

EXPERIMENTAL ANALYSIS OF STEEL FIBER-REINFORCED CONCRETE

Submitted in partial fulfilment of the requirements for the award of
Bachelor of Engineering degree in
Civil Engineering

By

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**DEPARTMENT OF CIVIL ENGINEERING SCHOOL
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SATHYABAMA

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

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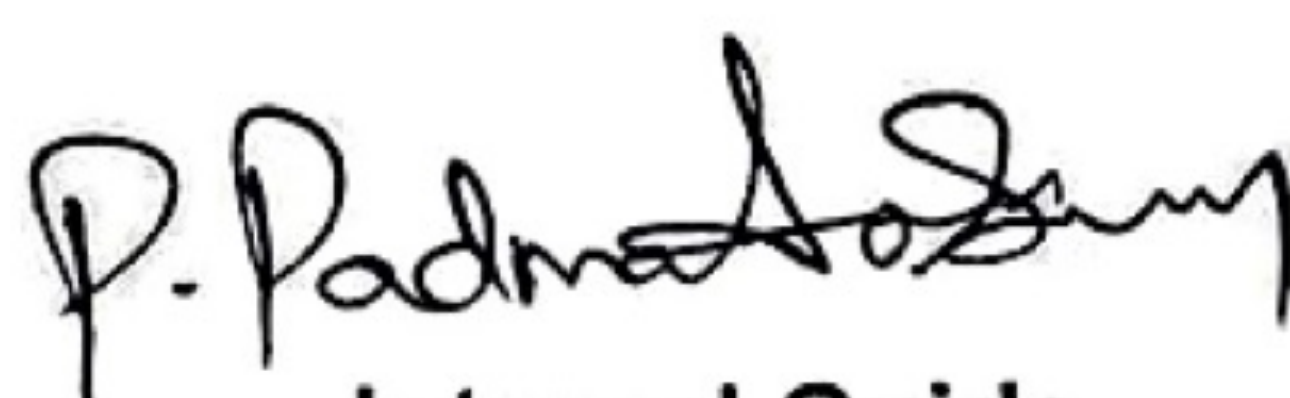
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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **Rubalagan R (40200010) & Ajai Kishore M (40200706)**, who carried out the project entitled "**Experimental analysis of steel fiber-reinforced concrete**" under our supervision from November 2023 to April 2024.


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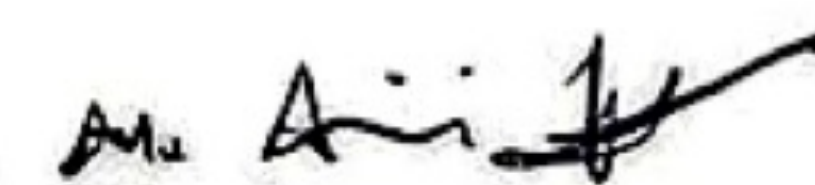

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We, Rubalagan R (40200010) & Ajai Kishore M (Register No: 40200706) , hereby declare that the Project Report entitled "Experimental analysis of steel fiber-reinforced concrete" done by us under the guidance of Mr. P. PADMALOSAN is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering degree in Civil Engineering.

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ABSTRACT

The innovative integration of steel Fiber-reinforced concrete (SFRC) sans traditional reinforcement marks a groundbreaking stride in structural engineering. As structures scale greater heights, the beams they rely on confront escalating loads, demanding larger beam dimensions to uphold structural integrity. Yet, this enlargement poses challenges in construction feasibility and material economy. The inclusion of steel Fibers into concrete presents a promising remedy by bolstering the material's structural performance. In this study, the chosen steel Fibers exhibit both accessibility and the crucial attribute of load-bearing capacity. At a 3% incorporation rate into the concrete mix, these fibers significantly enhance tensile strength and ductility. This infusion obviates the necessity for conventional reinforcements like steel bars, thereby simplifying construction processes and potentially cutting costs. The concrete mix design follows M20 grade specifications, ensuring the resulting SFRC maintains requisite compressive strength and durability for structural use. Through meticulous experimentation, this novel concrete formulation's performance is rigorously scrutinized. The research methodology encompasses parameters such as compressive, tensile, and flexural strength, alongside workability assessments, comprehensively evaluating SFRC's viability and efficacy. Furthermore, to elucidate SFRC beam behaviour over time, deflection tests are conducted at intervals of 7, 14, 21, and 28 days during curing. This systematic evaluation characterizes the material's mechanical properties and its load-bearing capacity under varying curing conditions. The data gleaned from these tests offer invaluable insights into SFRC's long-term performance and durability in practical settings, guiding future design considerations and engineering practices. In summary, the experimental exploration of steel fiber-reinforced concrete without traditional reinforcement epitomizes a substantial leap in structural engineering. Leveraging the inherent properties of steel fibers, this pioneering approach holds vast potential for augmenting the efficiency, sustainability, and resilience of contemporary construction methodologies.

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LIST OF SYMBOLS AND ABBREVIATIONS

ACRONYMS

EXPANSIONS

%	PERCENTAGE
N	NEWTON
Mpa	MEGA PASCAL
psi	PER SQUARE INCH
ml	MILLI LITER
Kg	KILO GRAMS
gm	GRAMS
mm	MILLI METER

CHAPTER 1

INTRODUCTION

1.1 CONCRETE

Water, aggregate, and cement are the main components of the composite material known as concrete. The desired physical qualities can be produced in concrete by adding reinforcements and additives to the mix. These ingredients combine to generate a solid mass that is simple to shape when combined in a certain ratio. The cement in the mixture hardens over time to form a tough matrix that binds the other components together, producing a long-lasting, rigid material with many uses, including building pavements, buildings, and other structures. The earliest known application of concrete technology was in ancient Rome, where it was widely used. The Roman Empire made great use of concrete technology, using it to construct buildings like the Colosseum in Rome. Another illustration of the sophisticated concrete technology used by the Romans is the dome of the Pantheon, which is the biggest unreinforced concrete structure in the world. After the Roman Empire fell in the middle of the fifth century, the technology of employing concrete declined in use. However, concrete has emerged as the most often used man-made material in terms of tonnage in recent times.

1.2 HISTORICAL BACKGROUND

- **Early Developments:** In the 19th century, researchers began experimenting with adding various materials such as iron and steel Fibers to concrete to improve its properties. These early attempts were limited by the technology and understanding of materials at the time.
- **World War II:** During World War II, there was a surge in research on reinforced materials due to the need for stronger and more durable structures. This period saw advancements in understanding the behaviour of materials under load, leading to the development of fiber-reinforced polymers (FRPs) and composites.
- **1950s - 1960s:** Significant progress was made in the development of synthetic Fibers, such as glass and synthetic polymers like nylon and polypropylene.

These Fibers offered better durability and tensile strength compared to natural Fibers.

- 1970s - 1980s: The use of FRC gained traction in construction projects, particularly in infrastructure and industrial applications. Researchers and engineers explored various fiber types, mix designs, and manufacturing methods to optimize the performance of FRC.
- 1990s - Present: FRC has become increasingly popular in construction due to its ability to enhance properties such as toughness, impact resistance, and durability. Advances in fiber technology, concrete mix design, and construction techniques have further expanded the applications of FRC in areas like pavements, tunnels, bridges, and high-rise buildings.

1.3 PROPERTIES OF CONCRETE

Despite having a low tensile strength compared to other construction materials, concrete has a high compressive strength. It is frequently mixed with substances like steel in order to increase its tensile strength. At low stress levels, the elasticity of concrete is unaffected; nevertheless, when stress levels rise, matrix cracking appears which causes the elasticity to diminish. Concrete shrinks as it ages because it has a low coefficient of thermal expansion. Therefore, strain and shrinkage tend to cause some cracking in concrete buildings. Concrete may creep as a result of long-term stresses. Various tests can be carried out to make sure the qualities of concrete fulfil the requirements for particular uses. Concrete's strength is expressed in psi or MPa, and different ingredient mixtures produce concrete with varying strengths. Low-strength concrete, which is obtained by adding air or foam or lightweight particles, may be utilised for lightweight purposes, however this lessens the strength of the concrete. Concrete with strength of 3000 to 4000 psi is frequently utilised for normal building projects. Due to its durability, 5000 psi concrete is frequently chosen for big civil projects. Concrete strength above 5000 psi is often employed for certain architectural parts, such as the bottom floor columns of high-rise buildings, where concrete with a strength of 12,000 psi or more is used to keep the column sizes small.

1.4 STRUCTURES CONSTRUCTED USING FIBRE REINFORCED CONCRETE

Pantheon de la Patria, Dominican Republic: The renovation of this historical monument included the use of fiber-reinforced concrete to improve its structural

integrity. The Shard, London, UK: The Shard, one of the tallest buildings in Europe, used fiber-reinforced concrete in its construction to enhance the strength of various structural elements. Burj Khalifa, Dubai, UAE: While the primary material in Burj Khalifa is traditional reinforced concrete, fiber-reinforced concrete may have been used in specific applications to enhance performance. One World Trade Centre, New York, USA: Fiber-reinforced concrete may have been utilized in the construction of the foundation and other structural elements of the iconic One World Trade Centred Tower, Qatar: This skyscraper used fiber-reinforced concrete in its construction to achieve a balance of strength and flexibility.

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

The following major research project has been taken from international journals as reference to concepts for the project.

2.2 REVIEW OF THE LITERATURES

Chenggong Zhao (2022)

Chenggong Zhao et al. (2022) Recent research in Fiber-Reinforced Concrete (FRC) addresses tensile strength enhancement and crack reduction in concrete. Disputes persist regarding the effectiveness of various fiber types and their impact on concrete properties. Understanding of mixing laws and effects in Hybrid Fiber Reinforced Concrete (HFRC) is limited. This paper reviews current FRC research, providing guidance for future studies and applications.

Muhammad Nadeem Khan (2022)

Muhammad Nadeem Khan et al. (2022) Concrete, widely used in construction, has limitations like brittleness and low tensile strength. To address these issues, researchers have added synthetic and natural Fibers to enhance concrete properties. Fiber-reinforced concrete improves tensile strength, flexural strength, and durability while reducing shrinkage cracks. However, it can decrease workability. This paper reviews the effects of fiber inclusion on concrete performance.

Lakshmi Keshav (2022)

Lakshmi Keshav et al. (2022) Steel fibers enhance concrete beam performance. Improved strength and structural integrity. Economical solution with exceptional ultimate and shear strength. Uniform distribution of energy and stress under cyclic loading. 20% increase in compressive and flexural strength. Reinforcement mechanism and concrete composition crucial for quality and performance.

