# EVALUATION OF COMPRESSIVE STRENGTH & TENSILE STRENGTH OF STEEL FIBER REINFORCED CONCRETE

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A thesis submitted to the Department of Civil Engineering in partial fulfillment for the degree of Bachelor of Science in Civil Engineering

Department of Civil Engineering
Sonargaon University
147/I, Green Road, Dhaka-1215, Bangladesh

Section: 26B+27B
Semester - Fall-2025

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# DECLARATION

It is hereby declared that this thesis/project or any part of it has not been submitted elsewhere for the award of any degree or diploma.

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***Dedicated***

***To our parents, family & teachers***

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# ABSTRACT

By adding steel fibers, concrete can overcome its noticeable brittleness and low tensile strength and strain capacity. The mechanical characteristics of concrete reinforced with high-strength steel fibers were examined in this study. The toughness index, compressive and splitting tensile strengths were among the characteristics. Steel fibers were introduced at 0.5%, 1.0%, 1.5%, 2.0%, 2.5%, 3.0% volume fractions. At 2.5% volume fraction, the fiber-reinforced concrete's compressive strength peaked.

The splitting tensile strength and of the fiber-reinforced concrete improved with increasing the improvements, respectively. The compressive index of the fiber-reinforced concrete improved with increasing the compressive strength. Strength models were established to predict the compressive and splitting tensile strengths of the fiber-reinforced concrete. The models give predictions matching the measurements.

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# CHAPTER 1

# Introduction

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## 1.1 General

The term steel fiber reinforced concrete (SFRC) refers to hydraulic cement concrete that contains discrete fibers and fine and coarse aggregate. SFRC improves the characteristics of concrete by randomly dispersing and distributing thousands of tiny fibers throughout the mixture. The SFRC is being rapidly being utilized to increase fatigue strength, energy absorption capability, and static and dynamic tensile strength. Determined that the ultimate strength and ductility are increased by the addition of steel fiber, When the plain structure experiences the maximum tensile force, it breaks into two parts and is unable to sustain more load or deformation. Typically, steel fibers are utilized to improve concrete's tensile strength. Steel fibers should typically be utilized in addition to reinforcing bars for structural applications. Steel fibers can consistently prevent cracking and enhance resistance to material degradation brought on by thermal loads, fatigue, impact, and shrinkage. A reasonable yet cautious approach to structural members that experience flexural or tensile loads, as elevated slabs, beams, or columns.

## 1.2 Background and motivations

One of the most popular building materials is concrete, which is renowned for its strength, adaptability, and durability. However, new materials like steel fiber reinforced concrete have been developed in response to the demands of contemporary building and environmental concerns. The fiber-reinforced concrete or cement will be regarded as a composite material consisting of fibers and matrix. The fiber component can be made of a ductile, low modulus material or a ductile, high modulus material like steel or asbestos. nylon, polyethylene, or polypropylene, for example. Kevlar, an organic fiber that DuPont recently introduced, has a modulus similar to that of asbestos or glass. Physical test results and theoretical models for each component's strength, fiber, and other properties are abundant in the technical literature. The beneficial influence of steel fibers in concrete depends on many factors such as type, shape, length, cross section, strength, fiber content; SFs bond strength, matrix strength, mix design, and mixing of concrete.

## 1.3 Objectives if the Reserch

The objectives of the research are following:

- To investigate properties of steel fiber concrete.
- To determine the compressive strength and split-tensile strength of steel fiber concrete.
- To determine the porosity, permeability of steel fiber concrete.

## 1.4 Purpose and Scope

### Purpose:

The primary purpose of steel fiber reinforced concrete is to enhance the mechanical properties of conventional concrete, making it more durable, flexible, and resistant to cracking. Steel fibers improve concrete's toughness, impact resistance, and post-crack loadbearing capacity. SFRC is particularly useful in applications where traditional reinforcement (rebar or mesh) is insufficient or difficult to use.

1. **Highway and air-field pavements:** SFRC can be utilized to repair existing pavements or to build new ones by applying bonded or unbounded overlays to the slab underneath. Because of its increased flexural strength, less pavement thickness is needed. In addition, the opposition. There will be more exposure to impact and repeated loads. Compared to plain concrete, the maximum fracture widths decrease due to SFRC's higher tensile strain capacity.
2. **Hydraulic Structures:** The most important advantage of using SFRC in hydraulic structures is the resistance of SFRC to cavitation’s or erosion due to the high velocity of water flow compared to conventional RC.
3. **Fiber Concrete:** Bridge repair, tunnel lining, and rock slope stabilization are all applications for fiber concrete. Perhaps to avoid surface discoloration from SF corrosion, a thin layer of ordinary concrete is monolithically put on top of the fiber concrete. It is possible to employ fiber concrete for protection of steel constructions.

4. **Refractory Concrete**: According to reports, steel-fiber reinforced refractory concretes are more resilient than their unreinforced counterparts in the face of mechanical abuse, high temperatures, thermal shock, and thermal cycles. The longer service duration is most likely

the result of The SFs provides improved toughness, crack management, stalling, and abrasion resistance.

5. **Precast Application:** SFRC can be used in the construction of precast products such as manhole covers, concrete pipes, and machine bases and frames. Improved flexural strength and impact resistance of SFRC may allow the use of these products in rough handling situations.
6. **Structural Applications:** Addition of SFs into the conventional RC members has several advantages such as the followings, thereby increasing the use of steel-fiber-added RC (SFARC) structures compared to conventional RC members.

   **Bridges & Flyovers**: Used in deck slabs, beams, and girders to enhance load capacity and fatigue resistance.

   **Tunnels & Underground Structures:** Provides better resistance against stress, seismic loads, and deformations.

   **Precast Concrete Elements:** Used in segments of precast pipes, panels, and modular structures to increase durability.

7. **Specialized Applications**:

   **Seismic-Resistant Structures:** Increases ductility and energy absorption capacity**.**

   **Blast-Resistant & Military Structures:** Provides higher impact resistance and security.

   **Hydraulic Structures (Dams & Canals**): Ensures erosion resistance and longevity**.**

### 1.5 Organization of the Thesis

In the first chapter background, objectives of the study are described. In second chapter literature review is discussed about the steel fiber reinforced concrete. In chapter three experimental schemes are described. Chapter four consist of result and discussion. In chapter five conclusions and recommendations are described.

# CHAPTER 2

# Literature Review

## 2.1 Introduction

Steel fiber (SF) is the most popular type of fiber used as concrete reinforcement. Initially, SFs are used to prevent/control plastic and drying shrinkage in concrete. Further research and development revealed that addition of SFs in concrete significantly increases its flexural toughness; the energy absorption capacity, ductile behavior prior to the ultimate failure, reduced cracking, and improved durability. This paper reviews the effects of addition of SFs in concrete, and investigates the mechanical properties, and applications of SF reinforced concrete (SFRC).

### 2.2 Background of the Study

The mix design of steel fiber reinforced concrete (SFRC) is one of the most critical factors in determining its properties and performance. Steel fiber (SF) is the most popular type of fiber used as concrete reinforcement. Initially, SFs are used to prevent/control plastic and drying shrinkage in concrete. Further research and development revealed that addition of SFs in concrete significantly increases its flexural toughness, the energy absorption capacity, ductile behavior prior to the ultimate failure, reduced cracking, and improved durability (Altun et al., 2006). This paper reviews the effects of addition of SFs in concrete, and investigates the mechanical properties, and applications of SF reinforced concrete (SFRC).

Reinforcement of concrete using various fibers to improve their mechanical performance against dynamic loads such as drop weight, high velocity small projectile, and blast, goes back several decades. Several researches have been conducted to clarify the behavior of fiber reinforced concrete subjected to dynamic loads. In this regard, Ramakrishna and Sundararajan (October 2015) showed that employing natural fibers results in 3–18 times increase in impact resistance compared to plain mortar slab.

Another study was performed on behavior of steel reinforced concrete in two-way slabs by Sundarsana Rao et al. And showed that increasing the fiber volume fraction from 8% up to 12% leads to significant increase in energy absorption characteristics.

