

# **EXPERIMENTAL INVESTIGATION OF STEEL FIBER REINFORCED CONCRETE BEAM USING GFRP AS REBAR**

Submitted in partial fulfilment of the requirements for the award of

Master of Engineering Degree in

Structural Engineering

by

**KABILAN BHARATHI A J M (41380007)**



**DEPARTMENT OF CIVIL ENGINEERING  
SCHOOL OF BUILDING AND ENVIRONMENT**

## **SATHYABAMA**

**INSTITUTE OF SCIENCE AND TECHNOLOGY  
(DEEMED TO BE UNIVERSITY)**

**Accredited with Grade “A” by NAAC**

**JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI – 600 119**

**MAY 2023**



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Jeppiaar Nagar, Rajiv Gandhi Salai, Chennai – 600 119

[www.sathyabama.ac.in](http://www.sathyabama.ac.in)



## DEPARTMENT OF CIVIL ENGINEERING

### BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **KABILAN BHARATHI A J M (41380007)**, who carried out the project entitled "**EXPERIMENTAL INVESTIGATION OF STEEL FIBER REINFORCED CONCRETE BEAM USING GFRP AS REBAR**" under my supervision from December 2022 to May 2023.

**Internal Guide**

**(Mrs.B.Priyadharshini ,M.E.)**

**Head of the Department**

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Submitted for the Viva-voce Examination held on 05/05/2023

**Internal Examiner**

**External Examiner**

## DECLARATION

I, **KABILAN BHARATHI A J M (41380007)** hereby declare that the Project Report entitled “**EXPERIMENTAL INVESTIGATION OF STEEL FIBER REINFORCED CONCRETE BEAM USING GFRP AS REBAR**” done by me under the guidance of **Mrs.B.Priyadharshini** at **SATHYABAMA INSTITUTE OF SCIENCE AND TECHNOLOGY** is submitted in partial fulfilment of the requirements for the award of Master of Engineering Degree in Structural Engineering.

*J.Kabilan bharathi*

**DATE** : 05-05-2023  
**PLACE** : Chennai

**SIGNATURE OF THE CANDIDATE**

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## **ABSTRACT**

The desirable properties, concrete can be utilized in a variety of innovative designs. It has the ability to be cast in various shapes, possesses high compressive strength and stiffness, and has low thermal and electric conductivity. However, concrete is generally brittle, which can lead to sudden and catastrophic failure in structures subjected to earthquakes, blasts, etc. This disadvantage can be overcome by incorporating fibers, such as steel, into the concrete. When the load imposed on concrete approaches failure, cracks will propagate rapidly, and the fibers provide a means of stopping the crack growth. The use of fiber-reinforced concrete has been shown to yield superior results when compared to standard concrete.

This study provides a comprehensive experimental analysis of the mechanical characteristics of Steel Fiber Reinforced Concrete (SFRC) with varying percentages of steel fibers. The study focuses on the compressive strength, split tensile strength, and flexural strength of SFRC manufactured with M40-grade concrete containing 0%, 0.75%, 1.0%, and 1.25% steel fibers. In addition, the interaction between Steel Fiber Reinforced Concrete (SFRC) and Glass Fiber Reinforced Polymer (GFRP) rebar is examined by using these blends in beams. Furthermore, an analytical investigation is conducted using ABAQUS finite element software. The study found out that the optimal mix for SFRC is a 1% volume fraction of steel fibers in it.

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## **LIST OF ABBREVIATIONS**

|      |                                 |
|------|---------------------------------|
| FRC  | Fiber Reinforced Concrete       |
| GFRP | Glass Fiber Reinforced Polymer  |
| OPC  | Ordinary Portland Cement        |
| RC   | Reinforced Concrete             |
| SFRC | Steel Fiber Reinforced Concrete |
| VF   | Volume Fraction                 |

# **CHAPTER 1**

## **INTRODUCTION**

### **1.1 CONCRETE**

Concrete is a composite material composed of cement, aggregates (sand, gravel, or crushed stone), and water. Its strength, longevity, and adaptability make it one among the most frequently used construction materials in the world. Concrete can be moulded into various shapes and sizes and is used in a wide range of construction applications, such as buildings, bridges, roads, and dams. Hydration is the chemical interaction that occurs between cement and water that enables the combination to harden and gain strength over time. Concrete can also be reinforced with steel bars or fibers to increase its strength and resist cracking. Despite its many benefits, concrete can be prone to cracking due to various factors, including temperature changes, moisture, and improper installation. Proper design, installation, and maintenance are essential for ensuring the long-term performance of concrete structures.

### **1.2 FIBER REINFORCED CONCRETE (FRC)**

Fiber Reinforced Concrete (FRC) is a composite material made of Portland cement, aggregates, and discrete fibers. These fibers can be made of various materials, such as glass, steel, or synthetic materials, and are added to the concrete mix to enhance its mechanical properties. FRC is widely used in construction for its ability to resist cracking, increase tensile strength, and improve durability. The fibers act as reinforcement and help distribute stresses throughout the concrete, reducing the risk of cracking and increasing its ability to withstand loads. FRC can be used in a variety of applications, such as road pavements, bridges, tunnels, and industrial flooring. Its increased strength and durability make it a popular choice for projects requiring long-lasting, low-maintenance concrete structures.

### **1.3 STEEL FIBER REINFORCED CONCRETE (SFRC)**

Steel Fiber Reinforced Concrete (SFRC) is a type of fiber reinforced concrete that uses steel fibers as reinforcement. These fibers are made of thin, short, and discrete lengths of steel wire, which are mixed with the concrete. The steel fibers improve the mechanical properties of concrete, such as its tensile and flexural strength, toughness, and impact resistance. SFRC is commonly used in industrial flooring, tunnels, bridges, and other structures that require high-performance concrete. The steel fibers form a three-dimensional reinforcement network that helps distribute stresses throughout the concrete matrix, thereby reducing the formation and propagation of cracks. SFRC can also enhance the energy absorption capacity of concrete structures, making them more resistant to seismic events and other dynamic loads.

### **1.4 GLASS FIBER REINFORCED POLYMER (GFRP)**

Glass Fiber Reinforced Polymer (GFRP) is a composite material made of a polymer matrix reinforced with glass fibers. The glass fibers are typically made of silica-based materials, such as E-glass, which provide high tensile strength and stiffness. The polymer matrix can be made of various materials, such as polyester, epoxy, or vinyl ester resins, and is used to hold the fibers together and protect them from external environmental factors. GFRP is a lightweight, high-strength material that is resistant to corrosion and has good fatigue and impact resistance. It is widely used in the construction industry for applications such as reinforcement of concrete structures, bridge decks, and wind turbine blades. GFRP offers several advantages over traditional materials such as steel, including its low weight, high strength-to-weight ratio, and non-conductive properties. Due to these qualities, GFRP is a desirable substitute for steel and other materials in a variety of structural applications. Epoxy, or vinyl ester resins, are used to hold the fibers together and protect them from external environmental factors. GFRP is a lightweight, high-strength material that is resistant to corrosion and has good fatigue and impact resistance. It is widely used in the construction industry for applications such as reinforcement of concrete structures, bridge decks, and wind turbine blades. GFRP

offers several advantages over traditional materials such as steel, including its low weight, high strength-to-weight ratio, and non-conductive properties. These properties make GFRP an attractive alternative to steel and other materials in many structural applications.

## **1.5 TYPES OF FIBERS USED IN CONCRETE**

The various types of fibres typically used in concrete structures are listed below.

### **1.5.1 *Steel Fiber***

Steel fibers are thin, short, and discrete lengths of steel wire used as reinforcement in concrete. These fibers are typically made of high-strength steel and are mixed with concrete to improve their mechanical properties. Steel fibres aid in the distribution of stresses within the concrete, thereby limiting the emergence and spread of cracks. They enhance the tensile and flexural strength of concrete and improve its toughness and impact resistance. Steel fibers are commonly used in industrial flooring, tunnel linings, and shotcrete applications, where they can provide superior performance compared to traditional reinforcement methods. Depending on the intended use, steel fibres are available in a variety of sizes and shapes, including hooked, crimped, and flat. Steel fibres can also help concrete become more cost-effective by lowering the amount of steel needed for reinforcement. However, proper design and installation practises are crucial for ensuring the optimal performance of steel fiber reinforced concrete structures.

### **1.5.2 *Polypropylene Fiber***

Polypropylene fiber is a kind of synthetic fiber used as reinforcement in concrete. It is made from polypropylene, a thermoplastic material known for its high strength, low weight, and resistance to chemicals and water. Polypropylene fibers are typically added to concrete in small quantities and are uniformly distributed throughout the mixture to improve its mechanical properties. These fibers help to reduce shrinkage and cracking, increase impact resistance, and improve durability.

They also improve the flexural strength of concrete and help distribute stresses throughout the structure, reducing the formation of cracks. Fibers made of polypropylene are frequently used in concrete products like shotcrete, precast products, and flooring. They are lightweight, easy to handle, and do not corrode, making them an attractive alternative to traditional reinforcement methods. However, proper design, installation, and curing practises are important to ensure the optimal performance of polypropylene fiber reinforced concrete structures.

### ***1.5.3 Glass Fiber***

Glass fibre is a type of synthetic fibre created from materials with a silica base such as E-glass. It is commonly used as a reinforcement material in composite materials, including concrete, due to its high strength, stiffness, and resistance to corrosion. Glass fibers are lightweight, easy to handle, and do not conduct electricity, making them an attractive alternative to traditional reinforcement materials such as steel. In concrete, glass fibers are typically added in small quantities and uniformly distributed throughout the mixture to enhance its mechanical properties. They help reduce shrinkage, cracking, and improve impact resistance. Glass fibres are frequently used in products like shotcrete, precast concrete, and industrial flooring. However, using them can also come with difficulties, such as the possibility of fiber-matrix debonding and the requirement for an appropriate mix design to guarantee even distribution. The successful usage of glass fiber reinforced concrete structures over the long term depends on proper design, installation, and maintenance procedures.

### ***1.5.4 Asbestos Fiber***

Asbestos fiber is a naturally occurring mineral fiber that was widely used in construction until its health risks were recognized. Asbestos is composed of long, thin, and durable fibers that are resistant to heat, fire, and chemicals. Due to these properties, asbestos was commonly used in insulation, roofing, flooring, and other building materials. However, exposure to asbestos fibers has been linked to several serious health problems, including lung cancer, mesothelioma, and asbestosis. Inhalation of asbestos fibers can lead to the build-up of scar-like tissue in the lungs,

which can interfere with breathing and increase the risk of cancer. The use of asbestos in construction and industry has been heavily regulated in many countries, and its use is now banned in several countries. The removal and disposal of asbestos-containing materials must be performed by trained professionals using proper safety equipment and procedures to minimize the risk of exposure.

#### ***1.5.5 Carbon Fiber***

Carbon atoms are linked together in long chains to create carbon fibre, a type of synthetic fibre. It is known for its high strength, stiffness, and low weight, which make it a popular material in a variety of applications, including aerospace, automotive, and sporting goods. Carbon fibers are typically produced by heating a precursor material, such as polyacrylonitrile or pitch, to high temperatures in an oxygen-free environment. The resulting fibers are then treated with a resin or other material to enhance their mechanical properties. In concrete, carbon fibers are used as a reinforcement material to improve its strength, toughness, and durability. They are often added in small quantities and uniformly distributed throughout the mixture. In order to create hybrid composites with even better mechanical properties, carbon fibres can be combined with other reinforcement materials, such as steel or glass fibres. To ensure the best performance of carbon fibre reinforced concrete structures, proper design and installation techniques are crucial. However, using carbon fibres in concrete can be expensive.

#### ***1.5.6 Organic Fiber***

Organic fiber refers to a wide range of natural fibers that are derived from plants, animals, and other organic sources. These fibers include cotton, wool, jute, hemp, silk, and bamboo, among others. Organic fibres are well-liked textile materials in the textile industry because of their comfort, breathability, and softness. They are also used as reinforcement materials in composite materials, including concrete. In concrete, organic fibers are typically used to enhance the durability and toughness of the material. They can act as a natural, sustainable alternative to artificial reinforcement materials like glass fibres and can reduce shrinkage cracking

and increase impact resistance. However, the use of organic fibres in concrete can present challenges such as variable quality and degradation over time, making proper design and installation practises crucial for ensuring the optimal performance of organic fibre reinforced concrete structures.

## **1.6 FACTORS GOVERNING FIBER REINFORCED CONCRETE**

Fiber Reinforced Concrete (FRC) is a composite material that is commonly used in construction to improve the strength and durability of concrete structures. The properties of FRC are influenced by a variety of factors, including the type, length, and orientation of the fibers, as well as the volume fraction of fibers, the type of matrix material, and the manufacturing process used to create the composite.

The kind and length of the fibres used are one of the key elements influencing how FRC behaves. The strength, stiffness, and durability of various fibre types, including steel, glass, and natural fibres, can have an impact on the composite's overall mechanical properties. The properties of FRC can also be significantly influenced by the fibre length, with longer fibres typically offering more reinforcement to the matrix material.

Another important factor affecting the properties of FRC is the volume fraction of fibers. As the volume fraction of fibers increases, the mechanical properties of the composite typically improve, as the fibers provide increased reinforcement to the matrix material. However, increasing the volume fraction of fibers can also make the composite more difficult to work with and may increase the cost of manufacturing.

Finally, the manufacturing process used to create FRC can also affect its properties. To maximise the mechanical properties of the composite, the fibres must be mixed and distributed properly within the matrix material. The properties of FRC can also be affected by the curing process, which includes the temperature and humidity levels. Inadequate curing may result in decreased strength and durability. Proper design and engineering practises are essential for ensuring the optimal properties of FRC for a wide range of construction applications.

## **1.7 VARIOUS APPLICATIONS OF FIBERS**

Fibers are used in a variety of applications, from textiles to construction materials. Different types of fibers offer different properties, such as strength, stiffness, and durability, which make them suitable for a wide range of applications. Some common fibers used in construction include steel, glass, polypropylene, and carbon fibers, each with their own unique properties and applications.

Steel fibres are frequently used in the construction industry for things like flooring, precast concrete, shotcrete, bridges, and roads. The high strength and stiffness of steel fibers make them ideal for reinforcing concrete structures, improving their durability and resistance to cracking and other forms of damage. Steel fibers are also corrosion-resistant, making them well-suited for use in harsh environments.

Glass fibers are another common fiber used in construction for applications such as flooring, precast concrete products, and residential construction. Glass fibers offer high tensile strength and stiffness, making them suitable for reinforcing concrete structures and improving their resistance to cracking and other forms of damage. Glass fibers are also lightweight and non-corrosive, making them well-suited for use in a variety of environments.

Polypropylene fibers are commonly used in residential construction for applications such as foundation walls, retaining walls, and structural slabs. The high durability and resistance to environmental factors of polypropylene fibers make them well-suited for these applications. Polypropylene fibers are also lightweight and easy to work with, making them a popular choice for many construction applications.

Carbon fibers are another high-performance fiber commonly used in construction for applications such as bridges, aircraft components, and sporting goods. Carbon fibers offer high strength and stiffness, as well as excellent fatigue resistance and corrosion resistance, making them well-suited for demanding

applications where performance is critical. Carbon fibers are also lightweight and have a high strength-to-weight ratio, making them ideal for applications where weight reduction is important.