Prashanth M. H. (2023)

Prashanth M. H. et al. (2023) Numerical modelling of Steel Fibrous Concrete Beams (SFCBs) using ABAQUS. Concrete grade: M25; beams of 500 mm × 100 mm × 100 mm. Five fiber volumetric percentages: 0.4%, 0.6%, 0.8%, 1.0%, and 1.5%. Crack lengths considered: 10 mm, 20 mm, and 30 mm. Load application via displacement control. Conclusion: Increased crack length decreases energy absorption and load-carrying capacity. Presence of fibers significantly enhances flexural performance and energy absorption of SFCBs.

M.T. Kazemi (2017)

M.T. Kazemi et al. (2017) - Experimental investigation on fracture behaviour of Steel Fiber Reinforced High Strength Concrete (SFRHSC) compared to plain High Strength Concrete (HSC). Three-point bending tests conducted on 54 notched beams as per RILEM recommendations. Fracture parameters measured using Work of Fracture Method (WFM) and Size Effect Method (SEM). Results: Fracture energy (GF in WFM, Gf in SEM) increases with steel fiber content, more significantly in WFM. Effective size of process zone (cf) and characteristic length (Lch) increase with steel fiber content, indicating increased ductility in SFRHSC. SEM accuracy acceptable for low steel fiber volume fractions. GF/Gf ratio increases from about 2.5 for HSC to around 10.5 for SFRHSC.

Jung-Jun Park (2016)

Jung-Jun Park et al. (2016) Investigated the hybridization effects on flexural behavior of Ultra-High-Performance Concrete (UHPC). Tested three steel fiber lengths: 13 mm (short), 19.5 mm (medium), and 30 mm (long). Found that the hybrid use of long and medium-length fibers enhances performance, while the combination of long and short fibers diminishes it. Micromechanical analysis highlighted the significant impact of the fiber bridging curve on post-cracking properties. Proposed equation establishes a relationship between the normalized modulus of rupture and the fiber reinforcing index, indicating the potential for achieving deflection-hardening behaviour with an index greater than 0.5.

Jun-Mo Yang (2017)

Jun-Mo Yang et al. (2017) Aimed to investigate eliminating minimum shear reinforcement in reinforced sustainable high-strength concrete (HSC) beams using 0.75% hooked steel fibers. Tested five large reinforced HSC beams, with and without stirrups and steel fibers. Beams designed with longitudinal steel bar ratios of 0.64–0.72% for minimum shear reinforcement. Results show higher flexural strength with steel fibers but lower ultimate deflection and ductility. Inclusion of steel fibers transformed failure mode from concrete crushing to longitudinal steel bar rupture, allowing efficient elimination of minimum shear reinforcement.

Nemkumar Banthia (2016)

Nemkumar Banthia et al. (2016) Investigated size effect on flexural behaviour of amorphous metallic fiber reinforced concrete (AM-FRC). Fabricated AM-FRC beams of varying sizes, w/cm ratios, and fiber volume fractions. Tested SFRC with identical mixture proportions and 0.75% hooked-end steel fibers for comparison. Found lower flexural performance with increasing specimen size regardless of parameters. High-strength concrete more sensitive to size effect on flexural strength, but hooked-end steel fibers more effective in reducing size effect due to better bond performance.

Doo-Yeol Yoo (2017)

Doo-Yeol Yoo et al. (2017) Studied rate-dependent behaviour of RC beams with and without steel fibers and stirrups. Tested at three loading rates: quasi-static, impact, and blast. Steel fibers enhanced load capacity and energy absorption, but couldn't prevent shear failure without stirrups. Beams with 0.5% steel fibers and stirrups showed highest performance. Aoude's model effectively predicted static shear strengths, highlighting steel fibers' effectiveness under static loading.

Gabriel B.S. Pereira (2019)

Gabriel B.S. Pereira et al. (2019) Experimental study on reinforced steel-fiber concrete beams (S/SFRC). Used hooked end steel fibers, varying volume content (0–2%) and high compressive strength. Full mechanical characterization performed, including post-peak properties. Digital image correlation (DIC) used to monitor displacement and cracking. Results show capacity gains, reduced crack openings, and adequate plastic rotation capacity, but localized cracking affects plastic hinge length.

Selcuk Saatci (2023)

Selcuk Saatci et al. (2023) Fiber-reinforced concrete (FRC) improves properties of plain cement concrete (PCC). Steel fiber is a commonly used reinforcement in FRC, enhancing mechanical properties. Waste tire fibers offer environmental benefits and can enhance PCC properties. Study investigates workability, compressive strength, and abrasion resistance. Proportions of steel and tire fibers tested: 0%, 0.25%, 0.75%, 1% of concrete volume. Results analysed to determine effects of fiber addition on concrete properties.

S. Amaan Mohammad (2022)

S. Amaan Mohammad et al. (2022) . Study aims to enhance PCC properties with steel and waste tire fibers at varied volumes. Evaluation of workability, compressive strength, and abrasion resistance in fresh and hardened states. Both steel and tire fibers show promise in improving mechanical properties. Potential environmental benefits highlighted with the use of waste tire fibers. Findings suggest a viable alternative to traditional methods, with reduced environmental impact.

Sergio Carmona (2019)

Sergio Carmona et al. (2019) Proposal suggests utilizing CAT images for determining fiber orientation in SFRC. Aim is to estimate residual strength through analysis of orientation coefficient. Assessment focuses on probability of active fibers and their strength contribution. Findings reveal deviations from experimental data attributed to factors like fiber dispersion and presence of cut fibers. Highlights challenges in accurately estimating strength in SFRC due to varying contributions.

Yi Min Xie (2022)

Yi Min Xie et al. (2022) Study examines effect of vibration time on steel fiber distribution and flexural behaviour in SFRC. Three vibration durations tested: 10 s, 30 s, and 60 s. SFRC with varying flowability levels evaluated (slump values: 80 mm to 200 mm). Flexural tests on beam specimens indicate longer vibration times cause increased settlement of steel fibers and segregation in high-flowing SFRC. Resulting effects include reduced flexural strength, toughness, and fracture energy. Optimal vibration times should be adjusted based on SFRC flowability to enhance flexural performance.

Hongzhi Cui (2024)

Hongzhi Cui et al. (2024) Research investigates the influence of water-to-binder ratio (w/b) on optimal nano-TiO₂ percentage in mortar strength. Utilizes an artificial neural network model for analysis. Findings indicate higher w/b ratios and lower age correlate with higher optimal nano-TiO₂ percentages. Results suggest nano-TiO₂ positively affects strength by reducing porosity. In low w/b mixes, nano-TiO₂ may decrease strength due to reduced hydration product content.

Shuanghua He (2022)

Shuanghua He et al. (2022) Study presents a design method for SFRC fracture performance considering steel fiber characteristics and aggregate gradation. Requires input parameters: steel fiber properties, aggregate gradation, specimen sizes, and peak load under static loading. Simultaneously determines fracture toughness and tensile strength of SFRC without size effect. Validated across 15 SFRC proportions, showing good agreement with experimental results. Analytical expressions linking peak load to fracture toughness and tensile strength developed, aiding in predicting minimum specimen size meeting linear elastic fracture requirements.

Jun Feng (2021)

Jun Feng et al. (2021) Investigated the effect of fiber orientation on SFRC tensile response. Employed double-sided inclined fiber pullout tests and SFRC dogbone tension tests. Developed a numerical model considering individual fibbers' bridging effect. Validated the model against experimental results. Found that increasing fiber inclined angle up to 60° enhanced ductility and energy absorption capacity. Lower fiber content SFRC exhibited greater improvement in properties. Emphasized the importance of fiber orientation in enhancing SFRC's bond-slippage behaviour and tensile properties. Suggested potential for cost-effective, high-performance material development through controlled fiber orientation.

Camillo Nuti (2021)

Camillo Nuti et al. (2021) Experimental study conducted on 36 Ultra-high-performance fiber-reinforced concrete (UHPFRC) samples with varied steel fiber volumes and aspect ratios. Results show that compressive strength and modulus of elasticity increase with higher fiber volume or aspect ratios, but the rate of increase

diminishes above 2% volume fraction. Steel fibers help restrain crack occurrence and propagation during compression, enhancing UHPFRC's structural integrity. However, they also reduce fresh UHPFRC's flowability, which can be detrimental. X-ray CT scanning reveals increased porosity and pore size in hardened UHPFRC with higher fiber volume fractions. A prediction model is developed considering both positive and negative effects of steel fiber. Semi-empirical prediction formulas for compressive strength and modulus of elasticity are proposed, validated, and refined using experimental data from literature. A relationship formula between modulus of elasticity and compressive strength of UHPFRC is presented and verified with a global experimental database of 320 tests.

Ding guo Yang (2024)

Ding guo Yang et al. (2024) Conducted mechanical performance tests on 33 Steel Fiber and Steel Reinforced Concrete (SFSRC) specimens. Variables included steel fiber content, shear span ratio, stirrup ratio, and longitudinal reinforcement configuration. Revealed failure mechanisms under shear, bending, and interface slip modes, summarizing typical load-deflection curves. Proposed a formula for calculating interface slip strength based on steel fiber crack strength theory. Determined distribution coefficients through regression analysis for composite beam components. Introduced bond influence coefficient based on interface failure mechanism. Proposed calculation formulas for shear strength of composite beams and bearing capacity under normal section bending and interface slip failure. Results of proposed formulas aligned well with experimental data upon comparison and verification.

Ajay Swarup (2019)

Ajay Swarup et al. (2019) Modern fibers used in construction often have rough surfaces, hooked ends, or are crimped or undulated. Steel fibers commonly available today are made from drawn steel wire. These steel fibers typically have equivalent diameters ranging from 0.15 mm to 2 mm. The lengths of steel fibers usually vary from 7 to 75 mm. Aspect ratios of steel fibers generally fall within the range of 20 to 100. Despite increased awareness, Steel Fiber Reinforced Concrete (SFRC) is not commonly used in load-bearing or shear-critical building structural elements.

Shashikant Shrivastava (2020)

Shashikant Shrivastava et al. (2020) Steel fibers are more effective in controlling cracking compared to conventional reinforcing steel bars because they are closely spaced. Steel fibers are used in concrete to control or prevent plastic and drying shrinkage. When compared to unreinforced concrete and concrete with welded wire fabric reinforcement, fiber-reinforced concrete exhibits higher flexural strength. Steel fibers extend across the concrete, providing strong bonding with the cement matrix and the ability to carry tensile loads. Bond strength is influenced by the surface area of the fiber, and deformed steel fibers come in a variety of sizes to enhance this bond strength.

