SUSTAINABLE POTENTIAL OF RECYCLED TEXTILE COTTON FIBER REINFORCED CONCRETE BEAM

Submitted by

Jagodish Nandi

Student ID: 211-47-1172

Muzahid Matubber

Student ID: 211-47-1174

Md. Mirazul Islam

Student ID: 211-47-436

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The thesis titled "**Sustainable Potential Of Recycle Textile Cotton Fiber Reinforced Concrete Beams**" submitted by Jagodish Nandi, Muzahid Matubber, Md. Mirazul Islam, student ID: 211-47- 1172, 211-47-1174, 211-47-436, has been accepted as satisfactory in partial fulfilment of the requirement for the degree of Bachelor of Science in Civil Engineering on 20th November 2024.

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Md. Asaduzzaman Naeem

Lecturer

Department of Civil Engineering

Daffodil International University

Jagodish

Muzahid

Mirazul

Jagodish Nandi	Muzahid Matubber	Md. Mirazul Islam
211-47-1172	211-47-1174	211-47-436

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DEDICATION

This thesis is dedicated to all of our parents, relatives, and teachers who inspired us to make this effort possible.

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ABSTRACT

The construction industry significantly contributes to environmental degradation due to its high consumption of natural resources and waste production. To address these challenges, a growing interest is in developing sustainable construction materials that can reduce the industry's environmental footprint. This study explores the sustainable potential of recycled textile cotton fiber as a reinforcement material in concrete beams. Recycled cotton fibers, derived from textile waste, offer an eco-friendly substitute to conventional reinforcement materials, providing both waste management solutions and enhanced material properties.

Consider how much the beam deflection and load are reduced or increased when replaced with steel-reinforced beams and consider where the textile reinforcement can be used. A comparison of flexural behavior is made between reinforcement concrete beams and textile-reinforced concrete beams. Two different beams were constructed for comparison with reinforcement concrete beams.

The research investigates the mechanical properties, durability, and environmental impact of recycled cotton fiber-reinforced concrete (RCFRC) beams through a series of experimental tests. Results indicate that incorporating recycled textile cotton fiber reinforced concrete beams can't be better than reinforced concrete beams the tensile strength, flexibility, and crack resistance of concrete beams while reducing the carbon footprint associated with traditional concrete production. Additionally, the use of recycled fibers aligns with circular economy principles, promoting resource efficiency and waste reduction. The reason for the research was to compare steel reinforcement concrete beams and what steel can be.

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CHAPTER ONE

INTRODUCTION

1.1 General

The recycled cotton rope symbolises sustainable innovation and a crucial aspect of our world. It is woven into various sectors, such as maritime, fashion, and interior design, and serves as a sustainable alternative for mooring and rigging. The textile industry, a major consumer of cotton, is one of the largest contributors to environmental pollution. The textile industry generates significant waste, much of which ends up in landfills. Utilising recycled cotton fibers in concrete helps mitigate this issue by providing a valuable use for waste materials. By shifting our focus to recycled cotton rope, it can uncover the potential for significant reductions in water usage, energy consumption, and waste generation. This is not just about environmental stewardship but also a question of survival, ensuring that our planet remains a place where life can thrive. Considering how the type of fabric affects the response, many studies have focused on carbon fibers because of their availability (Valeri et al., 2020).

Recycled Textile Cotton Fiber Reinforced Concrete (RTCFRC) applications have not yet been widely used. This is primarily due to RTCFRC's lack of design guidelines. Significant efforts have been undertaken in recent years, particularly within the framework of two German collaborative research institutes, to create models that describe the load-bearing behavior of Textile Reinforced Concrete and to offer the necessary design criteria. To learn more about load-bearing behavior and to provide clear design methods, experimental research on Textile Reinforced Concrete members is being carried out.

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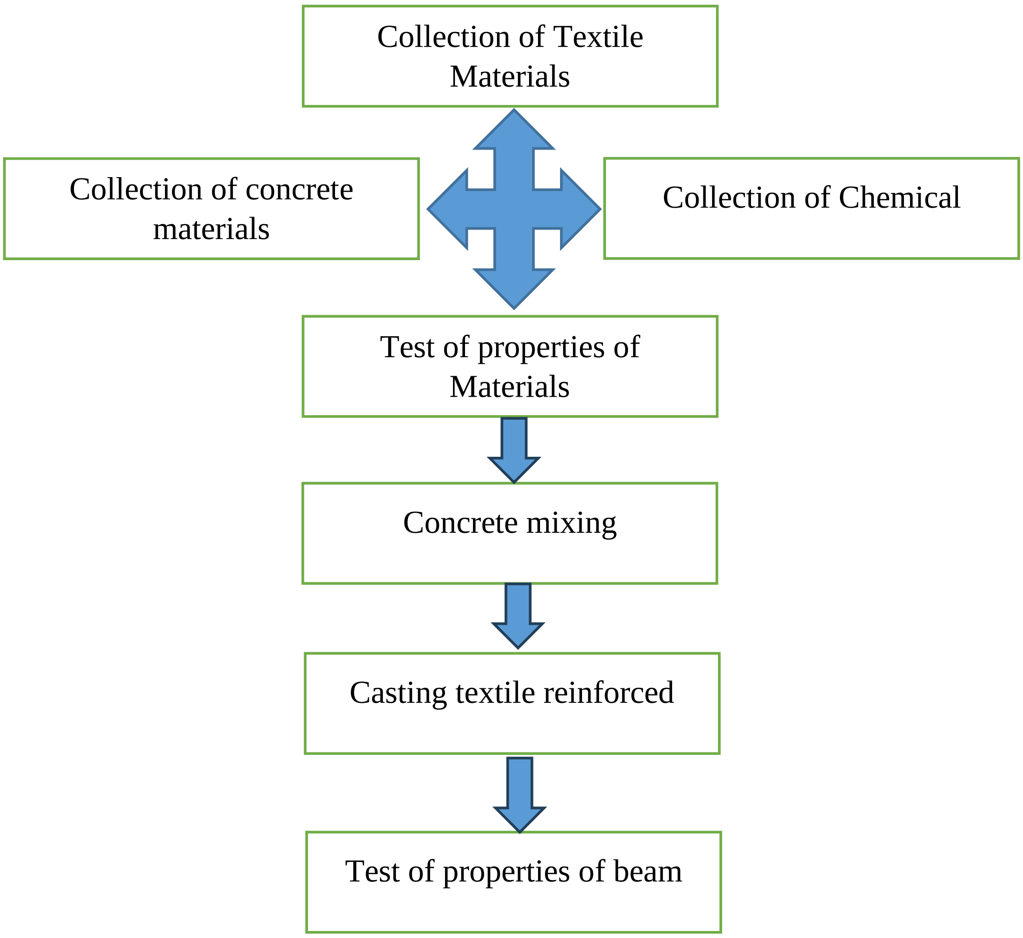
1.2 Working flow chart



1.3 Principal of planning

1.3.1 Principles of planning details:

Flexibility: The beam should be planned with future requirements in mind.