## **1.8 OBJECTIVES**

- I. To determine the physical properties of the materials used such as coarse aggregate and fine aggregate.
- II. To ascertain the steel fibre reinforced concrete's (SFRC) compressive strength and split tensile strength, and to compare the results for various steel fibre volume fractions.
- III. To determine the flexural behaviour of SFRC beams reinforced with GFRP (Glass fiber reinforced polymer) rebars.
- IV. To create and analyse analytical models of SFRC and conventional concrete beams reinforced with GFRP rebars using ABAQUS.
- V. To compare the Analytical results and experimental results (flexural strength) of the beams.

## **1.9 SCOPE**

To conduct an experimental investigation into the effects of different steel fibre volume fractions in concrete. The main aim is study to changes in mechanical properties and how Steel Fiber Reinforced Concrete interacts with Glass fiber reinforced polymer (GFRP) rebars when used in structural elements.

## **1.10 NEED FOR RESEARCH**

- I. LIMITED RESEARCH: Compared to traditional steel-reinforced concrete beams, there has been limited research on the use of GFRP reinforced SFRC beams. Therefore, further research is needed to better understand the behaviour of these beams and optimize their design.

- II. SUSTAINABLE MATERIALS: GFRP is a sustainable material that can reduce the carbon footprint of construction projects. By using GFRP instead of traditional steel, we can reduce the amount of carbon dioxide emitted during the manufacturing process.
- III. STRUCTURAL SAFETY: The safety and reliability of structures are critical. Understanding the behaviour of GFRP reinforced SFRC beams can help engineers design more resilient and safe structures.
- IV. COST-EFFECTIVENESS: The cost of GFRP is higher than traditional steel, but it can be more cost-effective in the long run due to its durability and reduced maintenance requirements. Therefore, further research can help optimize the design of GFRP reinforced SFRC beams to make them more cost-effective.

## CHAPTER 2

### LITERATURE REVIEW

#### 2.1 LITERATURE'S

**Lu et al., (2022)**, A research project was carried out to investigate the flexural behavior of Steel-Fiber-Reinforced Concrete (SFRC) beams that were fortified with a combination of Glass Fiber Reinforced Polymer (GFRP) and steel bars. The study included a comparison of the test results of the SFRC beams to those of plain concrete beams. The outcomes demonstrated that incorporating steel fibers together with GFRP and steel bars substantially improved the flexural strength, serviceability, and crack resistance of the SFRC beams compared to the plain concrete beams.

**Fallah-Valukolaee et al., (2022)**, The possibility of using Glass Fiber Reinforced Polymer (GFRP) rebars instead of steel rebars in concrete beams was investigated in order to create structural members that are both lightweight and long-lasting. The research results showed that incorporating steel fibers in the beams increased their flexural stiffness, toughness, and fracture energy, while use of GFRP bars enhanced the flexural capacity of the beams.

**Abbas et al., (2022)**. The aim of this paper is to investigate how changing the quantity and arrangement of steel and glass fiber-reinforced-polymer (GFRP) rebars affects the flexural characteristics of reinforced concrete (RC) beams. The study's findings showed that the concrete's initial stiffness and first crack-load were both improved by the addition of steel fibres.

**Gopu & Sofi, (2022).** According to this study, conventional concrete beams and all fiber-reinforced concrete beams had comparable or superior corrosion resistance. In instances where the specimens were not cracked, the incorporation of fibers into the concrete resulted in a 6% increase in the period it takes for corrosion to begin compared to conventional concrete. The findings indicate that the use of fiber-reinforced concrete reduces the occurrence of cracks caused by corrosion while also boosting the residual flexural strength. Specifically, the residual flexural strength of beams made of steel fiber-reinforced concrete was 16% higher than that of beams made of conventional concrete.

**Yang et al., (2021).** This paper intends to analyse the steel fibre reinforced concrete's compressive strength and elastic modulus. The compressive properties of Ultra High-Performance Fiber Reinforced Concrete studied in this paper include compressive strength and modulus of elasticity. The test revealed that both of them rise as the fibre volume ratio or aspect ratio rises. In this study, the impact of steel fibre on compressive properties is generally more favourable than adverse.

**Nematzadeh & Fallah-Valukolaee, (2021).** The efficiency of utilizing different layers of fiber in beams fortified with both steel and Glass Fiber Reinforced Polymer (GFRP) rebars was investigated in research. The findings shown that a two-layer composite member made of plain concrete and fiber-reinforced concrete may greatly enhance flexural behavior, guarantee an optimal distribution of steel fibers, and lower the cost of these structural components. The study also found that due to their higher strength-to-weight ratio, GFRP rebars can be a practical alternative to steel rebars in reinforced concrete beams.

**Tahenni et al., (2021).** Conducted an experimental and numerical investigation of the impact of steel fibers on the deflection behavior and stiffness contribution of tensioned concrete in steel fiber reinforced concrete (SFRC) beams without stirrups, tested under four-point bending. The research focused on various testing parameters, such as the compressive strength of the concrete, the volume

fraction of the fibers, and their aspect ratio. The study compared the mid-span deflections of the beams measured experimentally with the theoretical predictions.

**Rezakhani et al., (2021).** This investigation focused on identifying the impact of various types of steel fibers on the quasi-static mechanical behaviour of ultra-high-performance concrete (UHPC) through different laboratory experiments as well as their numerical modelling. The main benefits offered by the smaller fibers occurred prior to reaching the ultimate load carrying capacity. Once the ultimate strength was reached, larger fibers were more effective in bridging larger cracks.

**Shi et al., (2020).** Shi et al. (2020) conducted research on the compression and tension behaviours of steel fiber reinforced concrete (SFRC) under uniaxial compression and tension. Full-range constitutive curves for SFRC mixtures under these conditions are generally not available in the literature. The study investigated two types of SFRC, namely straight and hooked fibers, with varying fiber volume contents under uniaxial compression and tension. The findings indicated that the fibers significantly improved the post-cracking behaviors of the concrete, resulting in increased ductility, residual strength, and toughness under both compression and tension.

**Li et al., (2020).** This work investigates the tensile strength and failure pattern of high-performance steel fibre reinforced concrete under dynamic splitting strain. While strain rate is constant, tensile stress increases with increasing fibre content. When fibre content is constant, tensile stress increases with climbing strain rate, but the growth rate decreases. Samples lacking steel fibre exhibit a distinctly brittle failure mode and insufficient tensile strain capacity. On the other hand, samples reinforced with steel fibres exhibit delayed ductile failure traits.

**Dev et al., (2020).** In this shear behaviour of hybrid fiber reinforced concrete beams with GFRP bars is studied. Both the synthetic and hybrid fibers improved the

shear strength, post cracking behaviour, and pseudo-ductility of the GFRP-reinforced beams under shear.

**Han et al., (2019).** Studying the effects of steel fibre length and coarse aggregate maximum size on the mechanical properties of steel fibre reinforced concrete (SFRC). The study's findings showed that increasing the length of steel fibres improved the performance of SFRCs in a number of areas, including mixture slump, splitting tensile strength, flexural strength, initial flexural toughness ratio, flexural toughness ratio, fracture energy, and unstable fracture toughness.

**Vakili et al., (2019).** Conducted a study on the shear behaviour of fibers and hybrid fibers in lightweight concrete beams reinforced with GFRP bars. The aim was to investigate the impact of fibers and hybrid fibers on the shear strength of the beams. The study concluded that the behavior of the beams was influenced by the addition of different types of fibers.

**Iqbal et al., (2019).** This paper examines the mechanical characteristics of closed steel fibres. When 0.75 percent volume of Straight Steel Fibers and 0.75 percent volume of Closed Steel Fibers were added to concrete, respectively, the flexural strength of the concrete increased by 23.8 percent and 43 percent.

**Abbass et al., (2018).** Research was done to see how adding fibers to concrete affects its strength. Concrete is weak when it comes to pulling or bending, but adding steel fibers can make it stronger. The study showed that adding more fibers to the concrete made it even stronger. When smaller fibers were used, the concrete could be up to 124% stronger. When longer fibers were used, the concrete was up to 140% stronger than plain concrete.

**Araba & Ashour, (2018).** The research paper highlights the findings from an experiment involving five large-scale continuous beams made of hybrid glass fiber

reinforced polymer (GFRP) and steel reinforced concrete. Two concrete continuous beams reinforced with either steel or GFRP bars were also tested as reference beams, along with two simply supported concrete beams reinforced with hybrid GFRP/steel. The study focused on investigating the effect of the amount of longitudinal GFRP and steel reinforcements, as well as the area of steel bars to GFRP bars. The results of the experiment demonstrated that an increase in the GFRP reinforcement ratio in both sagging and hogging zones resulted in an increase in the load capacity.

**Lee et al., (2018).** Conducted a study on the structural behavior of reinforced concrete (RC) beams, with and without steel fibers and stirrups, which are dependent on the loading rate.

**Wu et al., (2016).** conducted a study to examine how the mechanical properties of ultra-high-performance concrete are affected by different shaped steel fibres and fibre contents. The study looked at how three different steel fibre types straight, corrugated, and hooked end with various fibre contents (0%, 1%, 2%, and 3% percent by volume) affected concrete's flowability, compressive strength, and flexural behaviour. Based on the characteristics of the obtained three-point flexural load-deflection curve and the current constitutive model of uniaxial compression, a new model for the flexural load-deflection based on least square fitting was proposed.

**Berrocal et al., (2015).** The objective of this ongoing project is to examine how fiber reinforcement affects the corrosion of rods in chloride environments. The inclusion of fiber reinforcement, particularly at low dosages (<1% volume), did not have an influence on the flexural and compressive strength of concrete. However, it significantly improved the toughness of the concrete.

## 2.2 SUMMARY OF LITERATURE'S

- I Flexural strength, serviceability, crack resistant increased with usage of steel fibers with GFRP and steel bars.
- II Steel fibres increased the flexural stiffness, toughness, and fracture energy of beams, and GFRP bars did the same.
- III The glass fiber reinforced polymer (GFRP) rebar can serve as a proper alternative for the steel rebar in reinforced concrete beams considering its superior strength to weight ratio compared with the steel rebar.
- IV The increase in the fiber content increased the flexural strength compared to the concrete without any fibers.
- V The fibers had a significant impact on the post-cracking behavior of the concrete, resulting in increased ductility, residual strength, and toughness under both compression and tension.
- VI Splitting tensile strength, flexural strength, initial flexural toughness ratio, flexural toughness ratio, fracture energy and unstable fracture toughness of SFRC increase as steel fiber volume increases.
- VII The primary advantages provided by the smaller fibers were observed before reaching the ultimate load carrying capacity. After the ultimate strength was attained, the larger fibers were more efficient in spanning bigger cracks. The load capacity increased through enhancing both GFRP reinforcement ratio in the sagging and hogging zones.
- VIII The incorporation of steel fibers in concrete improved the first crack-load and initial stiffness.
- IX The positive outcome of steel fiber on compressive properties is generally larger than adverse effect.
- X The flexural and compressive strength of concrete were not influenced by the addition of fiber reinforcement at low dosages (<1% volume.) at the same time as toughness was greatly enhanced.

## CHAPTER 3

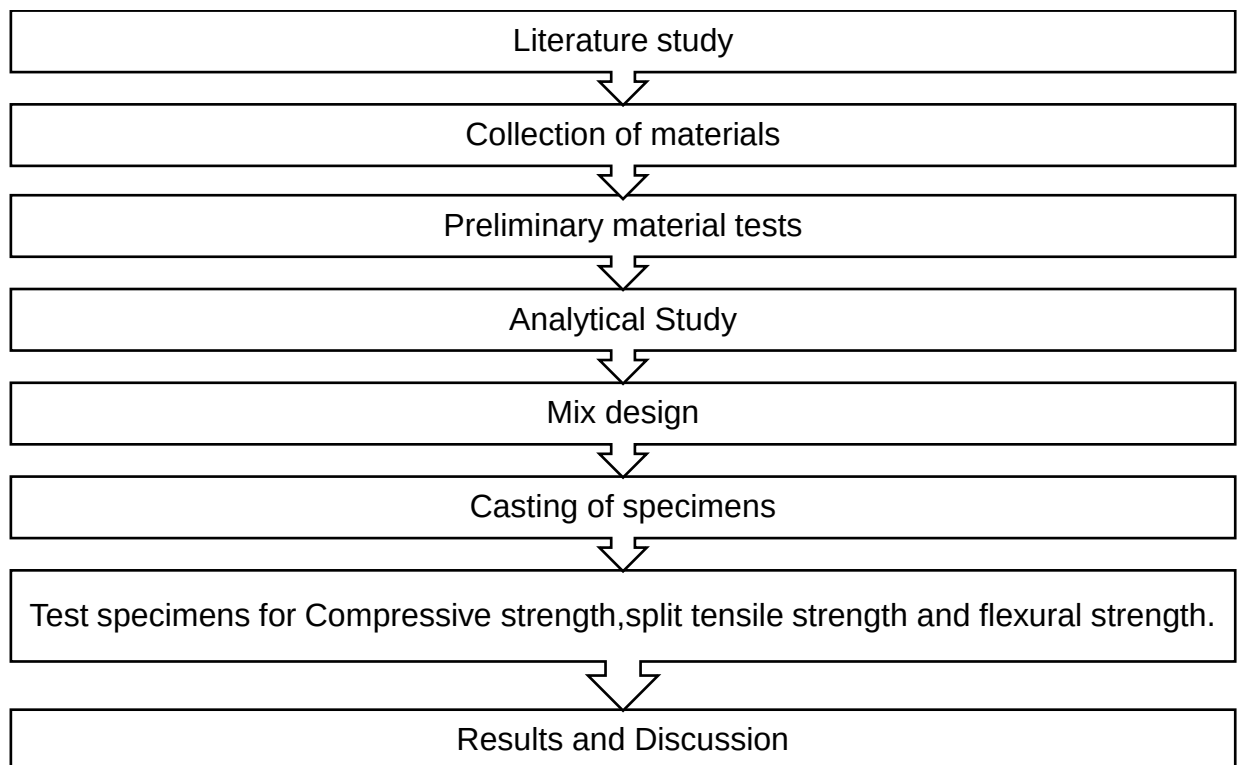
### METHODOLOGY AND MATERIALS

#### 3.1 INTRODUCTION

In this chapter we discuss about methodology which is nothing but systematic approach employed in conducting research or studying a particular subject matter. This chapter also discusses about various materials used in this study like cement, fine aggregate and coarse aggregate etc.

#### 3.2 FLOW CHART

The flow chart in fig 3.1 gives us a better way to represent the workflow of the study.



***Fig 3.1 Methodology flow chart***

### **3.3 MATERIALS USED**

This section discusses about the various materials used like cement, fine aggregate, coarse aggregate etc in this study.

#### ***3.3.1 Ordinary Portland cement***

Ordinary port cement (OPC) of grade 53 will be used for the entire investigation. The required quantity will be stored in air tight bags and will be used in experimental work. Good quality cement will be used for the entire process, using high grade of cement offer many advantages for making of strong concrete.

#### ***3.3.2 Water***

Water is the most important and least expensive ingredient of concrete. Ordinary potable water will be used for the experimental investigations and curing purposes. Water used for mixing and curing free from impurities such as oils, acids, alkalis, salts, organic materials or other substances that will be delirious to concrete. The Ph value of water used was less than 6 as per code reference of IS456: 2000.

