INFLUENCE OF USING STEEL AND POLYPROPYLENE FIBERS ON THE BENDING OF SIFCON


https://doi.org/10.32970/CS.2024.1.2

Wisam K. Tuama – György L. Balázs

Slurry Infiltrated Fiber Concrete (SIFCON) is a special kind of fiber-reinforced concrete that has significant durability and ductility, and it has a higher tensile strength compared to other fiber-reinforced concrete. SIFCON contains a lot of fiber, up to 20% or even more. This study focuses on discovering the effect of two types of fibers, steel and polypropylene, on the bending of SIFCON. A certain number of SIFCON laminates specimens were cast with dimensions of 300×100 mm, with different thicknesses ranging between 10, 20, and 30 mm. Cubes and prisms were also cast to determine the compressive and flexural resistance of the SIFCON concrete for each type of fiber used. After checking all the results, the highest compressive and flexural strength were achieved for SIFCON with steel fiber by 118 and 32.6 MPa respectively, as well as the maximum stress for SIFCON laminates with steel fiber and 30 mm thickness by 16.73 MPa.

Keywords: Slurry Infiltrated Fiber CONcrete, SIFCON laminates, Bending, Steel and Polypropylene fibers

1. INTRODUCTION

Fiber-reinforced cementitious composites (FRCCs) have significantly advanced since the 1970s. It is well acknowledged that FRCC increases the qualities of normal concrete, including tensile strength, stiffness, and fracture resistance. These advantages have encouraged the adoption of FRCC in civil engineering construction. Lankard developed slurry infiltrated fiber concrete (SIFCON), a modification on standard FRCC, in 1984, by putting the steel fiber in mold using huge volumes of it to produce a very dense network of fibers; it is then infiltrated by cement slurry through the network of fibers without employing coarse aggregates in its creation (Lankard R., 1984). The fiber content by volume in SIFCON may vary from 4 to 20%, which is much higher than the typical 2% in conventional fiber-reinforced concrete because of workability and mixing requirements, where the fibers are blended with the other constituents of the concrete: cement, sand, and gravel. Because of its high fiber content, SIFCON has unique mechanical qualities that are superior in ductility, tensile strength, and impact resistance (Fatimah H., and Abeer S., 2020, and Wisam K., György L., 2023).

SIFCON is a steel fiber-reinforced cement composite with exceptional toughness and superior mechanical properties, including compressive, tensile, shear, and flexural strength (Metin I., and Mecbure A., 2019). This new type of special concrete is ideal for explosion-proof military buildings, industrial floors, and bridge piers due to its great toughness and flexural strength (Görkem H., Ferhat A., 2019). The unit weight of SIFCON is high, which exceeds the unit weight of fiber reinforced concrete, because of the high fiber content. The amount of fiber may vary depending on the geometry, aspect ratio, and assignment procedures. If the aspect ratio is reduced, the volume percentage of fibers can be raised. Mild vibrations might also raise the volume fraction. (Ali H., and Nada M., 2022).

The mechanical properties of SIFCON are influenced more by fiber properties such as fiber geometry (shape, length, diameter, and aspect ratio), volume fraction (amount), orientation, fiber type (steel, polymer, elastoplastic, polyolefin, polyethylene, and nylon, or hybrid), tensile strength, and elastic modulus of fibers. Although, the behavior of SIFCON constructed with steel fibers in various shapes, such as straight, hooked end, and crimped (non-straight) fibers, with different aspect ratios, has been documented (Renuka J., and Rajasekhar K., 2021 and Wisam K., György L., 2024).

In this study, the bending of SIFCON laminates specimens containing steel or polypropylene fibers is tested to determine the extent of the effect of using these different types of fibers on SIFCON resistance to bending and recording the maximum load, as well as comparing and discussing the results of the compressive and flexural resistances that were obtained, as well as the difference in SIFCON weight in the two cases.

Review objectives

This paper investigates the properties of slurry infiltrated fiber concrete when using different types of fibers. This study focuses on two main topics: (1) the bending of SIFCON laminates (2) the properties of SIFCON (compressive and flexural strength).

Emphasis is placed on studying how SIFCON bending property is affected by the use steel or polypropylene fibers. Results of this study and summary of how to improve the properties of SIFCON and the bending resistance also discussed.