Environmentally friendly: The Beam design should be environmentally friendly and helpful to the environment.

1.3.2 Future requirement:

To make the beam lightweight. To make the beam thin and strong at the same time. The textile materials should be chemical-free so that it does not harm the structure. To use the textile materials to replace the steel bar which gets corroded over time. To make an opportunity to overcome the steel bar problems.

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1.3.3 Orientation:

The placement of the beam should make the inner and outer look of the structure good. The beam can be shapeable to the requirements of the buildings. To make the beam much stronger using different materials.

1.3.4 Prospect:

Beam should be carried load but it also should look good from the outside. It should adapt well to the column and other members of the structure.

1.3.5 Aspect:

The main aspect of the RTCFRC is to make an economical and eco-friendly substitute for steel reinforcement.

1.4 Research objectives

The principal aim of this project is to explore the possible use of RTCFRC for future buildings. To meet the overall aim of the project, the following sub-objectives, related to sustainability and flexural behavior, were defined for the preliminary stages:

I. To investigate the sustainable potential of RTCFRC compared to conventional reinforced concrete.
II. To analyze the mechanical properties and structural performance of RTCFRC beams.
III. Cost comparison between normal reinforced concrete and textile reinforced concrete.

1.5 Significance of the study

The findings of this research hold significant implications for the construction industry. By demonstrating the viability of RTCFRC beams, this study aims to contribute to the development of sustainable construction materials that align with global environmental goals. The potential for reducing the carbon footprint, improving resource efficiency, and enhancing the structural performance of concrete structures could lead to a paradigm shift in how infrastructure is designed and built.

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CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Recycled Textile Cotton Fiber Reinforced Concrete (RTCFRC) integrates various types of fibers into conventional concrete to enhance its mechanical properties and sustainability. This review explores recent research findings, expert opinions, methodologies, challenges, and areas for improvement in RTCFRC beams. The research's fundamental aim was to find out if using any textile materials in place of steel reinforcement can take enough tensile force and provide the same resisting ability as steel bars. Therefore, the literature review was to determine the issues and gaps in the available literature to justify the research objectives. In the first part, it studied the materials and their characteristics. The second part discussed the effects and behaviour of the material under pressure. The third part discussed the effects of chemicals on the material pressure for fiber reinforcement concrete beams.

2.2 Types of beams and their classifications

A beam is a structural element that carries vertical loads and transfers the loads horizontally to the columns. It usually stays on one or more supports and transfers the loads to the supports that have been applied to it. According to the number of supports, it can divide them into 5 types:

1. Simply Supported Beam

2. Cantilever beam.

3. Over-hanging beam.

4. Fixed Beam.

5. Continuous beam.

2.2.1 Simply supported beam:

Supported at both ends, typically with one pin and one roller support. The load is transferred directly to the supports. The bending moment is zero at the supports and reaches its maximum between them.

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2.2.2 Cantilever beam:

Fixed at one end and free at the other. Capable of holding loads at the free end. Creates moments and deflections that are resisted by the fixed support.

2.2.3 Over-hanging beam:

A beam that extends beyond one or both of its supports. Combines characteristics of simply supported and cantilever beams. Common in structures where part of the beam extends beyond a wall or column.

2.2.4 Fixed beam:

Both ends of the beam are fixed, restricting movement and rotation. Capable of bearing higher moments than simply supported beams. Common in rigid frame construction, where stability and minimal deflection are important.

2.2.5. Continuous beam:

Spans across three or more supports. More efficient than simply supported beams for long spans. Distributes loads more evenly, resulting in reduced bending moments and deflections.

The beam itself carries all the loads of a concrete structure and transfers them to the column. I carry loads and shear loads. Usually, the loads work at the center of the member, creating a tensile zone at the bottom. Cement is venerable to tensile strength. Use steel bar bars to carry the tensile force. But the problem is that the steel bar is very costly and makes the structure load extra load that's why the design of the structure gets thicker. Use textile materials at the tensile zone so that they will carry the tensile load. This goal is to make an economic and environment-friendly alternative to steel bars out of textile materials.

2.3 Previous sustainable potential of RTCFRC

In a study by Nguyen & Ngo, they tested Textile Reinforced Concrete (TRC) with Reinforced Concrete (RC) beams. Their goal was to evaluate how well TRC could strengthen RC beams in terms of both flexure (bending) and shear (resistance to sliding). The results were promising—TRC significantly improved the beams' ability to tolerate loads in both areas. The bond between the textile fibers and the concrete was strong enough to safely transfer the load.

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However, not all textile materials performed equally well. Some fabrics were found to be unsuitable for use in TRC due to their weaker performance in certain conditions. (Nguyen & Ngo, 2020).

A recent test showed that not all textile materials are suitable for Textile Reinforced Concrete (TRC). The experiment focused on multifilament yarns, examining how these fibers behave under different levels of stress. The results revealed that these yarns are not ideal for use in concrete, as they don't hold up well under the conditions required for TRC. (U. Häussler-Combe & F. Jesse & M. Curbach, 2000).

Researchers tested textile-reinforced concrete to determine its ability to handle both standard and shearing loads. They gathered data from multiple tests on different bonding methods to ensure accuracy. Interestingly, using concrete with textile reinforcement can enhance its performance, potentially making it a more effective material. On a different note, achieving success in any goal—whether it's weight loss or otherwise—requires determination and the right approach. Success, in this sense, can often lead to positive changes, like losing weight. (BrückNer et al., 2006).