Many researchers have conducted investigations to study different characteristics of fiber reinforced concrete in the past. The mechanical properties of concrete and mortar reinforced with randomly distributed smooth steel fibers were investigated by Shah and Rangan . It was observed that the post-cracking resistance of the material was considerably influenced by the length, orientation and stiffness of the fibers used. Batson et al (2008). Tested conventional reinforced concrete beams in flexure wherein the shear stirrups were replaced by fibrous concrete containing steel fibers of various shapes, sizes and volume fractions.

Steel fiber hybrid composites can be viable alternatives to synthetic fiber reinforced composites as structural or semi-structural components, especially in lightweight applications (Sathishkumar et al., 2014, Sanjay and Yogesha, 2017, Yusriah et al., 2014). Nowadays, replacing synthetic fibers with Steel fibers in the automotive industry can yield economic, environmental and social benefits. This area of research continues to be of interest to engineers and professionals as steel fiber composites turning out to be an alternative solution to the everdepleting non-renewable sources (Hom et al., 2015, Karnani et al., 1997, Singleton et al., 2003, Zah et al., 2007). It has been found that these steell fiber composites possess better electrical resistance, good mechanical properties, good thermal and acoustic insulating properties, as well as higher resistance to fracture (Vijaya Ramnath et al., 2014, Sanjay et al., 2015, Sanjay et al., 2016a, Yelin et al., 2016).

Roychand et al. carried out a thorough investigation on steel fiber from rubber concrete composed of used auto tires in 2020. In their review study, they looked at how various recycling techniques, replacement percentages, and rubber steel fiber particle size affected the mechanical properties of steel fiber concrete that have been researched over the past 30 years. However, in order for rubber recycling to be approved by the concrete industry, scientists must devise a technique that solves the issues of steel fiber particles' high flammability and when they catch fire.

Concrete is one of the most widely available and cost-effective construction materials. In comparison to other engineered building materials, concrete has a low manufacturing cost. However, concrete has poor tensile strength and fracture energy, as well as a quasi-brittle failure mechanism. Fibers are incorporated into concrete to compensate for the aforementioned weaknesses, resulting in fiber-reinforced concrete (SFRC).

## 2.3 Summary

Steel fiber reinforced concrete (SFRC) is widely used due to its ability to improve the mechanical performance of conventional concrete. Initially introduced to control plastic and drying shrinkage cracks, steel fibers were later found to significantly enhance flexural toughness, energy absorption capacity, ductility, crack resistance, and durability. Numerous studies have shown that the performance of SFRC is strongly influenced by mix design, fiber type, volume fraction, and fiber geometry.Research over several decades has demonstrated the effectiveness of fiber reinforcement in improving concrete resistance to dynamic loads such as impact and blast. Experimental studies indicate that increased fiber content enhances post-cracking behavior and energy absorption. Steel fibers have also been shown to partially replace traditional shear reinforcement in structural elements. In addition, hybrid and recycled steel fiber composites offer economic, environmental, and sustainability benefits. Overall, the incorporation of steel fibers addresses the inherent limitations of conventional concrete, making SFRC a promising material for modern structural applications.

# CHAPTER 3

# Methodology

## 3.1 General

The aim of the experimental inquiry is to establish the concrete's compressive strength and mechanical properties for steel fiber replacement of cement. This chapter presents the test findings, steel fiber, fine aggregates, and coarse aggregates for casting concrete. Then, test procedures for compressive strength and tensile strength are covered. According to this study, steel fiber may be used in place of some boost the tensile strength of fresh concrete. For high strength concrete, the ideal steel fiber replacement percentage is 0% to 3.0 %. High strength concrete is much more in demand now.

**Figure 3-1. SFRC Floors - For Steel Fiber Reinforced Concrete Slab - Industrial Flooring**.

## 3.2 Materials Properties

### 3-2.1 Cement (OPC)

Ordinary Portland Cement (OPC) is a hydraulic cement that's commonly used in construction. It's made by grinding clinker, gypsum, and other materials into a fine powder. OPC is mixed with water and aggregates to form concrete, mortar, or paste.

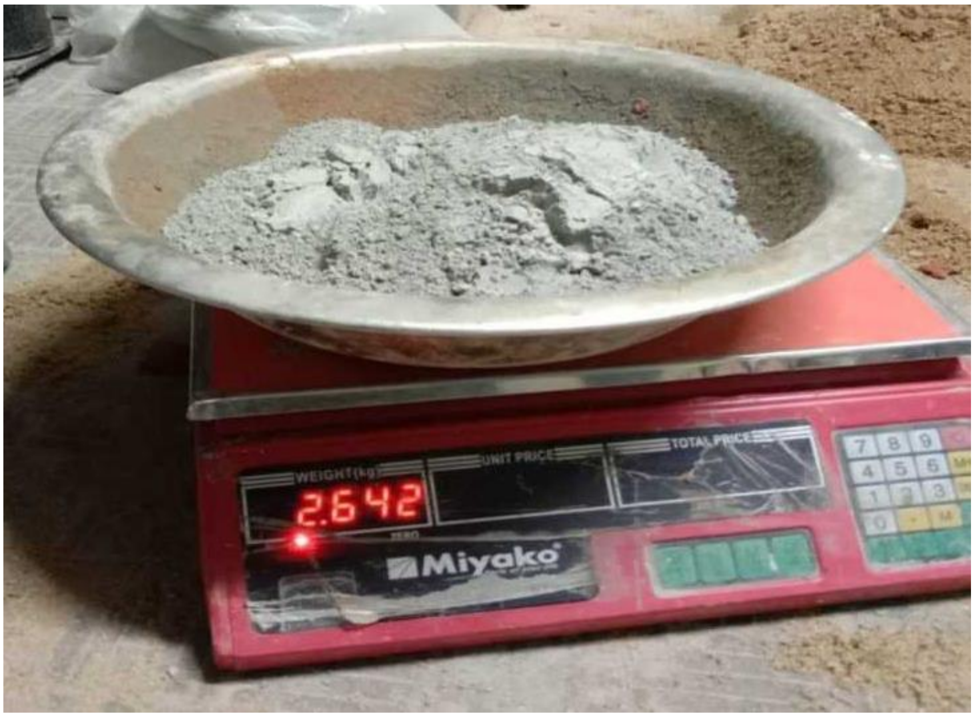

**Figure 3-2. Cement**

**Consistency:**

The normal consistency of ordinary Portland cement is typically between 25% and 30% by weight of water added to the cement.

**Specific Gravity:**

The specific gravity of OPC is around 3.1–3.16.

**Setting Time:**

Initial Setting Time: Minimum 30 minutes.

Final Setting Time: Maximum 10 hours

### 3-2.2 Steel Fiber

Steel Fiber Reinforced Concrete (SFRC) is a composite material consisting of conventional concrete mixed with discrete, randomly distributed steel fibers. The inclusion of steel fibers significantly improves the tensile strength, toughness, impact resistance, and crack control of concrete, making it an advanced alternative to conventional reinforced concrete in various structural applications. The use of steel fiber properties is 25 mm length.

**Figure 3-3. Steel Fiber 25 mm**

**Figure 3-4. Auto mobile tire**

### 3-2.3 Course Aggregate:

Coarse aggregate is a key component in concrete and other construction materials, typically consisting of larger particles than fine aggregates. Here are some important points about coarse aggregate.

**Size:** Generally larger than 12 to 20 mm in diameter (uniform coarse aggregate).

**Shape:** Can be angular, rounded, or irregular, affecting workability and strength.

**Texture:** Surface texture can be smooth or rough, influencing bonding with cement

**Specific Gravity:** Usually ranges from 2.5 to 3.0, affecting the density of concrete.

Figure 3-5. Coarse aggregate.

Figure 3-6. Coarse aggregate Sieve analysis.

Figure 3-7. For coarse aggregate Standard Sieve.

### 3.2.4 Fine Aggregate

Fine aggregate Fine aggregate is a material made up of small particles, usually sand, that are used in concrete mixes. Fine aggregates are typically 4.75 millimeters or smaller in size, and can pass through a number 4 sieve. Sylhet sand is a fine, red-colored sand that's commonly used in Bangladesh for construction and FM 2.5 millimeters.