Sangeetha.S.P (2020)

Sangeetha.S.P et al. (2020) Natural fibers such as Bamboo, Banana, coir, Sisal, Jute, pineapple, Kenaf, etc., have characteristics like low density, high specific strength, and stiffness. Beam-column joints are critical in concrete moment-resisting frames, especially when subjected to cyclic, static, or dynamic loads. These joints must resist both direct and lateral forces to minimize deformation. Structural members in beam-column connections with fiber-reinforced concrete benefit from increased flexural strength and deformation capacity. The use of fibers can help reduce issues related to rust development in steel embedded within concrete.

S.H. Alsayed (2021)

S.H. Alsayed et al. (2021) This paper discusses the application of steel fiber-reinforced concrete in tunnel lining and its performance.

H. K. Abbas (2022)

H. K. Abbas et al. (2022) This research explores the mechanical properties of steel fiber-reinforced concrete, which is crucial for understanding its structural performance.

J. Young (2015)

J. Young et al. (2015) This article delves into the durability aspects of steel fiber-reinforced concrete, which is vital for assessing its long-term performance and service life.

John (2017)

John et al. (2017) Investigates the mechanical properties and durability performance of fiber reinforced concrete. Examines the effects of different types and dosages of fibers on the concrete's strength, toughness, and resistance to cracking. Discusses the potential of fiber reinforced concrete in enhancing the durability and service life of concrete structures.

Emily (1998)

Emily et al. (1998) Focuses on the flexural behavior and performance of steel fiber reinforced concrete (SFRC) beams. Analyzes the load-deflection response, crack patterns, and failure modes of SFRC beams. Compares the flexural behavior of SFRC beams with that of traditional reinforced concrete beams.

Michael (2018)

Michael et al. (2018) Explores the impact resistance of concrete containing polypropylene fibers. Investigates the energy absorption capacity and cracking behavior of fiber reinforced concrete subjected to impact loads. Analyzes the role of fiber content and fiber aspect ratio in enhancing the impact resistance of concrete.

Sarah (2010)

Sarah et al. (2010) Provides an overview of non-destructive testing (NDT) techniques for evaluating fiber reinforced concrete. Discusses the application of NDT methods, such as ultrasonic testing, impact-echo testing, and ground-penetrating radar, in assessing fiber content, fiber distribution, and mechanical properties of fiber reinforced concrete.

Vivek mane (2022)

Vivek mane et al. (2022) This paper reviews mechanical properties of steel fiber reinforced concrete (SFRC), including compressive and tensile strength. SFRC is utilized for enhancing concrete's cracking resistance and strength. Research findings indicate that steel fibers confer considerably more strength compared to regular concrete. Some studies show linear increases in compressive and tensile strength with higher steel fiber content. However, other research suggests non-linear relationships between strength and steel fiber content. There is evidence indicating

that mechanical strength peaks at a certain volume fraction of fibers, diminishing with further increases.

2.3 INFERENCE FROM THE LITERATURES

1. **Enhancement of Concrete Properties with Fiber Reinforcement:** Several studies highlight the benefits of using fiber reinforcement in concrete to enhance its properties such as tensile strength, flexural strength, and durability. Both synthetic and natural fibers are used for this purpose.

2. **Effectiveness of Steel Fibers:** Steel fibers, in particular, are noted for their ability to improve concrete performance. They enhance properties such as compressive and flexural strength, as well as energy absorption under cyclic loading.

3. **Hybridization of Fibers:** There's interest in hybridizing different types and lengths of fibers to optimize concrete performance. Studies suggest that a combination of fibers, particularly long and medium-length steel fibers, can enhance performance.

4. **Numerical Modelling and Experimental Studies:** Both numerical modelling and experimental studies have been conducted to understand the behaviour of fiber-reinforced concrete structures. These studies provide insights into factors such as crack propagation, fracture behaviour, and the influence of fiber orientation on mechanical properties.

5. **Size Effect on Flexural Behaviour:** Research indicates that the flexural behaviour of fiber-reinforced concrete can be influenced by specimen size, with larger specimens exhibiting lower flexural performance. However, the inclusion of steel fibers helps in reducing the size effect on flexural strength.

6. **Shear Performance and Failure Mechanisms:** Studies on shear performance highlight the effectiveness of steel fibers in enhancing load capacity and energy absorption. However, shear failure mechanisms may vary depending on factors such as loading rates and the presence of stirrups.

7. **Optimization of Fiber Content and Distribution:** Research suggests that the optimization of fiber content and distribution is crucial for improving concrete

properties. Factors such as vibration time, fiber volume fraction, and aggregate gradation need to be carefully considered to achieve desired performance.

8. Mechanical Properties and Durability: Various studies have investigated the mechanical properties and durability performance of fiber-reinforced concrete. Understanding the relationship between fiber content, concrete strength, and durability is essential for long-term structural performance.

9. Application and Challenges: While fiber-reinforced concrete offers numerous benefits, challenges such as fiber orientation, dispersion, and bond strength need to be addressed for optimal performance. Additionally, the application of non-destructive testing techniques can aid in evaluating fiber-reinforced concrete properties and performance.

10. Future Directions: The literature suggests avenues for future research, including exploring novel fiber types, optimizing fiber reinforcement strategies, and addressing sustainability concerns by incorporating alternative fibers.

These inferences provide a comprehensive understanding of the current state of research in fiber-reinforced concrete and offer insights that can guide the development and application of fiber-reinforced concrete in your project.

2.4 AIM OF THE PROJECT

To Achieve superior structural strength and durability through the effective integration of high-quality fibers into concrete, ensuring enhanced crack resistance, increased load-bearing capacity, and prolonged service life in various construction applications.

2.5 OBJECTIVE OF THE PROJECT

- To help us Improve Crack Resistance by Reducing Shrinkage Cracks and Mitigate Crack Propagation.
- To determine the Increase Load-Carrying Capacity by Enhancing the Ability to Bear Loads.
- To enhance Structural Performance by Improving Tensile Strength, Increase in Ductility, Enhance Overall Structural Integrity.

2.6 SCOPE OF THE PROJECT

The scope of this project includes the following tasks:

- **Project Objectives:** Clearly define the goals and outcomes of using fiber reinforced concrete.
- **Material Selection:** Specify the type and properties of fibers to be used (e.g., steel, synthetic, glass).
- **Mix Design:** Develop a concrete mix design incorporating fibers to meet project requirements.
- **Testing Plan:** Outline testing procedures to ensure the performance and durability of the fiber reinforced concrete.
- **Construction Methodology:** Detail the procedures for mixing, placing, and curing fiber reinforced concrete.
- **Quality Control:** Implement measures to monitor the quality of the concrete during production and placement.
- **Safety Measures:** Address safety protocols for handling fiber reinforced concrete materials.
- **Project Timeline:** Establish a schedule for all project phases, including material procurement, construction, and testing.
- **Budgeting:** Estimate the costs associated with materials, labour, equipment, and testing.
- **Risk Management:** Identify potential risks and develop strategies to mitigate them during the project.
- **Stakeholder Communication:** Define communication channels and reporting mechanisms to keep stakeholders informed of project progress.
- **Environmental Considerations:** Address any environmental impacts associated with the use of fiber reinforced concrete and implement mitigation measures.
- **Compliance:** Ensure compliance with relevant codes, standards, and regulations governing the use of fiber reinforced concrete in construction projects.
- **Documentation:** Maintain detailed records of all project activities, including material specifications, test results, and construction progress reports.

CHAPTER 3

MATERIAL AND METHOD OF INVESTGATION

3.1 METHODOLOGY

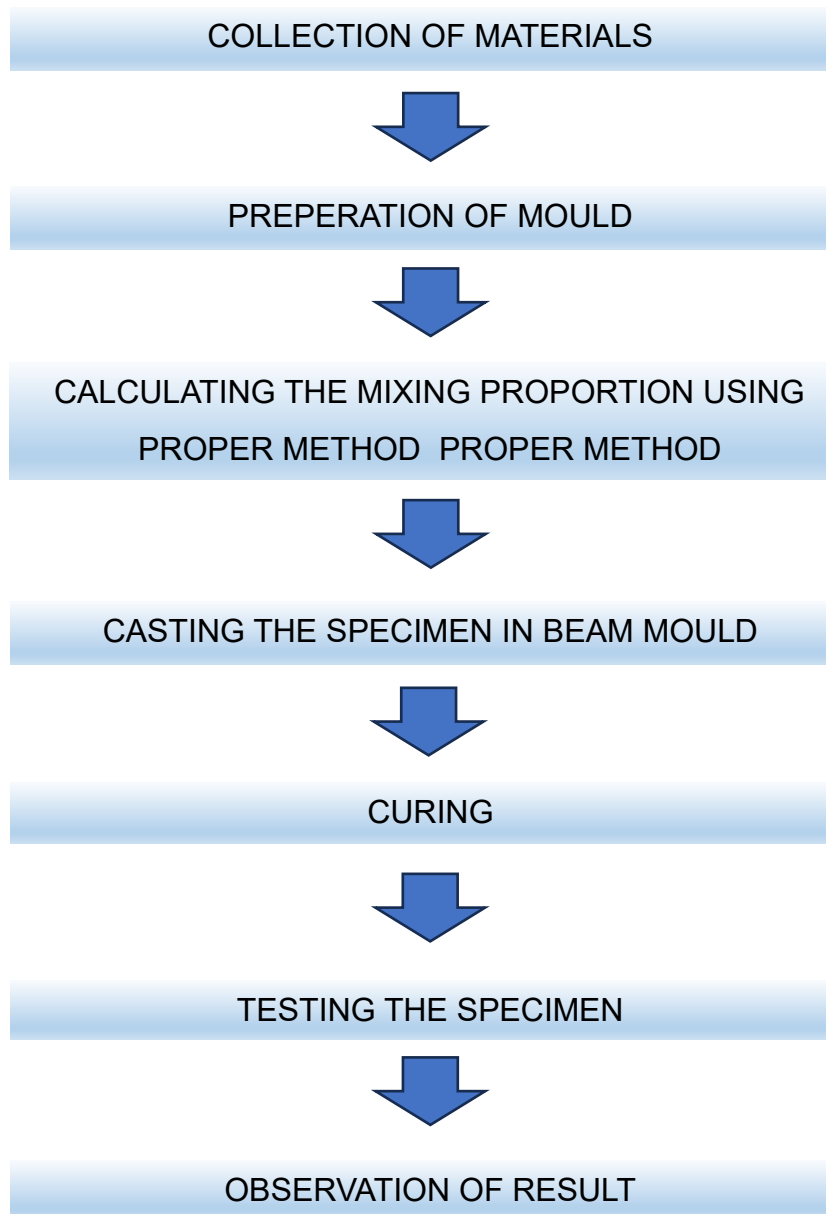


Figure 3.1: Methodology flow chart

3.2 CEMENT

Ordinary Portland Cement (OPC), which is a key component of concrete, mortar, stucco, and the majority of non-specialty grout, is the type of cement that is most frequently used globally. The raw components are heated to create clinker, which is subsequently ground into a fine powder to create this cement. Following the grinding stage, minor amounts of other ingredients are added. There are many different types of cement on the market, but 53 Grade OPC Cement is renowned for offering consistently stronger strength than other variations. We used 53 Grade OPC Cement from Ultratech Company for this experiment, which was obtained from a single batch and stored in airtight containers to shield it from the effects of the environment. Constructional cements, also known as hydraulic cements, are frequently employed in building projects because of their special ability to set and solidify even in water. Portland cement is the hydraulic cement that is most frequently used. This study goes into the chemical composition, characteristics, manufacturing process, historical development, and testing procedures for cement. Portland cement and other hydraulic cements are the main topics of discussion, but other varieties like high-alumina and slag-containing cement are also covered.

