OPTIMIZATION OF COMPRESSIVE STRENGTH IN CONCRETE USING NYLON AS A SYNTHETIC FIBER

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

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147/I, Green Road, Dhaka-1215, Bangladesh

Section: 26B

Semester Year: Fall-2025

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Dedicated

to

“Only our beloved parents.”

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude to all those who contributed to the successful completion of this thesis. First and foremost, I am profoundly thankful to Almighty Allah for granting me the strength, patience, and perseverance needed to complete this research work on Fiber Reinforced Concrete.

My heartfelt thanks go to the faculty members of the Department of Civil Engineering, Sonargaon University, for their academic support, insightful lectures, and encouragement throughout my academic journey. I am also grateful to the laboratory technicians and staff whose assistance in sample preparation, testing, and data collection made the experimental phase of this study possible.

ABSTRACT

Fiber Reinforced Concrete (FRC) has emerged as an effective alternative to conventional concrete by improving structural performance through the incorporation of randomly distributed fibers. This study investigates the mechanical properties, workability, and overall performance of FRC using different fiber dosages. Experimental tests were conducted to evaluate compressive strength. Standard procedures following ASTM guidelines were used to prepare, cure, and test all specimens.

The results indicate that the inclusion of fibers significantly reduces crack propagation, and improves concrete strengths. The overall structural efficiency and reduction in reinforcement demand can lead to long-term savings.

Overall, the research confirms that Fiber Reinforced Concrete provides superior performance for structural applications, particularly where enhanced toughness, crack resistance, and durability are required. The findings highlight FRC as a viable solution for modern construction, offering improved safety, economy, and long-term serviceability.

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CHAPTER 1

INTRODUCTION

1.1 Background of FRC in Modern Construction

Concrete is the most widely used construction material in the world due to its high compressive strength, durability, and ease of availability. However, conventional concrete has two major weaknesses: low tensile strength and brittleness. These limitations often result in cracking, reduced service life, and poor performance under dynamic or impact loads.

To overcome these drawbacks, Fiber Reinforced Concrete (FRC) has emerged as an effective solution. FRC is a composite material consisting of cement, aggregates, water, and discrete fibers uniformly distributed throughout the mix. The fibers act as crack arresters and enhance the ductility, toughness, post-cracking performance, fatigue strength, and impact resistance of concrete.

Different types of fibers—such as synthetic, steel, glass, and natural fibers—are used in modern construction. Among these, synthetic fibers are particularly attractive for their low cost, light weight, corrosion resistance, and ease of mixing. As a result, FRC is being increasingly used in pavements, precast products, industrial floors, tunnel linings, earthquake-resistant structures, and repair/rehabilitation works.

1.2 Research Objectives and Overview

To evaluate the mechanical performance of Fiber Reinforced Concrete (FRC) using synthetic fibers and compare it with conventional concrete.

1.2.1 Specific Objectives

1. To investigate the effect of synthetic fiber content on the compressive strength of concrete.
2. To compare the results with conventional concrete and determine the optimum fiber percentage for best workability and performance.

1.3 Organization of the Thesis

This thesis is organized into five chapters, each addressing a specific aspect of the study on Fiber Reinforced Concrete (FRC):

Chapter 1: Introduction
This chapter presents the background, problem statement, objectives, scope, and significance of the study. It also highlights the current limitations of conventional concrete and introduces the potential benefits of Fiber Reinforced Concrete. The overall organization of the thesis is also outlined.

Chapter 2: Literature Review
This chapter provides a comprehensive review of existing research related to FRC. It discusses different types of fibers, their mechanical behavior, influence on concrete properties, and applications in structural engineering. The chapter also summarizes previous experimental findings and identifies research gaps.

Chapter 3: Methodology
This chapter details the materials, mix design, specimen preparation procedures, and testing methods used in the research. Standards followed (ASTM and others) are presented along with the experimental setup for compressive, tensile, and flexural tests. Fiber dosage, curing process, and quality control measures are also described.

Chapter 4: Results and Discussion
This chapter presents the experimental results obtained from various tests conducted on both conventional concrete and fiber-reinforced concrete. The effects of fiber inclusion on workability, compressive strength, tensile strength, and flexural behavior are analyzed. Graphs, tables, and comparisons are included to interpret the results.

Chapter 5: Conclusion and Future Work
This chapter summarizes the key findings of the research and highlights the overall contribution of the study. Limitations are addressed, and recommendations for future research and practical application of FRC in structural engineering are provided.

CHAPTER 2

Literature Review

2.1 Introduction

Concrete is the most widely used construction material, but its low tensile strength and brittle nature limit its performance in many structural applications. To overcome these weaknesses, researchers have introduced fibers into the concrete matrix, leading to the development of Fiber Reinforced Concrete (FRC). FRC improves crack resistance, ductility, toughness, and post-cracking behavior through the bridging action of fibers.

Over the years, numerous studies have examined different fiber types, dosages, and mix designs to evaluate their effects on mechanical properties such as compressive, tensile, and flexural strength, as well as durability and workability. This chapter summarizes key findings from previous research, highlights the benefits and limitations of FRC, and identifies existing knowledge gaps that form the basis for the experimental work presented in this thesis.