Figure 3-8. Sylhet Sand (FM 2.5 mm)

### 3-2.5 Water

Water is one of the most important elements in mortar. The water is required for preparation of mortar. The quality and quantity of water has much effect on the strength of mortar. The water used for mixing and curing should be clean and free from injurious quantities of alkalis, acid, oils, salt, sugar, organic materials, vegetable growth and other substances that may be deleterious to bricks, stone, concrete or steel. Potable water is generally considered satisfactory for mixing. The pH value of water should be not less than 6**.**

**Figure 3-9. water**

### 3.3 Mix Design

Total Cylinder= 28 Pieces

14 days curing= 14 pcs

28 days curing= 14 pcs

Concrete Grades = M35

Concrete Mix Ratio = **1:1.6:2.91**

Cement: Ordinary Portland Cement

Coarse Aggregates Size=12 mm

Moisture Content= 0.32%

Specification of Fine Aggregate: FM 2.5 mm

Slump Test of 0% Steel Fiber = 73mm

Slump Value for 0.5% to 3.0% Steel Fiber= 55-95mm

Water used: Drinking Water w/c ratio= 0.7-kg for 1 Cylinder

Steel Fiber=25 mm length (941 gm)

Cement: 19.88 kg

Fine aggregate: 31.64 kg

Coarse aggregate: 58.8 kg

### 3.4 Molds and Tools

Cylindrical molds were used for concrete casting. The molds have a detachable base plate and were 8 inches by 4 inches in dimension, with the top surface open and the bottom surface closed (as seen in Figure). Quick-acting clamps that are welded to the mold are used to split molds along their two sides. The mold partially springs apart when it is opened to allow specimen removal. The tamping rod had a diameter of 16 mm, was 60 cm long, and had a rounded end. When the concrete mixture is still wet, it is compacted using a tamping rod to increase its strength and durability.

**Figure 3-10. Cylindrical mold sand tamping rod.**

**Figure 3-11. Cylindrical molds.**

### 3.5 Specimen Preparation

For defining the basic characteristics of pervious concrete, pervious mortar and pervious pavement systems, an experimental investigation was conducted to study the following properties: density, porosity, water permeability, compressive strength, and drying shrinkage. The materials, mixture proportions, measurements and test method used in this study are described in this section. Mix proportions for pervious concrete mixes, by weight as shown in table.

**Table 1-1. Mix proportions for 0% steel fiber concrete mixes, by weight**

**=Ratio 1:1.6:2.91**

| Material | Ratio | 4 Cylinder (kg) |
|---|---|---|
| Cement | 1 | 2.84 |
| Fine Aggregate | 1.6 | 4.52 |
| Coarse Aggregate | 2.91 | 8.4 |
| Steel Fiber | 0% | 0 |
| Water | W/c =0.32 | 0.908 |

**Table 1-2. Mix proportions for 0.5% steel fiber concrete mixes, by weight =Ratio 1:1.6:2.91**

| Material | Ratio | 4 Cylinder (kg) |
|---|---|---|
| Cement | 1 | 2.84 |
| Fine Aggregate | 1.6 | 4.52 |
| Coarse Aggregate | 2.91 | 8.4 |
| Steel Fiber | 0.5% | 0.0448 |
| Water | W/c =0.32 | 0.908 |

**Table 1-3. Mix proportions for 1.0% steel fiber concrete mixes, by weight =Ratio 1:1.6:2.91**

| Material | Ratio | 4 Cylinder (kg) |
|---|---|---|
| Cement | 1 | 2.84 |
| Fine Aggregate | 1.6 | 4.52 |
| Coarse Aggregate | 2.91 | 8.4 |
| Steel Fiber | 1.0% | 0.0896 |
| Water | W/c =0.32 | 0.908 |

**Table 1-4. Mix proportions for 1.5% steel fiber concrete mixes, by weight =Ratio 1:1.6:2.91**

| Material | Ratio | 4 Cylinder (kg) |
|---|---|---|
| Cement | 1 | 2.84 |
| Fine Aggregate | 1.6 | 4.52 |
| Coarse Aggregate | 2.91 | 8.4 |
| Steel Fiber | 1.5% | 0.1336 |
| Water | W/c =0.32 | 0.908 |

**Table 1-5. Mix proportions for 2.0% steel fiber concrete mixes, by weight = Ratio 1:1.6:2.91**

| Material | Ratio | 4 Cylinder (kg) |
|---|---|---|
| Cement | 1 | 2.84 |
| Fine Aggregate | 1.6 | 4.52 |
| Coarse Aggregate | 2.91 | 8.4 |
| Steel Fiber | 2.0% | 0.1796 |
| Water | W/c =0.32 | 0.908 |

**Table 1-6. Mix proportions for 2.5% steel fiber concrete mixes, by weight =Ratio 1:1.6:2.91**

| Material | Ratio | 4 Cylinder (kg) |
|---|---|---|
| Cement | 1 | 2.84 |
| Fine Aggregate | 1.6 | 4.52 |
| Coarse Aggregate | 2.91 | 8.4 |
| Steel Fiber | 2.5% | 0.2244 |
| Water | W/c =0.32 | 0.908 |

**Table 1-7. Mix proportions for 3.0% steel fiber concrete mixes, by weight =Ratio 1:1.6:2.91**

| Material | Ratio | 4 Cylinder (kg) |
|---|---|---|
| Cement | 1 | 2.84 |
| Fine Aggregate | 1.6 | 4.52 |
| Coarse Aggregate | 2.91 | 8.4 |
| Steel Fiber | 3.0% | 0.2688 |
| Water | W/c =0.32 | 0.908 |

### 3.6 Casting of Specimens

For this test, a total of 28 cylinder casts were used. The molds have a detachable base plate and were 8 inches by 4 inches in dimension, with the top surface open and the bottom surface closed. The aim of this study is to ascertain the effects of partially substituting fly ash for cement on the link between compressive strength. A percentage cube needs to be cast from the same batch in order to remain uniform throughout the concreting process.

**Figure 3-12. Mortar mix (Dry)**

**Figure: 3.13 Mortar mix (Wet)**

**Figure: 3-14. Slump Test**

Figure 3-15. Casted Mold

### 3.7 Curing of the Specimen

Throughout the curing process, concrete retains its moisture content. Curing ensures that the cement is hydrated, increasing the strength and longevity of the concrete. The gel (C-S-H) calcium silicate hydrate, which is created when cement and water react, binds the components of concrete together securely and causes it to harden into a mass. The specimens were let to solidify for a day after casting. They were removed from the mold and left to cure the next day. The test materials used in this investigation were subjected to 14 and 28-day curing process. They were submerged in water at the SU Department of Civil Engineering. The specimens were removed from the water after the curing process, left to dry in the sun, and then rayed for a test of compressive strength.

**Curing Period**: The standard curing period is similar to conventional concrete, generally 7–28 days, depending on strength development.

Due to its porous structure, no-fines concrete has a slower strength gain compared to normal concrete. Adequate curing ensures uniform strength development.

Figure: 3-16. After casting cylinder

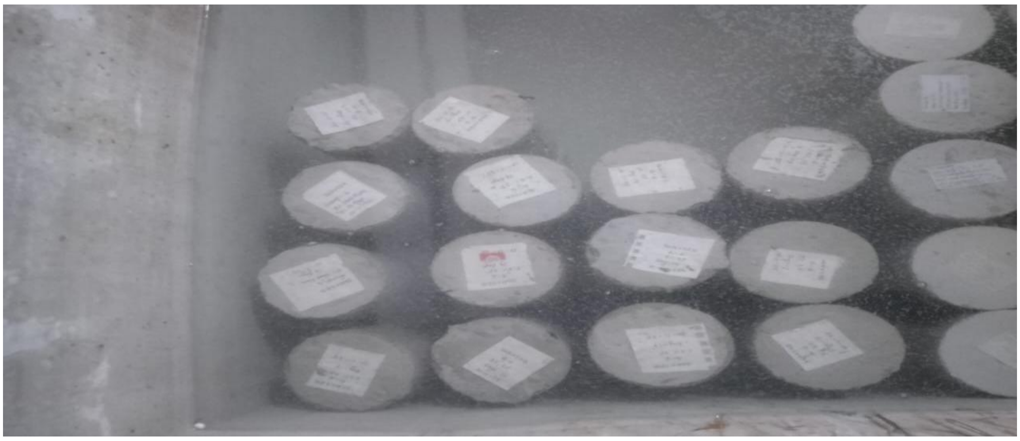

Figure 3-17. Curing of Cylinder

Figure: 3-18. After curing of casting cylinder

**Figure: 3-19. After dry of casting cylinder**

## 3.8 Testing Procedure

### 3.8.1 Compressive Strength Testing

Ability of a material to withstand forces that cause it to compress is known as its compressive strength. Tests of compressive strength are performed on cube or cylinder-shaped specimens. Platen restraint is the amount of friction produced between the concrete's up/down surface and the loading plates of the compressive strength testing apparatus. Because typical cube specimens can support heavier loads than cylinders, the contact area is larger.