2. EXPERIMENTAL WORK

2.1 Materials and mix design

In the area of this study, normal quartz sand with 1-4 mm size was used as a fine aggregate. Portland cement type CEM I, and silica fume according to (ASTM C1240, 2020) were used as a binder. Thirty percent used as a water to cementitious materials ratio (w/c), and BASF Master Glenium 300 as a superplasticizer with 1.75 % used in the mix to set adjust consistency of concrete flow (ASTM C494, 2015). In this work, two types of fibers (6%) with different shapes and aspect ratios were used. The first shape was hooked-end steel fibers with a length of 30 mm and a diameter of 0.5 mm. A new type of polypropylene fiber with a length of 25 mm and a diameter of 0.54 mm was also used. *Fig. 1* (a and b) shows the hooked steel fiber and polypropylene fiber used in this research. *Table 1* introduces the technical properties of the two types of fiber used according to the manufacturing company. *Table 2* shows the mixing ratios for SIFCON concrete.

In this experimental work, 6% of the fiber volume fraction was used to achieve the required performance, and a suitable volume of the molds was applied. The procedure of mixing: Blend the dry material for 2 minutes; after that, add 2/3 of water and mix for 3 minutes; leave to rest for 3 minutes. Add the remaining amount of water (1/3) that was mixed with SP and continue mixing for 2 minutes. In this test, the workability of the slurry was achieved with an expansion diameter of 260 mm.

2.2 Test samples

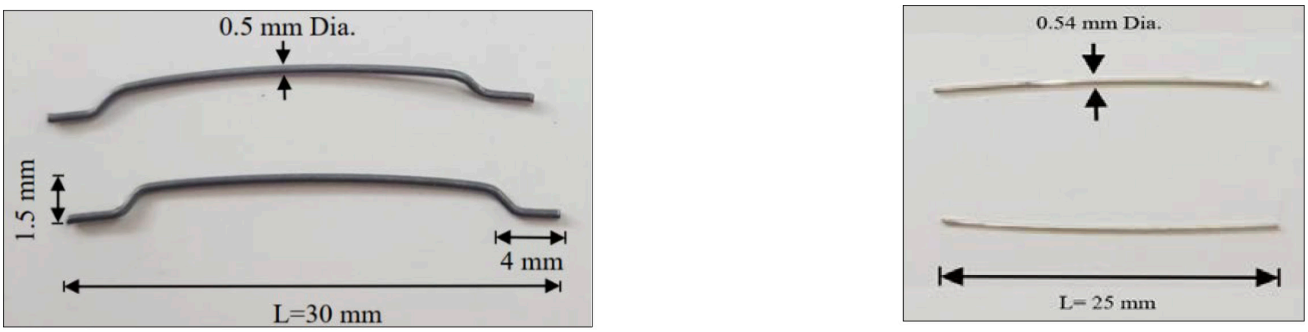
This study included testing of compressive strength and flexural strength of SIFCON and the bending of SIFCON concrete laminates. The compressive strength test was done on 100 mm cubes. The test of flexural strength was done on 40×40×160 mm prisms. The bending tests were performed laminates with 300×100 mm with different thicknesses of 10, 20, and 30 mm.

The results are the average of three cubes or prisms for all sets at the age of 28 days. Also, concrete laminate specimens were examined, and their average was taken. Before casting, the molds of cubes, prisms and laminates were completely cleaned and lubricated. The fiber amount was placed at once before pouring the slurry to penetrate the fibers. To achieve penetration, the mold was lightly knocked with a hand rod. Related to demolding, all samples sank in the basin with water at 25 °C in agreement with (ASTM C192, 2007). *Fig. 2* shows the steps for preparing and lubricating the molds, placing the fibers, pouring the SIFCON concrete, the tamping, and test the different specimens using various examination devices after curing for 28 days.

3. RESULTS AND DISCUSSION

3.1 Mechanical properties

Investigating the compressive strength was done by using a compression testing machine with a loading capacity of 3000 kN at a load rate of 5 kN/s for 100 mm cubes as shown in the pictures in *Fig. 2* and flexural strength of SIFCON concrete was done by using a three-point bend testing machine on a concrete prism. The strength of compressive and flexural at the age of 28 days for the cubes and prisms prepared for this purpose was tested. As a result, the SIFCON reinforced with steel fiber achieved the highest values of 118 and 32.6 MPa



(a) (b)

Fig. 1: Types of fiber (a- hooked-end steel fiber and b- polypropylene fiber)

Table 1: Technical properties of the fibers

Fiber type	Length (mm)	Diameter (mm)	Aspect ratio	Density (kg/m^3)	Tensile strength (MPa)
Steel	30	0.5	60	7,850	1,650
polypropylene	25	0.54	46.3	910	490

Table 2: SIFCON optimal mixing proportions for 1 m^3.