2.2 Literature Review Overview

Concrete is a composite material primarily composed of cement, fine aggregate, coarse aggregate, and water. Although it has been widely used in construction due to its compressive strength, durability, and low cost, it suffers from several inherent deficiencies:

Brittleness: Conventional concrete shows brittle behavior under loading. Once the stress exceeds its tensile capacity, the concrete cracks suddenly without significant deformation. This lack of ductility makes structures vulnerable to impact, blast, and seismic loads.

Low Tensile Strength:

- Tensile strength of concrete is typically only 8–12% of its compressive strength**.**
- This leads to premature cracking under tension, shrinkage, or thermal stresses.
- Reinforcing bars (steel) can resist tensile forces, but microcracks still form in the concrete matrix.

Poor Crack Resistance: Concrete develops microcracks even before loading due to drying shrinkage and temperature variations. Under load, these microcracks propagate and significantly reduce serviceability.

Given these limitations, researchers have explored various modifications, such as fiber addition, to improve performance.

2.3 Fiber Types in Concrete:

- Synthetic Fibers
- Steel Fibers
- Glass Fibers
- Natural Fibers

2.4 Mechanical Performance of FRC: Findings from Previous Research:

Compressive Strength: Research reports the following trends;

- Synthetic fibers generally slightly increase or maintain compressive strength**.**
- Higher percentages may reduce workability, causing voids and lowering strength.
- Moderate fiber percentages (2–10% by volume) show notable improvement in ductility.

Tensile Strength: Fibers significantly improve tensile properties by bridging cracks and preventing sudden fracture.

Shrinkage & Crack Control: Synthetic fibers are particularly effective in;

- Plastic shrinkage reduction
- Restricting early-age cracks
- Limiting crack width, even after cracking initiates

Durability Performance: Fibers enhance durability by;

- Reducing water penetration
- Minimizing crack propagation
- Improving freeze–thaw resistance
- Enhancing fatigue resistance

2.5 Research on Synthetic Fiber Reinforced Concrete: Several studies indicate the following;

1. Polypropylene fiber improves shrinkage resistance and reduces crack width.
2. Synthetic fiber volume of 0.5%–5% generally yields optimal workability and mechanical improvement.
3. Higher fiber content (above 5%) may reduce slump and make mixing difficult.

4. Synthetic fibers improve post-cracking behavior, making concrete more ductile.
5. For compressive strength, results vary but improvements up to 5–10% have been reported.

These findings align with this study's chosen fiber percentages (0%,2%,3%,5%,10% by volume).

2.6 Applications of FRC in Structural Elements:

- Pavements and Industrial Floors
- Tunnel Linings & Shotcrete
- Precast Elements
- Earthquake-Resistant Construction
- Repair & Rehabilitation

2.7 Summary of Research Gaps

From the reviewed literature:

- Most studies focus on steel fibers; research on synthetic fibers in high percentages is limited.
- Effects of synthetic fibers on compressive strength vary between studies.
- Limited data is available for mixes in 1:1.5:3 ratio using local materials.
- Few studies evaluate the practical optimum fiber content for both strength and workability.

This thesis attempts to fill these gaps by testing 0%,2%,3%,5% and 10% synthetic fiber content in a controlled experimental setup.

CHAPTER 3

Methodology

3.1 Introduction

This chapter describes the experimental procedures followed in this research, including material selection, mix design, preparation of test specimens, curing process, and testing methods. Standards such as ASTM and BNBC were followed to ensure accuracy and reliability of results. The purpose of this methodology is to investigate the influence of synthetic fibers on the compressive strength of concrete.

3.2 Materials Used

Cement:

- Ordinary Portland Cement (OPC), conforming to ASTM C150 Type I**.**
- Fresh and free from lumps. Specific gravity considered as 3.15.

Fine Aggregate (Sand):

- Clean, well-graded natural sand.
- Conforming to ASTM C33 requirements.
- Specific gravity ~ 2.60.
- Free from silt and organic impurities.

Table 3.1. Sieve Analysis of Fine Aggregate

Sieve size (mm)	Weight retained (g)	Retained	Cumulative % Retained	% Passing
4.75 mm	66	66	6.60	93.40
2.36 mm	130	196	19.60	80.40
1.18 mm	240	436	43.60	54.40
600µ mm	110	546	54.60	44.40
300µ mm	244	790	79.00	20.00
150µ mm	110	900	90.00	9.00
75µ mm	72	972		
Total	972 gm	99.98%	∑F=293.40	

Fineness modulus of fine aggregate = (∑F/100)

= (293.40/100)

= 2.93

Coarse Aggregate:

- Crushed stone aggregate, maximum size 20 mm.
- Conforming to ASTM C33**.**
- Specific gravity ~ 2.70.
- Clean and dry.

