Studying of Compressive, Tensile and Flexural Strength of Concrete by Using Steel Fibers

Muslim Abdul-Ameer Khudhair Al-kannoon
Department of Civil Engineering, Faculty of engineering, Kufa University, Iraq.
moslemphd@gmail.com

Abstract

This research aims to study the effect of adding steel fibers on the mechanical properties of concrete. Steel fiber has a very significant effect on concrete because it delays the propagation of micro cracks that generate due to loading on concrete members such as beams and slabs, therefore ,it increases the strength of concrete. The steel fiber was used in this study as a percentage of the volume of concrete. Mix proportion was 1: 2:4 (cement: sand: gravel) by volume for all mixes and using 0% as (control mix),0.1 %,0.2%,0.5 % and 1.0% of steel fibers, these ratios leads to increase the compressive, tensile ,and flexural strength of concrete, where the improvement in flexural strength was significant.

Keywords: Steel fiber, Composite materials, Flexural strength, Tensile Strength, Compressive Strength.

الخلاصة

هدف هذا البحث هو دراسة تأثير اضافة الياف الحديد على الخواص الميكانيكية للخرسانة. الياف الحديد لها تأثير مهم جدا على الخرسانة لانها تؤخر ظهور التشققات التي تتولد نتيجة تحميل الاعضاء الخرسانية كالأعتاب والسقوف، لهذا هي تزيد من مقاومة الانضغاط للخرسانة.في هذه الدراسة استخدمت الالياف الحديدة كنسبة من حجم الخرسانة. نسبة الخلط كانت (1:2:4) (سمنت: رمل: حصى) نسبة حجمية لكل الخلطات واستخدمت الياف الحديد بالنسب (0%(كخلطة مصدرية)، 0,1% ، 0,2% ، 0,5% و 1%) أدت هذه النسب الى زيادة مقاومة الانضغاط، الشد ، والانثناء للخرسانة حيث أثبتت الدراسة زيادة مهمة في مقاومة الانثناء.

الكلمات المفتاحية: ألياف الحديد; المواد المركبة; مقاومة الانثناء; مقاومة الشد; مقاومة الانضغاط.

1.Introduction

Steel fiber reinforced concrete (SFRC) may be defined as a composite material made of hydraulic cements, water, fine and coarse aggregate, and a dispersion of discontinuous, small fibers. Early technological development of steel fiber reinforced concrete (SFRC) was hampered by lack of information and authenticated measures until the early 1960’s. Since that, researchers have done extensive researches on SFRC, driven by the promising performance enhancements in terms of strength, durability and toughness. Studies have shown increasing evidence that the brittle behavior of concrete can be overcome by the addition of short steel fibers of small diameters. Concrete fiber composites have been found more economical for use in Airport and Highway Pavements, Bridge Decks, Erosion resistance structures, slope stabilization, Refractory concrete, Earthquake resistance structures and Explosive resistance structures (ACI Committee 544,2006). Janesan, P.V. Indira and S. Rajendra Prasad (ACI Committee 544, 2006) reported the effect of steel fiber on the strength and behavior of reinforced concrete is two-way action. They concluded that the addition of steel fiber increases the ultimate strength and ductility (ACI committee 544, 3R-08, 2008).

The use of discrete steel fibers as a reinforcement system for cement based materials is now a current practice for several applications (Di Prisco *et. al.*, 2004). The resulting material is designated Steel Fiber Reinforced Concrete (SFRC). The post cracking residual stress is much higher in SFRC than in plain concrete (PC), due to fiber reinforcement mechanisms provided by fibers bridging the cracks (Barros *et. al.*, 2005). In consequence, SFRC allows high level of stress redistribution, providing a significant deformability capacity of a structure between crack initiation and its failure, which increases the structural safety. This is especially relevant in structures of a redundant number of supports (Barros, 1995). The level of the post cracking residual stress depends of several factors, namely: fiber geometric characteristics, fiber material properties, concrete properties, method of SFRC application.

There are numerous fiber types available for commercial experimental use. The basic fiber categories are steel, synthetic and natural fiber material. Hence this study explores the effective of steel fiber reinforcement, aim is to know the extent of the effect of steel fiber on the compressive and tensile strength of concrete.