Table 3.1: Cement properties

Sl. NO.	Properties	Test results
1.	Grade	OPC53
2.	Brand	Ultra tech
3.	Colour	Grey
4.	Fineness of cement	96.6%
5.	Consistency test	27%
6.	Initial Setting time	30min
7.	final Setting time	10 hours
8.	Specific gravity	3.15



Figure 3.2: Cement

3.3 FINE AGGREGATE

As a fine aggregate in concrete, this experiment used locally accessible river sand. The main components of the sand are finely divided stony material and mineral particles, with quartz, which is mostly composed of silica due to its chemical inertness and noteworthy hardness, being the most prevalent component. The sand was put through a number of tests, including gradation, fineness modulus, and specific gravity, in line with IS: 2386-1963, to make sure it complied with the required physical specifications. The sand was surface-dried before being used.

The following are characteristics of fine aggregates:

1. Cleanliness or the absence of lumps, biological material, etc.
2. It must to be sturdy and long-lasting.
3. After mixing, it shouldn't react with cement.
4. It should also have a sturdy floor.
5. It shouldn't soak up more water than 5% at a time.
6. These aggregates shouldn't be permeable or soft.

The broad consensus is that aggregates have a specific gravity of 2.7 in the absence of explicit instructions. This is due to the fact that the majority of aggregates from various sources have specific gravities that range from 2.6 to 2.8. To guarantee that the concrete mix produced for a particular project adheres to the necessary criteria,

it is crucial to establish the specific gravity of the aggregates. In conclusion, one crucial factor in the construction of a concrete mix is the specific gravity of the particles. In order to guarantee that the concrete mix produced for a particular project satisfies the necessary criteria, it is crucial to know the specific gravity of the aggregates.

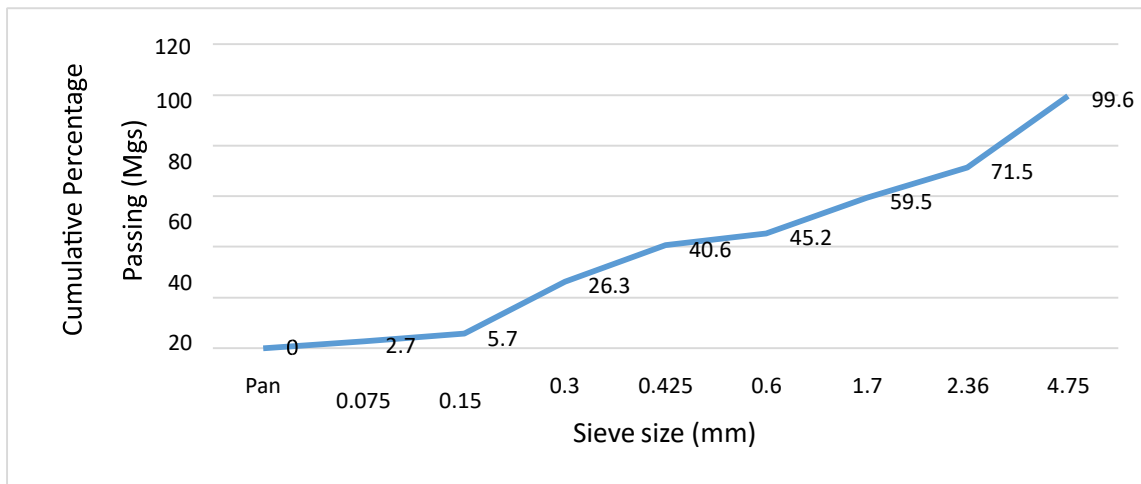


Figure 3.3: Sieve analysis for fine aggregate



Figure 3.4: Fine Aggregate

Table 3.2: Properties of Fine Aggregate

S.No.	Description Test	Result
1	Sand zone	Zone- II
2	Specific gravity	2.65
3	Fines modulus	4.93

3.4 COARSE AGGREGATE

Coarse aggregates, such as naturally occurring spherical gravels or irregularly broken stones, are used to make concrete that is intended for structural use. These coarse materials may include angular aggregates like granite and limestone or circular aggregates like river gravels. Aggregates greater than 4.75 mm in size are referred to as coarse aggregates by industry standards. In contrast, aggregates between 4.75 mm and 80 mm are categorized as coarse aggregates, while those between 150 microns and 4.75 mm are categorized as fine aggregates. It is important to remember that both fine and coarse aggregates often fall within the 4.75 mm size range. The characteristics that follow of the coarse aggregate used in the development are required: 1. It must be strong and long-lasting. 2. It ought to be strong and durable enough to withstand loads. 3. It must be clear of all dust and organic elements, as they may weaken the bonding power of adhesives like cement and bitumen. 4. After mixing, it must not exhibit a reaction with the cement. 5. It shouldn't be too soft or have a lot of pores. 6. It can only absorb up to 5% of water. 7. It has to be inert chemically. 8. It should, to the greatest extent practicable, be cubical, spherical, or angular in shape. 9. The report includes the table below, which lists the mixture's specific gravity and water absorption.

Table 3.3: Properties of coarse aggregate

Sl.No.	Description	Test Results
1	Nominal size	20mm
2	Specific gravity	2.74



Figure 3.5: Coarse aggregate

3.5 WATER

In defining the material's fresh and hardened qualities, concrete's water content is a key factor. These characteristics include of workability, compressive strength, permeability, water tightness, durability, weathering resistance, drying shrinkage, and cracking potential. For concrete to operate as best it can in a variety of applications, it is essential to understand how water content affects these attributes. To obtain desired fresh and hardened attributes such workability, compressive strength, permeability, water tightness, durability, weathering resistance, drying shrinkage, and resistance to cracking, effective management of the water content in concrete is essential. In order to provide optimal constructability and increase the service life of concrete structures, it is crucial to regulate and limit the water content of concrete. An important factor in determining the strength and durability of concrete is the ratio of

water to cementations components. Because wet aggregates attach to cement paste more effectively and uniformly than dry ones, water is required to saturate their surface and produce an adhesive bond. The strength and durability of the concrete are 19 increased by using this procedure, which also results in high-quality concrete with outstanding bonding capabilities. Water, which is necessary for complete hydration, has a significant impact on concrete's strength. The ideal amount of water to utilise for concrete is roughly 30% of the concrete's weight. For conventional concrete, a water-to-cement ratio of 0.35 is required. The cement paste created by mixing water and cement holds the fine and coarse particles together. However, applying too much water can cause bleeding and segregation, which weakens the concrete. Fibers can be used to absorb extra water and stop bleeding. On the other hand, insufficient workability will arise from employing too little water. It's crucial to utilize drinkable water with a pH of between 6 and 9 while creating concrete.

3.6 STEEL FIBERS

Steel fibers are a type of reinforcement material extensively used in concrete to enhance its mechanical properties and structural performance. Comprising high-strength carbon steel or stainless-steel alloys, these fibers come in various shapes and sizes, including hooked, crimped, straight, and wavy, catering to diverse project requirements. Their incorporation into concrete mixes improves tensile strength, toughness, ductility, and impact resistance. By effectively distributing tensile stresses, steel fibers mitigate cracking and prevent crack propagation, particularly under dynamic loading conditions. This reinforcement technique finds widespread application in industrial floors, pavements, bridge decks, tunnels, and precast elements, among others, where durability and structural integrity are paramount. Careful consideration of mix design factors such as fiber type, dosage, and concrete proportions is crucial to optimizing performance. Steel fiber-reinforced concrete offers cost-effective solutions for constructing resilient and long-lasting infrastructure capable of withstanding harsh environmental conditions and demanding operational loads. Steel fibers represent a crucial innovation in the realm of construction materials, offering an effective means of reinforcing concrete structures to meet the demands of modern engineering challenges. Comprised of high-strength carbon steel or stainless-steel alloys, these fibers serve as integral components within concrete matrices, imparting a multitude of advantageous properties. Their

incorporation significantly enhances the mechanical characteristics of concrete, including tensile strength, toughness, ductility, and resistance to cracking and fracture. This is achieved through the effective distribution of tensile stresses within the concrete, thereby mitigating the propensity for crack initiation and propagation, particularly in scenarios subjected to dynamic loading or impact. The versatility of steel fibers is evident in their diverse range of applications across various sectors of construction, including industrial flooring, pavements, bridge decks, tunnels, precast elements, and more. Whether reinforcing structural members or enhancing the durability of infrastructure subjected to harsh environmental conditions, steel fibers offer a reliable solution to bolster the longevity and resilience of concrete structures. Furthermore, advancements in manufacturing techniques have facilitated the production of steel fibers in a variety of shapes and sizes, such as hooked, crimped, straight, and wavy, enabling tailored solutions to meet specific project requirements. However, the successful integration of steel fibers into concrete necessitates careful consideration of factors such as fiber type, dosage, aspect ratio, and mix design, ensuring optimal performance and compatibility with existing construction practices. Overall, steel fiber-reinforced concrete stands as a testament to the continual evolution of construction materials, providing engineers and architects with an indispensable tool to realize their vision of sustainable, resilient, and structurally sound infrastructure in the face of evolving challenges and demands.