Table 3.2. Sieve Analysis Coarse Aggregate

Sieve size (mm)	Weight retained (g)	% Retained	Cumulative % Retained	% Passing
25 mm	0	0.00	00	100
20 mm	355.4	5.92	5.92	94.08
16 mm	1085.65	18.09	24.01	75.99
12.5 mm	1805.29	30.08	54.09	45.91
10 mm	1615.14	26.92	81.01	18.99
4.75 mm	1138.51	18.97	99.98	0.02
Total	5999 gm	99.98%	∑C=265.01	

Gradation of coarse aggregate = (∑C+500)/100

= {(265.01+500)/100}

= 7.65

Water:

- Potable water, free from oils, acids, and salts.
- Conforming to ASTM C1602**.**

Synthetic Fibers:

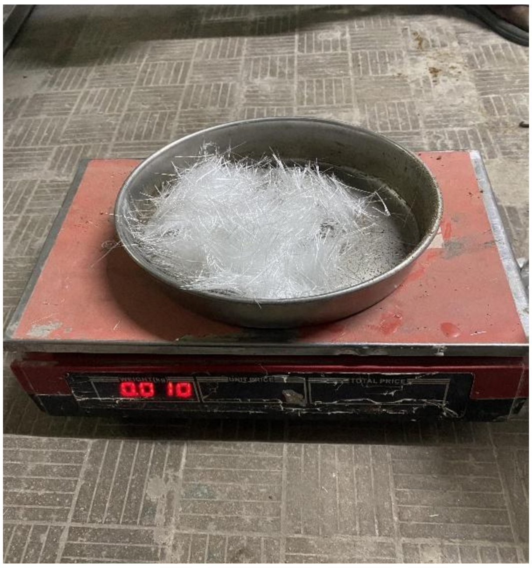
- Commercial-grade synthetic polymer fibers.
- Length: 20–25 mm (approx.).
- Volume fractions used in the mix: 0% (control),2%,3%,5% and 10%**.**
- Selected for high flexibility, corrosion resistance, and improved crack control.

3.3 Mix Design

A conventional mix proportion of 1 : 1.5 : 3 (cement : sand : coarse aggregate) was selected. Water–cement ratio was fixed at 0.45 for all mixes to maintain consistency.

Table 3.3. Proportion of mix design.

Mix Type(Per Set)	Fiber Content	Cement (kg)	Sand (kg)	Coarse Aggregate (kg)	Water (L)	Fiber (gm)
Mix 1	0% Synthetic fiber	1.914	3.6	7.488	0.861	0
Mix 2	2% Synthetic fiber	1.876	3.518	7.317	0.844	12
Mix 3	3% Synthetic fiber	1.859	3.486	7.250	0.836	18
Mix 4	5% Synthetic fiber	1.825	3.422	7.119	0.821	30
Mix 5	10% Synthetic fiber	1.72	3.231	6.722	0.774	60



3.4 Specimen Preparation:

Mold Specification:

- Cylindrical molds of 100 mm diameter × 200 mm height**.**
- Interior surfaces oiled before filling.

Mixing Procedure:

Mixing was performed using a mechanical mixer in the following sequence:

1. Dry mix coarse aggregate and sand for 1–2 minutes.
2. Add cement and mix for an additional 1 minute.
3. Add 75% of water and continue mixing.
4. Add synthetic fibers gradually to ensure uniform distribution.
5. Add remaining water and mix until a homogeneous mixture is achieved.

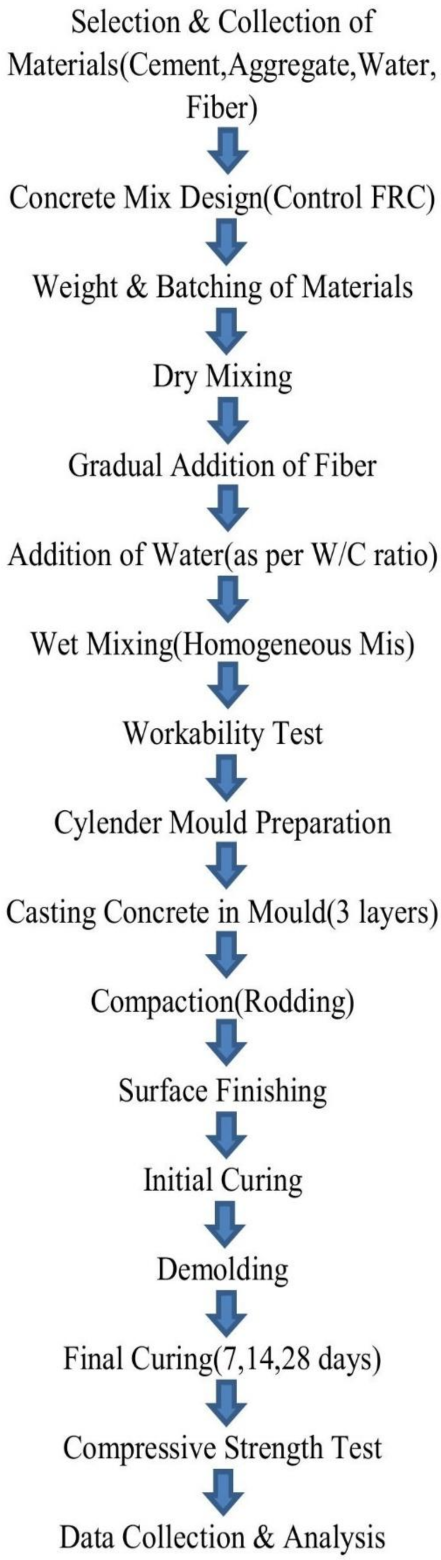
Casting Procedure:

- Fresh concrete was placed in three equal layers inside the cylinder molds.
- Each layer was compacted using a tamping rod (ASTM C31).
- Top surface was finished smoothly with a trowel.