This study provides valuable insights into how composite TRC (textile-reinforced concrete) and concrete structural elements behave, which can help guide future large-scale testing. For beam-like structures, using polymer-coated textiles and increasing the amount of textile reinforcement led to greater load-bearing capacity and flexibility. Interestingly, the roughness of the interface between TRC and concrete didn't seem to have a significant effect, based on the limited data collected.

In TRC formwork elements, the textiles can even replace traditional steel reinforcement bars, offering potential weight savings. The strain profile model developed in this research shows promise in accurately predicting the ultimate bending strength of composite TRC/concrete beams. When used as formwork for columns, TRC offers an exciting possibility—though construction practices will need to address potential buckling in the TRC shells. (Papanicolaou & Papantoniou, 2010).s

To help reduce CO_2 emissions and energy consumption, one effective approach is to use more sustainable materials that come from renewable resources or recycled materials. By incorporating re-cycling and reusing processes, it can significantly impact our environment. (Nautiyal et al., 2015).

Fiber-reinforced mortars have become increasingly popular in many areas of construction, including façade panels, roofing, raised floors, and masonry structures. (Ardanuy, Claramunt and Toledo Filho, 2015). These composite materials combine different types of fibers—such as steel, glass, or polymers—with a cement-based mixture like cement paste, lime binder, mortar, or concrete. The fibers play a crucial role by holding the material together when cracks form, improving its toughness and

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ability to absorb energy. (Pacheco-Torgal and Jalali, 2011). They also help the material perform better after cracking, making it more durable and resilient. (Lerch et al., 2018).

This study explores how waste microfibers, which are generated during fabric finishing, can potentially be recycled and used in cement-based products. The focus is on understanding how these microfibers affect the strength, workability, and heat resistance of the cement mixtures. (Aziz and Ansell, 2004). Specifically, the research looks at how fiber-reinforced cement (FRC) materials, which have been developed and improved over the years, are impacted by adding these recycled microfibers. (Shah and Rangan, 1971).

Fibers play a crucial role in enhancing concrete's performance, especially after cracks start to form. By adding fibers, the concrete becomes less brittle, making it more resistant to breaking apart. These fibers help the material absorb stress and prevent cracks from spreading. (Andersons et al., 2006). When fibers are used in amounts greater than 2%, they significantly improve the concrete's ability to handle bending, tension, and shear forces, making the overall structure much stronger and more durable. (Marchetti and Cutolo, 1991).

Traditionally, materials like steel, polypropylene, aramid, and glass have been the go-to choices for fibers. However, in recent years, there has been growing interest in exploring natural alternatives, especially hemp and cotton. (Bledzki and Gassan, 1999). Textile fibers share a similar structure with natural fibers, which opens up the possibility of using them in the production of Fiber Reinforced Concrete (FRC) composites. By incorporating textile fibers, improvements in mechanical properties, especially in flexural modulus and breaking strength, can be expected. (Sgriccia et al., 2008).

In this study, 4 different beams are made. The beam was intended to replace steel with textile reinforcement. Loads and deflections are compared with 2-12 mm diameter beams. Discuss how much and where recycled textile cotton fiber reinforcement can be used for 2-12 mm and 3-12 mm diameter bars, and how much is usable. Coarse aggregate, fine aggregate, cement reinforcement, and water are used as materials for making the beam. As a fine aggregate, selected sand with an FM of 1.6.and as a coarse aggregate, selected stone with a unit weight of 1680 kg/m^3. The coarse aggregate has an absorption of 0.5 percent and a bulk dry specific gravity of 2.68 and Reinforcement is replaced by textile cotton fibers, selected Textile cotton fibers with an Elongation Length of 75.67 mm as a Textile Cotton Reinforcement.

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CHAPTER THREE

MATERIALS AND METHODOLOGY

3.1 Material

This work used fine aggregate, coarse aggregate, cement, reinforced steel, and reinforced cotton fiber. The design of the concrete mix followed the ACI-M15 standards for conducting compressive strength tests. According to the mix ratio consists of 1 part Portland cement, 2 parts fine aggregate, 4 parts coarse aggregate, and 0.5 parts water. It maintains the water-cement ratio at 0.5 to achieve a compressive strength of 15 MPa after 28 days. The steel reinforcing bars used in the study were ASTM A615 Grade 60. The standard cylindrical molds used for casting the concrete specimens had a diameter of 101.6 mm and a height of 203.2 mm. There are some chemicals Sodium chloride (NaCl), Magnesium sulfate ($MgSO_4$), calcium carbonate ($CaCO_3$), and Sulfuric acid (H_2SO_4) used this test. All materials used in the study were sourced from reliable suppliers and were tested for quality and conformity with the relevant standards.

3.1.1 Fine aggregate:

Fine aggregate refers to small-sized particles used in construction, such as sand or crushed stone, that pass through a 4.75 mm sieve. It's a key component in concrete, providing volume, strength, and workability. Fine aggregate fills voids between coarse aggregates, enhancing the overall strength and durability of the concrete mix.

As a fine aggregate, selected sand with an FM of 1.6.

Figure 1: Fine aggregate

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Figure 2: Fiennes modulus for fine aggregate

