# BEHAVIOR OF STEEL FIBER REINFORCED CONCRETE SLAB DUE TO VOLUME FRACTION OF FIBER

**SHAHIRON SHAHIDAN**

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**By**

**Shahiron Shahidan**

**Supervisor : Dr Farah Nor Aznieta Abd Aziz**

**Faculty Engineering**

Generally, fibers are commonly used in engineering material. The characteristics and properties of fiber influence the properties concrete. This has been proven by the previous research. In this research steel fiber is used to study the behavior of reinforced concrete slab due to volume fraction of fiber subjected to flexural test based on computer simulation.

The application of steel fiber reinforced concrete in civil construction is the most popular due to its improvement in resistance to cracking, fatigue, abrasion, impact, durability, and conventional reinforced concrete. In this investigation,

finite element simulation will be used to analyze the normal reinforced concrete slab and steel fiber reinforced concrete slab due to diffrent percentage of volume fraction with 1%, 1.5%, 2%, 2.5% and 3%. Through this simulation, the loading is applied and analyzed by the increments of every 2 KN up to ultimate failure. The results are obtained from the computer programming simulation and being compared with published experimental results. The result of the analysis indicates that, by using and adding steel fiber into the conventional reinforced concrete, it will influence the ductility, toughness, energy absorption and strength of the concrete.

**Abstrak laporan projek dikemukakan sebagai memenuhi sebahagian daripada syarat penganugerahan Master of Science in Structural Engineering and Construction.**

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***oleh***

***Shahiron Shahidan***

**Penyelia : Dr Farah Nor Aznieta Abd Aziz**

**Fakulti : Kejuruteraan**

**Abstrak**

Secara umumnya, gentian keluii banyak digunakan dalam kejuruteraan bahan binaan. Namum begitu, pengunaan gentian keluli di dalam konkrit sangat meluas. Sifat-sifat dan jenis-jenis gentian keluli sangat mempengaruhi penggunaannya dalam konkrit tetulang. Hal ini telah terbukti oleh penyelidik yg lampau tentang kebaikan dan faedahnya dalam penggunaan gentian keluli di dalam konkrit tetulang. Justeru itu, kajian ini telah menggunakan gentian keluli dalam konkrit tetulang papak berdasarkan jumlah peratus kuatiti gentian keluli

serta diuji dengan *flexural test.* Penggunaan gentian keluli dalam pembinaan sangat terkenal, kerana ia dapat membaiki dan menambah baik pulihkan ketahanan, keretakan, kekukuhan serta kekuatan dalam konkrit tetulang. Oleh yang demikian, dalam kajian ini *finite element* simulasi digunakan untuk analysis kajian ini berdasarkan peratus penggunaan gentian keluli(1%, 1.5%, 2%, '2.5% and 3%). Dalam analysis ini, beban dikenakan dengan setiap kenaikan 2KN sehingga mencapai maximum beban berdasarkan penyelidik yang lepas. Tambahan lagi keputusan dari komputer simulasi dibezakan dengan kajian yang lepas untuk menunjukan ketepatan kaedah simulasi ini.Daripada analysis ini, ia menunjukan bahawa, penggunaan gentia keluli ini sangat mempengaruhi kekebalan, penyerapan tenaga dan kekuatan konkrit tetulang.

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# CHAPTER 1

# INTRODUCTION

## 1.1 Background study

Nowadays, the application of fiber in concrete increase gradually as an engineering material demands. The knowledge is not only necessary to provide safe, efficient and economical design for the present, but it also to serve as a rational basis for extended future application. The steel fiber has wide range of usage in pavement, bridge deck, industry floor, precast product and related area (Shah SP,et al 1999).

The application of steel fiber concrete in civil construction are the most popular due to its improvement resistance to cracking, fatigue, abrasion, impact, durability, and conventional reinforced concrete (Vondran 1991). However regarding to that, many researchers have done research on this area, such as by referring to Y.Mohammade et al,2006, the steel fiber can be considered increasing the toughness energy absorption capacity, reducing cracking area and also improving the impact resistance of the concrete. Many researchers have studied the behavior of steel fiber reinforced concrete under impact resistance compared to unreinforced concrete.

Regarding to that, the tensile and flexural strength of concrete are also enhanced significantly due to the addition of steel fiber. Nevertheless, the volume of friction steel fiber influences the improvement of concrete. Based on literature review, Ps song Hawng, 2004, proves that, the rising of volume fiction steel fiber from 0.5 % to 2% in concrete can be reached more than 80% improvement in concrete strength and rapture modulus of concrete.

According to A.R Khaloo, addition of fibers do not significantly increase the ultimate flexural strength of SFRC slabs. However, it improves the energy absorption capacity of slabs. In slabs with low fiber volume (0.5%) the resisting load after cracking is relatively small. The rate of improvement in energy absorption reduces with increment in fiber content. He recommended to use fiber volumetric percentages in the range of 0.75 to 1.75 and based on his research, the longer fibers provide the higher energy absorption in concrete slab.