#### ***3.3.3 Fine aggregates***

M-Sand conforming to zone III gradation of IS 383-1970 will be used throughout the experimental process. The image of M-sand used can be seen in Fig 3.2



***Fig 3.2 M-Sand***

### **3.3.4 Coarse aggregates**

Coarse aggregate of 20 mm hard broken granite conforming to IS 383-1970 will be used for the experimental investigation which is shown in Fig 3.3.



***Fig 3.3 Coarse aggregate***

### **3.3.5 Chemical admixtures**

Chemical admixture to improve the effectiveness of the water content of a concrete mix, was used in this experimental investigation.

### **3.3.6 Steel fibre**

Hooked end steel fibers of length (L)=60mm, diameter (D)= 0.75 mm and aspect ratio 80 (fiber aspect ratio =Length/Diameter = 60 mm/0.75 mm = 80) will be used in this study. The steel fibers used in this study is shown in Fig 3.4



**Fig 3.4 Steel Fibers**

### **3.3.7 GFRP rebars**

Glass Fiber Reinforced Polymer (GFRP) rebars of 10 mm diameter will be used in this study. The GFRP rebars used in this study is shown in Fig 3.5



***Fig 3.5 GFRP rebars***

## **CHAPTER 4**

### **ANALYTICAL INVESTIGATION**

#### **4.1 INTRODUCTION**

In this chapter we discuss about Analytical investigation which involves a thorough and systematic examination of a problem or situation to uncover its underlying causes and potential solutions. We did this analytical investigation using software called ABAQUS.

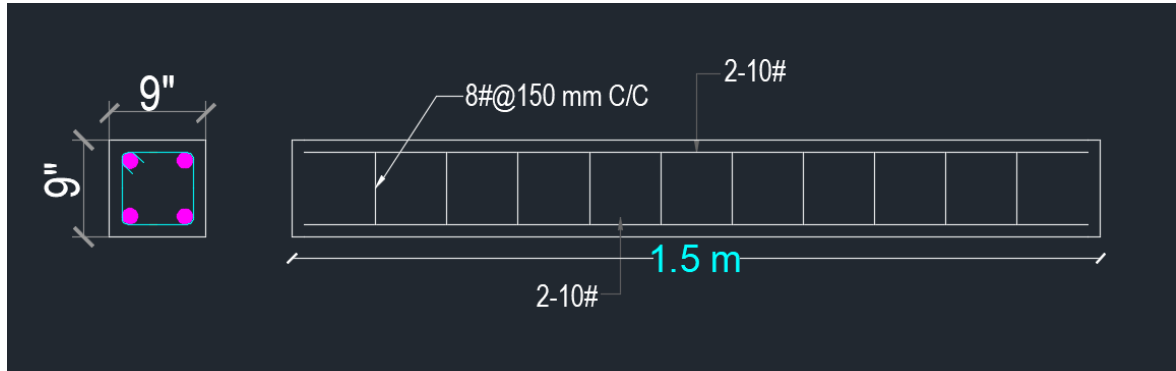
#### **4.2 ABAQUS SOFTWARE**

An analytical investigation using Abaqus involves a comprehensive analysis of structures and materials to understand their behaviour under various conditions. Abaqus is a finite element analysis software used extensively in engineering and research fields to simulate real-world scenarios and predict the behaviour of structures, materials, and systems. The software uses numerical techniques to solve complex mathematical equations and simulate the behaviour of physical systems. It provides a comprehensive set of tools for modelling, meshing, solving, and visualizing complex problems.

The Abaqus software has various features that allow engineers and researchers to perform detailed analyses of complex systems. For example, the software can simulate fluid-structure interaction, which is the interaction between a fluid and a solid structure, such as a bridge pylon in a river. Abaqus can also simulate the behaviour of composite materials, which are materials made from two or more different materials with different properties.

#### **4.2.1 Details of specimens analysed using ABAQUS**

Four beams of length 1.5 meter and cross-sectional dimensions of 228 mm x 228 mm or 9" x 9", with varying volume fraction of steel fibers VF=0% (control specimen) ,0.75% ,1% and 1.25% reinforced with GFRP rebars of 10 mm diameter were studied using ABAQUS software. Fig 4.1 shows pictorial representation of dimensions of beams used.

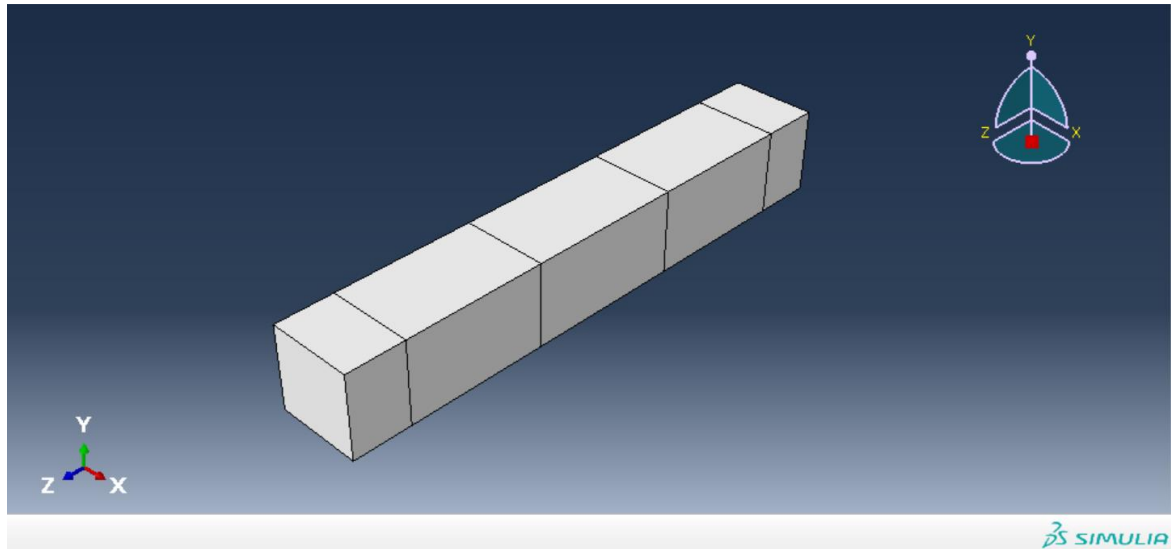


**Fig 4.1 Dimensions of beam specimens**

#### **4.2.2 Analysis of SFRC beams reinforced with GFRP rebars.**

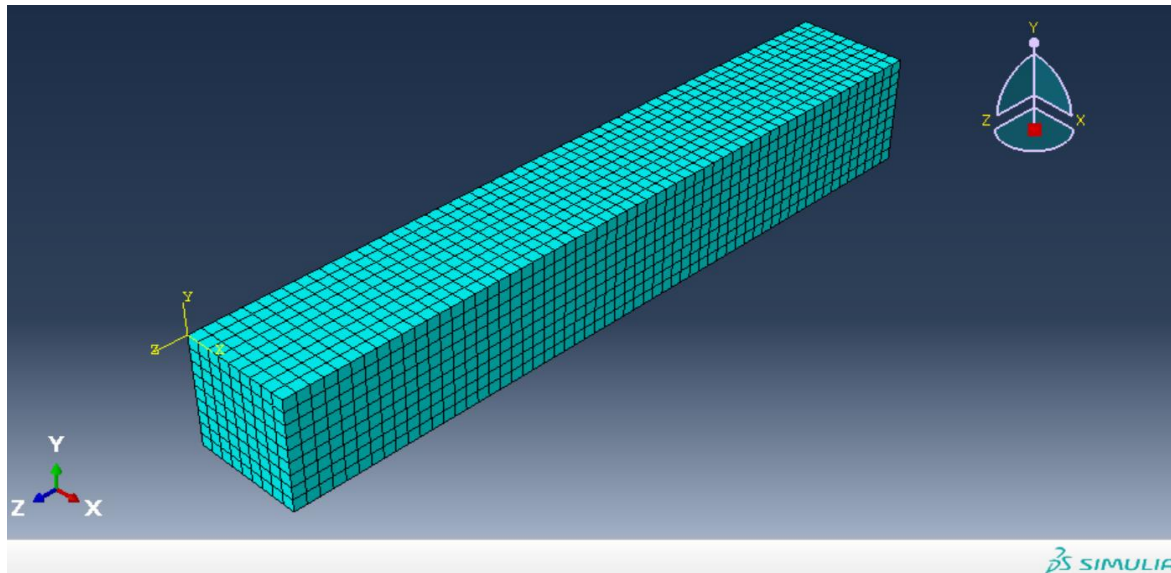
The analysis of SFRC (Steel Fiber Reinforced Concrete) beams reinforced with GFRP (Glass Fiber Reinforced Polymer) rebars by Abaqus software involves several steps. The following are the process involved in the analysis of SFRC beams reinforced with GFRP rebars by Abaqus software:

**Modelling:** The first step in the analysis is to create a 3D model of the SFRC beam reinforced with GFRP rebars in Abaqus software. The model should include all the necessary dimensions, materials, and boundary conditions. The model of the beam created in ABAQUS is shown in the fig 4.2



**Fig 4.2 Model of beam specimens**

Meshing: Once the model is created, the next step is to mesh the SFRC beam. This involves dividing the beam into small elements or nodes, which will be used to simulate the beam's behaviour under different loading conditions. The mesh should be fine enough to capture all the details of the beam's geometry and material properties which is shown in Fig 4.3.



**Fig 4.3 Meshed beam model**

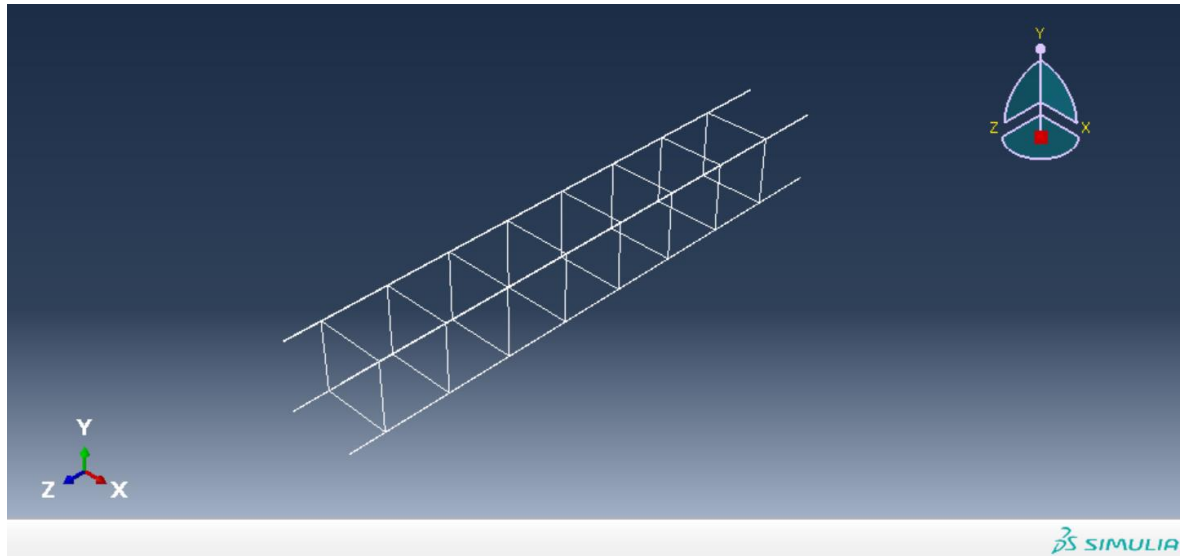
Material Properties: After meshing, the next step is to define the material properties of the SFRC beam reinforced with GFRP rebars. This includes specifying the Young's modulus, Poisson's ratio, and other material properties that are relevant

to the beam's behaviour under loading conditions. The properties of materials which were provided as input for analysis is mentioned in table 4.1

**Table 4.1 Material properties**

| <b>Material</b>         | <b>Modulus of Elasticity</b> | <b>Poisson ratio</b> | <b>Yield strength</b> |
|-------------------------|------------------------------|----------------------|-----------------------|
| Concrete M40<br>(VF=0%) | 31585 Mpa                    | 0.20                 | -                     |
| SFRC M40<br>(VF=0.75%)  | 34307 Mpa                    | 0.20                 | -                     |
| SFRC M40<br>(VF=1%)     | 36314 Mpa                    | 0.20                 | -                     |
| SFRC M40<br>(VF=1.25%)  | 35101 Mpa                    | 0.20                 | -                     |
| GFRP                    | 55000 Mpa                    | 0.28                 | 1250 Mpa              |

Rebar Properties: The next step is to define the properties of the GFRP rebars used to reinforce the SFRC beam. This includes specifying the Young's modulus, Poisson's ratio, and other material properties that are relevant to the rebars' behaviour under loading conditions. The 3D model of rebars is show in fig 4.4



**Fig 4.4 3D model of rebars**

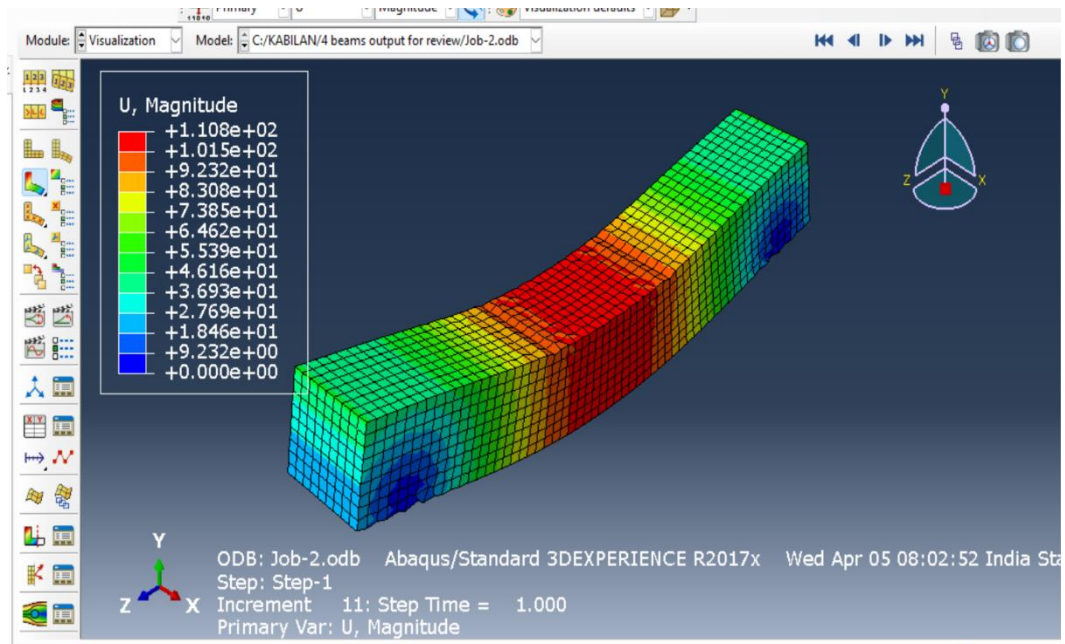
**Boundary Conditions:** The next step is to apply the boundary conditions to the SFRC beam reinforced with GFRP rebars. This includes fixing one end of the beam and applying the load to the other end. The boundary conditions are consistent with the actual conditions under which the beam will be used.