Curing of Specimens:

- Specimens were kept in molds for the first 24 hours**.**
- After demolding, they were submerged in a water tank for curing.
- Two curing durations were followed:
    - 7 days (early strength)
    - 28 days (standard strength)
- Temperature maintained according to ASTM C511 curing room conditions.

3.5 Figure 3.1. Follow Diagram



3.6 Methodology Overview

This study follows an experimental methodology to evaluate the mechanical and structural performance of Fiber Reinforced Concrete (FRC). The process begins with the selection of materials including cement, fine and coarse aggregates, water, and fibers. Mix designs for both conventional concrete and fiber-reinforced concrete were prepared based on ASTM standards.

Specimens were cast for compressive strength, split tensile strength, and flexural strength testing. Standard procedures were used for batching, mixing, compaction, and curing. After curing, all samples were tested using calibrated laboratory equipment to measure the effects of fiber dosage on mechanical behavior.

This methodology ensures systematic evaluation of FRC performance and supports reliable comparison with conventional concrete.

3.7 Summary

This research followed an experimental approach to evaluate the performance of Fiber Reinforced Concrete (FRC). Materials including cement, aggregates, water, and fibers were selected according to ASTM standards. Concrete mix designs were prepared for both conventional and fiber-reinforced concrete.

Specimens were cast for compressive strength, split tensile strength, and flexural strength tests. All samples were mixed, compacted, and cured using standard laboratory procedures. After the curing period, mechanical tests were conducted to examine the influence of fiber dosage on strength and crack resistance.

CHAPTER 4

Results and Discussion

4.1 Introduction

This chapter presents the experimental results obtained from the compressive strength tests of concrete cylinders prepared with 0%,2%,3%,5% and 10% synthetic fiber**.** The results include 7-day and 28-day compressive strengths,comparison between mixes, and discussion of the effect of fiber content on mechanical performance and failure modes. Graphs and tables are described clearly for thesis formatting.

4.2 Specific Aim

The specific aim of this study is to evaluate the mechanical and structural performance of Fiber Reinforced Concrete (FRC) compared to conventional concrete. The focus is to determine how different fiber dosages influence compressive strength, tensile strength, flexural strength, and crack resistance, as well as to assess potential material savings and cost efficiency in column sections. The results are analyzed to understand the effectiveness of fibers in enhancing concrete performance and to provide practical recommendations for structural applications**.**

4.3 Graphical Representation of Strength Results

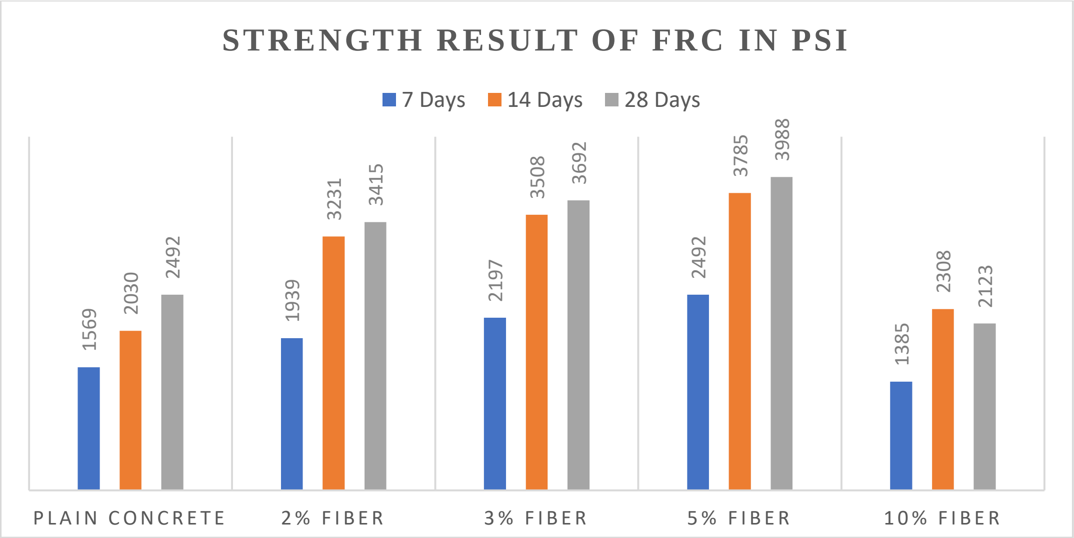


Figure 4.1. Overall strength result of FRC.