Review of literature, it is proven that steel fiber is capable and applicable in industry for further application and according to that, it needs further research on this area.

## 1.2 Significant of the Research

Based on my literature review, there are many cases of study on the behavior of Steel fiber reinforced concrete in plain concrete, beam and slab on grade. Regarding to that, this research studies on the behavior and the deflection of the simply supported reinforced concrete slab containing 1% volume of friction steel fiber due to bending test.

## 1.3 Objectives

The purpose of this research is to delineate and investigate the effects of steel fiber on reinforced concrete slab subjected to uniform distributed loading.

The objectives of this research are;

> To compare the computer simulation analysis between establish experimental work

> To compare the characteristic of strength between normal and SFRC slab

> To compare the effectiveness volume friction of SFRC slab due to computer simulation.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

Generally, concrete is strong in compression and weak in tension. Referring to Johan Magnusson 2004, Plain concrete is characterized by a relatively low tensile strength and brittle tensile failure. In structural application, the concrete will provide the reinforcing bars to carry the tensile forces once the concrete has cracked so that it remains largely in compression under load. In addition, the tensile failure strain of the reinforced concrete is significantly lower than the yield strain of the steel reinforced and the concrete crack before any significant load is transferred to the steel.

In industry application, the steel reinforced are needed to carry the tension forces in the concrete. Regarding to that, to develop the new application of reinforced concrete, additional fiber in the concrete are needed for improvement the mechanical properties of structural concrete. According to M.Behloul 2008, fiber reinforced concrete is one of these new materials opening new ways for concrete structure. By adding fiber to concrete, it is improve the mechanical resistance and ductility. Beside that, it's also reduced the plastic shrinkage; improve the resistance to abrasion, fire, impact, etc.

In addition, the effect of the fibers lays more in the nature of energy absorption and crack control than in an increased the load transfer capacity (Zollo 1997). There are many type of fibers used in the concrete such as, glass, wood, carbon, natural, steel, etc.

However each type of fibers has their own mechanical or physical properties. Thus, in this research the steel fiber reinforced concrete will be used in simply supported slab for bending testing. The reason using the steel fiber reinforced concrete because its increase the impact resistance of the concrete and improve the durability of the concrete behavior. The details explanation about the advantages and application will be in the next chapter

## 2.2 Historical Development

Historically, the steel fibers are commonly used since 1980 in united state, Europe, and Japan. The steel fiber have proven track record and has been used for a decade to economically toughen concrete floor, and pavement. Today, the steel fibers are major application in industrial floor and pavement in the world. In the United Kingdom, several million square meters of steel fiber reinforced slabs have been installed over the past ten years, both for ground-supported and pile supported floors. In addition, the other major application of Steel fiber include in shotcrete, composite slab on steel decking and precast element.

In Malaysia, the applications of steel fiber reinforced concrete are not widely use in industry. Nevertheless, researches on steel fiber reinforced concrete in Malaysia are needed for the further application.

## 2.3 Properties of Steel Fiber Reinforced

Generally, due to the application of steel fiber reinforced concrete in industry, there are a lot of research are conducted to investigate the properties of steel fiber in normal concrete. Regarding to that, the committee members from concrete society are conducted the research for further application in concrete. The reasons of committee member are to create the standard and the design guide for world application. Nevertheless, because of the variety type of steel fiber in the world, the committee members are successfully done the technical report for world references and design method for steel fiber reinforced concrete.

### 2.3.1 Technical Report

According to the technical report and previous research, there indicated that the properties of steel fiber are necessary to define and used for analyzing using the computer program. In addition, properties also need when doing the experimental work. Thus, this topic is divided by 2 parts as shown and explains below.

#### 2.3.1.1 Mechanical Properties

| | | |
|---|---|---|
| **Steel fiber**<br>(Hooked end ) | Density<br>Modulus of Elasticity<br>Poison Ratio<br>Yield Strength<br>Tensile Strength | 7.85 g/cm3<br>205 Gpa<br>0.29<br>1275 Mpa<br>1100Mpa |

Table 1 Mechanical Properties of Steel fiber (Kiang Hwee 1994.M.C Nataraja,2005)

According to the table 1, it indicated that the mechanical properties of steel fiber for all type steel fiber. Based on literature review, this properties are based on the previous research done and it almost used in the computer program software such as Abaqus, Fotran, Lusas and also for experimental work and designing the steel fiber in the concrete. From the table, the modulus of elasticity of steel fibers is higher and it will similarly to the steel reinforcement. However the yield strength of steel fiber can assist the concrete bonding during the cracking propagation. It cause of the high value of the "yield strength for steel fiber.

#### 2.3.1.2 Physical Properties

Regarding to the technical report no. 63, the producing of steel fiber are in various process and are supplied in many different shape, size type as shown in figure 1 -3. Tables 2.0 are shown the cross section and properties of steel fiber.

| PROPERTIES | VALUE(mm) |
|---|---|
| Diameter | 0.4-1.3 |
| Length | 25 - 60 |
| Tensile Strength | 2-3 time traditional fabric |

Table 2 Physical Properties of Steel fiber

Steel fibers have a greater tensile strength than traditional fabric reinforcement and it significantly greater surface area to develop bond with the concrete matrix. In addition, some of the physical characteristic of steel fiber directly affects on the concrete performance. The factor are considered to be the stronger influence on the performance of the concrete containing steel'fiber are bond, anchorage mechanisms(e.g Straight, deformed shape, or hooked end), fiber length, diameter, aspect ratio, and percentage of volume.