3.7 MIX DESIGN

Mix design is the process of carefully choosing the right materials and figuring out their proper ratios in order to produce concrete that is as strong and durable as possible while still being as economical as possible. Therefore, the fundamental objective of mix design is to balance creating concrete with the desired qualities while lowering production costs. According to the definition given above, mix design has two main objectives: first, to ensure that the concrete fulfils the standards for strength and durability, and second, to find the most economical way to produce the concrete. Therefore, achieving the desired strength and durability of the concrete while simultaneously maximizing the economics of the production process are the main goals of mix design. Various methods for proportioning concrete mixes have been proposed worldwide, but for the present work, the Indian Standard (IS) method was

chosen. The mix design employed in this study was determined using the IS method, as presented below.

3.7.1 Mix design used

Mix Design: M20

Mix Ratio: 1: 1: 2

Table 3.4: Mix proportions

Cement	$330 \text{ kg} \times 0.05175 \text{ kg} = 17.0775 \times 8 \text{ kg} = 136.62 \text{ kg}$
Water	$150 \text{ liter} \times 0.05175 \text{ kg} = 7.7625 \times 8 \text{ kg} = 62.1 \text{ kg}$
M-Sand	$720 \text{ kg} \times 0.05175 \text{ kg} = 37.26 \times 8 \text{ kg} = 298.08 \text{ kg}$
CA-1	$780 \text{ kg} \times 0.05175 \text{ kg} = 40.365 \times 8 \text{ kg} = 322.92 \text{ kg}$
CA-2	$420 \text{ kg} \times 0.05175 \text{ kg} = 21.735 \times 8 \text{ kg} = 173.88 \text{ kg}$
Admixtures	$2.2 \text{ grams} \times 0.05175 \text{ kg} = 0.11385 \times 8 \text{ kg} = 0.9108 \text{ kg}$

3.8 EXPERIMENTAL INVESTIGATION

In this experiment, we examined how the compressive strength of regular cement concrete changed with the addition of fiber reinforcement. The tests were conducted following IS code guidelines on the 7th, 14th, and 28th days to evaluate long-term strength development. Our investigation aimed to determine whether the inclusion of fiber reinforcement positively or negatively impacted the compressive strength of the concrete over time. We analysed the data to identify any significant variations in strength attributes and aimed to highlight the potential advantages of incorporating fiber reinforcement in concrete mixes, particularly focusing on enhancing strength properties.

3.8.1 Process

This experiment's method may be broken down into two primary phases: casting and testing. A total of 4 specimens were created during the casting phase in order to get the results for the compressive strength at 7, 14, and 28 days. To calculate the

average strength six specimens were made specifically for that type. Each specimen's compressive strength was assessed during the testing phase at the 7th, 14th, and 28th day points. The specimens' compressive strength at various time intervals was calculated using the results of these tests.

Table 3.5: Number of specimens

Type	FRC				Total no. of specimen
	7 th day	14 th day	21 st day	28 th day	
Beam	1	1	1	1	4

3.8.2 Casting

The investigations made to ascertain the material's qualities in accordance with Indian standards are described in this portion of the report. The investigations carried out were intended to pinpoint the precise properties of the substance. The paper also offers a concrete mix design that is based on Indian specifications.

3.8.3 Mould details

The internal dimensions of the mould are Cubic size = 230mmx300mm x1500mm

3.8.4 Mould

Metal moulds made of steel or cast iron must be thick enough to avoid distortion and allow safe removal of specimens. They need precise machining to ensure accurate dimensions, with a tolerance of 0.2mm for height and distance between faces. Angles between internal faces and surrounding ones, as well as with top and bottom planes, should be calculated. Inner faces must be flat within a 0.03mm deviation. Each mould needs a metal base plate to prevent leaks, attached with screws or springs. Assembled mould elements must be securely held during filling and handling, using suitable methods.

3.8.5 Preparation of mould

The preparation of moulds for casting concrete specimens, including those for fiber-reinforced concrete, is crucial to ensure accurate and consistent results. Here are the general steps for preparing moulds:

1. **Selecting the Mold Material:** Molds can be made from various materials such as plastic, wood, metal, or silicone rubber, depending on the specific requirements of the project. Silicone rubber moulds are often preferred for their flexibility and ease of demoulding.
2. **Cleaning the Molds:** Before use, ensure that the moulds are clean and free from any debris, dust, or residues from previous castings. Clean them thoroughly with water and a mild detergent if necessary, and allow them to dry completely.
3. **Applying Release Agent:** To facilitate easy demoulding and prevent the concrete from sticking to the moulds, apply a suitable release agent evenly to the inner surfaces of the moulds. Common release agents include moulds release sprays, oils, or commercial form release compounds.
4. **Assembling the Mold:** If using multipart moulds, assemble them securely, ensuring tight seals between the parts to prevent leakage of the concrete mix. Use clamps or rubber bands to hold the moulds together firmly during casting.
5. **Sealing the Seams:** Check for any gaps or seams in the moulds where concrete could leak out. Seal these areas using silicone caulk or tape to prevent leakage and ensure the desired shape and dimensions of the cast specimens.
6. **Preparing Support Base:** Place the assembled moulds on a level and stable surface, such as a flat table or casting bed. Ensure that the support base is clean and free from any obstructions that could affect the casting process.
7. **Applying Vibrations:** If required, apply vibration to the moulds during casting to help remove air bubbles and ensure proper compaction of the concrete mix. Vibrating tables or handheld vibrating tools can be used for this purpose.

8. **Checking Dimensions:** Before pouring the concrete mix, double-check the dimensions and alignment of the moulds to ensure they meet the desired specifications for the final concrete specimens.

By following these steps and ensuring proper preparation of the moulds, you can achieve accurate and consistent results in casting fiber-reinforced concrete specimens for testing and evaluation.



Figure 3.6: Preparation of mould

3.8.6 Preparation of concrete

The preparation of concrete involves several steps to ensure the proper mixing and placement of the material. Here's a general overview of the process:

1. **Gathering Materials:** Collect all the necessary materials for making concrete, including cement, aggregates (such as sand and gravel), water, and any admixtures or additives required for specific performance characteristics.
2. **Mixing:**
 - a. **Batching:** Measure the proportions of each material based on the desired mix design. This can be done by weight or volume, depending on the project requirements.
 - b. **Mixing:** Combine the dry ingredients (cement, aggregates) in a concrete mixer or mixing vessel. Mix them thoroughly until they are uniformly distributed. Gradually

add water while mixing until the desired consistency is achieved. The mixing time and method may vary depending on the type of mixer used and the specific mix design.

3. Adding Fibers: If the concrete is fiber-reinforced, add the specified type and dosage of Fibers to the mix during the mixing process. Ensure that the Fibers are evenly distributed throughout the mixture to enhance their effectiveness in improving the concrete's properties.

4. Transporting: Once the concrete is mixed to the desired consistency, transport it to the casting site using wheelbarrows, buckets, pumps, or other suitable equipment. Take care to minimize segregation or loss of workability during transportation.

5. Placing: Pour or place the concrete into the prepared moulds or formwork, ensuring even distribution and proper consolidation. Use vibration or tapping to remove air voids and ensure proper compaction of the concrete. Pay attention to any reinforcement or embedment's that need to be properly positioned within the concrete.

6. Finishing: After the concrete is placed, finish the surface as required for the specific application. This may involve smoothing the surface with a trowel, creating texture or patterns, or applying surface treatments or coatings.

7. Curing: Protect the freshly placed concrete from premature drying and maintain adequate moisture levels for hydration by applying curing methods such as wet curing, membrane curing, or curing compounds. Proper curing is essential for achieving the desired strength, durability, and performance of the concrete.

8. Demoulding and Maintenance: Once the concrete has gained sufficient strength, carefully remove the moulds or formwork. Perform any necessary finishing touches and ensure proper protection and maintenance of the concrete to maximize its longevity and performance.

By following these steps and paying attention to details throughout the preparation process, you can produce high-quality concrete that meets the requirements of your project.

3.8.7 Volume Batching

Volume batching in concreting involves measuring the component like aggregates, cement, and water by volume rather than weight. Using containers like buckets, the aggregates are measured separately, while cement and water are also measured by volume. While convenient for small projects, volume batching may lack precision due to variations in material density and moisture content. For larger projects or where accuracy is crucial, weight batching is preferred for consistent and quality concrete.

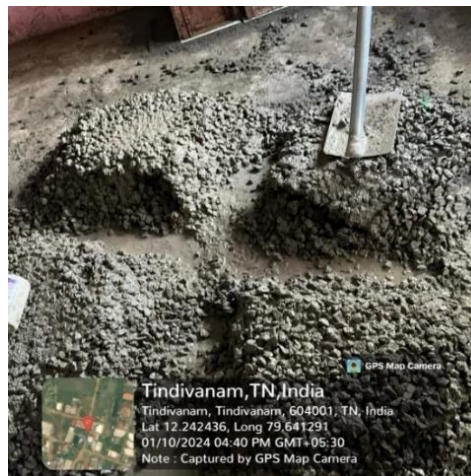


Figure 3.7: Volume batching

3.8.8 Mixing

To produce high-quality concrete, achieving uniformity is paramount. This entails meticulous material mixing to ensure consistent colour and texture throughout. Each component must be thoroughly blended to achieve homogeneity, ensuring that the final product meets aesthetic and performance standards. Proper mixing prevents issues such as patchiness or unevenness in colour or texture, enhancing the overall appearance and durability of the concrete. By prioritizing strict material mixing practices, producers can reliably deliver concrete that meets both functional and aesthetic requirements, satisfying the needs of various construction projects.

3.8.8.1 Hand mixing

Hand mixing concrete for small-scale, inconsequential projects is a typical practice. To ensure the quality of the final concrete, it is advised to add 10% more cement due to the limits of this approach. It is best to utilise a sizable, impervious concrete or brick floor that can fit one cement bag when mixing by hand. The cement should then be added after the coarse and fine aggregates have been laid out in alternate layers. The next step is to vigorously mix the mixture using a shovel until it has a uniform colour. When a uniform and homogenous concrete is achieved, the mixture should be spread out to a thickness of about 20 cm and water should be sprayed on using water can with a rose-head. It is essential to sprinkle water gently rather than spilling it. To get the desired consistency, a small amount of water can be added towards the conclusion of the mixing process. The ultimate quality of the concrete can be greatly affected by even a small variation in the amount of water applied at this stage.