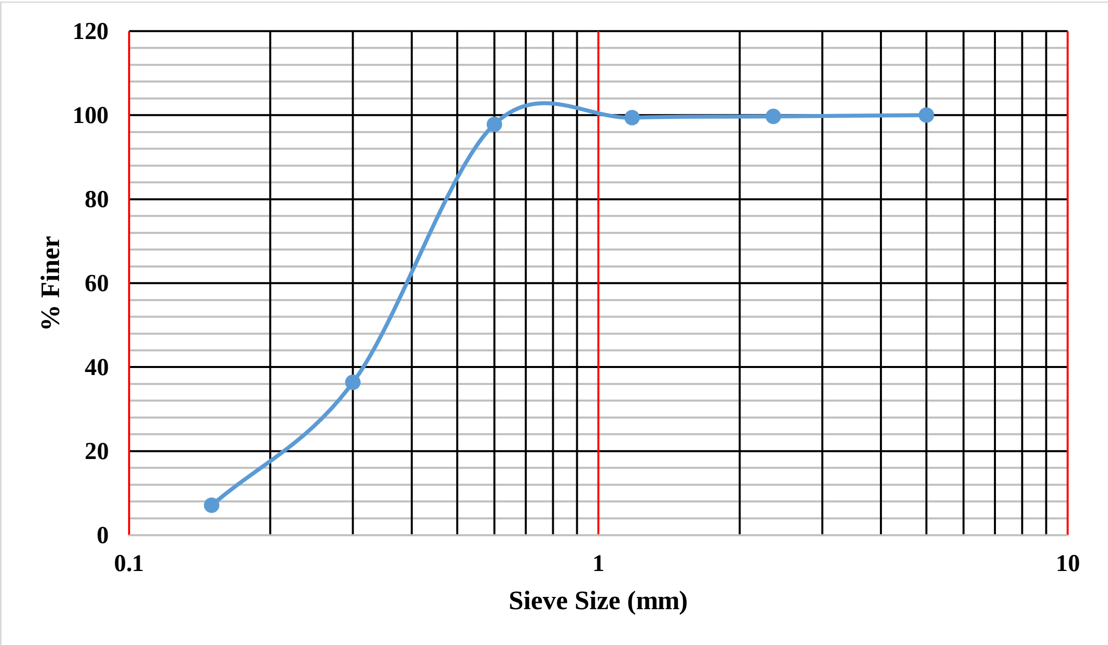

Figure 3: Sieve analysis for fine aggregate

3.1.2 Coarse aggregate:

Coarse aggregate consists of larger, naturally occurring or crushed stones, gravel, or other materials that are retained on a 4.75 mm sieve. It forms the bulk of the concrete mix and contributes significantly to its strength, durability, and structural integrity. As a coarse aggregate, selected stone with a unit weight of 1680 kg/m^3. The coarse aggregate has an absorption of 0.5 percent and a bulk dry specific gravity of 2.68.

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Figure 4: Coarse aggregate

Figure 5: Fiennes modulus for coarse aggregate

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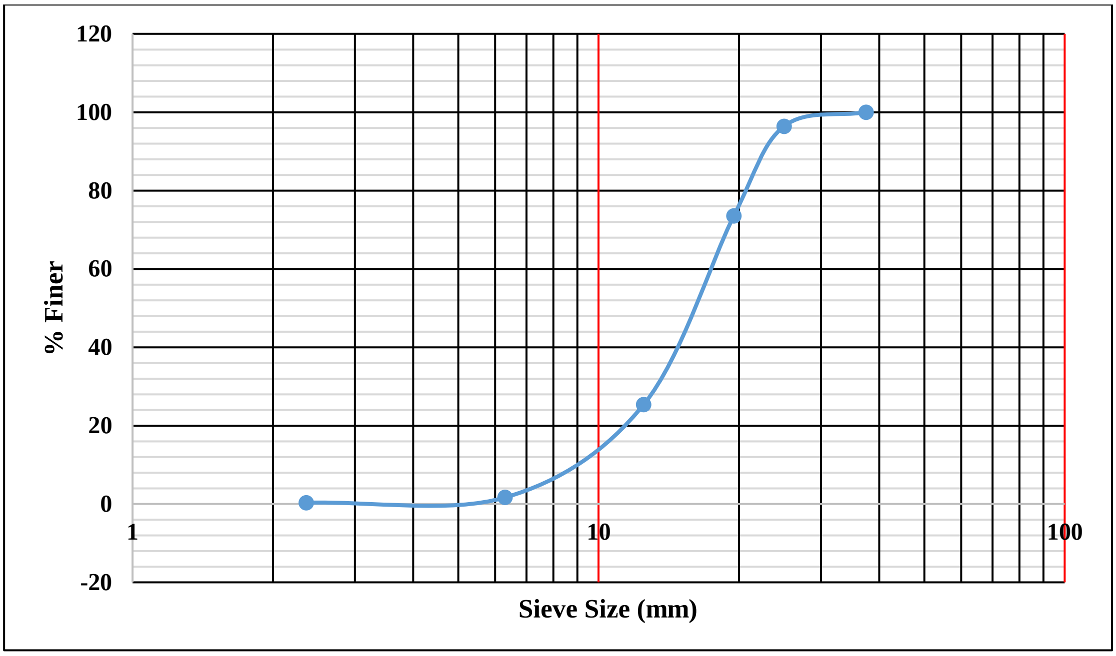

Figure 6: Sieve analysis for coarse aggregate

3.1.3 Concrete:

Coarse aggregates such as gravel, stone chips, and fine aggregates such as sand or gravel, binders such as cement or lime are mixed together with water and are called concrete. This type of concrete has high compressive strength. So, it is used where concrete has to withstand high pressure.

The details of mixtures of conventional concrete of class M15 used for all types of textiles reinforced are describe

Table 1: Quantity of materials (per Beam)

Component	kg/m^3
Cement	5.5
Sand	12.375
Stone	28.05
Water	2.75

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Table 2: Concrete compressive test for 28 days

Cylinder	Target Strength (MPa)	Test Strength (MPa)
1	15	16
2	15	17
3	15	15

Figure 7: Dry concrete mix

Figure 8: Manual mixing of concrete

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Figure 9: Wet concrete mix

Figure 10: Setup of compressive strength test for slender

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3.1.4 Reinforcement:

Selected Textile Cotton Fibers are made from a combination of natural fibers such as cotton or jute. Cotton yarn ropes are made from natural fibers, which are soft, flexible, and biodegradable. They are known for their gentle texture and are less abrasive on the hands compared to synthetic ropes. However, this also makes cotton a preferred material for certain applications like pet toys, hammocks, or decorative knot-tying where breathability and flexibility are essential. This particular rope appears to have a medium thickness. While cotton ropes are generally less strong compared to nylon or polyester, their thickness helps determine their suitability for certain loads or functions. The softness of cotton ropes makes them ideal for creating comfortable hammocks. However, cotton's absorbency means it should be kept dry to avoid rotting. While not as strong as nylon, cotton ropes are sometimes used for light outdoor tasks such as securing tents, hanging tarps, or making knots for general-purpose utility.

Figure 11: Textile cotton reinforcement

Figure 12: Setup for tensile test of textile reinforcement

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3.2 Chemical

A chemical test of a beam typically evaluates how the concrete, reinforcements, and other materials in the beam react to various chemicals that could cause deterioration over time. Testing beams with chemicals like sodium chloride, magnesium sulfate, calcium carbonate, and sulfuric acid is critical because these substances represent environmental conditions that concrete beams might face during their lifecycle.