According to the study’s finding, cube specimens are 25% more powerful than cylinders. For the compressive strength test in this investigation, cube specimens were used.

Figure 3-20. Compressive Strength Testing Machine

1. The sample was taken out of the water and any extra moisture was scraped off the surface after the designated curing period.
2. The sample size is a cylinder to the closest 0.2 m.
3. The testing device's bearing surface is cleaned.
4. The device's sample load is split across the cylinder's two opposing faces.
5. The sample is positioned in the middle of the machine's base plate.
6. The movable portion is manually turned slowly until it contacts the surface's upper surface.
7. Any unusual features of the failure type are noted, along with the maximum load.

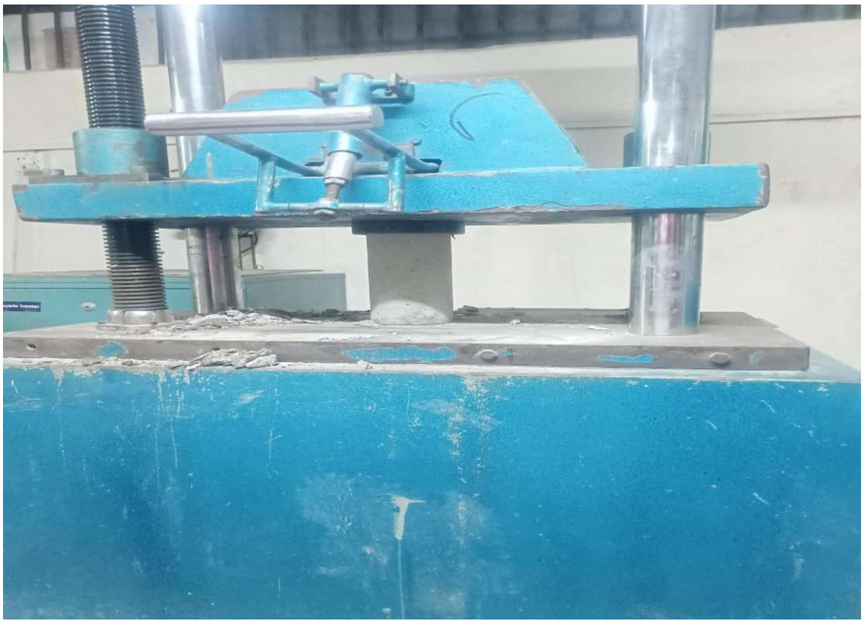

Figure 3-21. Compressive Strength Testing

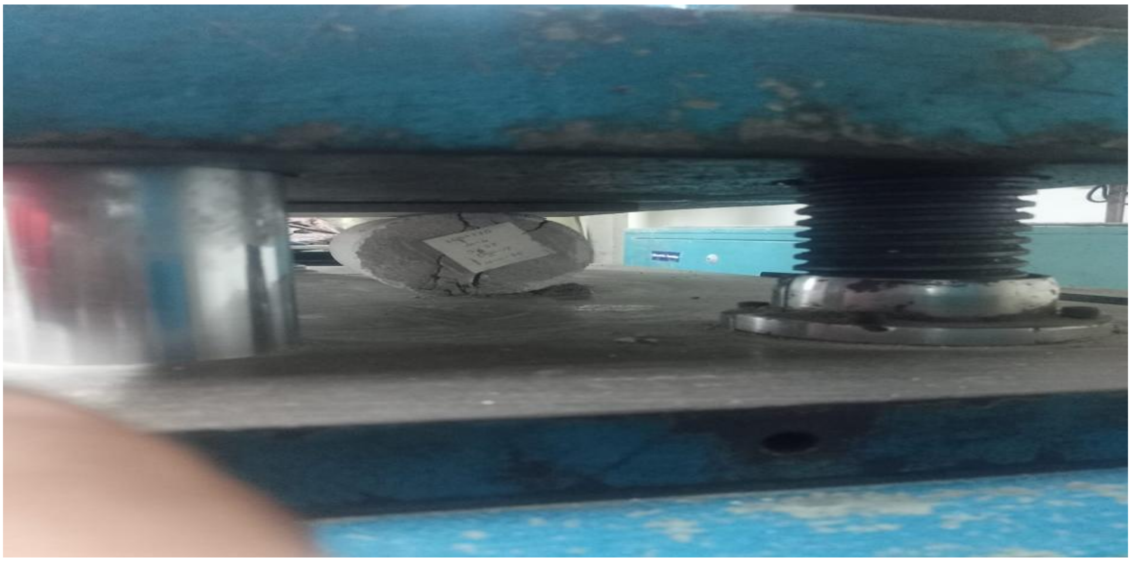

**Figure 3-22. Failure of Cylinder Specimen**

### 3.9 Splitting Tensile Strength of Cylindrical Testing

The split-tensile strength test was conducted on three (3) cylinders from each mixture. A column plot was used to illustrate the comparisons and correlations of the split-tensile strengths to their uniformity coefficients in figure.

**Figure 3-23. Splitting Tensile Strength Testing Machine**

Figure 3-24. Tensile Strength Testing

Figure 3-25. Failure of Cylinder Specimen

### 3.10 Methodology Overview

| | |
|---|---|
| 1st | • Preparation Of Materials |
| 2nd | • Preparing the Mix Design |
| 3rd | • Mixing the Materials |
| 4th | • Slump Testing of Sample |
| 5th | • Casting the Specimens |
| 6th | • Curing the Specimens |
| 7th | • Testing the Concrete Cylinders |
| 8th | • Analyzing and obtaining result and making conclusion |
| 9th | Recommendation of future Research |