Figure 3.8: Mixing of concrete

3.8.9 Placing

Implementing a well-thought-out and methodical approach is crucial for achieving the best outcomes in concrete placing. In order to pour the concrete properly and effectively and produce a final product of excellent quality, a methodical technique is essential. Consequently, for a concrete placement to be successful, a well-designed plan and a disciplined execution procedure are crucial.

3.8.10 Compaction

Concrete must be compacted a critical procedure that involves liberating trapped air. Particularly in concrete with low workability, air can become trapped during the mixing, transport, and placing of concrete. This indicates that compared to concrete 34 mixes with great workability, stiffer concrete mixes require more effort to compact and remove air. Concrete's strength can be greatly reduced if the air is not completely removed. In actuality, the quantity of air holes left by inadequate compaction directly correlates with the strength of concrete. In contrast, concrete with 10% voids can lose nearly 50% of its strength whereas concrete with 5% voids can lose up to 30% of its strength. To avoid the finished product losing strength, it is crucial to make sure that proper compaction is carried out during the construction process. To attain the best strength and durability, it is essential to make sure that the concrete is completely compacted. For small-scale concrete projects or when mechanical compaction is not possible, hand compaction techniques including rodding, ramming, and tampering are frequently used. With a layer thickness restriction of 15 to 20 cm, hand compaction maintains the concrete's consistency at a higher level. Using a 16mm diameter rod, often made of iron, bamboo, or cane, to pack the concrete and release trapped air between the reinforcement and pointed corners and edges are known as rodding. For the entire region to be compacted successfully, ongoing rodding is necessary.

3.8.11 Curing

The continual hydration of cement particle is thought to be the source of concrete's strength, according to study. This does not happen suddenly; it is a continual process that occurs over a long length of time. Despite starting out rather quickly, the rate of hydration eventually slows down. The amount of hydration that occurs determines the volume of hydration product and the volume of gel formed as a result of hydration. As mentioned previously, cement needs a water/cement ratio of about 0.23 to hydrate and a water/cement ratio of 0.15 to fill the spaces in gel pores. A water/cement ratio of roughly 0.38 is required in order to completely hydrate all cement particles and fill the space in gel pores. It is impossible to exaggerate the significance of appropriate curing, particularly given the rising demand for high-quality concrete. There is evidence to suggest that continuous and effective curing enhances the overall quality

of concrete. Concrete's quality may be severely damaged if curing is neglected in the early phases of hydration. This is due to the heat that concrete produces during hydration, which can be detrimental to volume stability. The finished product may suffer if the generated heat is not extinguished. On the other hand, through-water curing can lessen the harmful effects of heat creation during hydration. Ponding and wet covering are two cures that have been proven successful. These techniques entail keeping the concrete consistently wet for a long time, which can assist in controlling the temperature and preventing cracking or other damage. It is crucial to properly cure concrete in order to produce concrete of the highest calibres.

3.8.12 Preparation of specimens for testing

The specimens were taken out of the curing tank on the test day and prepared for surface testing. They were let an hour or so to air dry after any surface water and grit were removed. The specimens were then painted to indicate whether they were OPC or included 60mm fiber and then they were covered in a coating of white wash.

3.8.13 Test for deflection

A deflection test in concrete is a fundamental assessment method employed to evaluate the structural behaviour and load-bearing capacity of concrete elements like beams or slabs. In this test, a gradually increasing load is applied to the concrete member, simulating the forces it would experience in real-world conditions. As the load is applied, the amount of deflection or bending deformation exhibited by the concrete member is measured at specific points along its length. This measurement is crucial for understanding how the member responds to external loads and identifying any potential weaknesses or flaws in its design or construction. By analysing the relationship between the applied load and the resulting deflection, engineers can assess the stiffness, strength, and overall performance of the concrete structure. Deflection tests play a significant role in structural design, quality control, and safety assessment, providing valuable insights into the integrity and durability of concrete elements in various construction projects.

The actions below were conducted in order to ascertain the specimen's Deflection test:

- The specimen was taken out of the water when the natural process called for it, and any surplus water was wiped off the surface.
- The specimen's measurements were precisely measured, rounded to the nearest 0.2 meters.
- The testing device's bearing surface was properly cleaned and free of any impurities or dirt.
- The specimen was positioned in the machine so that the load would be distributed evenly across the other sides of the forged beam.



Figure 3.9: Deflection test

CHAPTER 4

RESULT AND DISCUSSION

4.1 DEFLECTION TEST

The Deflection test was conducted on 4 beams measuring 230mmx300mm x1500mm. The cubes were cast and tested after conducting workability tests, with testing performed at both 7 days, 14 days and 28 days. The results of the Deflection test are presented in the table below:

Table 4.1: 7th day deflection result

Load (N)	Experimental Deflection (mm)				Given deflection in (mm)	
	Left	Centre	Right	Average deflection	$5(PL^3)/(162EI)$	$23PI^3/648EI$
2500 N	07	10	08	7.5	2.39	2.75
5000 N	09	12	10	9.5	4.79	5.51
7500 N	10	14	12	11	7.18	8.26
10000 N	16	17	14	10	9.58	1.10
12500 N	18	19	16	17	1.19	1.37
15000 N	21	22	19	20	1.43	1.65
17500 N	22	25	24	23	1.67	1.92
20000 N	23	27	25	24	1.09	2.20
22500 N	28	29	26	27	2.15	2.48
25000 N	31	23	28	29.5	2.39	2.75

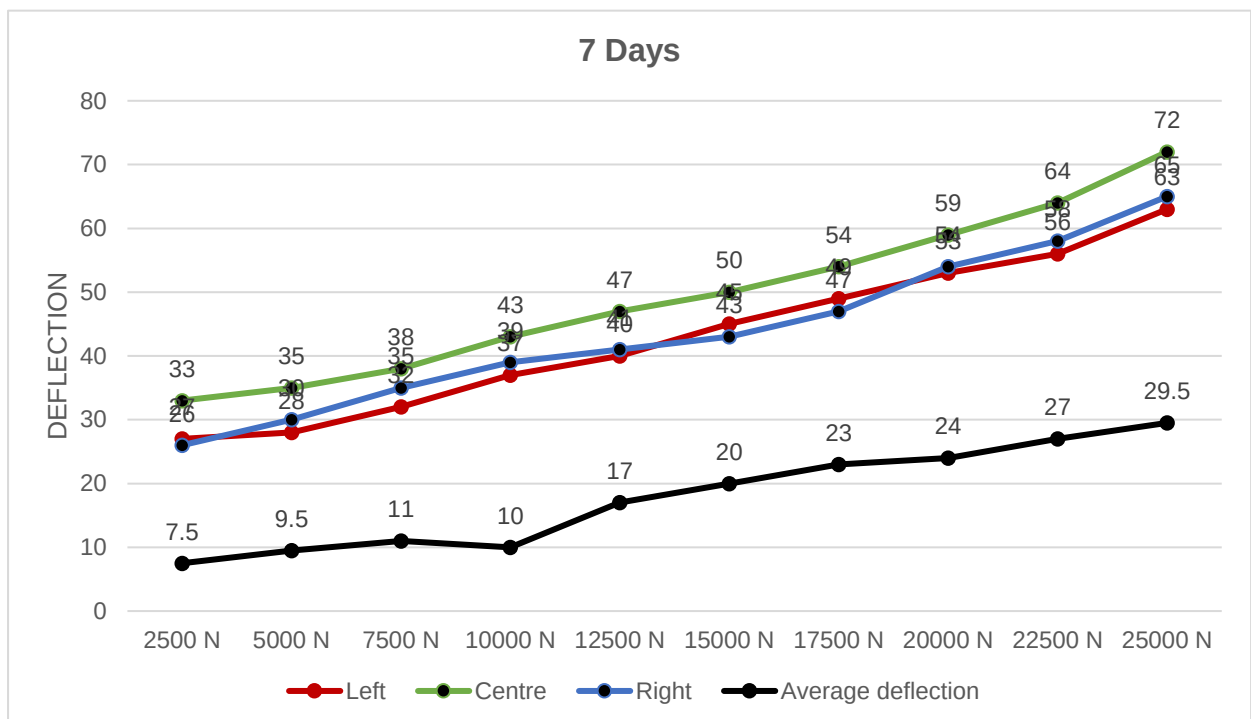


Figure 4.1: Deflection for 7th day

Table 4.2: 14th day deflection result

Load (N)	Experimental Deflection (mm)				Given deflection in (mm)	
	Left	Centre	Right	Average deflection	$5(PL^3)/(162EI)$	$23PI^3/648EI$
2500 N	18	20	17	17.5	2.39	2.75
5000 N	20	23	19	19.5	4.79	5.51
7500 N	22	27	25	23.5	7.18	8.26
10000 N	27	32	29	28	9.58	1.10
12500 N	29	34	31	30	1.19	1.37
15000 N	31	37	33	32	1.43	1.65
17500 N	33	39	36	34.5	1.67	1.92
20000 N	38	42	40	39	1.09	2.20
22500 N	40	45	43	41.5	2.15	2.48
25000 N	43	47	45	44	2.39	2.75