**Solving:** Once the boundary conditions are applied, the Abaqus software solves the equations governing the behaviour of the SFRC beam reinforced with GFRP rebars under loading conditions. This involves solving a large system of equations using numerical techniques.

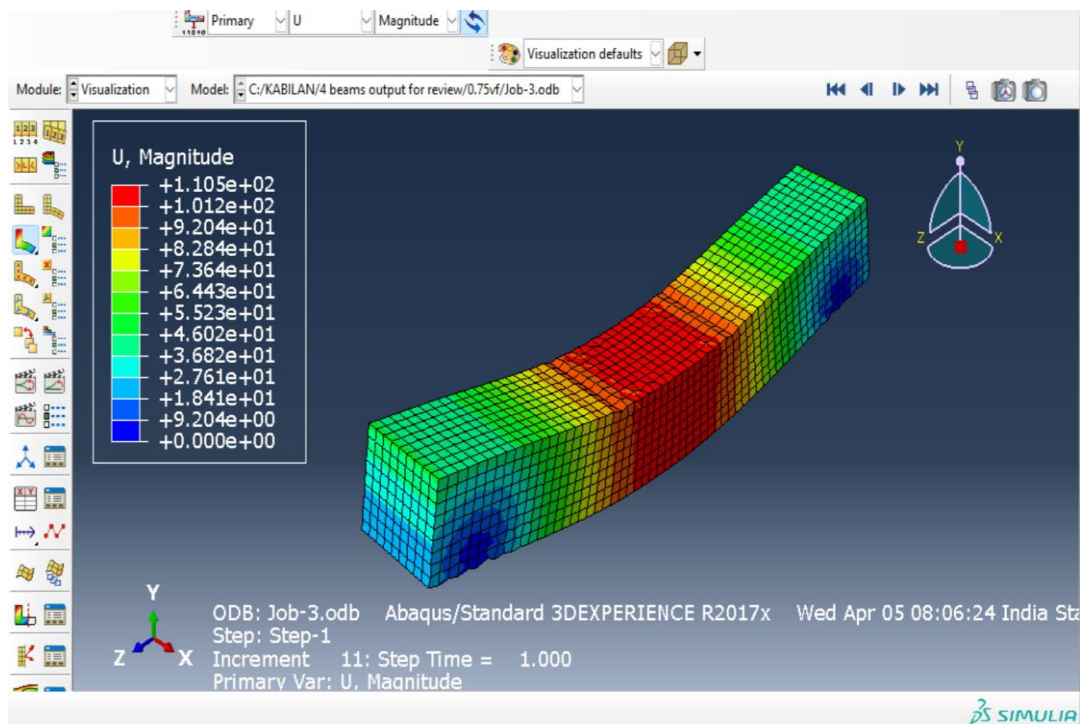
**Results:** After the solution is obtained, the Abaqus software provides the results in the form of stress, strain, and deformation plots. The results can be used to determine if the SFRC beam reinforced with GFRP rebars will be able to withstand the loads it is expected to experience in real-world conditions. Fig 4.5,4.6,4.7 and 4.8 shows the deformed shape of the beam due to load applied on it. Table 4.2 gives the values of flexural strength results for analytical investigation.

**Table 4.2 Flexural strength result for beam (Analytical)**

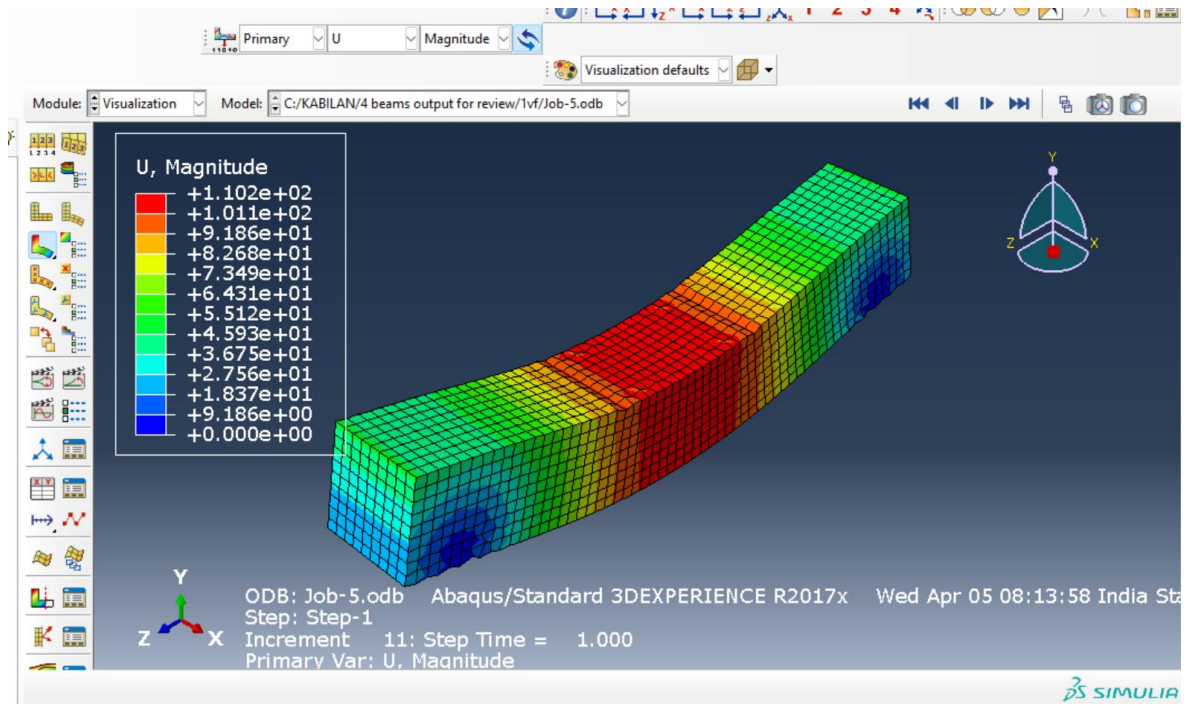
| Load (KN) | Conventional<br>concrete $v_f=0\%$ | SFRC<br>VF=0.75% | SFRC<br>VF=1% | SFRC<br>VF=1.25% |
|-----------|------------------------------------|------------------|---------------|------------------|
|           | DEFLECTION (mm)                    |                  |               |                  |
| 0         | 0.000                              | 0.000            | 0.000         | 0.000            |
| 10        | 0.069                              | 0.067            | 0.023         | 0.026            |
| 20        | 0.139                              | 0.136            | 0.064         | 0.085            |
| 30        | 0.228                              | 0.226            | 0.112         | 0.150            |
| 40        | 0.324                              | 0.328            | 0.165         | 0.213            |
| 50        | 0.424                              | 0.414            | 0.207         | 0.264            |
| 60        | 0.520                              | 0.500            | 0.231         | 0.302            |
| 70        | 0.603                              | 0.550            | 0.242         | 0.328            |
| 80        | 0.664                              | 0.600            | 0.249         | 0.365            |
| 90        | 0.723                              | 0.660            | 0.250         | 0.390            |
| 100       | 0.750                              | 0.700            | 0.260         | 0.410            |



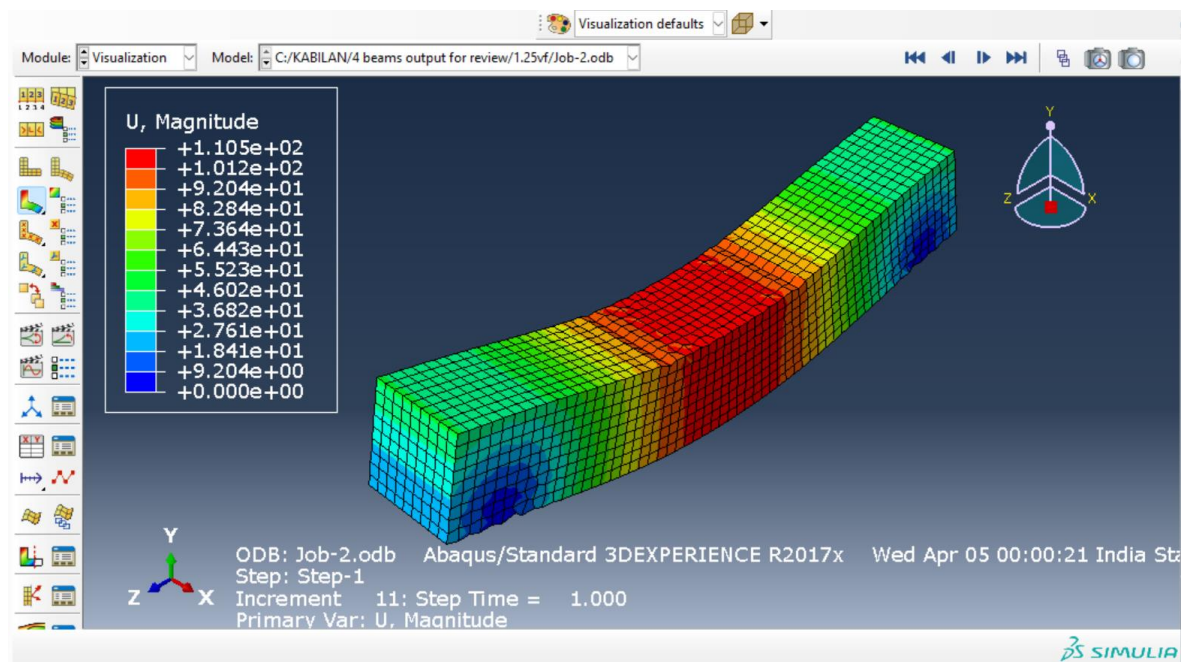
**Fig 4.5 Deformation of beam Conventional (VF=0%)**



**Fig 4.6 Deformation of beam SFRC (VF=0.75%)**



**Fig 4.7 Deformation of beam SFRC M40 (VF=1%)**



**Fig 4.8 Deformation of beam SFRC M40 (VF=1.25%)**

## CHAPTER 5

### EXPERIMENTAL INVESTIGATION

#### 5.1 INTRODUCTION

Experimental investigation includes the details of specimens, material testing, casting and testing of specimens of steel fiber reinforced concrete.

#### 5.2 TEST ON MATERIALS

The following tests were conducted to determine the properties of materials used in this investigation.

##### *5.2.1 Test on cement*

Ordinary port cement (OPC) of grade 53 conforming to IS 8112:1989 was used in this study and property of the cement used is shown in table 5.1.

**Table 5.1: properties of cement**

| S.No. | Name of the property | Test Results |
|-------|----------------------|--------------|
| 1     | Fineness of cement   | 7.2%         |
| 2     | Initial setting time | 35 minutes   |
| 3     | Specific gravity     | 3.15         |
| 4     | Consistency          | 27%          |
| 5     | Soundness            | 2 mm         |

### 5.2.2 Tests on coarse Aggregate

Coarse aggregate of 20 mm hard broken granite from pallavaram quarry conforming to IS 383-1970 was used. Specific gravity was found out to be 2.75 refer table 5.3. The result of sieve analysis is furnished in table 5.2 weight of sample taken is 1 kg or 1000 grams.

**Table 5.2: Gradation of coarse aggregate**

| Sieve size (mm) | Cumulative weight retained(gm) | Percentage retained | Cumulative percentage retained | Percentage passing |
|-----------------|--------------------------------|---------------------|--------------------------------|--------------------|
| 80              | 0                              | -                   | -                              | 100                |
| 40              | 0                              | -                   | -                              | 100                |
| 20              | 850                            | 85                  | 85                             | 15                 |
| 10              | 148                            | 14.8                | 99.8                           | 0.2                |
| 4.75            | 2                              | 0.2                 | 100                            | 0                  |

**Table 5.3: Specific gravity of coarse aggregate**

| Description |                                                | Values |
|-------------|------------------------------------------------|--------|
| a           | Weight of sample taken                         | 1000 g |
| b           | Weight of vessel + sample+ water (A)           | 3388 g |
| c           | Weight of vessel + water (B)                   | 2736 g |
| d           | Weight of saturated and surface dry sample (C) | 990 g  |
| e           | Weight of oven dry sample (D)                  | 941 g  |

|   |                                                           |      |
|---|-----------------------------------------------------------|------|
| f | Specific Gravity = $\left[\frac{D}{C-(A-B)}\right] * 100$ | 2.75 |
|---|-----------------------------------------------------------|------|

### 5.2.3 Tests on Fine aggregates

M-Sand conforming to Table 4 of IS 383-1970 zone III was used. The specific gravity of fine aggregate was found to be 2.64 refer table 5.5. The Results of sieve analysis of fine aggregate is furnished in table 5.4. Pycnometer used in finding specific gravity is shown in Fig 5.1.

**Table 5.4: Gradation of fine aggregate**

| Sieve Size  | Cumulative weight retained (gm) | Percentage retained | Cumulative percentage retained | Percentage passing |
|-------------|---------------------------------|---------------------|--------------------------------|--------------------|
| 4.75        | 0                               | 0                   | 0                              | 100                |
| 2.30        | 24                              | 2.4                 | 2.4                            | 97.6               |
| 1.18        | 344                             | 34.4                | 36.8                           | 63.2               |
| 600 microns | 150                             | 15.0                | 51.8                           | 48.2               |
| 300 microns | 180                             | 18.0                | 69.8                           | 30.1               |
| 150 microns | 230                             | 23.0                | 92.8                           | 7.2                |
| 75 microns  | 50                              | 5.0                 | 97.8                           | 2.2                |
| Pan         | 22                              | 2.2                 | 100                            | -                  |

**Table 5.5: Specific gravity of fine aggregate**

| Description |                                                             | Values |
|-------------|-------------------------------------------------------------|--------|
| a           | Weight of sample taken                                      | 2000 g |
| b           | Weight of saturated and surface dry aggregate (C)           | 500 g  |
| c           | Weight of pycnometer + Sample + water (A)                   | 1826 g |
| d           | Weight of pycnometer + water (B)                            | 1514 g |
| e           | Weight of oven dry sample (D)                               | 496 g  |
| f           | Specific Gravity = $\left[ \frac{D}{C-(A-B)} \right] * 100$ | 2.64   |



**Fig 5.1: Pycnometer apparatus**

### 5.3 MIX DESIGN

Mix design is the process of selecting the proportion of ingredients that will produce concrete of the desired strength and durability. The IS code method for mix design, as described in the IS code book number IS 10262:2009, provides a standardized approach for determining the mix proportions of concrete. The method involves selecting the target mean strength of concrete, calculating the water-cement ratio based on the maximum size of aggregate, the workability of concrete, selecting the cement content based on the water-cement ratio and the water content of the mix. The method also considers the properties of the aggregate, such as its grading and specific gravity, and the use of admixtures, if required. The IS code method for mix design ensures that the concrete produced meets the required strength and durability specifications and is suitable for the intended application. The concrete mix design was done according to IS code method to achieve the required design strength refer table 5.6 for details of mix design.