Cement (kg/m^3)	Sand (kg/m^3)	Silica Fume kg/m^3 10% rep.	Steel Fiber (%)	w/b or w/c ratio	SP (by wt. of binder) (%)	Slump flow (mm)
873	970	97	6	0.30	1.75	260

Fig. 2: Steps of pouring SIFCON concrete and test the different samples

for compressive and flexural strength respectively. When polypropylene fibers were used, the compressive and flexural strength decreased to 75 and 11.12 MPa respectively. The increase in strength can be explained by the ability of the fibers to restrict and prevent the expansion of the cracks as well as to reduce the growth rate of cracks and change their direction, depending on the characteristics of each type of fiber. This agrees with the researchers (Naser F., Abeer S., 2020, and Ali H., and Nada M., 2022). The reason for the increase in strength is the ability of the steel fiber to expand more than the polypropylene fiber with a greater volume fraction value because it has high tensile strength. It causes a decrease in the amount and the width of the cracks by acting as a bridge for the crack in the sides, which is due to the increasing strength. *Fig. 3* shows the shape of the concrete cube and prism pattern failure according to the use of the fibers and *Fig. 4* shows the compressive and flexural strength results.

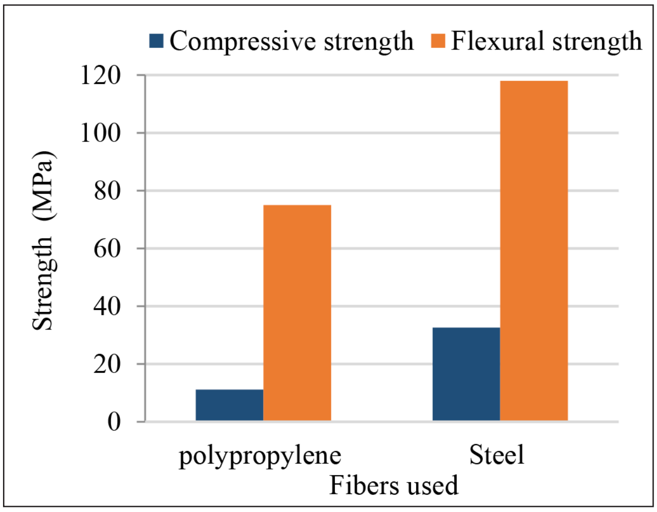


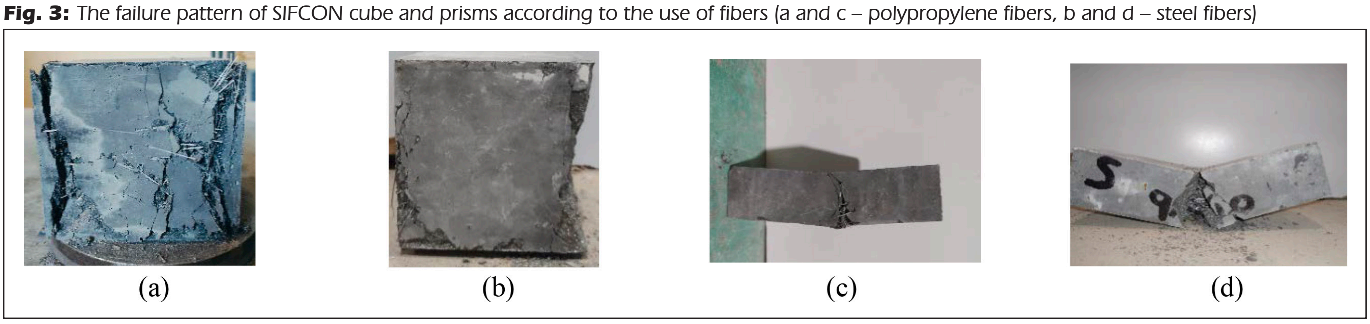
Fig. 4: Results on the compressive and flexural strengths

3.2 Bending of SIFCON

The main objective of this study is to learn the flexural strength of SIFCON concrete and to determine the maximum load that SIFCON laminates can carry. Therefore, SIFCON laminates with dimensions of 300×100 mm with different thicknesses of 10, 20, and 30 mm were cast and tested in a flexural testing device after curing in water for 28 days. The highest load was recorded for SIFCON laminates with the largest thickness of 30 mm when using steel fibers. *Fig.5* shows the maximum stress that can be tolerated by the SIFCON laminates of different thicknesses and according to the type of fibers used.