3.2.1 Sodium chloride (NaCl) test:

Sodium chloride, commonly found in de-icing salts and marine environments, can cause chloride-induced corrosion in the reinforcement (typically steel) within the concrete. The test determines the beam's resistance to chloride ingress. Testing the beam's resistance to chloride ingress is critical for ensuring its longevity in environments exposed to saltwater or de-icing salts.

3.2.2 Magnesium sulfate ($MgSO_4$) test:

Magnesium sulfate represents sulfate attack on concrete. This test evaluates how well the beam can resist the chemical reaction between sulfates and the components of the concrete, particularly calcium hydroxide. In areas with high sulfate concentrations in groundwater or soil, it is essential to ensure that beams can withstand sulfate attack, especially for long-term performance.

3.2.3 Calcium carbonate ($CaCO_3$) test:

Calcium carbonate is often involved in the carbonation process, where carbon dioxide from the air reacts with calcium hydroxide in the concrete to form calcium carbonate. This test evaluates the beam's carbonation resistance. Carbonation can be a significant cause of corrosion in reinforced concrete. If the concrete is poorly designed or too permeable, carbonation can reduce its effectiveness as a protective barrier for the reinforcement.

3.2.4 Sulfuric acid (H_2SO_4) test:

Sulfuric acid represents a severe chemical environment, often associated with acid rain or industrial pollution. This test evaluates the beam's resistance to acidic conditions, which can be highly aggressive to concrete. Sulfuric acid reacts with the calcium compounds in concrete to form gypsum, which is highly soluble and can lead to loss of material, surface deterioration, and weakening of the concrete. Acid attack is one of the most aggressive forms of chemical degradation for concrete. In acidic environments, such as near industrial plants or in areas affected by acid rain, this test helps determine how well the beam can resist acid attack and whether any protective measures (e.g., coatings or special admixtures) are necessary.

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The effect of 10% NaCl (by water) on the workability of concrete is that its use reduces workability. A solution was prepared using 10% NaCl in 1 liter of water. (Supit, S. W. M., & Shaikh, F. U. A. 2014).

Similarly, the effect of 10% $MgSO_4$ (by water) on the workability of concrete is that its use also reduces workability, and a solution was prepared using 10% $MgSO_4$ in 1 liter of water. (Oymael, S. 2008).

The effect of 1% $CaCO_3$ (by water) on the workability of concrete is similar, as its use reduces workability. Thus, a solution was prepared using 1% $CaCO_3$ in 1 liter of water. (Supit, S. W. M., & Shaikh, F. U. A. 2014).

Finally, the effect of 2% H_2SO_4 (by water) on the workability of concrete is that its use reduces workability as well. A solution was prepared using 2% H_2SO_4 in 1 liter of water. (S. Naseeruddin, D. Venkateswarlu, A.A. S. Kumar.2019).

The ropes were immersed in each chemical solution for 7 days, 14 days, and 28 days.

Figure 13: Chemical test of cotton

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Figure 14: Chemical solution submerged cotton drying

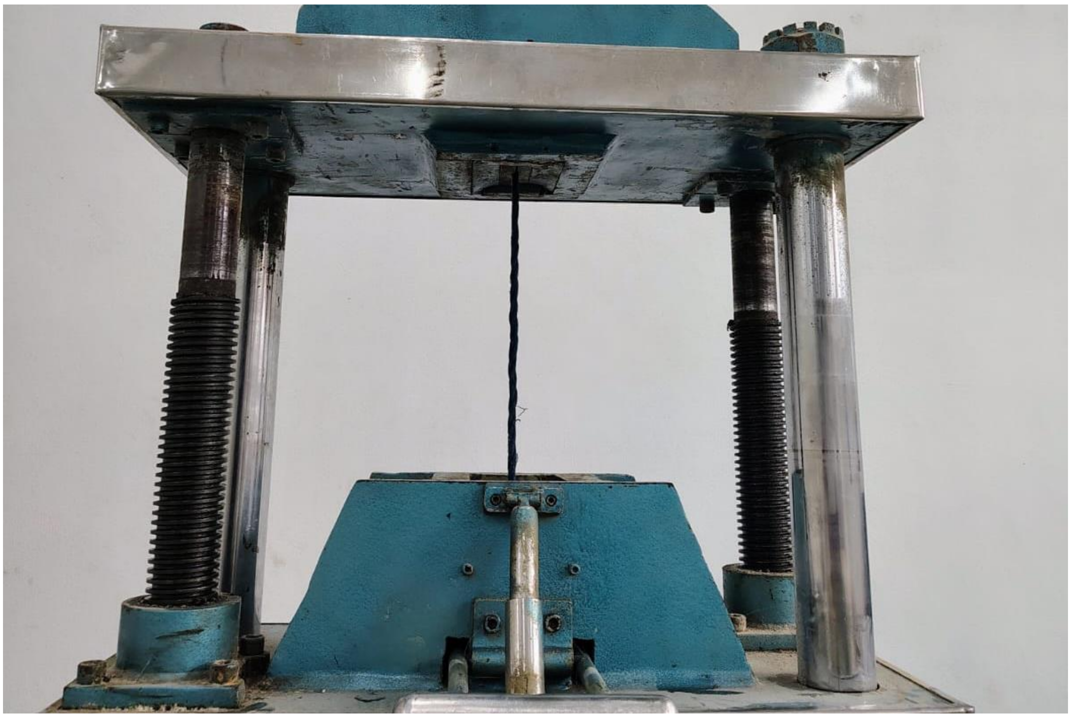

Figure 15: Setup of tensile test for cotton (after submerging in chemical solution) fiber

3.3 Cylinder pull-out test

The Cylinder pull-out test is a type of mechanical test that evaluates the bond strength between reinforcing fibers and the concrete matrix in a fiber-reinforced composite material. Specifically, it involves pulling out a Cylinder (long and narrow) fiber embedded in concrete to measure the force required to extract it. This helps assess the quality of the bond between the fiber and the concrete.

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Bond Strength Evaluation: In fiber-reinforced concrete beams (like those reinforced with recycled cotton fibers), the bond strength between the fibers and the concrete matrix is crucial. This bond influences the overall structural behavior, including how well the fibers transfer stress and prevent crack propagation.

Crack Resistance: A good fiber-concrete bond improves crack resistance, which is critical for the durability and load-carrying capacity of beams. It ensures that fibers help bridge cracks and enhance the beam's ductility.