**Figure 3-26. Methodology overview**

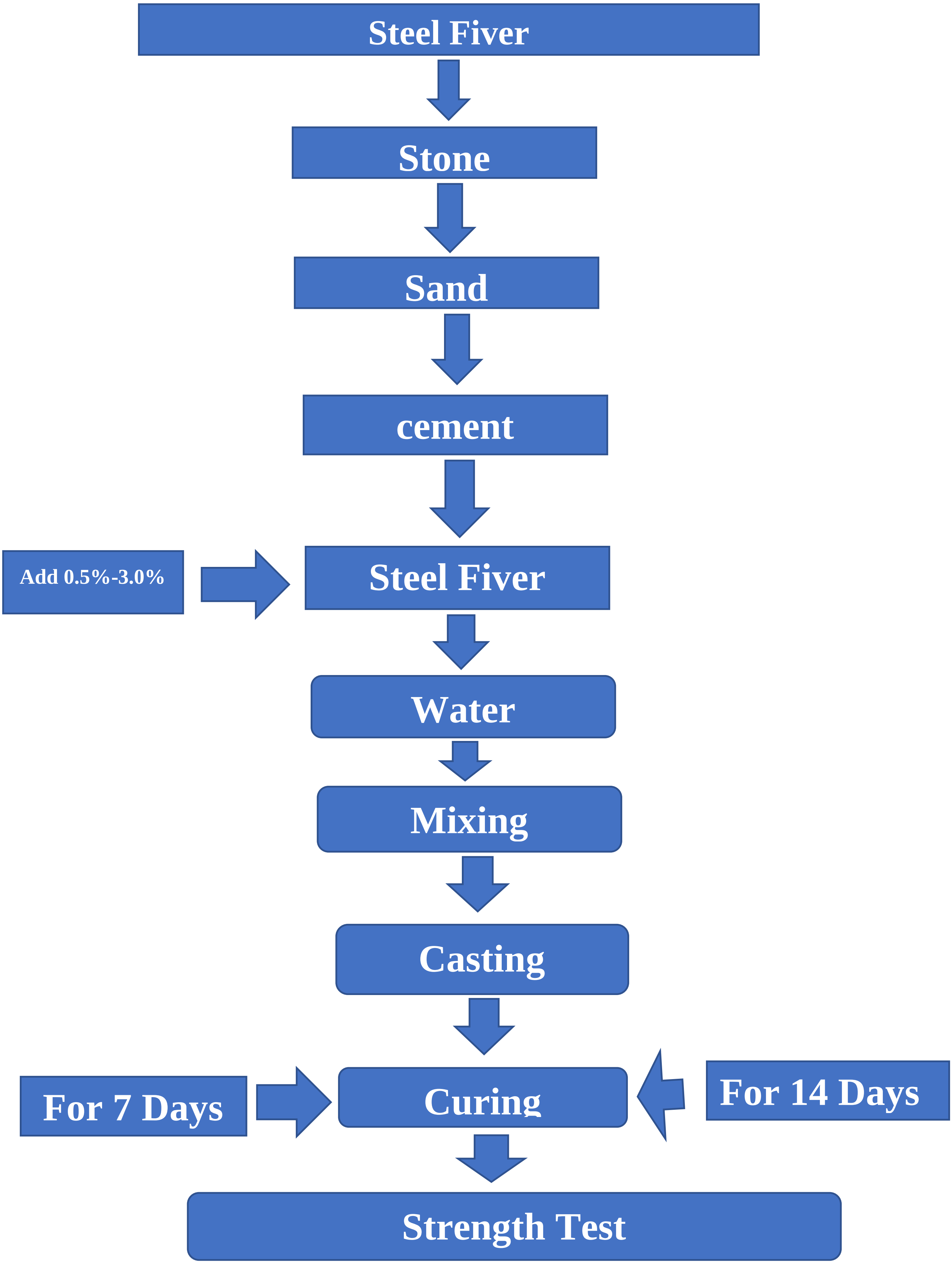

Figure 3-27. Overview of the SFRC

### 3.10 Summary

The methodology for studying steel fiber reinforced concrete (SFRC) involves systematic selection of materials, mix design, specimen preparation, and experimental testing. Ordinary Portland cement, fine and coarse aggregates, water, and steel fibers of varying types, lengths, and volume fractions are selected according to relevant standards. Proper mix design is carried out to achieve the desired workability and strength, often using superplasticizers to counteract reduced workability caused by fiber addition.

Steel fibers are gradually added during the mixing process to ensure uniform dispersion and to prevent fiber balling. Fresh concrete properties, such as workability and density, are evaluated using standard tests. Hardened concrete specimens are then cured and tested to determine mechanical properties including compressive strength, tensile strength, flexural strength, toughness, and energy absorption capacity. Durability tests such as water absorption, chloride penetration, and freeze–thaw resistance may also be conducted.

Finally, the experimental results are analyzed and compared with conventional concrete to assess the effectiveness of steel fibers. Where applicable, numerical modeling or non-destructive testing techniques are used to validate experimental findings and to predict SFRC behavior under different loading conditions.

# CHAPTER 4

## Results and Discussion

### 4.1 Introduction

This section will extensively discuss the results of the experiments described in the previous section. Comparisons will be provided of relevant relationships between water, sand aggregate, steel fiber and cement to show the influence each has on one another.

Displays the (HSFRC) strength test results and (HSC). The average of 7th test specimens was used for each strength test result. In reaction to the fiber volume fractions, the HSFRC's modulus of rupture, splitting tensile strength and compressive strength all increased to varying degrees.

### 4.2 Compressive Strength

The come strength development of HSFRC versus HSC appears Fig.4.4.1, declaring that for 14 days curing the compressive strength 0% of HSC was 19.09 MPa and of HSFRC provided an improvement at each volume fraction. The improvement, as the strength-effectiveness in Table 4.4, was 17.82 MPa at 0.5% fraction, 15.28 MPa at 1.0% fraction, 17.18 at 1.5% fraction, 17.18 MPa at 2.0%, 24.19 MPa at 2.5% and reduced to 21.64 at 3.0% fraction, and 28 days curing the compressive strength 0% of was 21.64 MPa and 20.62 MPa at 0.5% fraction, 15.91 MPa at 1.0% fraction, 21.64 at 1.5% fraction, 26.35 MPa at 2.0%, 29.28 MPa at 2.5% and reduced to 24.19 at 3.0% fraction, being a reduction small compared to the maximum pressure improvement at 2.5% fraction.

### 4.3 Tensile strength

The development of splitting tensile strength of HSFRC at various volume fractions is shown in table 4.5; compared to HSC, the strength of HSFRC improved with increasing the volume fraction. From the strength effectiveness in Table 4.5 for 14 days the improvement started from 1. 66 MPa at 0.5% fraction and expanded to 1.69 MPa at 3.0% fraction but higher value is 1.75 MPa is 2.5% fraction. For 28 days curing the improvement started from 1. 88 MPa at 0.5% fraction and expanded to 2.56 MPa at 3.0% fraction but higher value is 2.64 MPa is 2.5% fraction.

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### 4.4 Compressive Strength Test:

**Table 4.1. Compressive Strength for 0% to 3.0 % Steel Fiber Cylinder concrete at 28 days**

| Age in Days | Specimen Designation | Specimen Area ($mm^2$) | Crushing Load (KN) | Compressive Strength (MPa) |
|---|---|---|---|---|
| 28 | 0% | 7853.89 | 170 | 21.64 |
| 28 | 0.5% | 7853.89 | 162 | 20.62 |
| 28 | 1.0% | 7853.89 | 125 | 15.91 |
| 28 | 1.5% | 7853.89 | 170 | 21.64 |
| 28 | 2.0% | 7853.89 | 207 | 26.35 |
| 28 | 2.5% | 7853.89 | 230 | 29.28 |
| 28 | 3.0% | 7853.89 | 190 | 24.19 |

**Table 4-2. Compressive Strength for 0% to 3.0 % Steel Fiber Cylinder concrete at 14 days**

| Age in Days | Specimen Designation | Specimen Area ($mm^2$) | Crushing Load (KN) | Compressive Strength (MPa) |
|---|---|---|---|---|
| 14 | 0% | 7853.89 | 150 | 19.09 |
| 14 | 0.5% | 7853.89 | 140 | 17.82 |
| 14 | 1.0% | 7853.89 | 120 | 15.28 |
| 14 | 1.5% | 7853.89 | 135 | 17.18 |
| 14 | 2.0% | 7853.89 | 135 | 17.18 |
| 14 | 2.5% | 7853.89 | 190 | 24.19 |
| 14 | 3.0% | 7853.89 | 170 | 21.64 |