**Table 5.6: Mix Proportion**

| SL no | Description                         | Values                  |
|-------|-------------------------------------|-------------------------|
| 1     | Required strength                   | 40 N/mm <sup>2</sup>    |
| 2     | Standard deviation                  | 5 N/mm <sup>2</sup>     |
| 3     | Target average compressive strength | 48.25 N/mm <sup>2</sup> |
| 4     | Maximum size of aggregate           | 20 mm                   |
| 5     | Shape of aggregate                  | Angular                 |
| 6     | Quantity of Water required          | 198 kg/m <sup>3</sup>   |
| 7     | Quantity of Fine aggregate required | 638 kg/m <sup>3</sup>   |

|    |                                        |               |
|----|----------------------------------------|---------------|
| 8  | Quantity of Coarse aggregate required  | 1155 $kg/m^3$ |
| 9  | Quantity of super plasticizer required | 1.08 $kg/m^3$ |
| 10 | Specific gravity of cement             | 3.15          |
| 11 | Specific gravity of fine aggregate     | 2.64          |
| 12 | Specific gravity of coarse aggregate   | 2.75          |
| 13 | Water cement ratio                     | 0.43          |
| 14 | Mix proportion                         | 1:1.47:2.66   |

#### 5.4 STEEL FIBER DOSAGE

Hooked end steel fibers of length  $L=60\text{mm}$ , diameter  $D= 0.75\text{ mm}$  and aspect ratio of 80 is used in this work.

$$\text{Fiber aspect ratio} = \text{Length/Diameter} = 60\text{ mm}/0.75\text{ mm} = 80$$

This steel fiber is added to the concrete to produce SFRC (Steel Fiber Reinforced Concrete). steel fiber dosage refers to the amount of steel fibers added to the concrete mix per unit weight of the mix. The dosage is be expressed as the mass of fibers per unit volume of concrete, typically in  $kg/m^3$ .

The optimal fiber dosage for a specific SFRC mix depends on various factors, including the type, length, diameter, and aspect ratio of the fibers, as well as the properties of the concrete mix, such as the water-cement ratio, aggregate type and size, and workability. The stel fiber dosage for different volume fraction of steel fibers is given in table 5.7.

**Table 5.7: Steel Fiber Dosage**

| S.NO. | FIBER VOLUME FRACTION | DOSAGE                  |
|-------|-----------------------|-------------------------|
| 1     | 0%                    | 0                       |
| 2     | 0.75%                 | 18.18 Kg/m <sup>3</sup> |
| 3     | 1%                    | 24.24 Kg/m <sup>3</sup> |
| 4     | 1.25%                 | 30.30 Kg/m <sup>3</sup> |

Formula to calculate fiber dosage in Kg/m<sup>3</sup> = fiber volume in % \* Density of concrete, where density of concrete used is 2424 Kg/m<sup>3</sup>.

## **5.5 PREPARATION OF SPECIMENS**

### **5.5.1 Moulds**

As per the recommendation of IS: 516-1959, specimens of nominal dimensions were made. Metal moulds preferably steel or cast iron, thick enough to prevent distortion were used. The cylinder mould is required to be of metal which shall not be less than 3 mm thick.

### **5.5.2 Mixing**

Mixing of fibre reinforced concrete needs attention to avoid balling of fibers, segregation and in general. The difficulty of mixing the materials uniformly Increase with the aspect ratio of fibres, volume percentage of fibers and size and quantity of coarse aggregate intensify the difficulties and balling tendencies. Steel fibre content in excess of 2 percent by volume and an aspect ratio of more than 100 are difficult to mix.

It is important that the fibers are dispersed uniformly throughout the mix This was done by the addition of fibres before the addition of water. The fibres were

mixed uniformly in the concrete through a wire mesh basket. Chemical admixture was added to fiber reinforced concrete to increase the workability of the mix.

### **5.5.3 Compaction**

The test cube specimens were made soon after mixing and in such a way as to produce full compaction of the concrete without segregation. The concrete was filled in to the mould in layers approximately 50 mm deep. Each layer was compacted by tamping rod. After the top layer had been compacted the surface of the concrete was brought to the finished level, using a trowel. Voids left by the tamping bar, were filled by tapping the sides of the mould.

### **5.5.4 Curing**

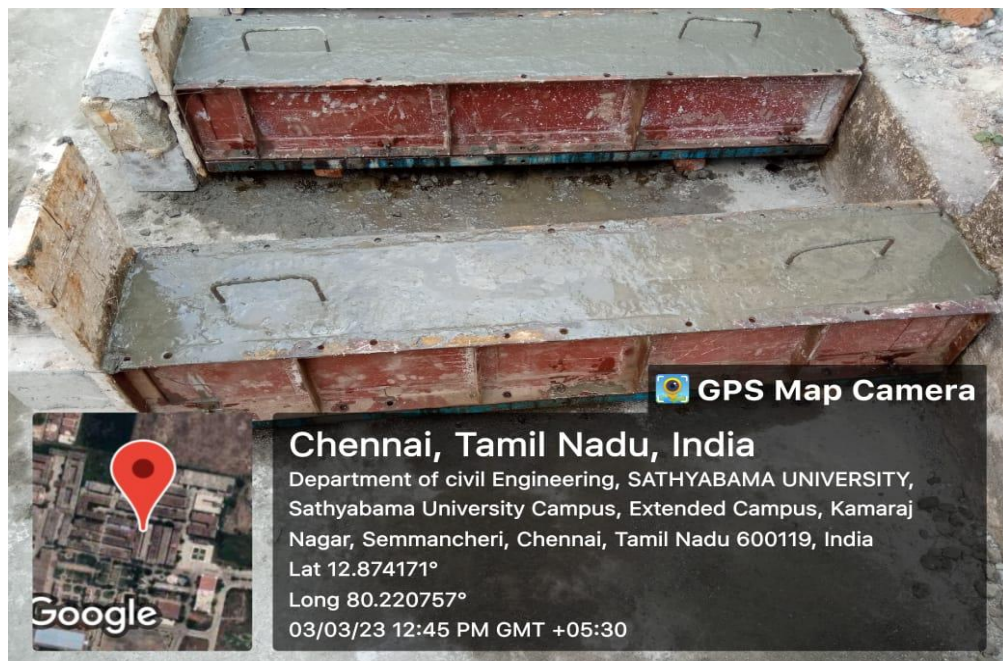
The test specimens were stored in a place free from vibration at a temperature of  $27^{\circ} \pm 2^{\circ}$  C for 24 hours from the time of addition of water to the dry ingredients. After this period, the specimens were marked and removed from the moulds and immediately kept immersed in clean fresh water until taken out, prior to test. The specimens were not dried at any time until the time of testing.

## **5.6 DETAILS OF SPECIMENS CAST**

Three types of tests were performed compressive strength test, split tensile strength test and flexural strength test. For cube specimens and cylindrical specimens compressive and split tensile tests were performed. Beam specimens were used for flexural strength test. Concrete cube specimens of dimensions (L=150 mm, B=150 mm, H=150 mm) were made by varying the volume fraction of steel fibers total of 36 cube specimens were cast. Split tensile strength test specimens of cylindrical shape 150 mm diameter and 300 mm height were made by varying the volume fraction of steel fibers total of 36 cylindrical specimens were cast. Four Beam specimens of length 1500 mm and cross section of 230mm x 230mm were made for flexural strength test. Table 5.8 shows the details of specimens and fig 5.2, 5.3 and 5.4 shows images of specimens cast



***Fig 5.2: Casted Cylinder specimens***



***Fig 5.3: Casted beam specimens***



**Fig 5.4: Casted Cube and cylinder specimens**

**Table 5.8: Specimen details**

| SI NO. | NAME OF THE TEST       | % OF STEEL FIBRE ADDED | NO. OF SPECIMENS |
|--------|------------------------|------------------------|------------------|
| 1.     | Compressive strength   | 0%                     | 9 Nos            |
|        |                        | 0.75%                  | 9 Nos            |
|        |                        | 1%                     | 9 Nos            |
|        |                        | 1.25%                  | 9 Nos            |
| 2.     | Split tensile strength | 0%                     | 9 Nos            |
|        |                        | 0.75%                  | 9 Nos            |
|        |                        | 1%                     | 9 Nos            |
|        |                        | 1.25%                  | 9 Nos            |

|    |                   |       |       |
|----|-------------------|-------|-------|
| 3. | Flexural strength | 0%    | 1 Nos |
|    |                   | 0.75% | 1 Nos |
|    |                   | 1%    | 1 Nos |
|    |                   | 1.25% | 1 Nos |

## 5.7 COMPRESSIVE STRENGTH

The cube specimens were tested after 7 days, 14 days and 28 days of curing. They were placed in the compressive testing machine of capacity 100 tones and subjected to uniform rate of loading. The load was increased till the specimens failed and the maximum load resisted by the specimen was noted. split tensile strength of specimens reinforced with different volume fraction of steel fiber content after 7, 14, 28 days of curing is provided in table 5.9,5.10,5.11 and 5.12 respectively. The test set up for compressive strength test is shown in fig 5.5.

$$\text{Compressive strength} = \text{Load at failure} / \text{Cross-sectional area}$$

Where "load at failure" is the maximum load applied to the specimen during the test and "cross-sectional area" is the area of the specimen where load is being applied.

**Table 5.9: Compressive strength of control specimens (VF=0%)**

| Sample No | Days of curing | Compressive force at failure (KN) | Compressive strength    |
|-----------|----------------|-----------------------------------|-------------------------|
| 1A        | 7              | 595                               | 26.44 N/mm <sup>2</sup> |
| 2A        | 7              | 620                               | 27.55 N/mm <sup>2</sup> |
| 3A        | 7              | 625                               | 27.77 N/mm <sup>2</sup> |
| 4A        | 14             | 650                               | 28.88 N/mm <sup>2</sup> |
| 5A        | 14             | 730                               | 32.44 N/mm <sup>2</sup> |
| 6A        | 14             | 655                               | 29.11 N/mm <sup>2</sup> |
| 7A        | 28             | 855                               | 38.00 N/mm <sup>2</sup> |
| 8A        | 28             | 850                               | 37.77 N/mm <sup>2</sup> |
| 9A        | 28             | 860                               | 38.22 N/mm <sup>2</sup> |

**Table 5.10: Compressive strength of SFRC specimens (VF=0.75%)**

| <b>Sample No</b> | <b>Days of curing</b> | <b>Compressive force at failure (KN)</b> | <b>Compressive strength</b> |
|------------------|-----------------------|------------------------------------------|-----------------------------|
| 1B               | 7                     | 630                                      | 28.00 N/mm <sup>2</sup>     |
| 2B               | 7                     | 635                                      | 28.22 N/mm <sup>2</sup>     |
| 3B               | 7                     | 645                                      | 28.66 N/mm <sup>2</sup>     |
| 4B               | 14                    | 730                                      | 32.44 N/mm <sup>2</sup>     |
| 5B               | 14                    | 745                                      | 33.11 N/mm <sup>2</sup>     |
| 6B               | 14                    | 735                                      | 32.66 N/mm <sup>2</sup>     |
| 7B               | 28                    | 890                                      | 39.55 N/mm <sup>2</sup>     |
| 8B               | 28                    | 910                                      | 40.44 N/mm <sup>2</sup>     |
| 9B               | 28                    | 900                                      | 40.00 N/mm <sup>2</sup>     |

**Table 5.11: Compressive strength of SFRC specimens (VF=1%)**

| <b>Sample No</b> | <b>Days of curing</b> | <b>Compressive force at failure (KN)</b> | <b>Compressive strength</b> |
|------------------|-----------------------|------------------------------------------|-----------------------------|
| 1C               | 7                     | 720                                      | 32.00 N/mm <sup>2</sup>     |
| 2C               | 7                     | 700                                      | 31.11 N/mm <sup>2</sup>     |
| 3C               | 7                     | 725                                      | 32.22 N/mm <sup>2</sup>     |
| 4C               | 14                    | 825                                      | 36.66 N/mm <sup>2</sup>     |
| 5C               | 14                    | 800                                      | 35.55 N/mm <sup>2</sup>     |
| 6C               | 14                    | 810                                      | 36.00 N/mm <sup>2</sup>     |
| 7C               | 28                    | 920                                      | 40.88 N/mm <sup>2</sup>     |
| 8C               | 28                    | 910                                      | 40.44 N/mm <sup>2</sup>     |
| 9C               | 28                    | 930                                      | 41.33 N/mm <sup>2</sup>     |

**Table 5.12: Compressive strength of SFRC specimens (VF=1.25%)**

| <b>Sample No</b> | <b>Days of curing</b> | <b>Compressive force at failure (KN)</b> | <b>Compressive strength</b> |
|------------------|-----------------------|------------------------------------------|-----------------------------|
| 1D               | 7                     | 720                                      | 32.00 N/mm <sup>2</sup>     |
| 2D               | 7                     | 710                                      | 31.55 N/mm <sup>2</sup>     |
| 3D               | 7                     | 705                                      | 31.33 N/mm <sup>2</sup>     |
| 4D               | 14                    | 810                                      | 36.00 N/mm <sup>2</sup>     |
| 5D               | 14                    | 830                                      | 36.88 N/mm <sup>2</sup>     |
| 6D               | 14                    | 800                                      | 35.55 N/mm <sup>2</sup>     |
| 7D               | 28                    | 920                                      | 40.88 N/mm <sup>2</sup>     |

|    |    |     |                         |
|----|----|-----|-------------------------|
| 8D | 28 | 900 | 40.00 N/mm <sup>2</sup> |
| 9D | 28 | 930 | 41.33 N/mm <sup>2</sup> |



**Fig 5.5: Compressive strength testing of SFRC specimen**

## 5.8 SPLIT TENSILE STRENGTH

The split tensile strength test is a commonly used method to determine the tensile strength of concrete. This test involves subjecting a cylindrical concrete specimen to an axial compressive load, which is applied along the longitudinal axis of the specimen. After loading, the specimen is then split along its diameter using a splitting tensile testing machine, and the tensile strength of the concrete is calculated using the formula based on the maximum load sustained during the test. This test is crucial in evaluating the durability and quality of concrete, as it provides an indication of the ability of the material to resist cracking and withstand tensile

stresses. The split tensile strength test is widely is often used to determine the suitability of concrete for different applications.

$$\text{Split tensile strength} = \frac{2P}{\pi dl}$$

Where,

P = Maximum load sustained during the test

d = Diameter of the cylindrical specimen

l = length of the cylindrical specimen

split tensile strength of specimens reinforced with different volume fraction of steel fiber content after 7, 14, 28 days of curing is provided in table 5.13,5.14,5.15 and 5.16 respectively. The test set up of split tensile strength test is shown in fig 5.6.