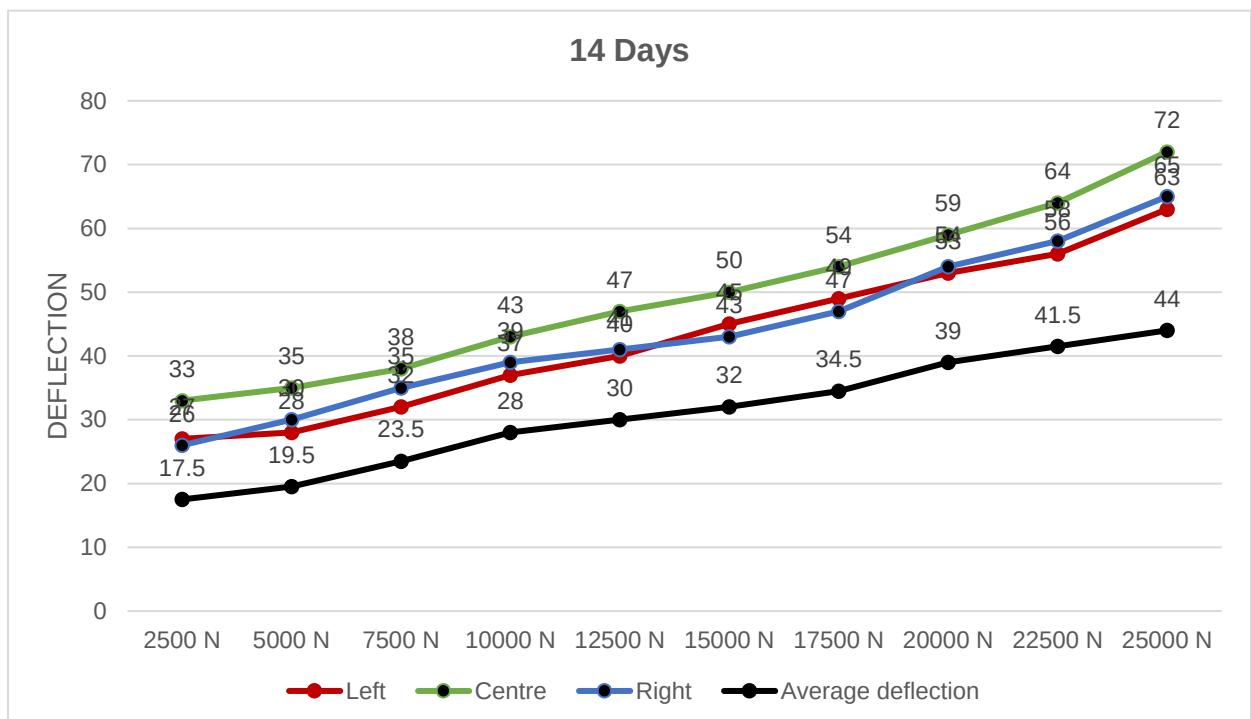


Figure 4.2: Deflection for 14th day

Table 4.3: 21st day deflection result

Load (N)	Experimental Deflection (mm)				Given deflection in (mm)	
	Left	Centre	Right	Average deflection	$5(PL^3)/(162EI)$	$23Pl^3/648EI$
2500 N	27	33	26	26.5	2.39	2.75
5000 N	28	35	30	29	4.79	5.51
7500 N	32	38	35	33.5	7.18	8.26
10000 N	37	43	39	38	9.58	1.10
12500 N	40	47	41	40.5	1.19	1.37
15000 N	45	50	43	44	1.43	1.65
17500 N	49	54	47	48	1.67	1.92
20000 N	53	59	54	53.5	1.09	2.20
22500 N	56	64	58	57	2.15	2.48
25000 N	63	72	65	64	2.39	2.75

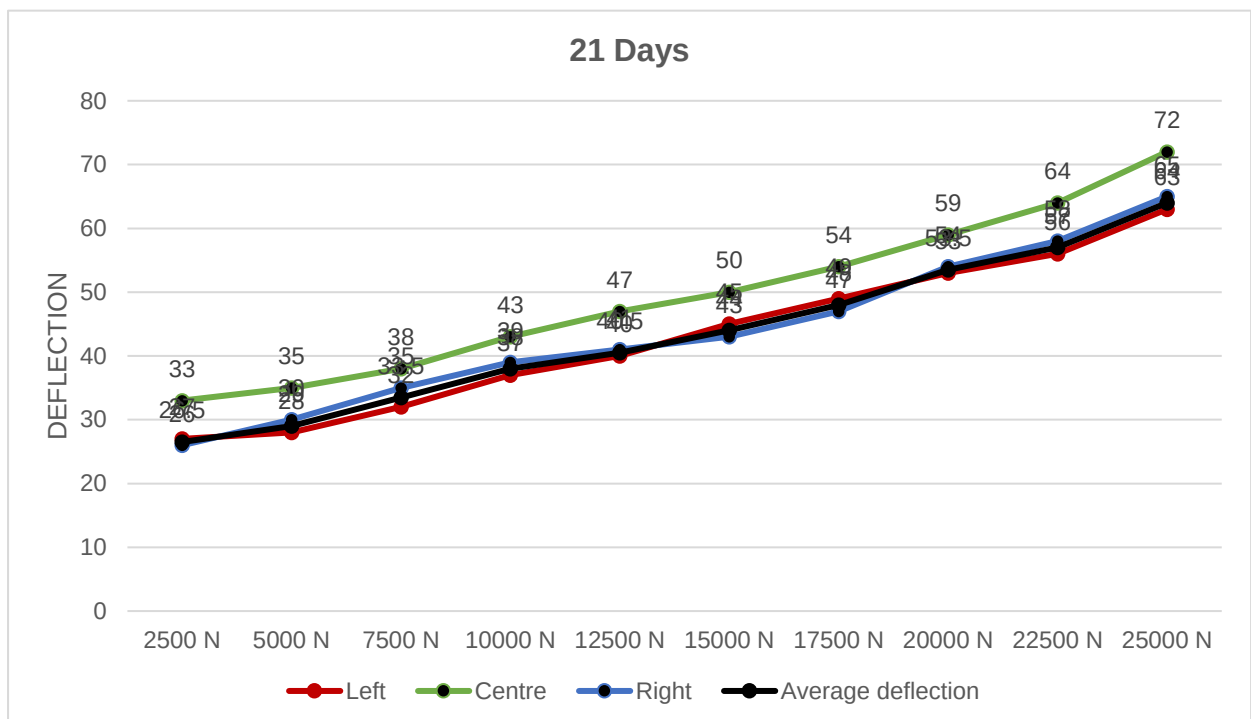


Figure 4.3: Deflection for 21st day

Table 4.4: 28th day deflection result

Load (N)	Experimental Deflection (mm)				Given deflection in (mm)	
	Left	Centre	Right	Average deflection	$5(PL^3)/(162EI)$	$23Pl^3/648EI$
2500 N	37	40	39	38	2.39	2.75
5000 N	40	45	43	41.5	4.79	5.51
7500 N	44	56	47	45.5	7.18	8.26
10000 N	51	68	54	52.5	9.58	1.10
12500 N	58	72	64	61	1.19	1.37
15000 N	65	79	71	68	1.43	1.65
17500 N	72	84	76	74	1.67	1.92
20000 N	77	90	85	81	1.09	2.20
22500 N	83	96	89	86	2.15	2.48
25000 N	92	109	98	95	2.39	2.75

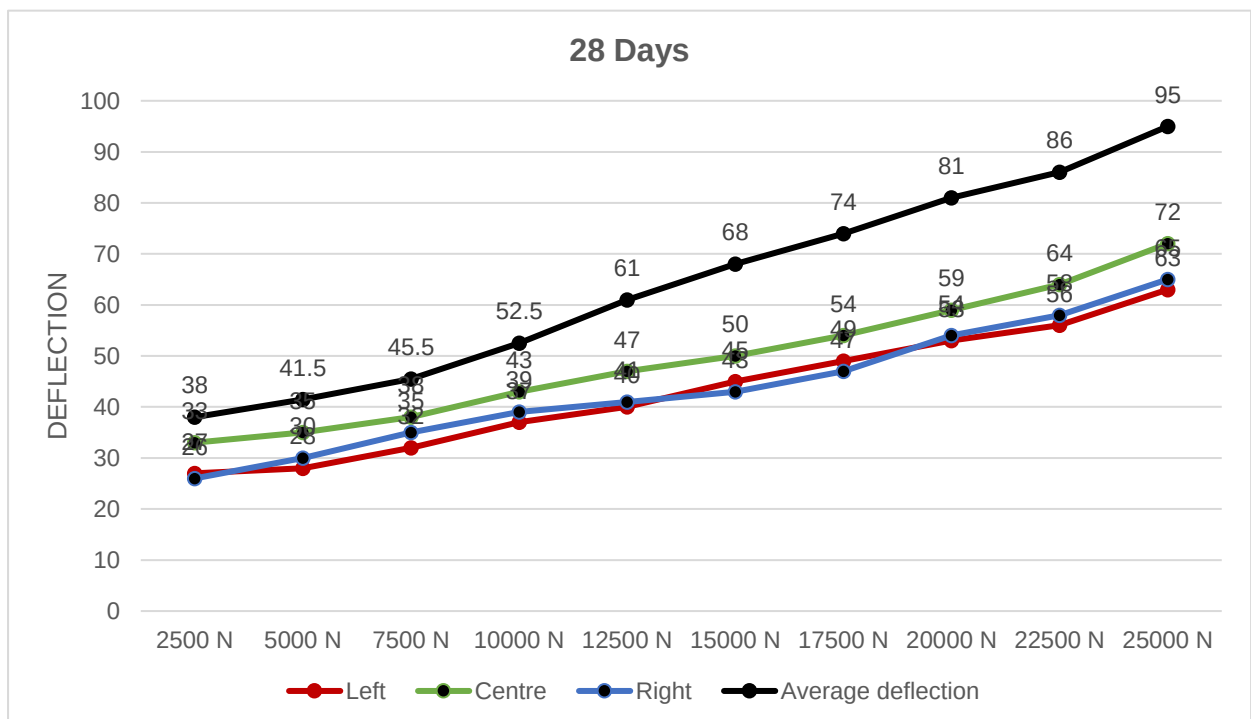


Figure 4.4: Deflection for 28th day

4.2 SEM ANALYSIS

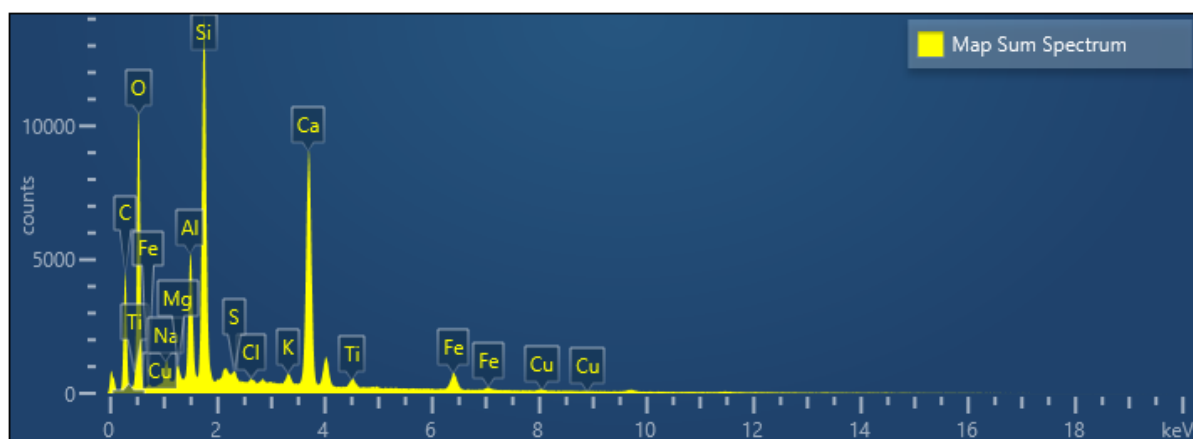


Figure 4.5: Intensity Map

Table 4.5: Atomic percentage of elements

Map Spectrum	Sum				
Element	Line Type	Weight %	Weight Sigma	%	Atomic %
C	K series	34.30	0.42		46.65
O	K series	39.62	0.30		40.45
Na	K series	0.99	0.03		0.70
Mg	K series	0.46	0.02		0.31
Al	K series	3.11	0.04		1.88
Si	K series	8.64	0.07		5.02
S	K series	0.18	0.02		0.09
Cl	K series	0.14	0.01		0.07
K	K series	0.37	0.02		0.15
Ca	K series	9.44	0.08		3.85
Ti	K series	0.53	0.02		0.18
Fe	K series	1.90	0.04		0.55
Cu	K series	0.33	0.05		0.09
Total		100.00			100.00