Load Distribution: Fibers within the concrete work to redistribute load and reduce the likelihood of brittle failure. The slender pull-out test helps quantify how well the fibers will perform in distributing forces.

Durability: Understanding the pull-out behavior helps predict long-term durability. Fibers that bond well with the concrete matrix will contribute to the beam's resistance to wear, shrinkage, and environmental degradation.

Pull-out samples are made in cylinder molds. And some samples are kept in an oven at 200 degrees Celsius for 1 hour and then pull-out test is done. And, some pull-out samples are tested for 28 days by making cylinders from chemically soaked rope.

Figure 16: Setup of pull-out test for specimen

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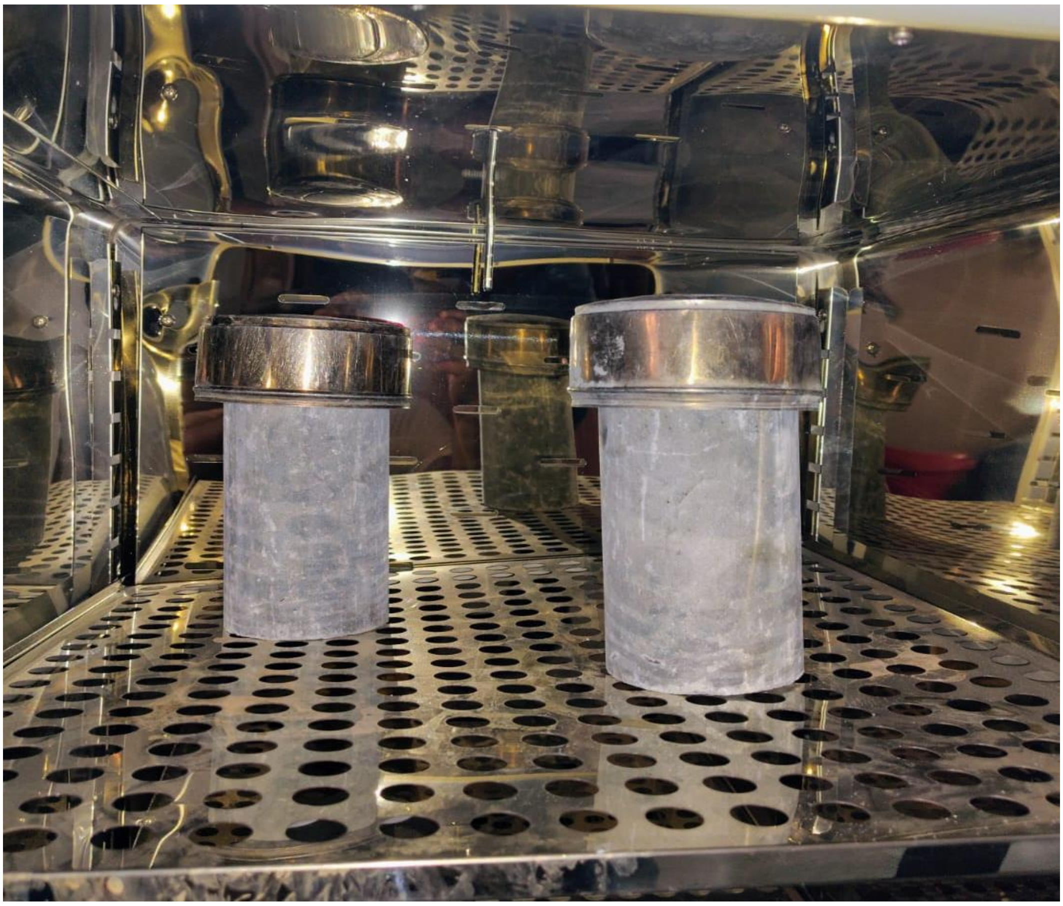

Figure 17: Oven-dry of specimen at 200°C for 1 hour

3.4 Comparison variants

A total of four variants of concrete facade panels were compared:

Type-1. Use Pure concrete

Type-2. Use 2-12 mm dia. bar Steel

Type-3. Use 2-12 mm dia. bar Textile Fibers

Type-4. Use 3-12 mm dia. bar Textile Fibers

3.5 Bending tests of specimens

To estimate the flexural performance of recycled cloth cotton fiber reinforced concrete (RTCFRC) shafts in two distinct circumstances, three- point bending tests were performed on each sample of the two conditions. Rustic formwork with the necessary final confines was used to cast the shafts. Formwork of 25.4 mm thickNess is used. To set the cotton fibers in the formwork, holes are drilled on both sides of the formwork

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and the cotton fibers are taken out from the inside, and the cotton fibers are twisted with grout on the outer side to increase the strength of the cotton fibers has been. Before the ray was horizontally cast as illustrated, the constructed pen underpinning was set into the formwork. After 48 hours, shafts were taken out of the formwork and stored in a sticky chamber until the test day, which was when they were 28 days old. Three- point bending tests in a UTM-universal testing machine hydraulic system with a 1000 kN capacity were carried out to assess the structural strength of the cotton cloth-corroborated concrete. Employed to measure themed-span deviation of the shafts, the trials were driven by relegation at a 1 mm/ min rate. The shafts were set over support breakers that were spaced 762 mm piecemeal. The cargo was applied 381 mm piecemeal from both sides. The breakers used for support and cargo operation have free vertical relegation.

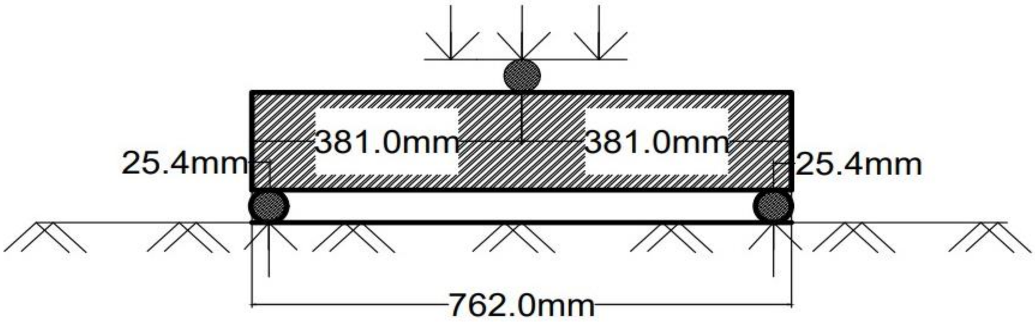

Figure 18: Beam section for test

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Figure 19: Formwork setup

Figure 20: Concrete casting

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Figure 21: Beam two day after casting

Figure 22: Beam curing

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Figure 23: Beams after 28 days of curing

Figure 24: Beam setup for test

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CHAPTER FOUR

RESULT AND DISCUSSION

4.1 Reinforcement test

Selected Textile Cotton Fibers with an Elongation Length of 75.67 mm as a Textile Cotton Reinforcement.