**Table: 5.13: Split tensile strength of control specimens (VF=0%)**

| Sample No | Days of curing | Tensile force at failure (KN) | split tensile strength |
|-----------|----------------|-------------------------------|------------------------|
| 1E        | 7              | 225                           | 3.10 N/mm <sup>2</sup> |
| 2E        | 7              | 230                           | 3.25 N/mm <sup>2</sup> |
| 3E        | 7              | 175                           | 2.47 N/mm <sup>2</sup> |
| 4E        | 14             | 235                           | 3.32 N/mm <sup>2</sup> |
| 5E        | 14             | 230                           | 3.25 N/mm <sup>2</sup> |
| 6E        | 14             | 225                           | 3.18 N/mm <sup>2</sup> |
| 7E        | 28             | 245                           | 3.46 N/mm <sup>2</sup> |
| 8E        | 28             | 235                           | 3.32 N/mm <sup>2</sup> |
| 9E        | 28             | 235                           | 3.32 N/mm <sup>2</sup> |

**Table 5.14: split tensile strength of SFRC specimens (VF=0.75%)**

| Sample No | Days of curing | Tensile force at failure (KN) | split tensile strength |
|-----------|----------------|-------------------------------|------------------------|
| 1F        | 7              | 230                           | 3.25 N/mm <sup>2</sup> |
| 2F        | 7              | 215                           | 3.04 N/mm <sup>2</sup> |
| 3F        | 7              | 200                           | 2.83 N/mm <sup>2</sup> |
| 4F        | 14             | 245                           | 3.46 N/mm <sup>2</sup> |
| 5F        | 14             | 240                           | 3.39 N/mm <sup>2</sup> |
| 6F        | 14             | 245                           | 3.46 N/mm <sup>2</sup> |
| 7F        | 28             | 250                           | 3.53 N/mm <sup>2</sup> |

|    |    |     |                        |
|----|----|-----|------------------------|
| 8F | 28 | 235 | 3.32 N/mm <sup>2</sup> |
| 9F | 28 | 260 | 3.68 N/mm <sup>2</sup> |

**Table 5.15: split tensile strength of SFRC specimens (VF=1%)**

| <b>Sample No</b> | <b>Days of curing</b> | <b>Tensile force at failure (KN)</b> | <b>split tensile strength</b> |
|------------------|-----------------------|--------------------------------------|-------------------------------|
| 1G               | 7                     | 230                                  | 3.25 N/mm <sup>2</sup>        |
| 2G               | 7                     | 225                                  | 3.18 N/mm <sup>2</sup>        |
| 3G               | 7                     | 225                                  | 3.18 N/mm <sup>2</sup>        |
| 4G               | 14                    | 250                                  | 3.53 N/mm <sup>2</sup>        |
| 5G               | 14                    | 245                                  | 3.46 N/mm <sup>2</sup>        |
| 6G               | 14                    | 255                                  | 3.60 N/mm <sup>2</sup>        |
| 7G               | 28                    | 300                                  | 4.24 N/mm <sup>2</sup>        |
| 8G               | 28                    | 290                                  | 4.10 N/mm <sup>2</sup>        |
| 9G               | 28                    | 260                                  | 3.68 N/mm <sup>2</sup>        |

**Table 5.16: split tensile strength of SFRC specimens (VF=1.25%)**

| <b>Sample No</b> | <b>Days of curing</b> | <b>Tensile force at failure (KN)</b> | <b>split tensile strength</b> |
|------------------|-----------------------|--------------------------------------|-------------------------------|
| 1H               | 7                     | 225                                  | 3.18 N/mm <sup>2</sup>        |
| 2H               | 7                     | 215                                  | 3.04 N/mm <sup>2</sup>        |
| 3H               | 7                     | 230                                  | 3.25 N/mm <sup>2</sup>        |
| 4H               | 14                    | 250                                  | 3.53 N/mm <sup>2</sup>        |
| 5H               | 14                    | 245                                  | 3.46 N/mm <sup>2</sup>        |
| 6H               | 14                    | 250                                  | 3.53 N/mm <sup>2</sup>        |
| 7H               | 28                    | 275                                  | 3.89 N/mm <sup>2</sup>        |
| 8H               | 28                    | 280                                  | 3.96 N/mm <sup>2</sup>        |
| 9H               | 28                    | 290                                  | 4.10 N/mm <sup>2</sup>        |



***Fig 5.6: Split tensile strength testing of SFRC specimen***

## **5.9 FLEXURAL STRENGTH TEST**

The four-point beam flexural test is a common method used to determine the flexural or bending strength. This test involves applying a load to a beam supported at two points while measuring the deflection or deformation of the beam. The load is applied at two points in the middle of the beam span, while the beam is supported at the ends. The resulting load vs deflection curve can provide valuable information about the material's strength and elasticity.

During the test, the load is gradually increased until the beam reaches its maximum load capacity or until it fractures. The deflection of the beam is measured at specific load intervals using a displacement gauge, and the load and deflection data are recorded. The load vs deflection curve is then plotted to show the relationship between the applied load and the resulting deformation of the beam. The slope of the curve represents the stiffness or rigidity of the material, while the maximum load capacity indicates the material's ultimate strength. The four-point beam flexural test is widely used in materials testing and is a reliable method for

determining the flexural strength of materials. Four beams of length 1.5 meter and correctional dimensions of 230 mm x 230 mm were casted with varying volume fraction of steel fibers in concrete, the percentage of steel fibre used in the beam were VF=0% (control specimen) ,0.75% ,1% and 1.25%. The load versus deflection values of the four beams tested are provided in table 5.17 and the test set up used in testing beams is shown in fig 5.7.

**Table 5.17: Load vs Deflection values of beam specimens**

| Load (KN) | Conventional<br>concrete VF=0% | SFRC<br>VF=0.75% | SFRC<br>VF=1% | SFRC<br>VF=1.25% |
|-----------|--------------------------------|------------------|---------------|------------------|
|           | DEFLECTION (mm)                |                  |               |                  |
| 0         | 0                              | 0                | 0             | 0                |
| 10        | 0.35                           | 0.30             | 0.10          | 0.22             |
| 20        | 0.70                           | 0.60             | 0.28          | 0.40             |
| 30        | 1.00                           | 0.86             | 0.42          | 0.69             |
| 40        | 1.30                           | 1.15             | 0.56          | 0.85             |
| 50        | 1.70                           | 1.44             | 0.60          | 1.06             |
| 60        | 2.05                           | 1.70             | 0.84          | 1.30             |
| 70        | 2.60                           | 2.00             | 0.88          | 1.48             |
| 80        | 3.00                           | 2.50             | 1.08          | 1.79             |
| 90        | 3.00                           | 2.91             | 1.26          | 2.12             |
| 100       | 3.00                           | 2.91             | 1.26          | 2.12             |



***Fig 5.7: Flexural test for beam specimen***

## **5.10 YOUNGS MODULUS USING COMPRESSOMETER**

Young's modulus is a material property that describes its stiffness or ability to resist deformation under stress. It is a measure of how much stress is required to cause a given amount of deformation in a material. The modulus is calculated as the ratio of stress to strain, where stress is the force applied per unit area, and strain is the resulting deformation.

To determine Young's modulus using a compression test, a compressometer is typically used. A compressometer is a device that measures the amount of compression or deformation of a material under a given load. Results of young's modulus calculated for different volume fraction of steel fiber in concrete is given in table 5.18,5.19,5.20 and 5.21 and the test setup used is shown in fig 5.8.

**Table 5.18: Youngs modulus using compressometer conventional concrete**

| S.NO | CONCRETE TYPE                      | FORCE APPLIED (KN) | STRESS (N/mm <sup>2</sup> ) | LENGTH (mm) | CHANGE IN LENGTH (mm) | STRAIN                | YOUNGS MODULUS (MPa) |
|------|------------------------------------|--------------------|-----------------------------|-------------|-----------------------|-----------------------|----------------------|
| 1    | Conventional concrete of M40 grade | 30 KN              | 1.69 N/mm <sup>2</sup>      | 300 mm      | 0.0164 mm             | 5.47x10 <sup>-5</sup> | 30822 Mpa            |
| 2    |                                    | 60 KN              | 3.39 N/mm <sup>2</sup>      | 300 mm      | 0.0321 mm             | 1.07x10 <sup>-4</sup> | 31623 Mpa            |
| 3    |                                    | 90 KN              | 5.08 N/mm <sup>2</sup>      | 300 mm      | 0.0478 mm             | 1.59x10 <sup>-4</sup> | 31919 Mpa            |
| 4    |                                    | 120 KN             | 6.78 N/mm <sup>2</sup>      | 300 mm      | 0.0636 mm             | 2.12x10 <sup>-4</sup> | 31978 Mpa            |
| 5    | Average young's modulus (Mpa)      | 31585 Mpa          |                             |             |                       |                       |                      |

**Table 5.19: Youngs modulus using compressometer SFRC VF=0.75%**

| S.NO | CONCRETE TYPE                 | FORCE APPLIED (KN) | STRESS (N/mm <sup>2</sup> ) | LENGTH (mm) | CHANGE IN LENGTH (mm) | STRAIN                | YOUNGS MODULUS (MPa) |
|------|-------------------------------|--------------------|-----------------------------|-------------|-----------------------|-----------------------|----------------------|
| 1    | SFRC VF=0.75%                 | 30 KN              | 1.69 N/mm <sup>2</sup>      | 300 mm      | 0.0151 mm             | 5.05x10 <sup>-5</sup> | 33552 Mpa            |
| 2    |                               | 60 KN              | 3.39 N/mm <sup>2</sup>      | 300 mm      | 0.0301 mm             | 1.00x10 <sup>-4</sup> | 33862 Mpa            |
| 3    |                               | 90 KN              | 5.08 N/mm <sup>2</sup>      | 300 mm      | 0.0438 mm             | 1.40x10 <sup>-4</sup> | 34818 Mpa            |
| 4    |                               | 120 KN             | 6.78 N/mm <sup>2</sup>      | 300 mm      | 0.0582 mm             | 1.90x10 <sup>-4</sup> | 34998 Mpa            |
| 5    | Average young's modulus (Mpa) | 34307 Mpa          |                             |             |                       |                       |                      |

**Table 5.20: Youngs modulus using compressometer SFRC VF=1%**

| S.NO | CONCRETE TYPE                 | FORCE APPLIED (KN) | STRESS (N/mm <sup>2</sup> ) | LENGTH (mm) | CHANGE IN LENGTH (mm) | STRAIN                | YOUNGS MODULUS (MPa) |
|------|-------------------------------|--------------------|-----------------------------|-------------|-----------------------|-----------------------|----------------------|
| 1    | SFRC VF=1%                    | 30 KN              | 1.69 N/mm <sup>2</sup>      | 300 mm      | 0.0143 mm             | 4.76x10 <sup>-5</sup> | 35563 Mpa            |
| 2    |                               | 60 KN              | 3.39 N/mm <sup>2</sup>      | 300 mm      | 0.0283 mm             | 9.46x10 <sup>-5</sup> | 35890 Mpa            |
| 3    |                               | 90 KN              | 5.08 N/mm <sup>2</sup>      | 300 mm      | 0.0414 mm             | 1.38x10 <sup>-4</sup> | 36819 Mpa            |
| 4    |                               | 120 KN             | 6.78 N/mm <sup>2</sup>      | 300 mm      | 0.0550 mm             | 1.85x10 <sup>-4</sup> | 36987 Mpa            |
| 5    | Average young's modulus (Mpa) | 36314 Mpa          |                             |             |                       |                       |                      |

**Table 5.21: Youngs modulus using compressometer SFRC VF=1.25%**

| S.N O | CONCRETE TYPE                | FORCE APPLIED (KN) | STRESS (N/mm <sup>2</sup> ) | LENGTH (mm) | CHANGE IN LENGTH (mm) | STRAIN                | YOUNGS MODULUS (MPa) |
|-------|------------------------------|--------------------|-----------------------------|-------------|-----------------------|-----------------------|----------------------|
| 1     | SFRC VF=1.25%                | 30 KN              | 1.69 N/mm <sup>2</sup>      | 300 mm      | 0.0145 mm             | 4.84x10 <sup>-5</sup> | 34998 Mpa            |
| 2     |                              | 60 KN              | 3.39 N/mm <sup>2</sup>      | 300 mm      | 0.0290 mm             | 9.69x10 <sup>-5</sup> | 35072 Mpa            |
| 3     |                              | 90 KN              | 5.08 N/mm <sup>2</sup>      | 300 mm      | 0.0434 mm             | 1.44x10 <sup>-4</sup> | 35133 Mpa            |
| 4     |                              | 120 KN             | 6.78 N/mm <sup>2</sup>      | 300 mm      | 0.0578 mm             | 1.92x10 <sup>-4</sup> | 35201 Mpa            |
| 5     | Average youngs modulus (Mpa) | 35101 Mpa          |                             |             |                       |                       |                      |



***Fig 5.8: Compressometer fixed on a specimen***

## CHAPTER 6

### RESULTS AND DISCUSSION

#### 6.1 INTRODUCTION

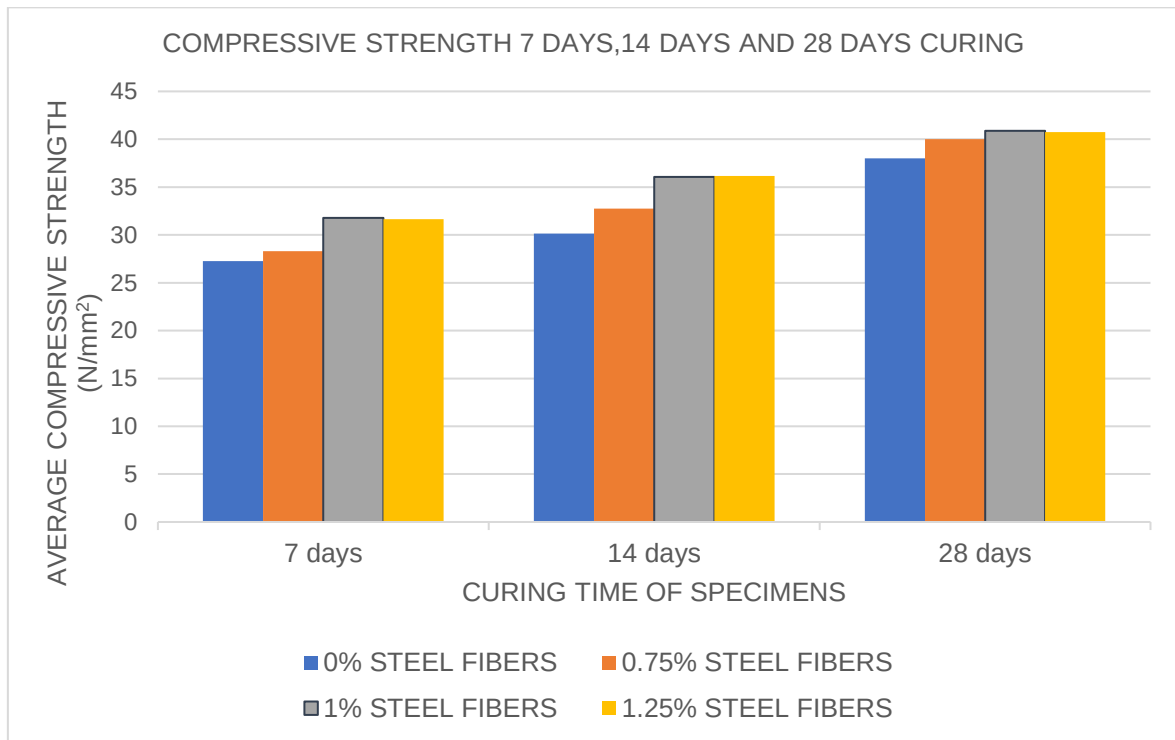
The results of various tests carried on steel fiber reinforced concrete specimens for different volume fraction of steel fibers are discussed in this chapter and also the behaviour of steel fiber reinforced concrete specimens with respect to the control or conventional concrete specimens is also discussed in this chapter.