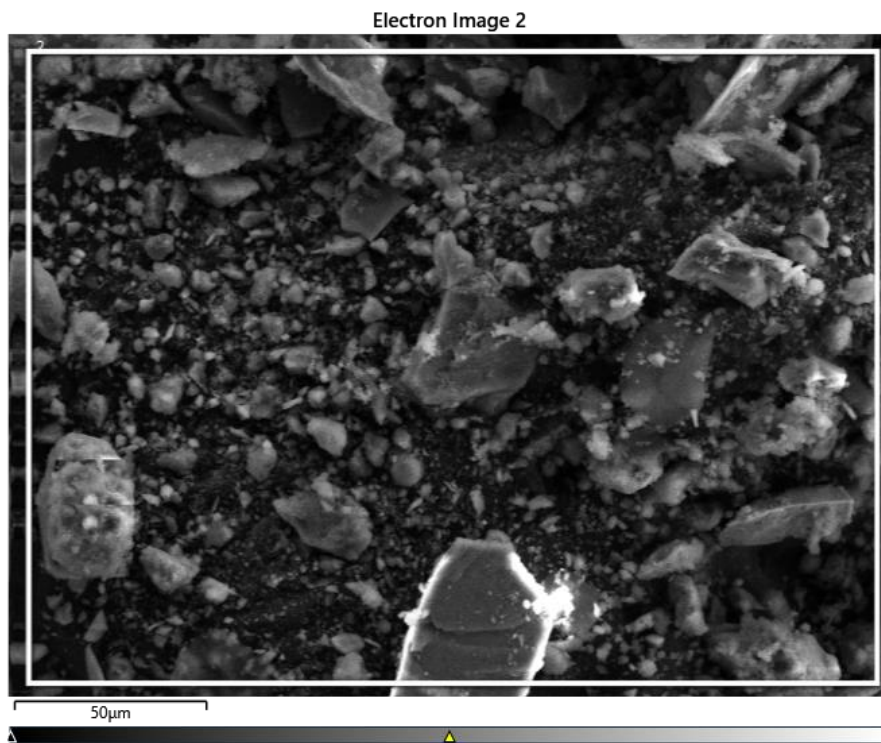


Figure 4.6: Sem Electron image

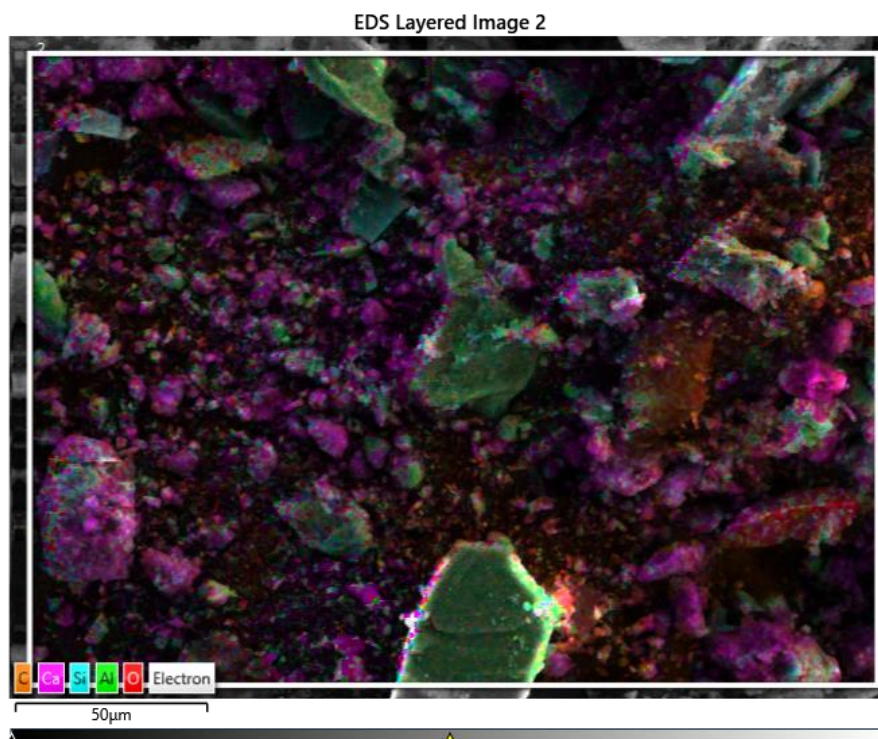


Figure 4.7: Sem EDS Layered image

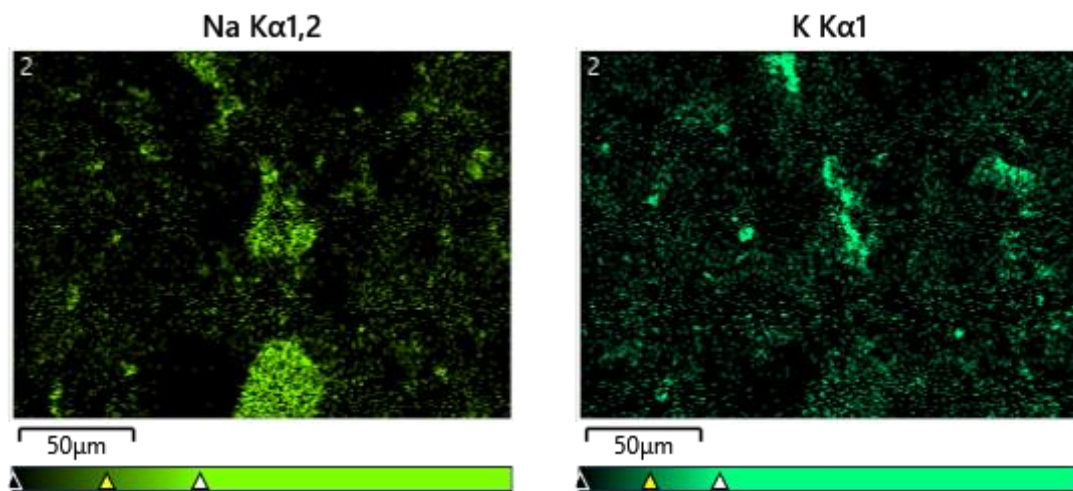


Figure 4.8: Presence of Sodium & potassium

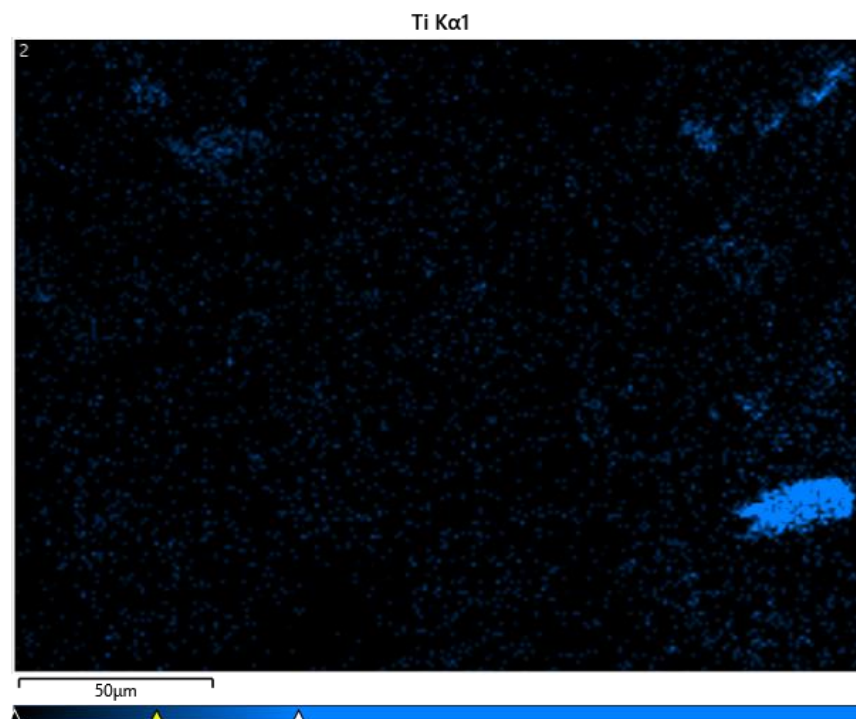


Figure 4.9: Presence of Titanium

CHAPTER 5

CONCLUSION

5.1 CONCLUSION

The present experimental investigation focused on examining the deflection resistance of steel fiber-reinforced concrete with varying fiber content. The study aimed to determine the optimal volume of steel fibers that could be added to concrete to enhance its deflection strength characteristics. It was observed that the addition of fibers in concrete volume significantly influenced the deflection strength of the material. Particularly, the incorporation of steel fibers in hybrid form demonstrated a greater impact on the concrete's deflection strength compared to adding them individually. The findings suggest that the maximum deflection strength of hybrid fiber-reinforced concrete was achieved through the combination of 3% steel fibers with a length of 100mm. This combination proved to be most effective in enhancing the concrete's ability to withstand deflection under load.

Suggestions for Future Study

- **Exploration of Higher Fiber Content:** Further investigation could explore increasing the percentage of steel fibers up to 2% of the concrete volume. Studying various proportions of fiber content would provide deeper insights into the relationship between fiber concentration and deflection strength.
- **Fiber Length Variation:** Investigating the effect of varying fiber lengths on deflection resistance could offer valuable data. Comparing different fiber lengths, along with varying percentages, would help identify the most optimal combination for maximizing deflection strength.

Incorporating these suggestions into future studies would contribute to a more comprehensive understanding of steel fiber-reinforced concrete's behaviour under deflection, leading to advancements in structural engineering and construction practices.

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