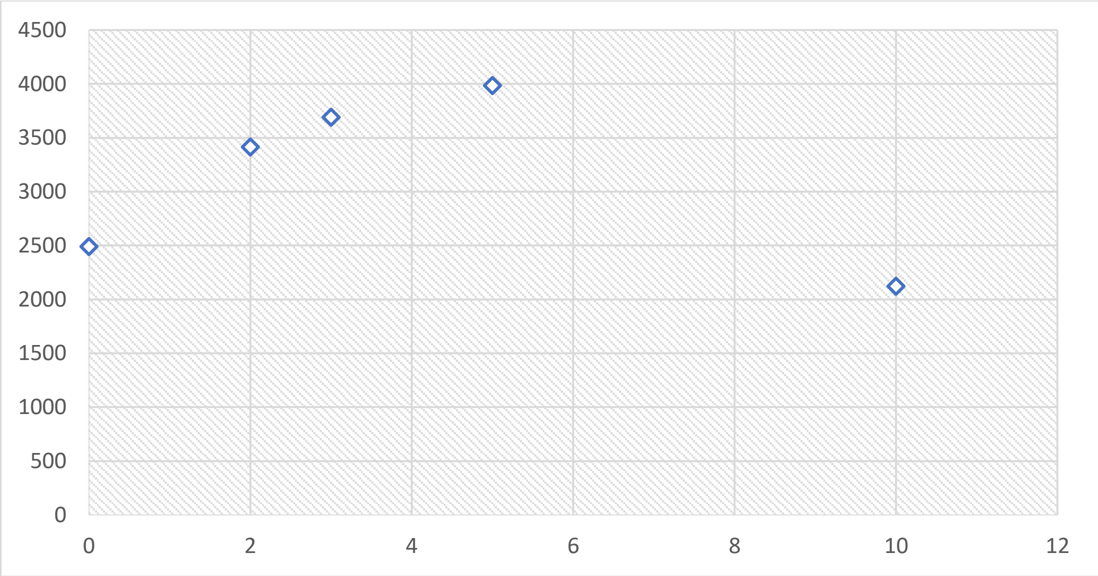


Figure 4.2. Variation of Compressive Strength with Fiber Content

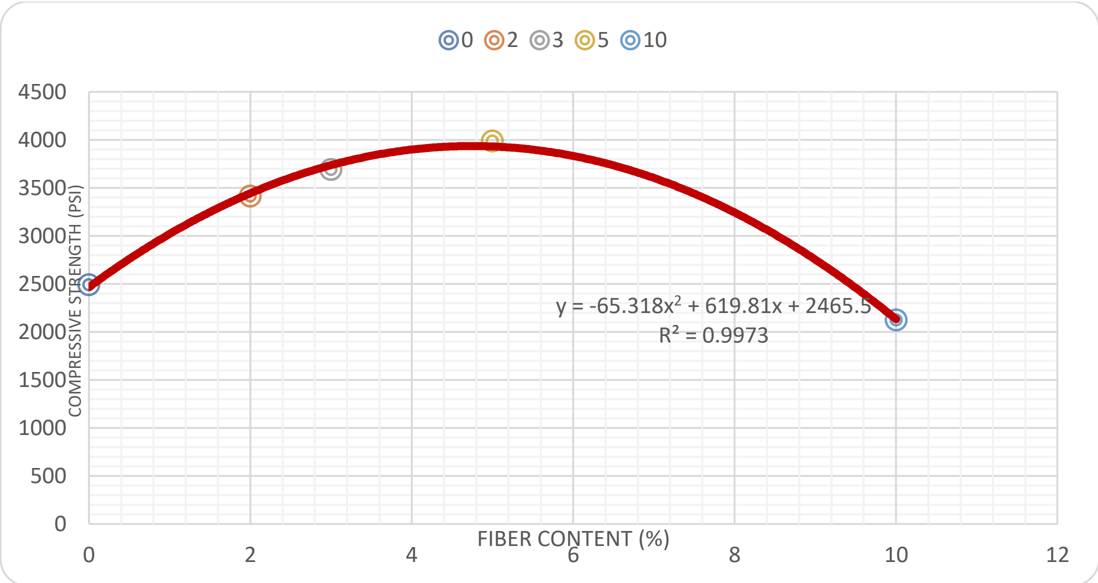


Figure 4.3. Parabolic Regression Curve for Optimum Fiber Content (28 Days)

