sample.

Fig. 4. **Testing setup**

For testing is used three-point bending test where lower points are 220mm apart from each other. Testing speed are 10mm/s and test end conditions are:

- Actual force is less than 80% of maximal force achieved at test.
- Deformation more than 20mm.

The study measures the maximal force and maximal deformation of concrete samples. For all tested samples the test end factor was force drop more than 80%.

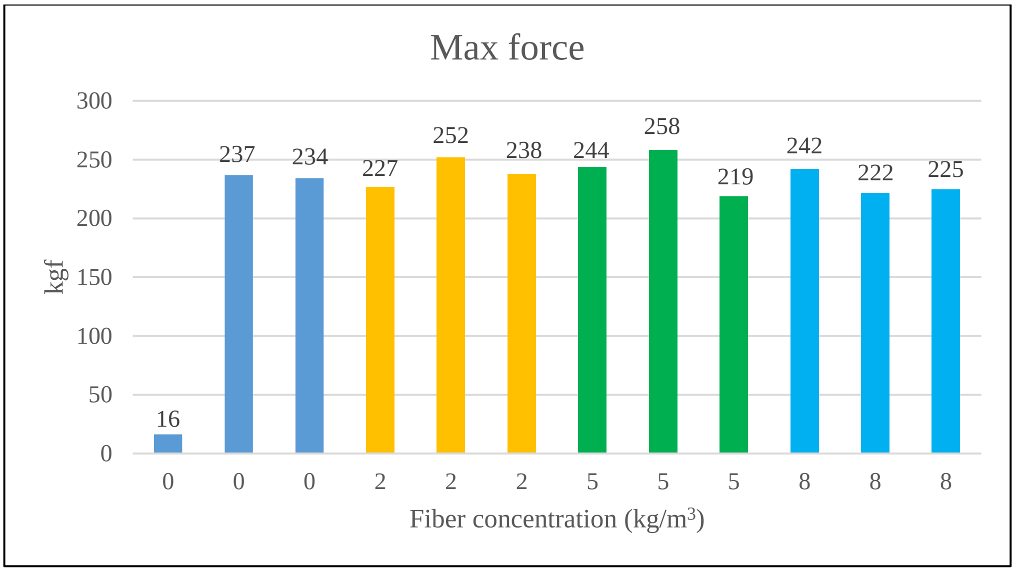

Chart 1. **Maximal force for each sample.**

One sample of three from plain concrete group was unsuccessfully tested and further it will not be considered. The graph reveals that maximal force remains relatively constant across all fiber concentrations, meaning that while synthetic fibers enhance post-cracking behavior, they do not significantly affect the concrete ability to withstand initial peak forces.

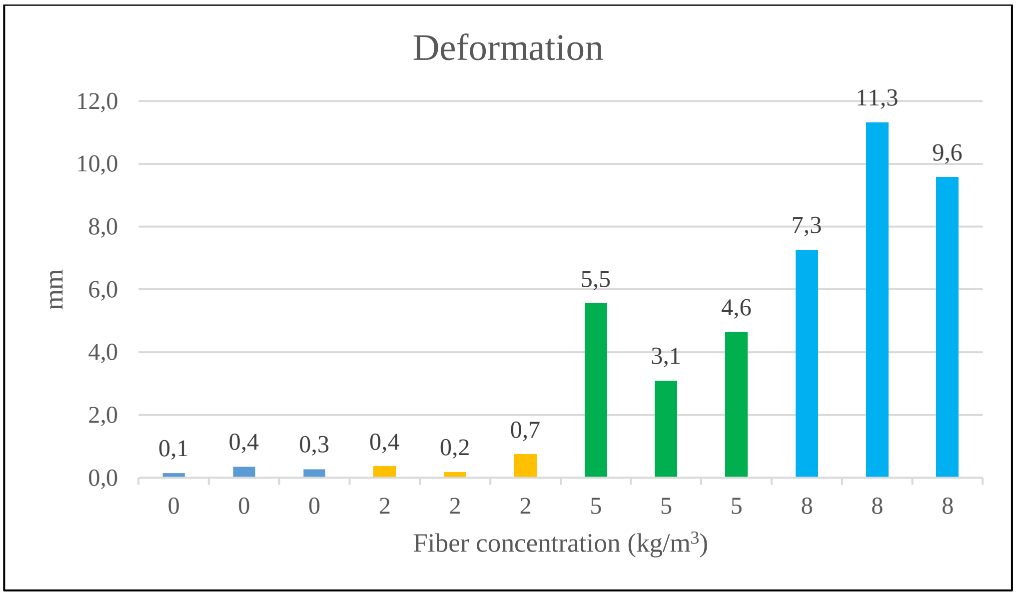

Chart 2. **Maximal deformation for each sample.**

This bar graph (*Chart 2*) correlates increased fiber content with greater deformation, indicating improved flexibility. Samples with 8 kg/m³ fiber exhibit the highest deformation, demonstrating significant enhancements in energy absorption and crack resistance.