The researches have been done by the previous research to show the evidence of the physical characteristic in concrete performance. The detail explanations about the behavior of steel fiber will be on next topics.

According to Calogero Cucchiara and Frizal, 2003, the fiber type hooked ends are reducing the severity of the failure mode which can change from a brittle shear into a ductile flexural failure. In addition, the conclusions are often based on the large number or volume of steel fiber in concrete matrix, because it influences the improving strength and ductility of concrete member.

Furthermore, the lengths of steel fiber are also taking into account to develop the ultimate tensile strength of it. However, one can successfully enhance the flexural toughness of steel fiber reinforced concrete are by using the large diameter of steel fiber.

In other hand, replacing a large portion of large diameter to small portion of diameter may not always guarantee a better performance,(N Banthia 2007).

According to the BS EN 14889-1, the steel fiber can classify into 5 groups based on the method of manufacture. There are shown in table 3.0 below.

| GROUP | TYPE |
|---|---|
| 1 | Cold-Drawn Wire |
| II | Cut Sheet |
| III | Melt Extract |
| IV | Shaved Cold Drawn Wire |
| V | Milled from Block |

Table 3 Steel fibers Classification

Based on the previous research, there is no common standard configuration for steel fiber. Each manufacture makes a particular configuration which produces its own unique performance characteristic. Generally information, steel fiber are made of cold drawn steel wire with low content of carbon © or stainless steel wire (ss 302/ss 304). Steel fibers are manufacture by various processes and supplied in many different shapes and size as shown in figure 1-3.

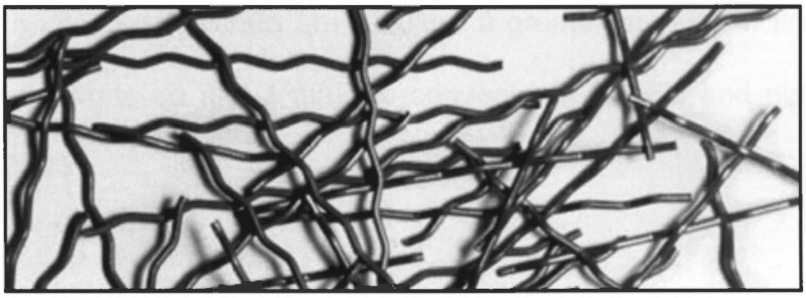

Figure 1 steel fiber type Undulated

Based on the previous research by P. Soroushian, Z. Bayasi 1991, the steel fiber geometry and matrix strength on the toughness characteristics of SFRC has been clearly found that it influenced the concrete properties when adding together. In addition the energy of absorption also influence according to types of steel fiber.

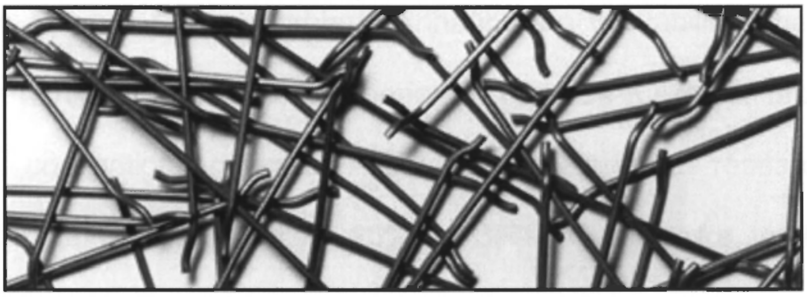

Figure 2 steel fiber types flat

All types of steel fiber in a concrete mix act essentially as rigid inclusion with a large surface area and a geometry.

The fiber reinforced concrete are requires a greater amount of fine material than plain concrete so that it may be conveniently handle and placed,( M.C Nataraja ,2005).

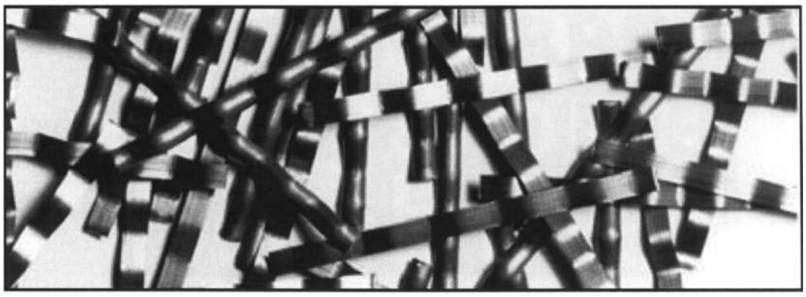

Figure 3 steel fiber type Hooked

The slender shape of the steel fiber are promotes to interlocking and the large surface are result in the drying of the mix by causing adsorption of the water that would otherwise be available to enhance the workability. Therefore the steel finer reinforced concrete are generally requires a greater proportion of paste than conventional concrete. According to the previous research, normal concrete contains approximately 25% to 35% of paste for total concrete volume. However in the Steel fiber reinforced concrete is requires a paste contents approximately up to 45% of the total volume. But it is depending on the geometry and the volume of steel fiber in the concrete paste (M.C Nataraja *et al* 2005).