Optimum Fiber Content ≈ 4.74%

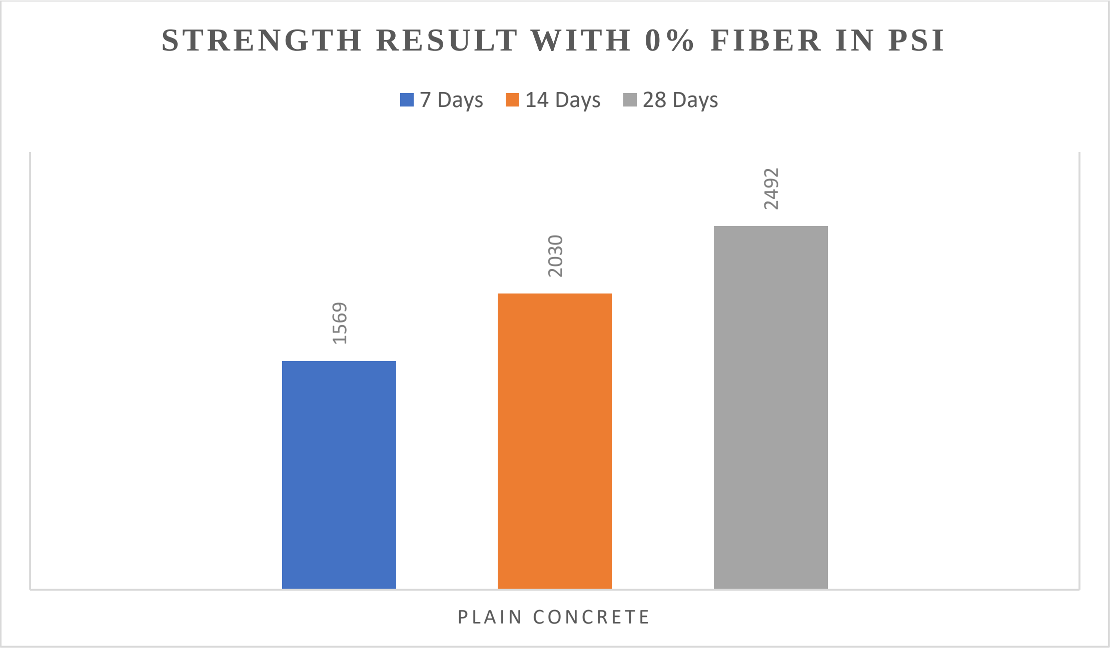


Figure 4.4. Strength result with 0% fiber.

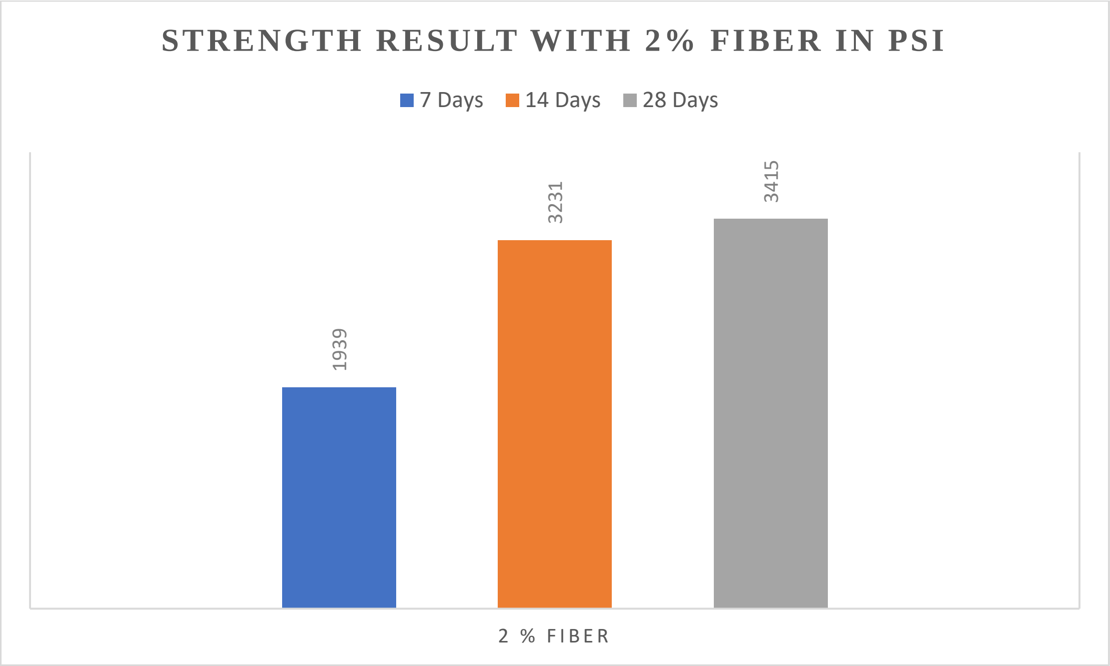


Figure 4.5. Strength result with 2% fiber.