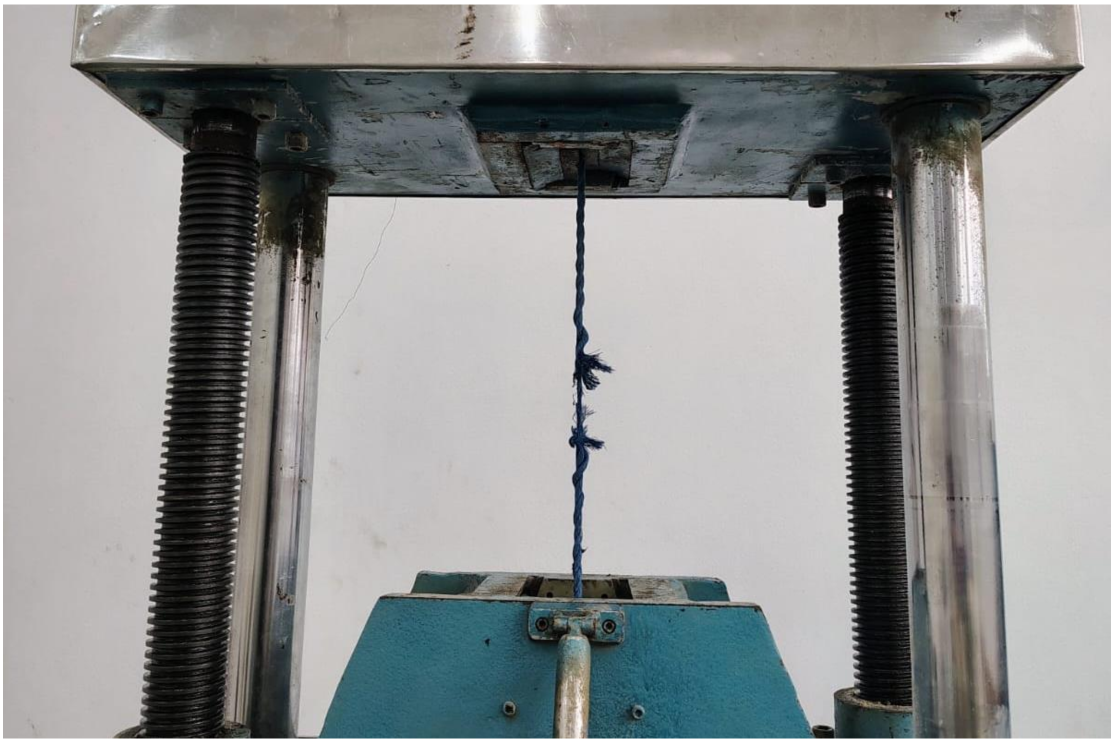

Figure 25: Tensile test of textile reinforcement

4.2 Chemical test

For recycle textile cotton fiber-reinforced concrete beams, chemical tests focus on understanding the interaction between the cotton fibers and the concrete matrix, as well as the durability and chemical stability of the fibers within the concrete. Cotton fibers can degrade in alkaline environments like concrete, affecting the overall performance and durability of the composite material. Here are some chemical tests relevant to beams reinforced with textile cotton fibers:

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4.2.1 Sodium chloride (NaCl):

a) Textile cotton fibers with an elongation length of 153.67 mm after curing in NaCl chemical for 7 days as textile reinforcement.
b) Textile cotton fibers with an elongation length of 127.33 mm after curing in NaCl chemical for 14 days as textile reinforcement.
c) Textile cotton fibers with an elongation length of 158.33 mm after curing in NaCl chemical for 28 days as textile reinforcement.

4.2.2 Magnesium sulfate ($MgSO_4$):

a) Textile cotton fibers with an elongation length of 161.33 mm after curing in $MgSO_4$ chemical for 7 days as textile reinforcement.
b) Textile cotton fibers with an elongation length of 159.67 mm after curing in $MgSO_4$chemical for 14 days as textile reinforcement.
c) Textile cotton fibers with an elongation length of 154 mm after curing in $MgSO_4$chemical for 28 days as textile reinforcement.

4.2.3 Calcium carbonate ($CaCO_3$):

a) Textile cotton fibers with an elongation length of 122.33 mm after curing in $CaCO_3$ chemical for 7 days as textile reinforcement.
b) Textile cotton fibers with an elongation length of 72 mm after curing in $CaCO_3$ chemical for 14 days as textile reinforcement.
c) Textile cotton fibers with an elongation length of 90.00 mm after curing in $CaCO_3$ chemical for 28 days as textile reinforcement.

4.2.4 Sulfuric acid (H_2SO_4):

a) Textile cotton fibers with an elongation length of 45.67 mm after curing in H_2SO_4chemical for 7 days as textile reinforcement.
b) Textile cotton fibers with an elongation length of 24.33 mm after curing in H_2SO_4 chemical for 14 days as textile reinforcement.
c) Textile cotton fibers with an elongation length of 45.67 mm after curing in H_2SO_4 chemical for 28 days as textile reinforcement.

These tests are crucial for understanding the chemical stability, durability, and overall performance of textile cotton fiber-reinforced concrete beams.

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4.2.5 Chemical effect on RTCFR:

Maximum Elongation for 7 days and 14 days is found in $MgSO_4$ Chemical Cotton fibers, and 28 days are found in NaCl chemical cotton fibers. The lowest elongation is found in H_2SO_4 Chemical cotton fibers.