The normal size steel fiber is 1mm diameter, 0.5 mm length and it is will increase the concrete tensile and flexural strength. These properties are based on the previous research done by Y.Mohammadi et all 2006.

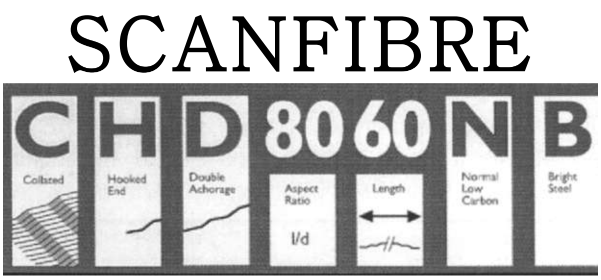


Figure 4(a) Size of steel fiber

However in this research, the Scanfiber will supply and provide the standard size which is use in Malaysia. The supplier Scancem Material suggests and provides the steel fiber size CHD8060NB.

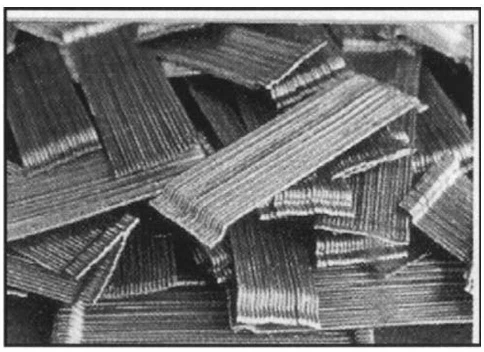

Figure 4 (b) Type of steel fibers used in this research

This size and type almost used in construction such as Giant and Tesco Hypermarket as shown in figure 5. In application, Malaysia normally used steel fiber as the ground slab. Based on the supplier Scancem Material, by adding the steel fiber in the ground slab it will reduce the macro-cracking and also can reduce the size of the steel reinforcement. Thus according to that this research will used the same properties of steel fiber for experiment and analysis.

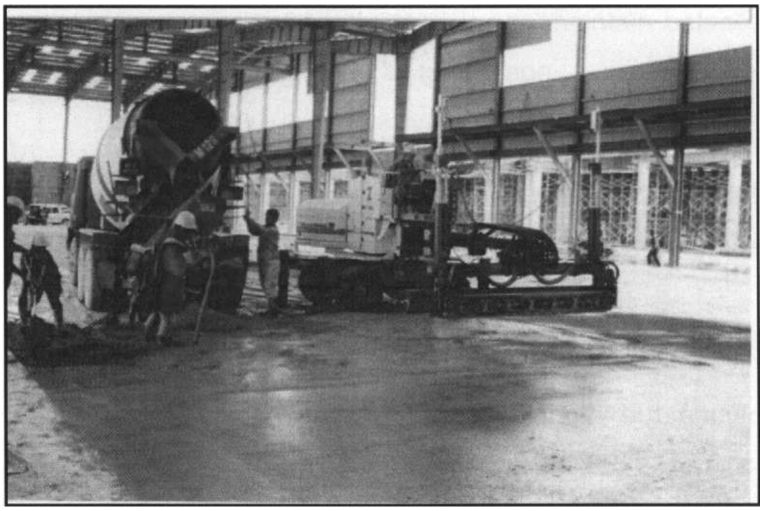

Figure 5 Construction SFRC slab in Giant Hypermarket

Table 4 indicates that, the detail properties of the steel fiber that was used from construction and will be used in this research. From the detail properties, it shows that the types of fiber are comfortable to use and will improve the strength of the concrete properties and type of cracking will developed.

| Detail | Explanation |
| --- | --- |
| **C for Collated** | Collation is where wire from forty spools is fed to a glue line where water dissolvable glue is applied. Collation of fibers was a major breakthrough in fiber technology |
| **H for Hooked end primary Anchorage** | The hooked end is designed to provide anchorage in a non rigid way. The fiber cross section remains uncharged so it can pull through the concrete at high loads to prevent brittle failure due to fiber breakage and to promote high energy absorption. The hook is design to balance the fiber strength |
| **D for Double( Secondary Anchorage)** | For optimum performance fiber deformation has to increase as concrete strength decrease to maintain balance between the wire strength and its anchorage. |
| **80 (aspect ratio)** | Aspect ration (length/diameter) is a key characteristic in determining performance. High aspect ratio leads to high performance (toughness) but without collection fibers tend to ball at aspect ratio over 50. |
| **60 Length** | Fiber can be supplied in any length but should be long enough to ensure aggregate overlap and short enough not to block equipment. |
| **N normal** | Normal low carbon steel is pulled through a series of dyes to give a wire strength in excess of 1000MPa |
| **B bright** | Bright steel is the norm for steel fiber in concrete. Corrosion is not general an issue, the fiber are not interconnected so there can be no corrosion current, hence galvanizing is not normally necessary. |