2. Experimental Work

2.1 Experimental Program

This research was designed to study the effect of adding of steel fibers on compressive, tensile and flexural strength of concrete. 0%, 0.1%, 0.2%, 0.5% and 1% steel fiber content were used to evaluate the influence of steel fibers on the compressive, tensile and flexural strength of concrete. For compressive and splitting tensile strength test, a set of fifteen cubes specimens (150x 150x 150) mm and cylinders specimens (100x200) mm were tested at 28 days age. Also, Third point loading test is used to examine twelve 100 x 100 x 400 mm prisms with three reference prisms to evaluate the influence of SFR on flexural strength of concrete.

2.2 Materials and Mixes

2.2.1 Cement

The cement used in this study was Ordinary Portland Cement (O.P.C.) produced at Kufa factory. This cement compiled with the Iraq specification No.5 i 1984 (Iraqi Organization of Standards, IOS5:1984, for Portland Cement).The physical properties of the cement shown in **Table 1**.

2.2.2 Fine aggregate(sand)

Al-Khaider well-graded natural Silica sand was used. The results of physical and chemical properties of the sand are listed in **Table 2**. Its grading conformed to the Iraqi specification No.45 / 1984(Iraqi Organization of Standards, IOS5 : 1984, for Aggregate.), zone (3).

Table 1: Physical Properties of Cement.

Physical Properties	Test results	I.O.S.5:1984 Limits
Fineness, Blain, cm^2/gm	3090	≥2300
Setting time, Vicat's method Initial hrs:min Final hrs:min	 1:57 3:20	 ≥1:0 ≤10:0
Compressive strength of 70.7mm cube, MPa 3 days 7 days	 20 27.5	 ≥15 ≤23

Table 2: Physical Properties of Sand.

Sieve size (mm)	Percent Passing	I.O.S.45:1984 limits zone 3
9.50	100	100
4.75	94	90-100
2.36	92	85-100
1.18	78	75-100
0.60	62	60-79
0.30	23	12-40
0.15	0	0-10
Properties	**Test results**	**I.O.S.45:1984limits zone 3**
Sulfate content, SO_3	0.27	≤0.5
Specific gravity	2.60	-
Absorption	1.75	-

2.2.3 Coarse Aggregate(gravel)

The gravel used was brought Al-Nibaii area with a maximum size of 19 rnm. The grading and other properties of this type of aggregate were tested and shown in **Table 3**.

Table 3: Physical Properties of Gravel.

Sieve size (mm)	Percent Passing	I.O.S.45:1984 limits (maximum size 5-20mm)
37.5	100	100
20.0	97.5	95-100
9.50	53.4	30-60
4.75	3.9	0-10
Properties	**Test results**	**I.O.S.45:1984 limits**
Sulfate content, SO3	0.07	≤0.1
Specific gravity	2.64	-
Absorption	0.70	-

2.2.4 Water

Ordinary potable water was used in mixing concrete and curing the samples.

2.2.5 Fibers

In this experimentation straight steel fibers were used. The **Table 4** shows physical and some mechanical properties of steel fiber used in this study. The different volume fractions adopted were 0%, 0.1%, 0.2%, 0.5% and 1% (by volume).

Table 4: Physical and Mechanical Properties of Steel Fiber.

Density of S.F (kg/m3)	Tensile strength (Mpa)	Length (mm)	Diameter (mm)	Color
7840	2850	13	0.2	Yellow(coated with brass)

3. Experimental Methodology

3.1 Mixing Procedure

The materials (1:2:4) (cement:sand:gravel) were mixed by mechanical mixer of 0.1 m3 capacity, then the steel fibers were added by sprinkling during mixing. w/c ratio was 0.5. Steel fiber was added as a percentage by volume, compacting of specimens done by a vibrator machine.

3.2 Compressive Strength Test

For compressive strength test, cube specimens with dimensions of 150 x 150 x 150 mm were cast. The molds were filled with 0%, 0.1%, 0.2%, 0.5% and 1% fibers. Vibration was given to the molds using table vibrator. The top surface of the specimen was leveled and finished.