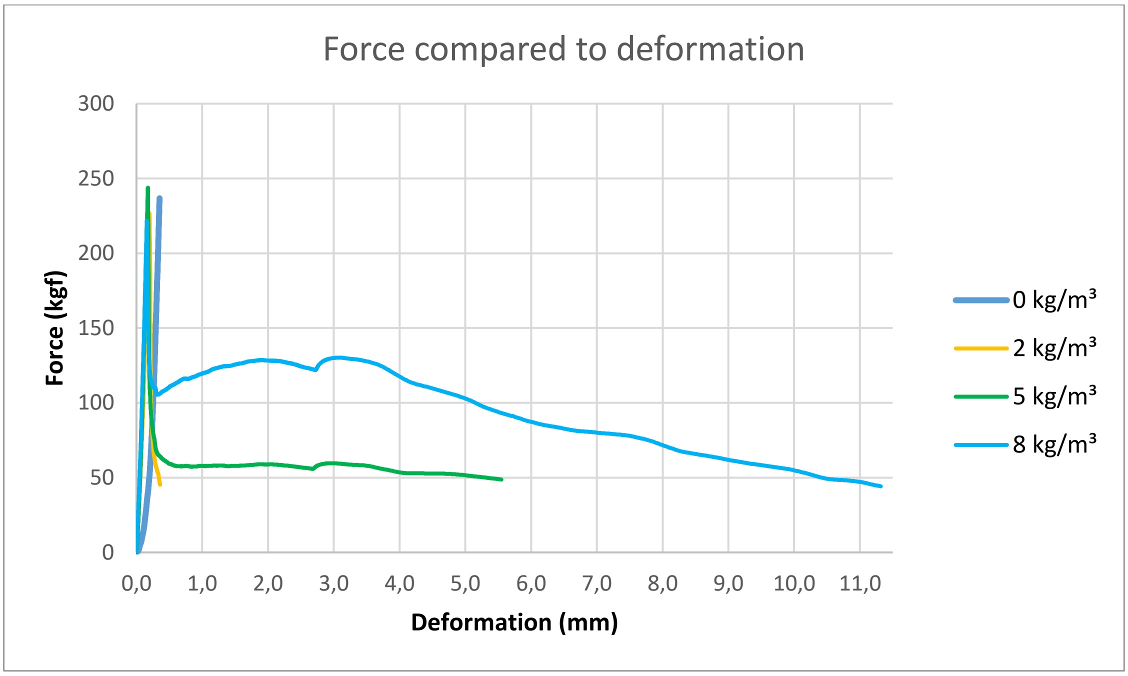

Chart 3. **Force compared to deformation.**

On Chart 3 we can better observe tendency of increased force endurance based on measuring devices travel distance. Also, distance traveled by 8 kg/m^3 fiber concentration is double compared to 5 kg/m^3. Average force after the concrete has cracked for 8 kg/m^3 is 106 kgf and for 5 kg/m^3 is 59 kgf. Unfortunately for 2 kg/m^3 test end conditions was met too soon to compare it to the rest fiber concentrations, but in the graph we can see that yellow line has started to stay horizontal.

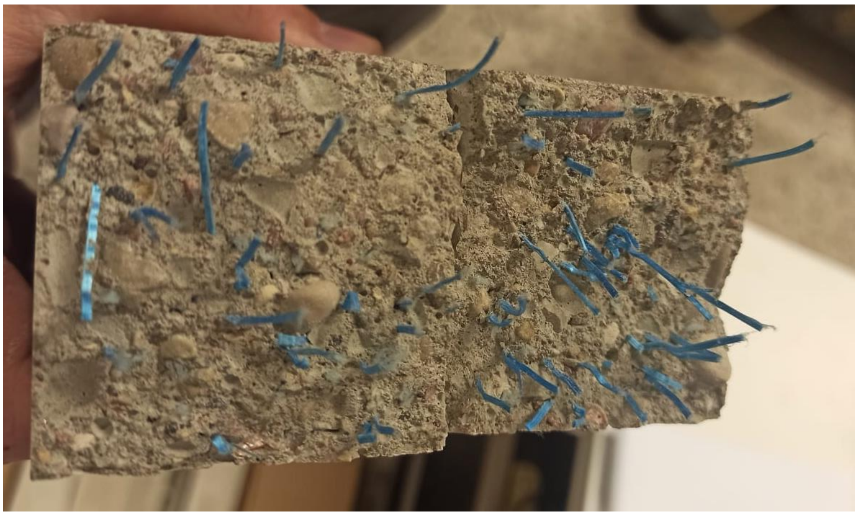

Fig. 5. C**ross-section of sample**

Results and discussion

Based on the end results, all of samples sustained approximately 236 kgf force. This shows that maximal force is not affected by amount of fibers in concrete. When the fiber concentration was increased from 5 kg/m³ to 8 kg/m³, the post-cracking force resistance increased by 55.6%. This also is shown as the deformation at 8 kg/m³ was 11,31 mm compared to 4,62 mm at 5 kg/m³, indicating improved flexibility.

Summary

This study examines the impact of synthetic fiber concentrations on the mechanical properties of concrete, focusing on post-cracking behavior through three-point bending tests. Results indicate that while maximum force resistance remains constant across varying fiber levels, deformation characteristics improve significantly with higher fiber concentrations. Specifically, increasing fiber content from 5 kg/m³ to 8 kg/m³ enhances post-cracking force resistance by 55.6%, demonstrating the fiber role in enhancing flexibility. In conclusion, higher fiber concentrations can substantially improve concrete performance offering valuable insights for designing more resilient concrete structures.

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