Table 4 the detail property of Steel fiber by Scancem Material Sdn Bhd

### 2.3.2 Steel Fiber Behavior

In this chapter, the behavior of steel fiber reinforced concrete under compression, tension, flexural and physical properties will be discussed in this topic. In investigation, Shah and Naaman 1976, conducted tensile strength, flexural and compressive strength test on concrete specimen with different length and volume friction of steel fiber and they observed that the strength of concrete are increase until two to three time than plain concrete.

#### 2.3.2.1 Compression

Regarding to the literature review, by adding the steel fiber in concrete matrix, the strength increase and exceeds to 25%. Commonly the strength is increase when using the deformed fiber and usually the quantity of steel fiber used in concrete is limit to 100 $lb/yd^3$ ($60kg/m^3$) or less than 0.75% as shown in figure 6. In special case, where the fiber volume content is more than 3% the strength are increase and not significant in high strength concrete (P.N.Balaguru,1992).

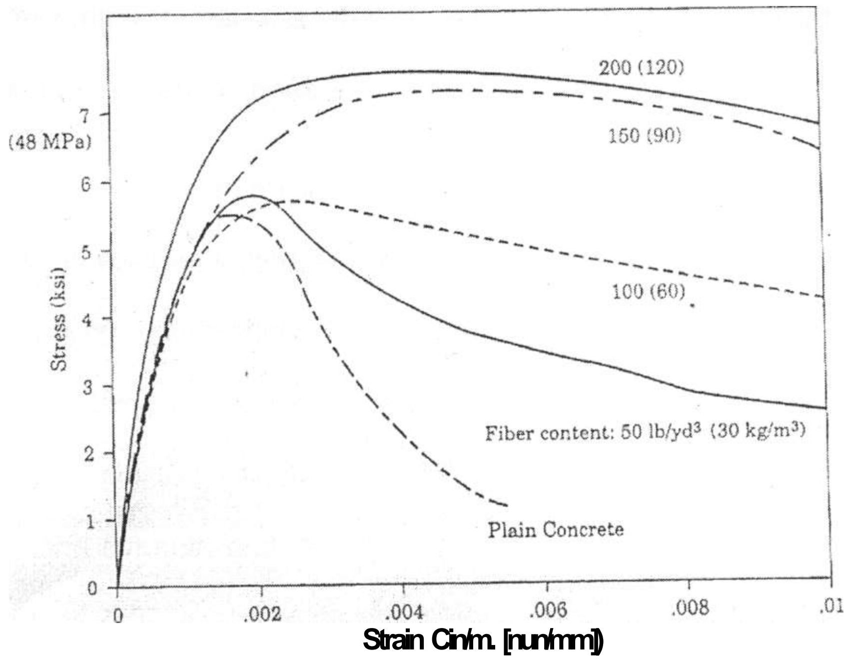


Figure 6 the Stress strain behavior of steel fiber for normal concrete strength containing 50 mm hooked end.

In the design process there are several factors that have to be consider, there are modulus of elasticity, strain at peak load and post peak behavior. Mostly base on the previous researcher, the change in modulus of elasticity are consider negligible.

Referring to the figure 6, the addition of steel fiber can increase the strain at peak load and more reproducible descending branch. Beside that, the steel fiber reinforced concrete also can absorb much more energy before start to failure compare to plain concrete. The test result from Nagakar, 1987 indicated that the compressive strength increase by addition steel fiber in the plain concrete. According to that, the strength is increase by 13% - 40% for steel fibrous concrete as mention before.

Additionally, the increase in ductility provided the steel depends on the several factors, such as volume friction, fiber geometry, and composition of concrete. The increasing of volume friction of steel fiber in concrete can improve and increase the energy absorption capacity of composite. The investigation by R.V Balendran indicated that, the high volume of steel fiber in range 5%-20% can improve the strength and the ductility of concrete. However regarding to A.R Khaloo et al 2002, in slab application, it is recommend using the steel fiber volumetric percentage in range 1-2% because it can provide the higher energy absorption. With respect to fiber geometry, the length, diameter and aspect ratio is important for the performance of steel fiber reinforced concrete. For example the aspect ratio increase, the ductility increases as long as fiber can be properly mix with the concrete.

Based on the previous research Naaman 1987, the strength and toughness of the composite were found to increase the higher loading based on the higher aspect ratio. Beside that, the shape of steel fiber such as, deformed fiber and hooked-end fiber will provide the good energy absorption. Referring to figure 6, It shown that the stress-strain behavior of hooked end steel fiber compare to plain concrete.

According to the previous research, by Y. Mohammadi et all 2008; figure 7 and 8 are shown the result of compressive strength test on plain concrete and steel fiber reinforced specimen with different fiber volume friction and different length. The result show in general, there is an increase in compressive strength varying from 3% to 26% on addition of steel fiber in the concrete.