#### 6.2 COMPRESSIVE STRENGTH

The average compressive strength of steel fiber reinforced concrete with and without fibers after 7 days ,14 days and 28 days curing are shown in table 6.1

**Table 6.1: Compressive strength results**

| S.NO | Volume Fraction of steel fibers VF | Average compressive strength in N/mm <sup>2</sup> |         |         |
|------|------------------------------------|---------------------------------------------------|---------|---------|
|      |                                    | 7 days                                            | 14 days | 28 days |
| 1    | 0%                                 | 27.25                                             | 30.15   | 38.00   |
| 2    | 0.75%                              | 28.30                                             | 32.74   | 40.00   |
| 3    | 1%                                 | 31.78                                             | 36.07   | 40.89   |
| 4    | 1.25%                              | 31.63                                             | 36.15   | 40.74   |



**Fig 6.1: Compressive strength results**

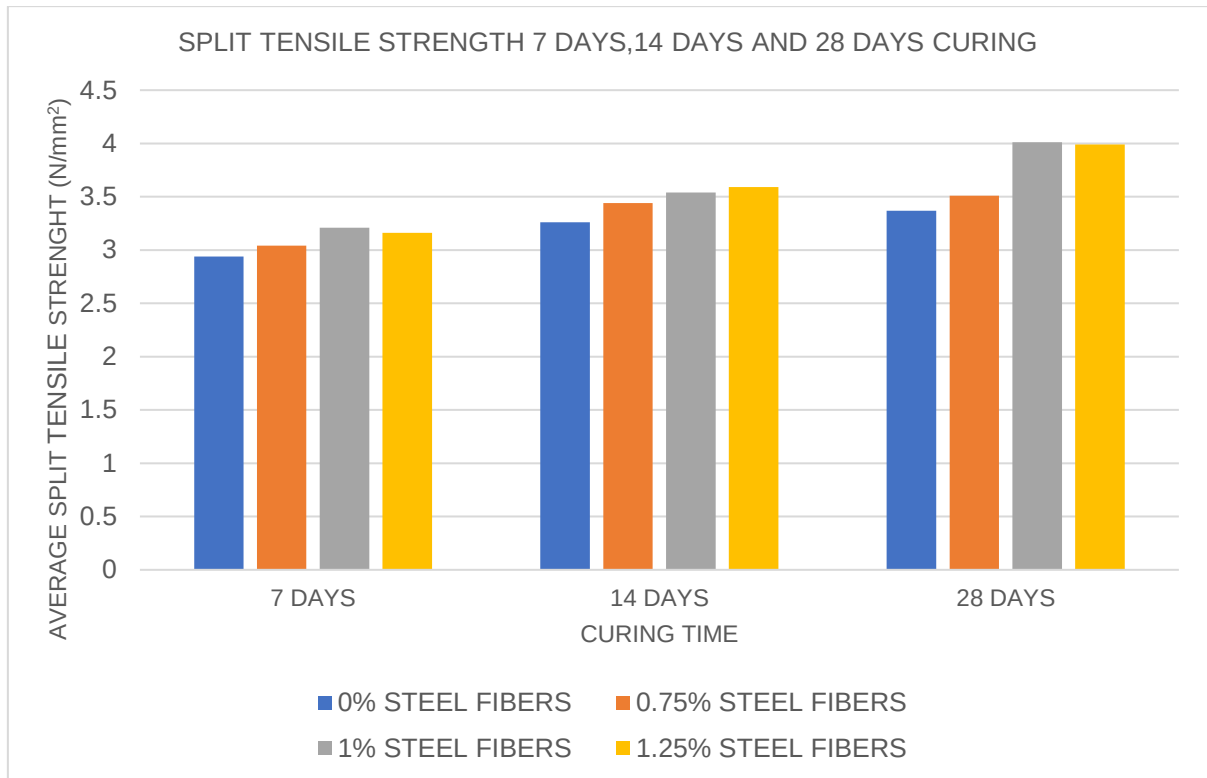
The compressive strength test results shows that concrete with 0.75 % hooked end steel fibers has seen increase in compressive strength by 5.26% compared to convention concrete of M40 grade. For 1% hooked end steel fibers increase in compressive strength is 7.6% compared to conventional concrete. Similarly, 1.25% volume fraction of steel fibers showed increase in compressive strength by 7.2% compared to conventional concrete, this can be seen represented in a graphical form fig 6.1.

### 6.3 SPLIT TENSILE STRENGTH

The average Split tensile strength of steel fiber reinforced concrete with and without fibers after 7 days ,14 days and 28 days curing are shown in table 6.2

**Table 6.2: Split tensile strength results**

| S.NO | Volume Fraction of steel fibers VF | Average split tensile strength in N/mm <sup>2</sup> |         |         |
|------|------------------------------------|-----------------------------------------------------|---------|---------|
|      |                                    | 7 days                                              | 14 days | 28 days |
| 1    | 0%                                 | 2.94                                                | 3.26    | 3.37    |
| 2    | 0.75%                              | 3.04                                                | 3.44    | 3.51    |
| 3    | 1%                                 | 3.21                                                | 3.54    | 4.01    |
| 4    | 1.25%                              | 3.16                                                | 3.59    | 3.99    |



**Fig: 6.2 Split tensile strength results**

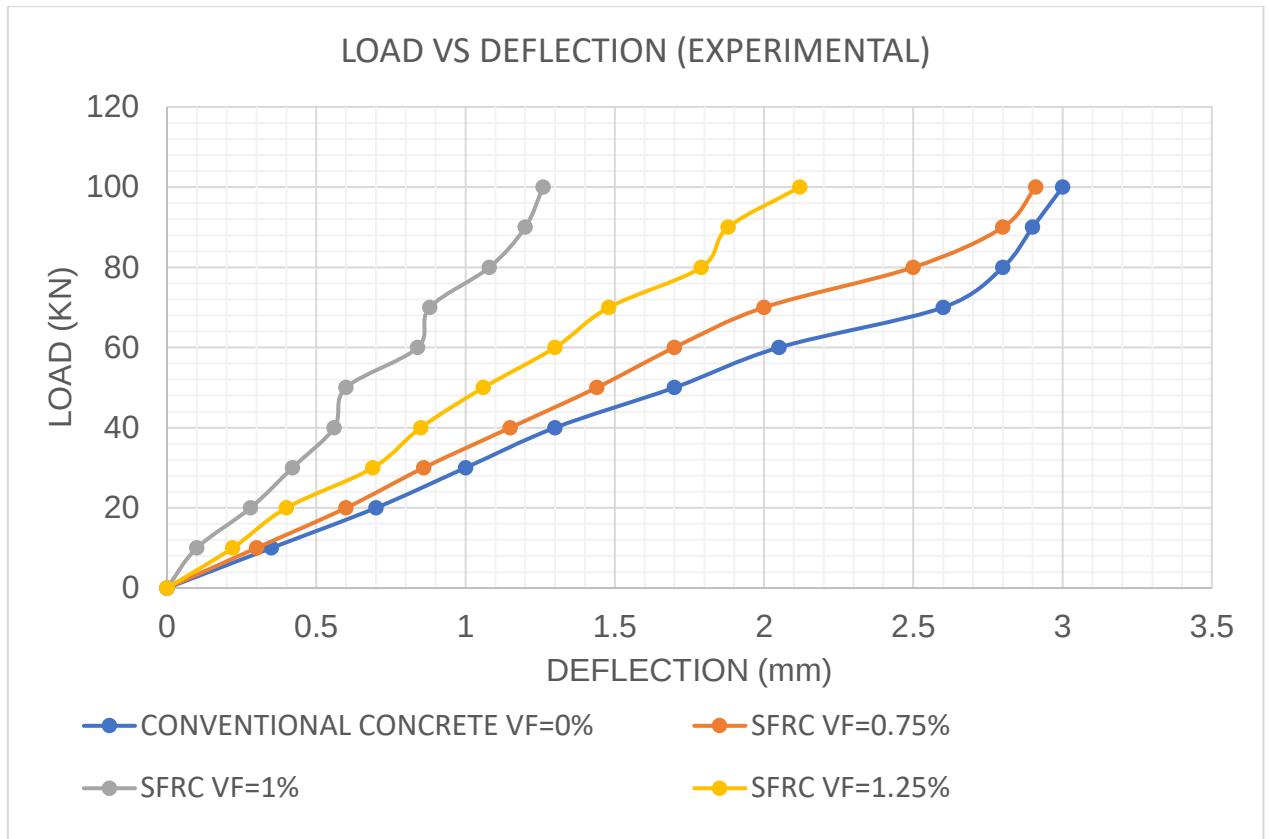
The split tensile strength test results shows that concrete with 0.75% volume fraction of hooked end steel fibers has seen increase in split tensile strength by 4.15% compared to convention concrete of M40 grade. Similarly for 1% hooked end steel fibers increase in split tensile strength is 19% compared to conventional concrete and for 1.25% volume fraction of steel fibers showed increase in split tensile strength by 18.1% compared to conventional concrete

#### 6.4 FLEXURAL STRENGTH EXPERIMENTAL METHOD

The load versus deflection values of beams casted with conventional and steel fiber reinforced concrete for different fiber volumes is given in the table 6.3 The load vs Deflection curve is drawn for all four beams which is shown in the fig 6.3. From the fig we can observe that beams reinforced with VF= 1% steel fibers has 50% lower deflection compared to control beam specimen, similarly beams with VF=0.75% and 1.25% has deflection reduced by 3% and 29% respectively compared to control beam specimen.

**Table 6.3: Flexural strength result for beam (Experimental)**

| Load (KN) | Conventioal<br>concrete VF=0% | SFRC<br>VF=0.75% | SFRC<br>VF=1% | SFRC<br>VF=1.25% |
|-----------|-------------------------------|------------------|---------------|------------------|
|           | DEFLECTION (mm)               |                  |               |                  |
| 0         | 0                             | 0                | 0             | 0                |
| 10        | 0.35                          | 0.30             | 0.10          | 0.22             |
| 20        | 0.70                          | 0.60             | 0.28          | 0.40             |
| 30        | 1.00                          | 0.86             | 0.42          | 0.69             |
| 40        | 1.30                          | 1.15             | 0.56          | 0.85             |
| 50        | 1.70                          | 1.44             | 0.60          | 1.06             |
| 60        | 2.05                          | 1.70             | 0.84          | 1.30             |
| 70        | 2.60                          | 2.00             | 0.88          | 1.48             |
| 80        | 2.80                          | 2.50             | 1.08          | 1.79             |
| 90        | 2.90                          | 2.81             | 1.20          | 1.88             |
| 100       | 3.00                          | 2.91             | 1.26          | 2.12             |



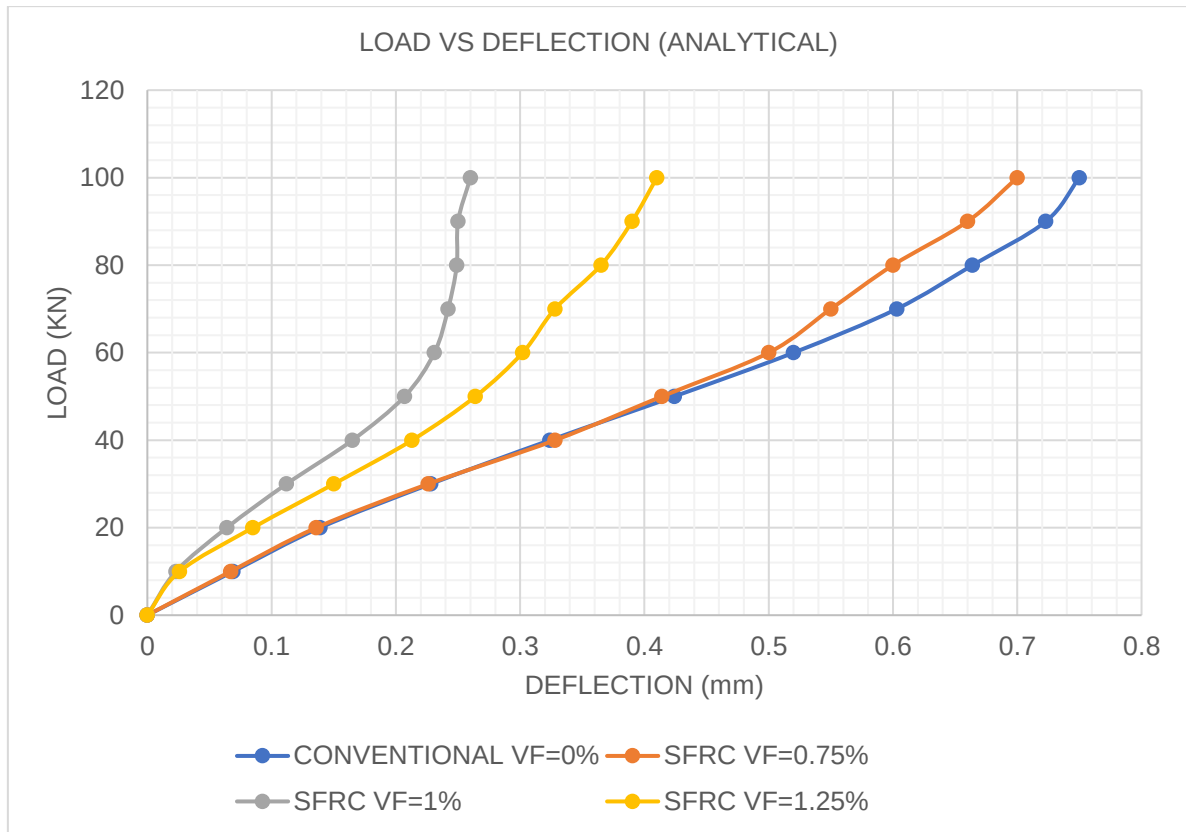
**Fig 6.3: Flexural strength result for beam (Experimental)**

## 6.5 FLEXURAL STRENGTH BY ANALYTICAL METHOD

The load versus deflection values of beams modelled with conventional and steel fiber reinforced concrete for different fiber volumes is given in the table 6.4. The load vs Deflection curve is drawn for all four beams which is shown in the fig. From the fig 6.4 we can observe that beams reinforced with VF= 1% steel fibers has 64% lower deflection compared to control beam specimen, similarly beams with VF=0.75% and 1.25% has deflection reduced by 17.40% and 48% respectively compared to control beam specimen.