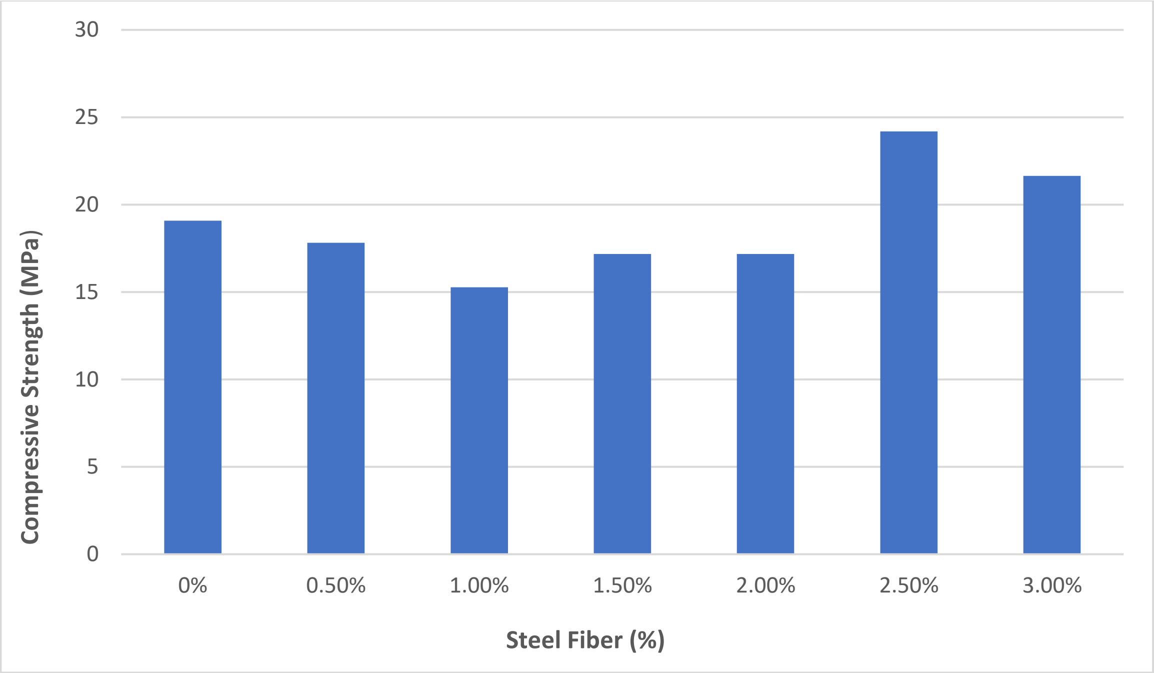

**Figure 4-1. Bar Graph for 14 days Compressive Strength**

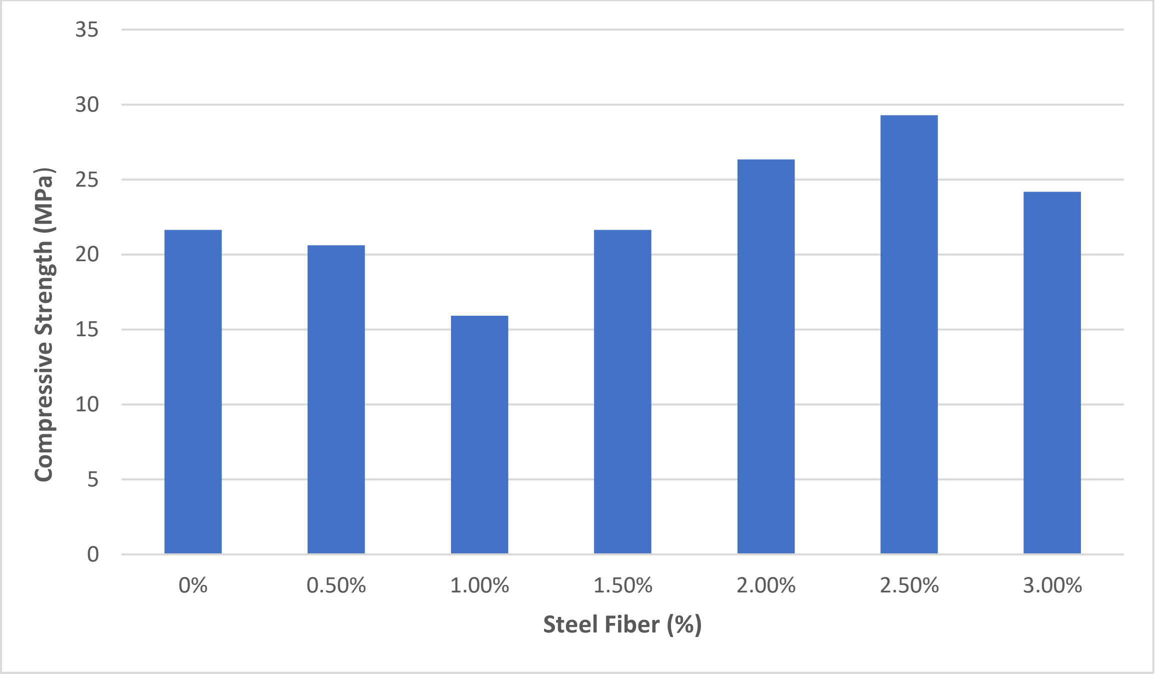

**Figure 4-2. Bar Graph for 28 days Compressive Strength**

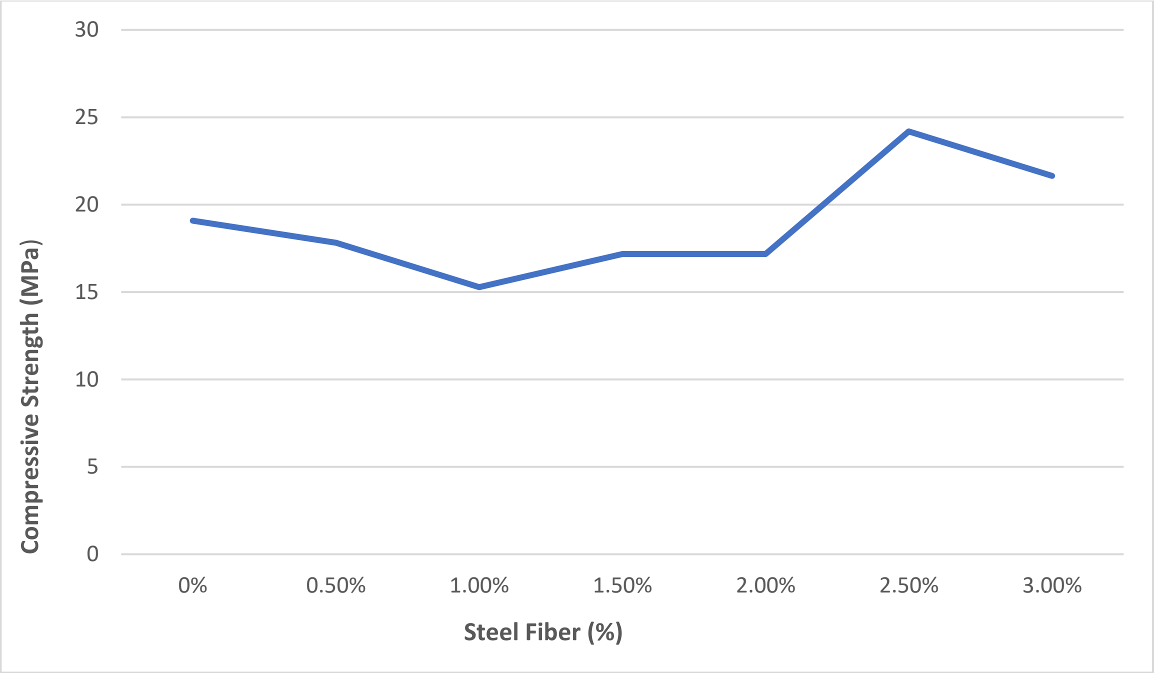

Figure 4-3. Graph for 14 days Compressive Strength

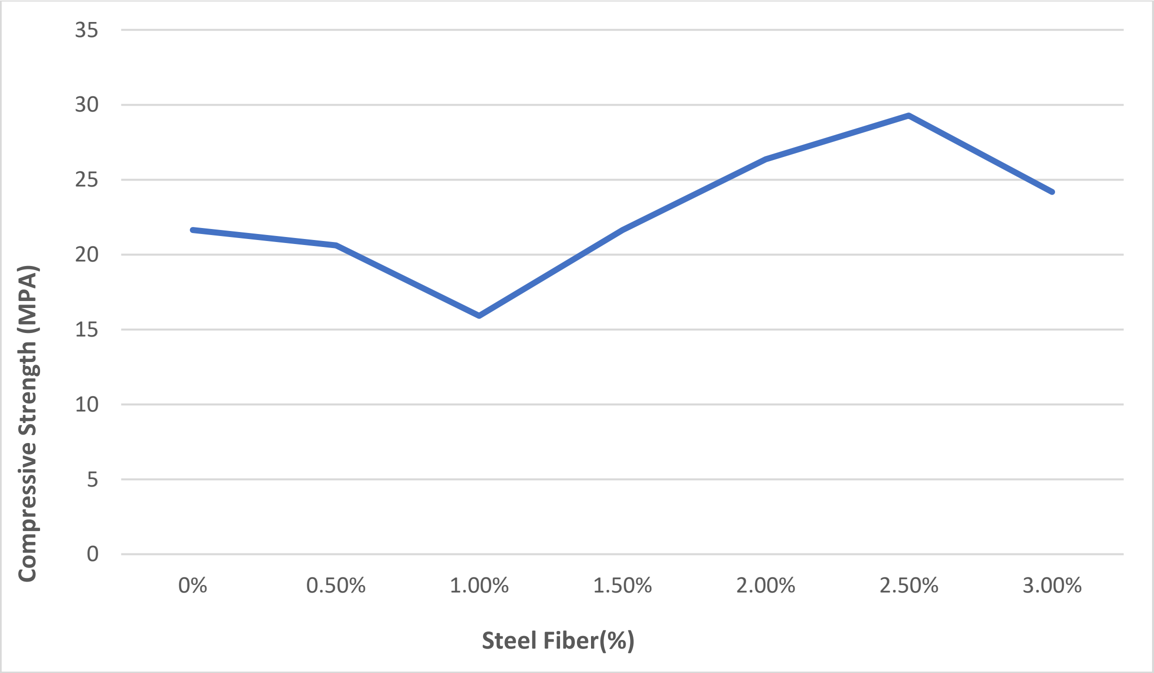

Figure 4-4. Graph for 28 days Compressive Strength

## 4.5 Splitting Tensile Strength Test:

**Table 4-3. Splitting Tensile Strength of 0% to 3.0% Steel Fiber Cylindrical Concrete at 14 days.**

| Age in Days | Specimen Designation | Length, l (mm) | diameter, d (mm) | Maximum applied load, P (N) | Splitting Tensile Strength, T (MPa) |
|---|---|---|---|---|---|
| 14 | 0% | 200 | 100 | 52000 | 1.66 |
| 14 | 0.5% | 200 | 100 | 49000 | 1.56 |
| 14 | 1.0% | 200 | 100 | 51000 | 1.62 |
| 14 | 1.5% | 200 | 100 | 53000 | 1.69 |
| 14 | 2.0% | 200 | 100 | 52000 | 1.66 |
| 14 | 2.5% | 200 | 100 | 55000 | 1.75 |
| 14 | 3.0% | 200 | 100 | 53000 | 1.69 |

**Table 4-4. Splitting Tensile Strength of 0% to 3.0% Steel Fiber Cylindrical Concrete at 28 days**

| Age in Days | Specimen Designation | Length, l (mm) | diameter, d (mm) | Maximum applied load, P (N) | Splitting Tensile Strength, T (MPa) |
|---|---|---|---|---|---|
| 28 | 0% | 200 | 100 | 59000 | 1.88 |
| 28 | 0.5% | 200 | 100 | 63000 | 2.00 |
| 28 | 1.0% | 200 | 100 | 67000 | 2.13 |
| 28 | 1.5% | 200 | 100 | 67000 | 2.13 |
| 28 | 2.0% | 200 | 100 | 77000 | 2.45 |
| 28 | 2.5% | 200 | 100 | 83000 | 2.64 |
| 28 | 3.0% | 200 | 100 | 80000 | 2.56 |