In the test, the specimens containing steel fibers had higher flexural strength (11.13, 13.47, and 16.73 MPa) than those containing polypropylene (6.92, 8.08, and 9.3 MPa) for laminates with thicknesses 10, 20, and 30 mm respectively. This increase in flexural resistance is considered to be due to the bridging effect of steel fibers in SIFCON, which transfers the stress across cracks more than polypropylene fibers. It was also noted that the difference in the increasing in the maximum load with the increase in the thickness of the specimen is higher when using steel fibers.

Fig. 3: The failure pattern of SIFCON cube and prisms according to the use of fibers (a and c – polypropylene fibers, b and d – steel fibers)



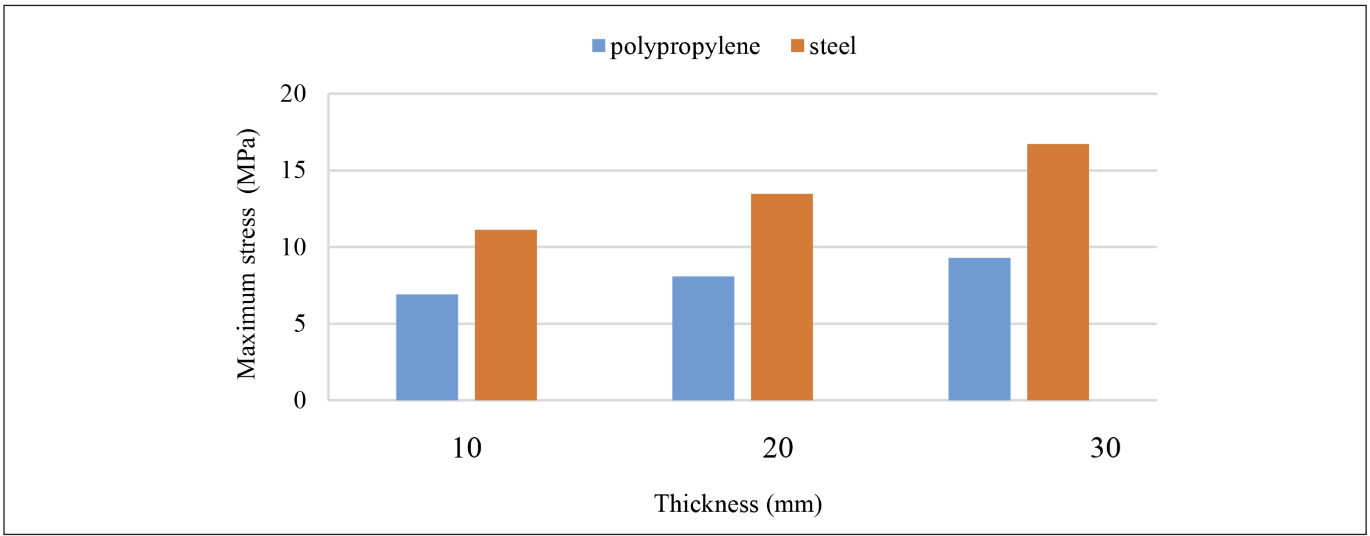


Fig. 5: The maximum flexural stress of the SIFCON laminates of different thicknesses according to fiber type

Fig. 6 shows the failure modes for a set of SIFCON laminates. It was observed that both types of fibers were able to obtain the maximum deflection. It was also observed from the results and failure modes that using other types of fibers, such as polypropylene fibers, performs a good function and gives high levels of bending resistance; although they are less than steel fibers, they are characterized by the weight of SIFCON concrete being less than compared to using steel fibers.