**Table 6.4: Flexural strength result for beam (Analytical)**

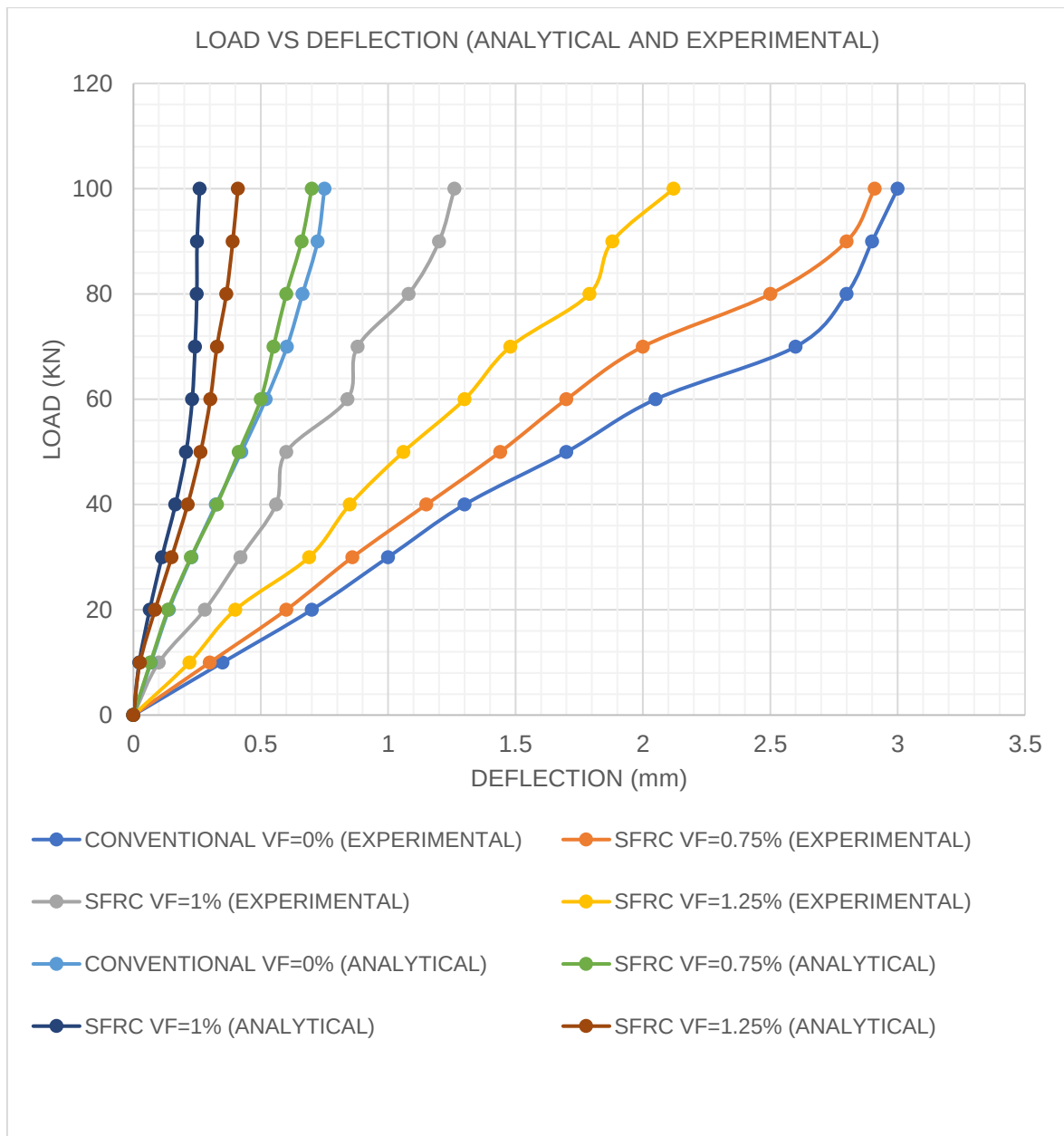
| Load (KN) | Conventioal<br>concrete VF=0% | SFRC<br>VF=0.75% | SFRC<br>VF=1% | SFRC<br>VF=1.25% |
|-----------|-------------------------------|------------------|---------------|------------------|
|           | DEFLECTION (mm)               |                  |               |                  |
| 0         | 0.000                         | 0.000            | 0.000         | 0.000            |
| 10        | 0.069                         | 0.067            | 0.023         | 0.026            |
| 20        | 0.139                         | 0.136            | 0.064         | 0.085            |
| 30        | 0.228                         | 0.226            | 0.112         | 0.150            |
| 40        | 0.324                         | 0.328            | 0.165         | 0.213            |
| 50        | 0.424                         | 0.414            | 0.207         | 0.264            |
| 60        | 0.520                         | 0.500            | 0.231         | 0.302            |
| 70        | 0.603                         | 0.550            | 0.242         | 0.328            |
| 80        | 0.664                         | 0.562            | 0.249         | 0.365            |
| 90        | 0.723                         | 0.600            | 0.250         | 0.390            |
| 100       | 0.750                         | 0.700            | 0.260         | 0.410            |



**Fig 6.4: Flexural strength result for beam (Analytical)**

## 6.6 FLEXURAL COMPARISON ANALYTICAL AND EXPERIMENTAL

Both analytical and experimental investigations show some similarities, particularly in the fact that beams with a steel fiber volume fraction of 1% exhibit very little deflection compared to other beams. This suggests that this specific volume fraction of steel fiber can withstand higher loads, making it an optimal mix for this study. However, there is a noticeable difference between the curves of the analytical and experimental work, as shown in the fig 6.5. This difference may be due to the uncontrolled working environment in which the concreting of beams was performed, in contrast to the controlled environment of finite element modelling.



**Fig 6.5: Flexural strength result for beam (Experimental and Analytical)**

## **CHAPTER 7**

### **SUMMARY AND CONCLUSION**

#### **7.1 SUMMARY**

- I. Through literature review was done to frame objectives of the study and a methodology suitable for study was chosen.
- II. The physical properties of the materials used in the study was determined.
- III. Mix design was conducted for both conventional concrete of M40 grade and steel fiber reinforced concrete.
- IV. The compressive strength and split tensile strength of steel fiber reinforced concrete with and without steel fibers were found and the results were compared for different volume fraction of steel fibers.
- V. The flexural behaviour of SFRC (Steel Fiber Reinforced Concrete) beams reinforced with GFRP (Glass fiber reinforced polymer) rebars were studied both experimentally and analytically.
- VI. Analytical models of SFRC and conventional concrete reinforced with GFRP rebars were created using ABAQUS software for analytical study. The Analytical results and experimental results (flexural strength) of the beams were compared and studied properly.

#### **7.2 CONCLUSION**

- I. The compressive strength test results shows that concrete with volume fraction 0.75 % hooked end steel fibers has seen increase in compressive strength by 5.26% compared to convention concrete of M40 grade. For Volume fraction of 1% hooked end steel fibers increase in compressive strength is 7.6% compared to conventional concrete, Similarly for Volume fraction of 1.25% increase in compressive strength is 7.2% compared to conventional concrete

- II. From compressive strength results it can be concluded that 1% volume fraction of steel fibbers is optimal for increase in compressive strength compared to 0.75% and 1.25%. with higher volume fraction of steel fibers 1.25% we can see slight reduction in compressive strength.
- III. The split tensile strength test results shows that concrete with volume fraction of 0.75 % hooked end steel fibers has seen increase in split tensile strength by 4.15% compared to convention concrete of M40 grade. For volume fraction of 1% hooked end steel fibers increase in split tensile strength is 19.0% compared to conventional concrete, Similarly for Volume fraction 1.25% increase in split tensile strength by 18.1% compared to conventional concrete.
- IV. From split tensile strength results it can be concluded that 1% volume fraction of steel fibbers is optimal for increase in split tensile strength compared to 0.75% and 1.25%. with higher volume fraction of steel fibers 1.25% we can see slight reduction in split tensile strength that is mainly due to the workability of the mix which decreases with increase in amount of steel fiber in concrete.
- V. Flexural strength results of beams show reduction in deflection for 1% volume fraction of steel fibers, compared to other volume fraction of steel fibers. Beam with no steel fibers showed highest deflection due to the absence of steel fiber in it, because steel fibers act as additional reinforcement to concrete along with GFRP rebars. Reduction in deflection can also be attributed to the bridging of cracks by the steel fibers in concrete. It can also be noticed that increase in deflection for 1.25% volume fraction of steel fibers compared to 1%. This increase in deflection can be due to various factors such as fiber cement matrix interaction and uncontrolled environment in which beams were casted. Similar trends were observed in analytical investigation because properties such as young's modulus and poisons ratio of materials used were taken from experimental investigation.
- VI. From flexural strength results of beams, it can be concluded that 1% volume fraction of steel fibbers is optimal for increase in flexural strength of beams compared to 0.75% and 1.25% steel fibers. with higher volume fraction of steel fibers 1.25% we can see slight reduction in flexural strength.

## REFERENCES

1. Abbas, H., Abadel, A., Almusallam, T., & Al-Salloum, Y. (2022). "Experimental and analytical study of flexural performance of concrete beams reinforced with hybrid of GFRP and steel rebars". *Engineering Failure Analysis*, Vol. 138, pp 332-345. <https://doi.org/10.1016/j.engfailanal.2022.106397>.
2. Abbass, W., Khan, M. I., & Mourad, S. (2018). "Evaluation of mechanical properties of steel fiber reinforced concrete with different strengths of concrete". *Construction and Building Materials*, Vol. 168, pp 556-569. <https://doi.org/10.1016/j.conbuildmat.2018.02.164>.
3. Araba, A. M., & Ashour, A. F. (2018). "Flexural performance of hybrid GFRP-Steel reinforced concrete continuous beams". *Composites Part B: Engineering*, vol. 154, pp 321-336. <https://doi.org/10.1016/j.compositesb.2018.08.077>.
4. Berrocal, C. G., Löfgren, I., Lundgren, K., & Tang, L. (2015). "Corrosion initiation in cracked fibre reinforced concrete: Influence of crack width, fibre type and loading conditions." *Corrosion Science*, Vol. 98, pp 128-139. <https://doi.org/10.1016/j.corsci.2015.05.021>.
5. Dev, A., Chellapandian, M., & Prakash, S. S. (2020). "Effect of Macrosynthetic and Hybrid Fibers on Shear Behavior of Concrete Beams Reinforced with GFRP Bars". *Journal of Bridge Engineering*, vol 25(7), pp 251-267. [https://doi.org/10.1061/\(asce\)be.1943-5592.0001557](https://doi.org/10.1061/(asce)be.1943-5592.0001557).
6. Fallah-Valukolaee, S., Hashemi, S. K., & Nematzadeh, M. (2022). "Effect of steel fiber on flexural performance of bilayer concrete beams with steel and GFRP rebars: Experiments and predictions". *Structures*, vol 39, pp. 405-418. <https://doi.org/10.1016/j.istruc.2022.03.007>.
7. Gopu, G. N., & Sofi, A. (2022). "The influence of fiber RC beams under flexure on the chloride-induced corrosion". *Case Studies in Construction Materials*, vol 36, pp. 410-417.
8. Han, J., Zhao, M., Chen, J., & Lan, X. (2019). "Effects of steel fiber length and coarse aggregate maximum size on mechanical properties of steel fiber

- reinforced concrete". *Construction and Building Materials*, vol 209, pp 577–591. <https://doi.org/10.1016/j.conbuildmat.2019.03.086>.
9. Iqbal, S., Ali, I., Room, S., Khan, S. A., & Ali, A. (2019). "Enhanced mechanical properties of fiber reinforced concrete using closed steel fibers". *Materials and Structures/Materiaux et Constructions*, vol 52(3), pp 110-115. <https://doi.org/10.1617/s11527-019-1357-6>.
  10. Lee, J. Y., Shin, H. O., Yoo, D. Y., & Yoon, Y. S. (2018). "Structural response of steel-fiber-reinforced concrete beams under various loading rates". *Engineering Structures*, vol 156, pp. 271–283. <https://doi.org/10.1016/j.engstruct.2017.11.052>
  11. Li, X., Zhang, Y., Shi, C., & Chen, X. (2020). "Experimental and numerical study on tensile strength and failure pattern of high-performance steel fiber reinforced concrete under dynamic splitting tension". *Construction and Building Materials*, vol 259, pp 25-31. <https://doi.org/10.1016/j.conbuildmat.2020.119796>
  12. Lu, C., Cai, Q., Xu, K., Sha, X., & Yan, Y. (2022). "Comparison of flexural behaviors between plain and steel-fiber-reinforced concrete beams with hybrid GFRP and steel bars". *Structures*, vol 43, pp. 1–11. <https://doi.org/10.1016/J.ISTRUC.2022.06.037>
  13. Nematzadeh, M., & Fallah-Valukolaee, S. (2021). "Experimental and analytical investigation on structural behavior of two-layer fiber-reinforced concrete beams reinforced with steel and GFRP rebars". *Construction and Building Materials*, vol 273, pp 22-31. <https://doi.org/10.1016/j.conbuildmat.2020.121933>
  14. Rezakhani, R., Scott, D. A., Bousikhane, F., Pathirage, M., Moser, R. D., Green, B. H., & Cusatis, G. (2021). "Influence of steel fiber size, shape, and strength on the quasi-static properties of ultra-high-performance concrete: Experimental investigation and numerical modelling". *Construction and Building Materials*, vol 296, pp 45-53. <https://doi.org/10.1016/j.conbuildmat.2021.123532>
  15. Shi, X., Park, P., Rew, Y., Huang, K., & Sim, C. (2020). "Constitutive behaviors of steel fiber reinforced concrete under uniaxial compression and tension". *Construction and Building Materials*, vol 233, pp 46-57. <https://doi.org/10.1016/j.conbuildmat.2019.117316>

16. Sijavandi, K., Sharbatdar, M. K., & Kheyroddin, A. (2021). "Experimental evaluation of flexural behavior of High-Performance Fiber Reinforced Concrete Beams using GFRP and High Strength Steel Bars". *Structures*, vol 33, pp 4256–4268. <https://doi.org/10.1016/j.istruc.2021.07.020>
17. Tahenni, T., Bouziadi, F., Boulekbache, B., & Amziane, S. (2021). "Experimental and numerical investigation of the effect of steel fibres on the deflection behaviour of reinforced concrete beams without stirrups". *Structures*, vol 33, pp 1603–1619. <https://doi.org/10.1016/j.istruc.2021.05.005>
18. Vakili, S. E., Homami, P., & Esfahani, M. R. (2019). "Effect of fibers and hybrid fibers on the shear strength of lightweight concrete beams reinforced with GFRP bars". *Structures*, vol 20, pp 290–297. <https://doi.org/10.1016/j.istruc.2019.04.006>
19. Wu, Z., Shi, C., He, W., & Wu, L. (2016). "Effects of steel fiber content and shape on mechanical properties of ultra-high-performance concrete". *Construction and Building Materials*, vol 103, pp 8–14. <https://doi.org/10.1016/j.conbuildmat.2015.11.028>
20. Yang, J., Chen, B., & Nuti, C. (2021). "Influence of steel fiber on compressive properties of ultra-high-performance fiber-reinforced concrete". *Construction and Building Materials*, vol 302, pp 33–25. <https://doi.org/10.1016/j.conbuildmat.2021.124104>
21. Yoo, D. Y., Banthia, N., & Yoon, Y. S. (2016). "Flexural behavior of ultra-high-performance fiber-reinforced concrete beams reinforced with GFRP and steel rebars". *Engineering Structures*, vol 111, pp 246–262. <https://doi.org/10.1016/j.engstruct.2015.12.003>
22. Zhou, J., Shen, W., & Wang, S. (2017). "Experimental study on torsional behavior of FRC and ECC beams reinforced with GFRP bars". *Construction and Building Materials*, vol 152, pp. 74–81. <https://doi.org/10.1016/j.conbuildmat.2017.06.131>
23. IS: 456-2000, "Plain and reinforced concrete".
24. IS: 516-1959, "Methods of tests for strength of concrete".
25. IS: 10262-2009, "Indian standard recommendations guide lines for concrete mix design"