After 24 hours the specimens were demoulded and were transferred to curing tank wherein they were allowed to cure for 28 days. After 28 days curing, these cubes were tested on digital compression testing machine as per I.S. 516-1959. The failure load was noted. In each category three cubes were tested and their average value is reported as shown in **Table 5**.

Table 5: Results of Compressive Strength Test.

Steel Fiber Ratio %	0	0.1	0.2	0.5	1
Average of Compressive Strength of Three Cubes (MPa)	23.73	30.58	33.25	38.45	48.36

3.3 Tensile Strength Test

For splitting tensile strength test, cylinder specimens of dimensions 100 x 200 mm were cast. The moulds were filled with 0%, 0.1%, 0.2%, 0.5% and 1% fibers. In each category three cubes were tested and their average value is reported as shown in **Table 6**. Splitting tensile strength was calculated as follows as split tensile strength: Splitting Tensile strength (MPa) = $2P / \pi DL$, Where, P = failure load, D = diameter of cylinder, L = length of cylinder.

Table 6: Results of Tensile Strength Test.

Steel Fiber Ratio %	0	0.1	0.2	0.5	1
Average of Splitting Tensile Strength of Three Cylinder(MPa)	2.456	3.236	3.326	4.189	5.126

3.4 Flexural Strength Test

Third point loading test to examine twelve 100 x100 x400 mm prisms with three reference prisms to evaluate the influence of SFR on flexural strength of concrete. The results of the test are shown in **Table 7**.

Steel Fiber Ratio %	0	0.1	0.2	0.5	1
Average of Flexural Strength of Three Prisms (MPa)	2.210	6.137	7.938	11.597	16.348

Table 7: Results of Flexural Strength Test.

4. Discussion of the Results

The results of this investigation show the improvement of mechanical properties of concrete due to adding different percentages of steel fiber especially the flexural strength, from 2.2 MPa for reference mix to 16.34 MPa for 1% steel fiber , the increment here is about 639% compared to reference mix, for compressive strength tests, the improvement was also good, the reference mix shows that the compressive strength was 23.7 MPa and this value was improved to 48.36 Mpa for 1% steel fiber mixes, and for tensile strength was improved from 2.45 to 5.12 MPa. Figures(1,2 and 3) show the increasing of compressive, tensile and flexural strength respectively. The main reasons of the improvement in those properties are due to the following reasons:

1- The influence of steel fiber at the bond between concrete ingredients and gives more strong bonds between particles(Milind,2012)

2- The mechanical properties of steel fiber itself , the steel fiber has very high tensile strength of about 2850 MPa and that improves the mechanical properties and gives more improvement, the **Table 4** shows physical and some mechanical properties of steel fiber used in this study.

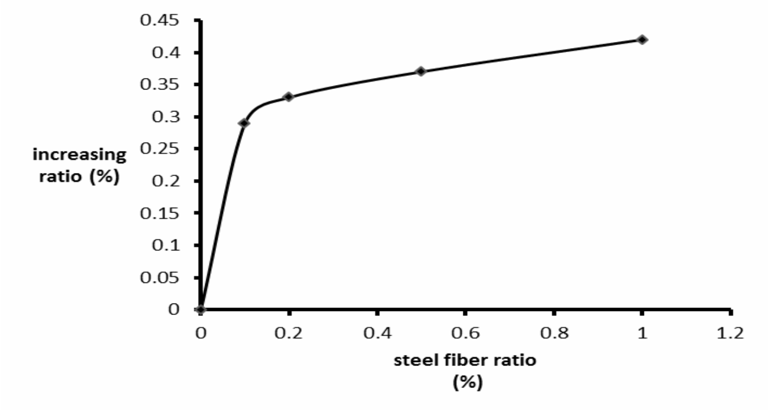

Figure (1): Increasing of compressive strength with various steel fiber ratio.