It can also be observe that there is an increase compressive strength from 3% to 21%, 11% to 25% and 7% to 26% for concrete having 1.0%, 1.5% and 2.0% volume of friction steel fiber respectively. However, there is an optimum volume fraction of fiber that give the maximum strength and this is 2% with 100% short fibers and the maximum increase in compressive strength was 26%.

Compressive and split tensile strength results of plain concrete and SFRC

| Fibre mix proportion by weight | | Fibre volume fraction (%) | 28 days strength (MPa) | | | |
|---|---|---|---|---|---|---|
| 50 mm (%) long fibres[a] | 25 mm (%) long fibres[b] | | Cube compression | % Increase | Split tensile | % Increase |
| 0 | 0 | 0 | 57.82[c] | 0 | 3.83 | 0 |
| 100 | 0 | 1.0 | 59.80 | 3 | 4.82 | 26 |
| 65 | 35 | 1.0 | 62.40 | 8 | 4.88 | 27 |
| 50 | 50 | 1.0 | 62.89 | 9 | 4.65 | 21 |
| 35 | 65 | 1.0 | 64.69 | 12 | 4.63 | 21 |
| 0 | 100 | 1.0 | 69.83 | 21 | 4.58 | 20 |
| 100 | 0 | 1.0 | 63.98 | 11 | 5.78 | 51 |
| 65 | 35 | 1.5 | 67.39 | 17 | 5.55 | 45 |
| 50 | 50 | 1.5 | 65.85 | 14 | 5.21 | 36 |
| 35 | 65 | 1.5 | 69.05 | 19 | 5.06 | 32 |
| 0 | 100 | 1.5 | 72.13 | 25 | 4.83 | 26 |
| 100 | 0 | 2.0 | 62.06 | 7 | 5.97 | 56 |
| 65 | 35 | 2.0 | 67.12 | 16 | 6.09 | 59 |
| 50 | 50 | 2.0 | 65.42 | 13 | 5.40 | 41 |
| 35 | 65 | 2.0 | 68.58 | 19 | 5.17 | 35 |
| 0 | 100 | 2.0 | 72.82 | 26 | 4.98 | 30 |

[a] Fibre aspect ratio = 20.
[b] Fibre aspect ratio = 40.
[c] Average of 10 tests, rest average of five tests.

Figure 7 Compressive and split tensile strength of plain concrete and SFRC by Y. Mohammadi et all 2008

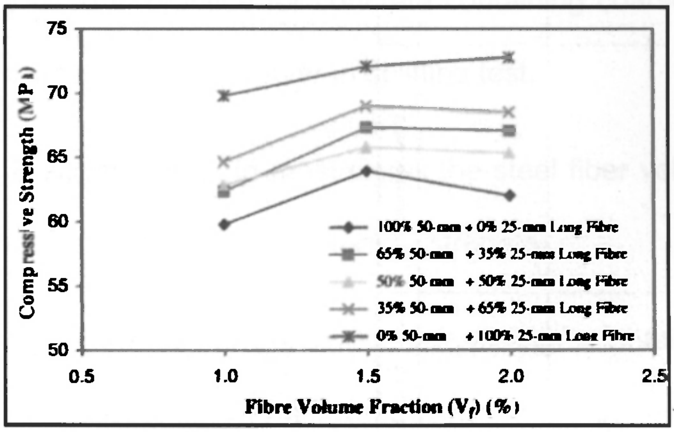


Figure 8 Cube compressive strength of fibrous concrete with mixed aspect ratio of fibres at different fibre volume fractions by Y. Mohammadi et all 2008

In general, it can conclude that on increasing the percentage of short fiber in concrete mix and with increase the fiber content, the strength of the concrete are increase as well. Shah and Rangan 1971, have also reported the increase in compressive strength up to 25% due to addition of steel fiber reinforced concrete.

#### 2.3.2.2 Tension

In this part, there are two type of tension test used for concrete, where as direct tension and splitting tension. Based on the previous research, the specimens such as dog-bone shapes are subjected to axial tension.

Such test is rarely used in practice for concrete containing coarse aggregate and cylindrical specimen is more popular in splitting test.

According to P.N Balaguru 1992, in most cases the steel fiber volume friction less than 2% do not improve the splitting tensile strength.

Figure 7 also present the result of the split tensile strength containing fiber of mixed aspect ratio corresponding to different fiber volume friction. Where as the figure 9 show the graph of split tensile strength. From that figure it shows that there is an increase in tensile strength to the tune of 20%-27%, 26%-51%, and 30%-59% for fibrous concrete mixes with 1.0%, 1.5%, and 2.0% volume fraction of fibers respectively (Y.Mohammadi, 2008). Regarding to that, it can summarize the increasing of the volume friction fiber in composite able to increase the tensile strength of steel fiber reinforced concrete.