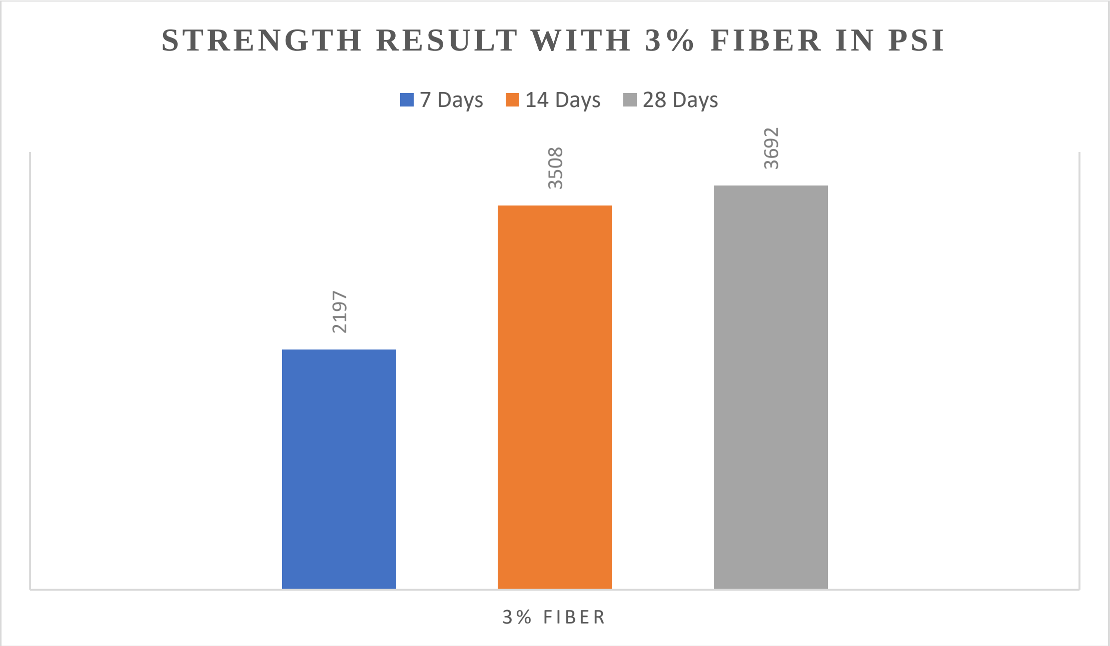


Figure 4.6. Strength result with 3% fiber.

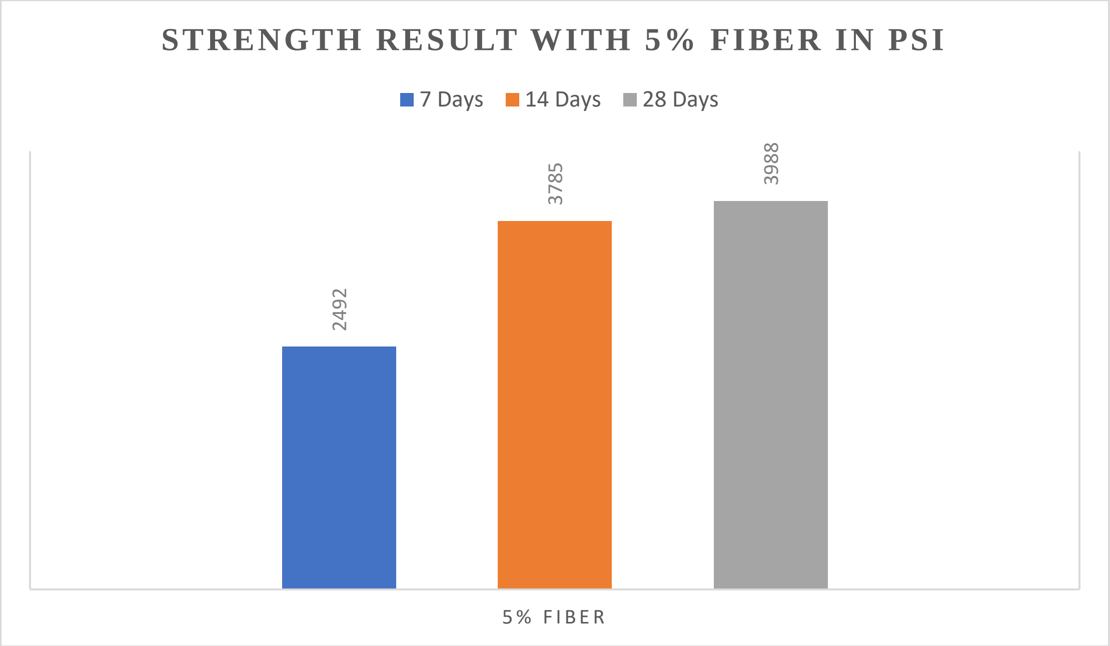


Figure 4.7. Strength result with 5% fiber.