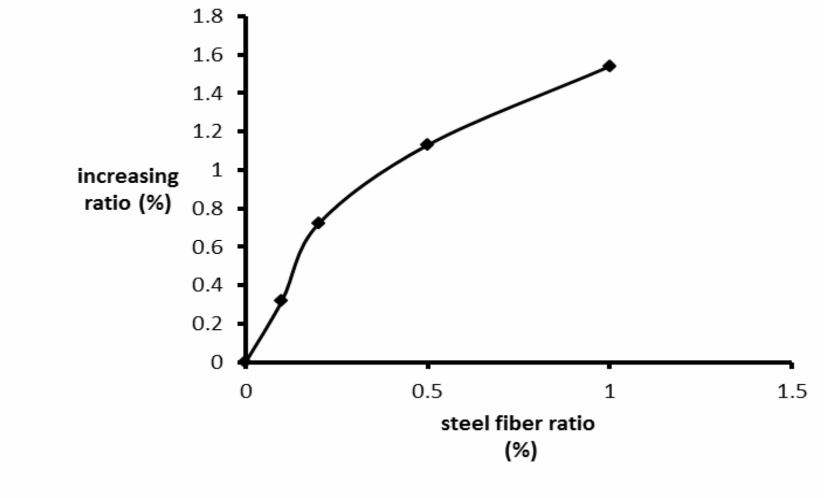

Figure (2): Increasing of tensile strength with various steel fiber ratio.

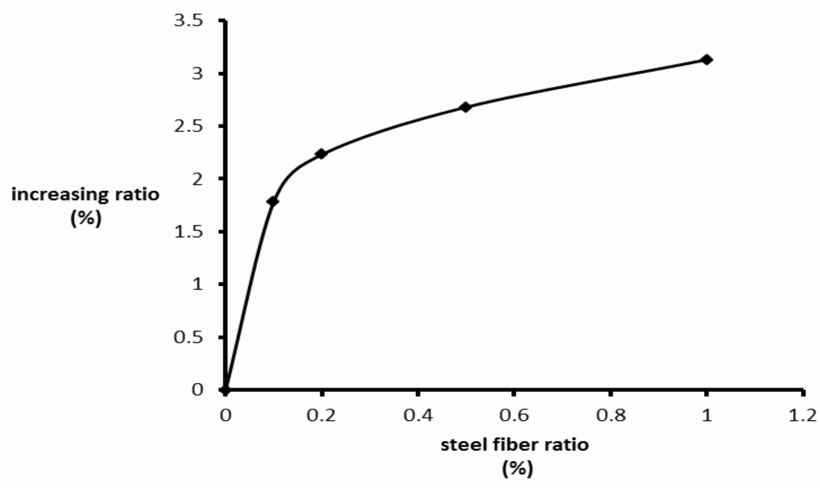

Figure (3): Increasing of flexural strength with various steel fiber ratio.

5. Conclusions

The influence of straight steel fiber on compressive, tensile and flexural strength of concrete was studied within the range of different steel fiber ratio in this investigation, the author may point out the following conclusions:

1. the increase in steel fiber percentage in concrete leads to improve the compressive strength of concrete, the increment in compressive strength due to increase steel fiber with comparison to reference mixes are given as follows:

- 28.8 %increment in compressive strength due to 0.1% of steel fiber.
- 40.1% increment in compressive strength due to 0.2% of steel fiber.
- 62.03% increment in compressive strength due to 0.5% of steel fiber.
- 103.8 % increment in compressive strength due to 1% of steel fiber.

2. The increment of tensile strength due to the increase of steel fiber as follows:

- 31.76% for 0.1% steel fiber with comparison to reference mixes.
- 35.42% for 0.2% steel fiber with comparison to reference mixes.
- 70.567 % for 0.5 % steel fiber with comparison to reference mixes.
- 108.71% for 1% steel fiber with comparison to reference mixes.

3. The increment of flexural strength due to the increase of steel fiber as follows:

- 177.7 % for 0.1% steel fiber with comparison to reference mixes.
- 259.2 % for 0.2% steel fiber with comparison to reference mixes.
- 424.7 % for 0.5 % steel fiber with comparison to reference mixes.
- 639.3 % for 1% steel fiber with comparison to reference mixes.

6. References

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