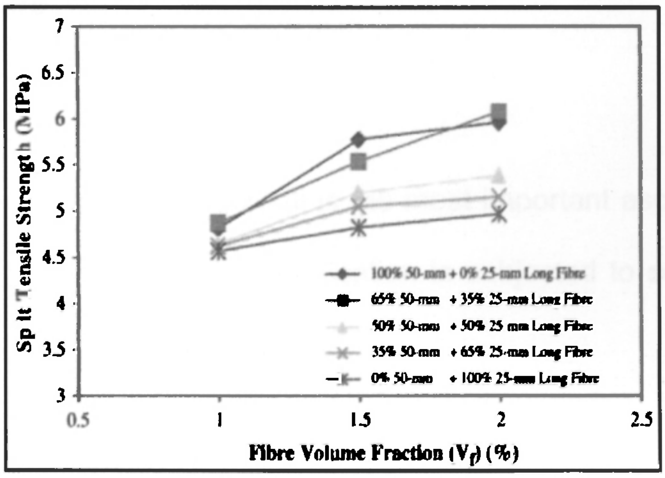


Figure 9 Split tensile strength of fibrous concrete with mixed aspect ratio of fibres at different fibre volume fractions by Y. Mohammadi et all 2008

Additionally, according to Janusz Potrzebowski 1983 ancient researcher, in fiber concrete the difficulties connected with the determination of the tensile strength are greater than in ordinary concrete, because the material is neither brittle nor isotropic. The splitting test therefore provides exact information up to first crack only, as the stress distribution after cracking is unknown. The anisotropy of fiber concrete elements arises from fiber distribution and fiber orientation during fabrication. As a result the majority of fibers tend to orientate perpendicular to the direction of the gravity forces and the greater tensile strength occurs in planes parallel to the direction of gravity.

#### 2.3.2.3 Flexure

Basically, the behavior under flexural is the most important aspect ratio for steel fiber, because the practical application is subjected to some kind of bending load.

P.N Balaguru 1987, indicate that based on his testing, the strength increase. However, for fiber content less then 2% are not substantial except for concrete containing silica fume. According to the current research, the steel fiber can provide extra increase in strength of the composite. It is because the composite have a better bond between fiber and concrete.

Commonly, based on literature review the increasing strength in flexural are higher and greater than compressive and splitting tensile strength but seldom researcher are found the vice and versa.

Based on the previous research by Mohammadi 2008, according to his project the maximum strength are increases in static flexural strength for concrete mix by having the increasing the volume friction of steel fiber.

According to figure 10, result from Y. Mohammadi 2008, the maximum increase in ultimate load deflection of 61%, 95% and 167% concrete specimen when having 100% long fiber for 1.0%, 1.5% and 2.0% volume friction of fiber respectively.

Maximum flexural loads, first crack loads and corresponding deflections

| Fibre mix proportion by weight | | Fibre volume fraction (%) | Maximum flexural load and corresponding deflection | | First crack load and corresponding deflection | |
|---|---|---|---|---|---|---|
| 50 mm long fibres (%) | 25 mm long fibres (%) | | Deflection (mm)ª | Load (kN)ª | Deflection (mm)ª | Load (kN)ª |
| 0 | 0 | 0 | 0.338 | 11.88 | 0.338 | 11.88 |
| 100 | 0 | 1.0 | 0.545 | 16.68 | 0.397 | 13.76 |
| 65 | 35 | 1.0 | 0.498 | 16.92 | 0.396 | 14.49 |
| 50 | 50 | 1.0 | 0.526 | 16.56 | 0.385 | 14.38 |
| 35 | 65 | 1.0 | 0.506 | 16.64 | 0.392 | 14.38 |
| 0 | 100 | 1.0 | 0.434 | 15.92 | 0.401 | 14.92 |
| 100 | 0 | 1.5 | 0.661 | 20.98 | 0.399 | 15.19 |
| 65 | 35 | 1.5 | 0.650 | 20.12 | 0.401 | 15.35 |
| 50 | 50 | 1.5 | 0.653 | 18.75 | 0.399 | 15.00 |
| 35 | 65 | 1.5 | 0.588 | 17.73 | 0.394 | 15.55 |
| 0 | 100 | 1.5 | 0.495 | 17.17 | 0.399 | 15.85 |
| 100 | 0 | 2.0 | 0.902 | 23.83 | 0.405 | 15.89 |
| 65 | 35 | 2.0 | 0.720 | 22.32 | 0.405 | 16.28 |
| 50 | 50 | 2.0 | 0.768 | 19.81 | 0.402 | 16.35 |
| 35 | 65 | 2.0 | 0.613 | 18.75 | 0.408 | 16.83 |
| 0 | 100 | 2.0 | 0.483 | 18.01 | 0.401 | 17.66 |

ª Average of three batches.

Figure 10 Maximum flexural test result of plain concrete and SFRC by Y. Mohammadi et all

From that figure, it can be observed that, there is maximum increase in first crack of 26%, 33% and 49% for concrete mix having 1%, 1.5%, and 2.0% fiber volume friction. In addition the concrete specimens also increase the strength with 100%short steel fiber. The maximum increase in first crack deflection of 14%-21% with respect to plain concrete specimen was observed for fibrous concrete specimen with increasing the fiber volume friction.