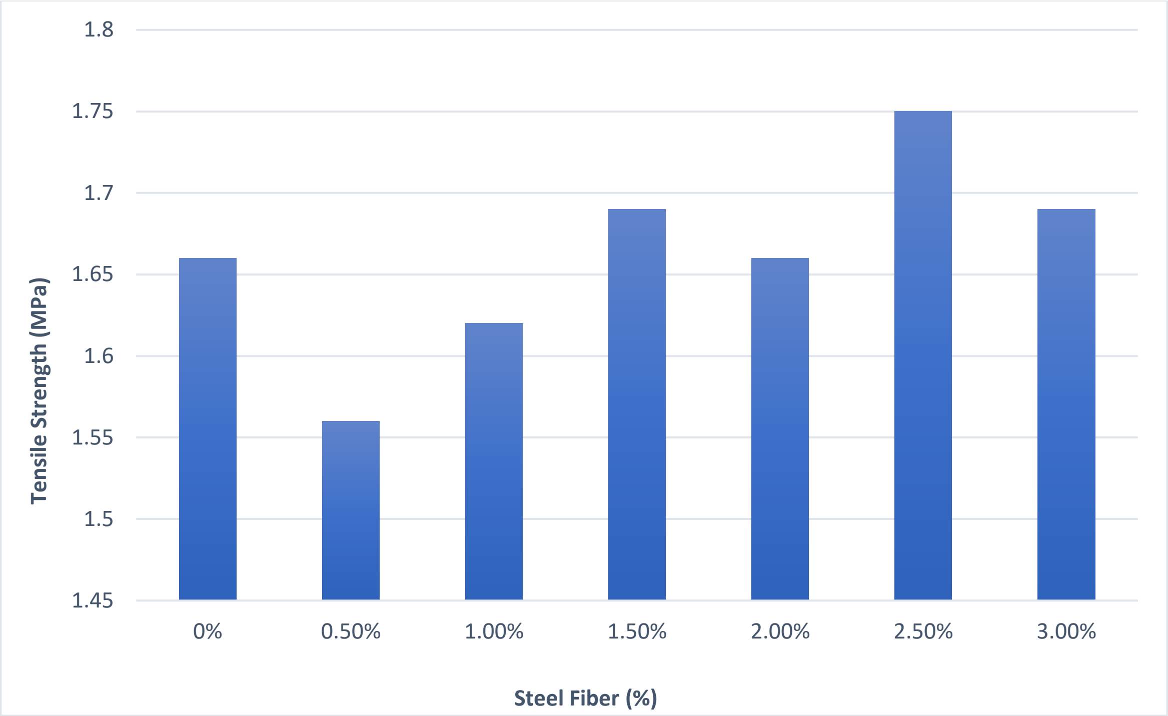

Figure 4-5. Bar Graph for 14 days Splitting Tensile Strength

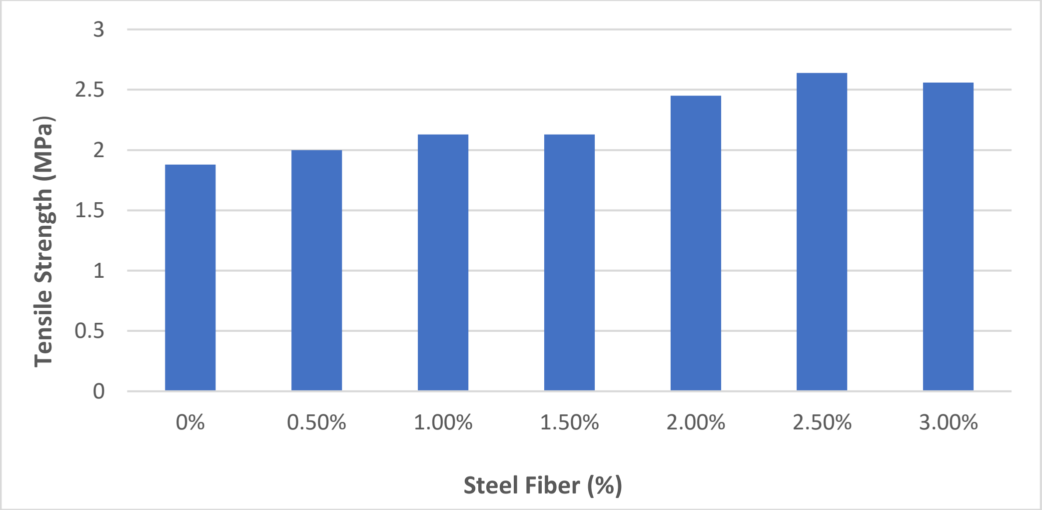

Figure 4-6. Bar Graph for 28 days Splitting Tensile Strength

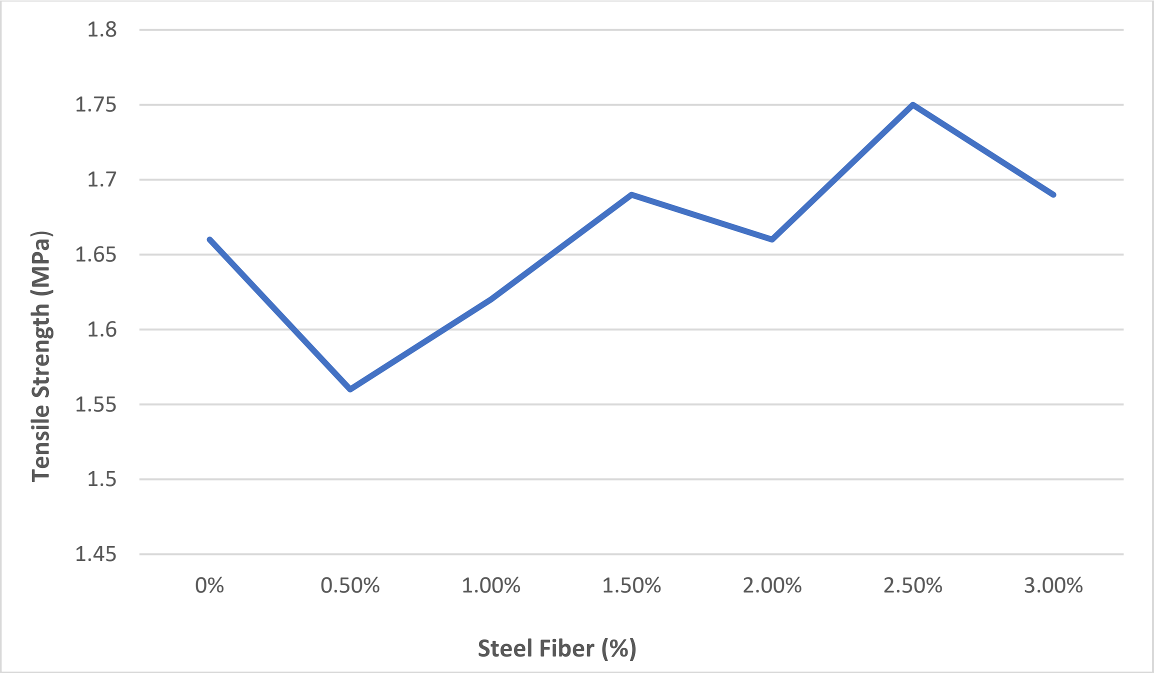

Figure 4-7.Graph Splitting Tensile strength for 14 days

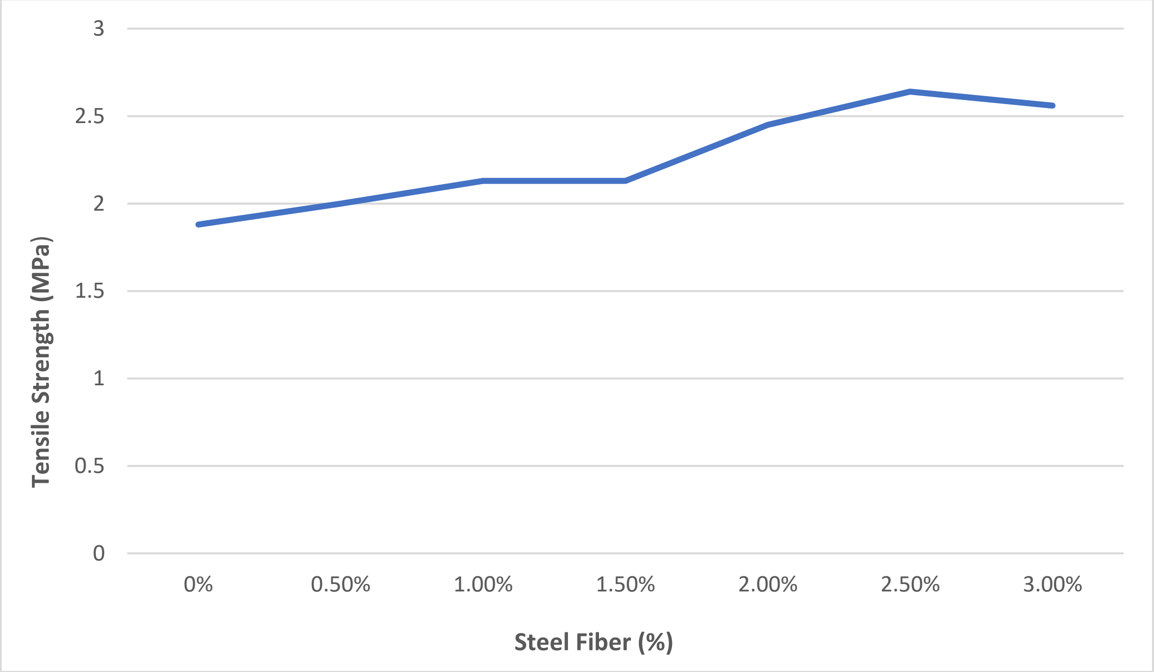

Figure 4-8. Graph Splitting Tensile strength for 28 days

## 4.6 Summary

Steel fiber inclusion significantly enhances both compressive and splitting tensile strengths of concrete, with an optimum fiber volume fraction of approximately 2.5%, beyond which strength gains tend to diminish.

# CHAPTER 5

# Conclusions and Recommendation

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## 5.1 General

The present investigation leads to the following conclusions:

- 2.50% steel fiber appears to be the optimal percentage, offering the best balance between compressive and tensile strength. Higher fiber percentages may lead to fiber congestion, reduced workability, and slight strength reductions.
- Its use in various structural applications can lead to cost-effective and long-lasting concrete solutions. However, challenges related to mix design, workability, and cost must be addressed to maximize its benefits.
- Due to its superior tensile properties and crack resistance, SFRC is widely used: Industrial floors and pavements (to reduce cracking and improve impact resistance).
- Tunnel linings and precast elements (to enhance durability and toughness).
- Bridge decks and airport runways (to withstand heavy loads and temperature variations).
- Seismic-resistant structures (due to improved ductility and energy absorption )

## 5.4 Practical Implication

Fiber reinforced concrete has practical applications such as pavements, bridge decks, building floors, and areas exposed to extreme weather conditions because it greatly reduces cracking in concrete structures, improves their impact resistance, increases their ductility, and prolongs their lifespan by fending off wear and tear.