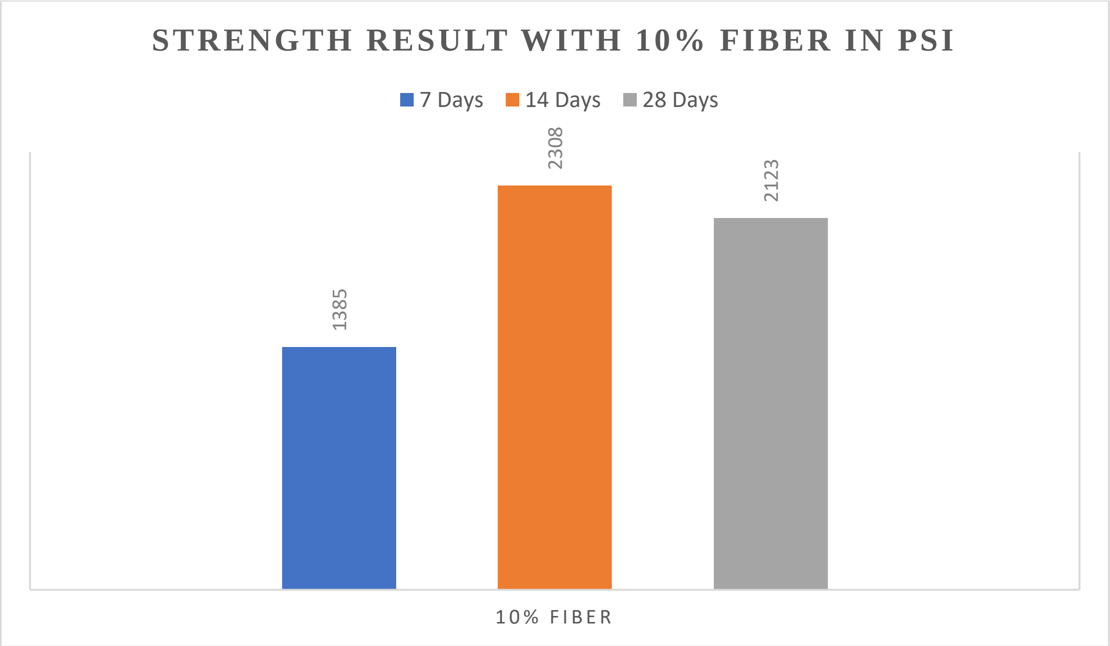


Figure 4.8. Strength result with 10% fiber.

CHAPTER 5

Conclusions and Future Works

5.1 Conclusions

This chapter presents the overall conclusions of the study on Fiber Reinforced Concrete (FRC) using synthetic fibers at different percentages (0%, 5%, and 10%). The major findings, engineering implications, and suggestions for future research are summarized based on the experimental results, discussions, and literature review presented in earlier chapters.

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5.2 Limitations and Recommendations for Future Works

Based on the study findings, the following recommendations are made for construction practice and future research.

5.3 Recommendations for Practice

1. Optimum Fiber Percentage
   - 5% synthetic fiber is recommended as the optimum dosage for general construction where strength and workability are both required.
2. Mixing and Handling
   - Fibers should be added gradually during mixing to prevent clumping.
   - Additional vibration may be required for mixes with high fiber content.
3. Applications Suitable for FRC
   - Pavements, tunnels, shotcrete works, precast products, slabs-on-grade, and seismic-resistant structures.
   - For structures requiring high impact resistance or fatigue resistance, higher fiber content (up to 10%) may be beneficial.
4. Curing Conditions
   - Adequate curing (minimum 7–28 days) is necessary for desirable strength development.

5.4 Recommendations for Future Research

To expand the scope of this study, the following areas are suggested:

1. Testing additional mechanical properties**,** such as:
   - Flexural strength
   - Split tensile strength

- Impact resistance
- Modulus of elasticity

2. Using different fiber types, such as steel, glass, natural fibers, or hybrid fiber systems.
3. Exploring various mix ratios and supplementary cementitious materials (e.g., fly ash, slag, silica fume).
4. Conducting microstructural analysis using:
    - Scanning Electron Microscopy (SEM)
    - X-ray diffraction
    - Image analysis for fiber distribution
5. Full-scale structural testing on beams, slabs, columns, and pavement panels.
6. Life-cycle assessment (LCA) to evaluate environmental impact and sustainability performance.

5.5 Final Remarks

This study demonstrates that synthetic fiber-reinforced concrete offers significant improvements in crack resistance and long-term durability. The 5% fiber mix showed optimal performance for strength, while the 10% mix exhibited maximum toughness. Fiber Reinforced Concrete is a promising material for future sustainable construction, and continued research will further expand its applications and benefits.

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Standard Code/Refferences	Description	Key Requirements	Measurements Used in This Study
ASTM C150	BNBC 2020-Part 6(Chapter-5-5.2.1.1)Standard Specification for Portland Cement	Initial setting ≥ 45 min. 28-day cement strength ≥ 28 MPa	OPC Type I used.
ASTM C33	"BUILDING DESIGN AND CONSTRUCTIO HANDBOOK" 6TH EDITION Federicks,Merritt & Jonathan T,Rickets 4.11. Normal weight aggregates for concrete	Fine Aggregate FM = 2.3–3.1 Aggregate passing through No.4 sieve to No.200 sieve.	Coarse aggregate size ¾" to No.4 sieve.
BNBC 2020	BNBC 2020-Part 6(Chapter-5-5.2.3.3-b)Making Cylindrical Specimens	Cylinder size: 100×200 mm.	Mold: 100×200 mm. Three layers, 25 strokes each Demolded after 24 hrs.
ASTM C39	Compressive Strength Test	Cylinder area = 7854 mm²	Test capacity: >2000 kN.
ASTM C470	Molds for Concrete Cylinders	Non-absorbent interior.	Steel molds Lightly oiled before casting.
ASTM C511	Curing Rooms & Water Tanks	Water tank cured.	All specimens water-cured for 7,14 & 28 days
BNBC 2020	Bangladesh National Building Code	w/c ratio ≤ 0.55. Minimum curing 7–10 days • Aggregates per ASTM C33	w/c ratio = 0.45 Cured for 7 & 28 days Aggregates per ASTM C33

APPENDIX