4. CONCLUSIONS

The purpose of the current study was to investigate the properties of slurry infiltrated fiber concrete when steel or polypropylene fibers are used (fiber characteristics are given in Fig. 1 and Table 1). This study focuses on investigating the flexural strength of SIFCON laminates and the strength properties of SIFCON (compressive and flexural strength). This study leads to the following conclusions:

1. The use of various fibers (steel and polymeric fibers) in SIFCON concrete makes it suitable for use according to the function that requires the use of this type of concrete, such as high deflection before failure, high energy absorption, and high maximum loads.
2. Among the tested specimens, SIFCON reinforced with steel fibers produced the highest compressive and flexural strength of 118 and 32.6 MPa respectively. When polypropylene fibers were used, the strength fell to 75 and 11.12 MPa for compressive and flexural strength, respectively.
3. The SIFCON laminates reinforced by steel fiber achieved the maximum bending stress of 11.13, 13.47 and 16.73 MPa for 10, 20, and 30 mm thick specimens respectively, and when polypropylene fibers were used, the strength decreased to 6.92, 8.08 and 9.3 MPa in case of 10, 20, and 30 mm thicknesses respectively.
4. It was observed that the SIFCON laminates containing steel fibers with a smaller thickness (10 mm) had higher strength (11.13 MPa) than the SIFCON laminates using polypropylene fibers with a larger thickness of 30 mm where it recorded a strength of 9.3 MPa.

5. ACKNOWLEDGEMENTS

Authors highly acknowledge the MAPEI Ltd. for providing polymeric fibres to the presented tests.

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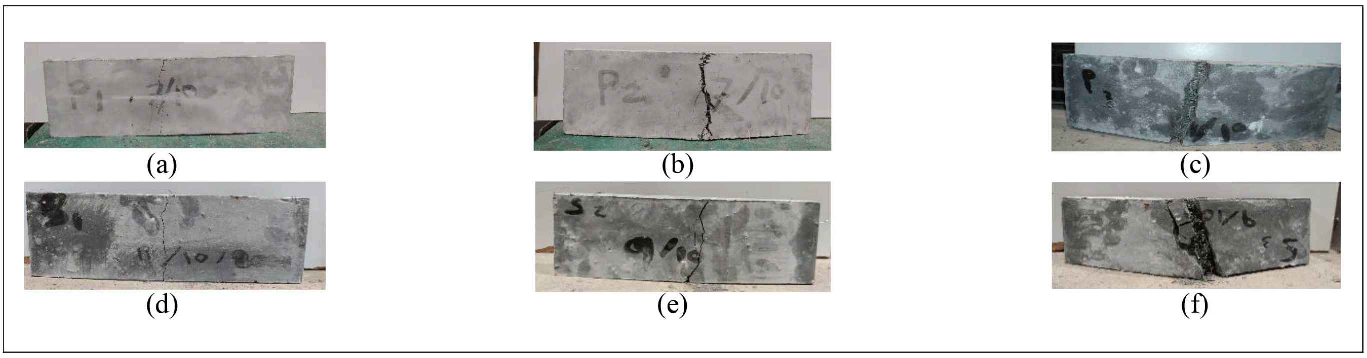
Fig. 6: The failure modes of SIFCON laminates (a, b, and c are SIFCON laminates that use polypropylene fiber with 10, 20, and 30 mm thickness respectively, and d, e, and f are SIFCON laminates that use steel fiber with 10, 20, and 30 mm thickness respectively)



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Wisam K. Tauma (1987), a Ph.D. student at the Department of Construction Materials and Technologies, Budapest University of Technology and Economics (BME). Finished his Bachelor's (2010) in Civil Engineering at the College of Engineering, Thi Qar University in Iraq, and finished his master studies (2019) Master of Science in Construction Materials Engineering at the College of Engineering, Babylon University in Iraq. Research areas: Fiber Reinforced Concrete, durability of concrete, Mechanical Properties of concrete. He is a member of the Hungarian Group of ***fib***.

György L. Balázs (1958), Civil Engineer, PhD, Dr.-habil., Professor of structural engineering at the Department of Construction Materials and Technologies of Budapest University of Technology and Economics (BME). His main fields of activities are experimental investigation and modeling of RC, PC, FRC, FRP, HSC, HPC, LWC, fire resistance and fire design, durability, sustainability, bond and cracking. He is chairman of several commissions and task groups of ***fib***. He is president of Hungarian Group of ***fib***, Editor-in-chief of the Journal "Concrete Structures". He was elected as President of ***fib*** for the period of 2011-2012. Since then, he is Honorary President of ***fib***. Chairman of ***fib*** Com 9 Dissemination of knowledge.