**Control of cracks:** Because the fibers bridge and distribute tensile loads, concrete fractures may be reduced, resulting in a more durable construction. This is the main advantage. Enhanced toughness: The concrete is more resilient to impact and abrupt loads because to the fibers' enhanced energy absorption capability.

**Increased flexural strength:** Fibers can increase the bending strength of concrete buildings by preventing cracks from spreading.

**Decreased permeability:** Concrete can improve its resistance to freeze-thaw cycles by becoming less porous to water, depending on the type of fiber used.

**Improved resistance to abrasion:** Some fiber kinds can greatly improve the concrete's ability to withstand abrasion-induced wear and tear.

**Environmental Benefits and Sustainability:**

Steel Fiber Reinforced concrete can offer substantial environmental benefits by reducing the overall material consumption of fine aggregates, which are increasingly scarce and environmentally costly to mine. The material's permeability also helps manage storm water more efficiently, reducing the need for traditional drainage infrastructure. Additionally, NFC can be produced using recycled aggregates or industrial by-products, making it a more sustainable alternative to conventional concrete in certain applications.

## 5.3 Recommendation for Future works

**Features of the fibers**: Various steel fiber kinds (hooked, crimped, and smooth) and how they affect the behavior of concrete. The effect of fiber aspect ratio (length to diameter) on tensile strength and fracture propagation. Steel fiber corrosion and mitigation techniques are durability issues. SFRC's resistance to chloride penetration under harsh conditions. The effect of fiber addition and freeze-thaw durability.

1) Explore the potential of recycled steel fibers from industrial waste or scrap materials to reduce environmental impact. Investigate SFRC with supplementary cementitious materials (SCMs) such as fly ash, silica fume, or slag to enhance sustainability. Research the carbon footprint and life-cycle analysis of SFRC compared to conventional reinforced concrete.
2) Develop design guidelines and standards for SFRC in load-bearing structural elements. Investigate the performance of SFRC in seismic applications, focusing on energy absorption and crack control. Promote real-world pilot projects and case studies to validate laboratory findings and encourage industry adoption.
3) Utilize non-destructive testing techniques (such as ultrasonic pulse velocity and digital image correlation) to evaluate SFRC properties. Develop finite element models for predicting SFRC behavior under different loading conditions.

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