At the same research result, it can be observed from the static flexural test results obtained in this investigation that the longer fibers have greater influence on the peak load and deflection at peak load.

**Reference:**


Ali R. Khaloo, Majid Afshari. Flexural Behaviour of Small Steel Fiber Reinforced Concrete Slabs, 2004.

Al-Ausi MA, Slih SA, Aldouri. Strength & Behaviour of Steel Fiber Reinforced Conrete Slab Subjected to Impact Loading, 1992.

Ahmad HA. Lagoudas CL. Effective Elastic Properties of Fiber Reinforced Concrete with Random Fibers, 1991.

ACI Committee 544, Properties of Fiber Reinforced concrete 1988.

A.Meda, Fracture behavior of SFRC slabs on grade, 2004.

Banti NP, Mindes S, Bentur A. SFRC Under Impact, 1987.

Balaguru P. Shah SP. Fiber Reinforced Cement Composite, 1992.

Burak Felekoglu, Selcu Turkel. Effects of Steel Fiber Reinforcement on Surface Wear Rresistance of Self-compacting Repair Mortars, 2005

Cengiz Duran Atis, Okan Karahan. Properties of Steel Fiber Reinforced Fly Ash Concrete, 2006.

Calogero Cucchiara, Lidia La Mendora, Maurizio Papia. Effectiveness of Stirrups and Steel Fiber as Shear Reinforcement, 2002.

Colin.D Johnston, Steel fiber reinforced concrete Present and Future in Engineering Construction, 1982.

E. Bonaldo. Efficient strengthening technique for reinforced concrete slab,2006

F.Buyle-Bodin, Performance and modeling of steel fiber reinforced pile under seismic loading,2002

Fatin Altun, Predicting the compressive strength of steel fiber added lightweight concrete, 2007.

Gopalaratnam VS, Shah SP. Strength, Deformation and Fracture Toughness of Fiber Cement Composite at Different Rates of Flexural Loading, 1995.

H.Falkaer and V. Henker, Application of Steel fiber Concrete For Underwater Concrete Slab, 1998

Hyun-Ho Lee. Shear Strength and Behaviour of Steel Fiber Reinforced Concte Columns under Seismic Loading, 2005

J.A.O Barros, Model for the analysis of steel fiber reinforced concrete slabs on grade, 2000.

Janusz Potrzebowksi, The splitting test applied to steel fiber reinforced Concrete, 1983

J. Yin, Structural performance of short steel fiber reinforced concrete beams with externally bonded FRP sheets, 2003.

Johan Magnusson. Fiber Reinforced Concrete beam subjected to Air Blast Loading

Khaled Marar. Effects of Limestone Crusher Dust and Steel Fibers on Concrete,2007.

M.K.Lee, B.I.G Barr. Strength and Fracture Properties of Industrially Prepared Steel Fiber Reinforced Concrete, 2001.

Muhammad N.S Hadi, Behavior of Eccentric Loading of FRP Confined Fiber Steel Reinforced Concrete Columns,2008.

Natarj Mc, Nagaraj TS. Reproportioning of Steel Fiber Reinforced Concrete Mixes and the impact Resistance, 2005.

Narayanan R, Darwish. Use of Steel Fiber as shear Reinforcement, 1999.

Parvizd,(Master of Structural Engineering and Construction) Master student, Universiti Putra Malaysia

Ramakrishnn V. Coyle WV. Performance Characteristic of Fiber Reinforced Concretes with Low fiber Content, 1981.

Raymond, Curling Failure of Steel fiber reinforced concrete slab, 2009

R.V Balendran, Influence of steel fiber on strength and ductility of normal and lightweight high strength concrete, 2001.

R. V. Balendran, F.P Zhou, A Nadeem. Influence of Steel Fibers on Strength and Ductility of Normal and Lightweight High Strength Concrete, 2000.

Scancem Materials (Products for Engineered Concrete) emails: info@scancemmaterials.com

Song Ps, Hwang S, Sheu Be, Strength Properties of Nylon and Fiber Reinfrced, 2005.

S.K Padmarajaiah, Ananth Ramawamy. Flexural Strength Predictions of Steel Fiber reinforced Hogh-strength Concrete in Fully/ Partial Prestressed Beam Specimens,2001.

Steel Fiber Reinforced Concrete For Industrial Floors-Practical Guide, ARCELOR MITTAL.

Semsi Yazie,Volkan Tabak, Effect of Aspect Ratio and Volume Fraction of Steel Fiber on the Mechanical Properties of SFRC,2006.

T.Mailhot, B.Bissonnette, Flexural fatigue behavior of steel fiber reinforced concrete before and after cracking, 2001,

Ukrainezy V. Rak Z. Post-fatigue Properties of Steel Fiber Reinforced Concrete, 1992.

Y.Mohammadi, S.P. Singah, S.K Kaushik. Properties of Steel Fibrous Containing Mixed Fibers in Fresh and Hardened State,2006.