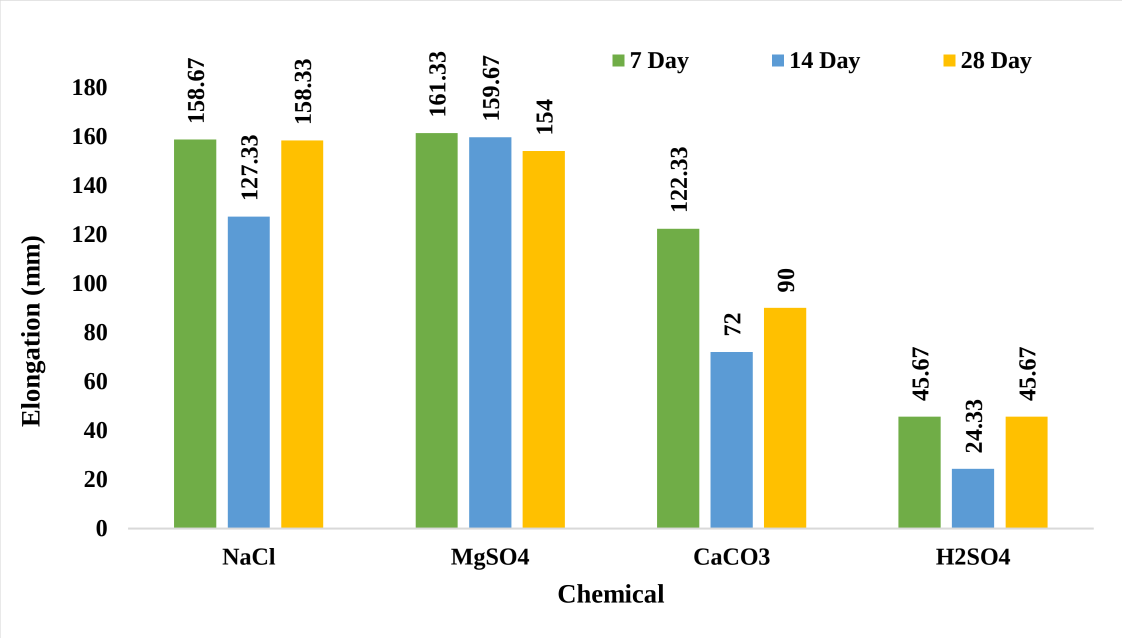

Figure 26: Chemical effect of cotton fiber

Figure 27: Tensile test for chemically submerged cotton fiber

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4.3 Pull-out test

The pull-out test is a system used to measure the adhesion strength between different accoutrements. In the case of cloth cotton fiber corroborated concrete structures, the pull-out test was used to estimate the bond strength in concrete and to test the strength of the cloth cotton fiber. There were three types of pull-out tests.

4.3.1 Normal recycle textile cotton fiber:

The elongation of the textile cotton fiber was found to be 49.53 mm in length under a tensile load.

4.3.2 Chemical effects on pullout test:

After curing in NaCl chemical result for 28 days, the elongation of the textile cotton fiber was found to be 158 mm in length under a tensile load, with an original gauge length of (L_0) 387 mm and a final length of (L_1) 545 mm.

After curing in $CaCO_3$ chemical result for 28 days, the elongation of the textile cotton fiber was found to be 00 mm in length under a tensile load.

After curing in H_2SO_4 chemical result for 28 days, the elongation of the textile cotton fiber was found to be 75 mm in length under a tensile load, with an original gauge length of (L_0) 390 mm and a final length of (L_1) 465 mm.

After curing in $MgSO_4$ chemical result for 28 days, the elongation of the textile cotton fiber was found to be 109 mm in length under a tensile load, with an original gauge length of (L_0) 420 mm and a final length of (L_1) 529 mm.

4.3.3 After heating of specimens:

The elongation of the textile cotton fiber was found to be 29.33 mm in length under a tensile load.

4.3.4 Pull-out test analyses:

Six different types of Cylinders have been constructed. It has a normal pull-out test for the first Cylinder. The second Cylinder is the NaCl Chemical pull-out test. The third

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Cylinder is the $MgSO_4$ chemical pull-out test. The fourth Cylinder is the $CaCO_3$ Chemical pull-out test. The fifth Cylinder is the H_2SO_4 Chemical pull-out test, and the last sixth Cylinder is the heat analyses pull-out test.

Because there is less Elongation in the sixth Cylinder and there is no elongation in the fourth cylinder.

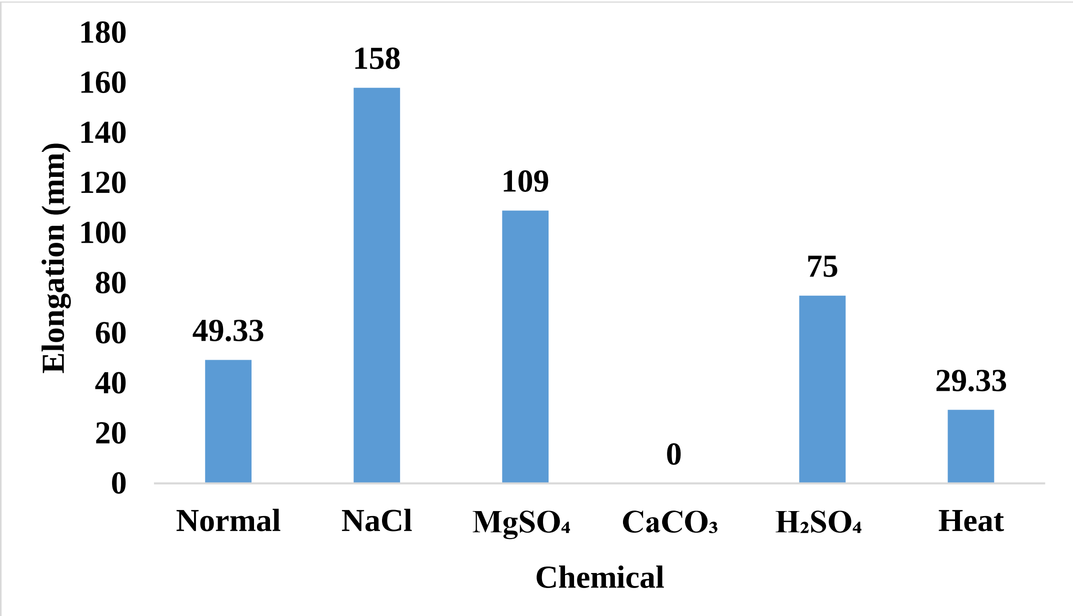

Figure 28: Pull-out test analyses

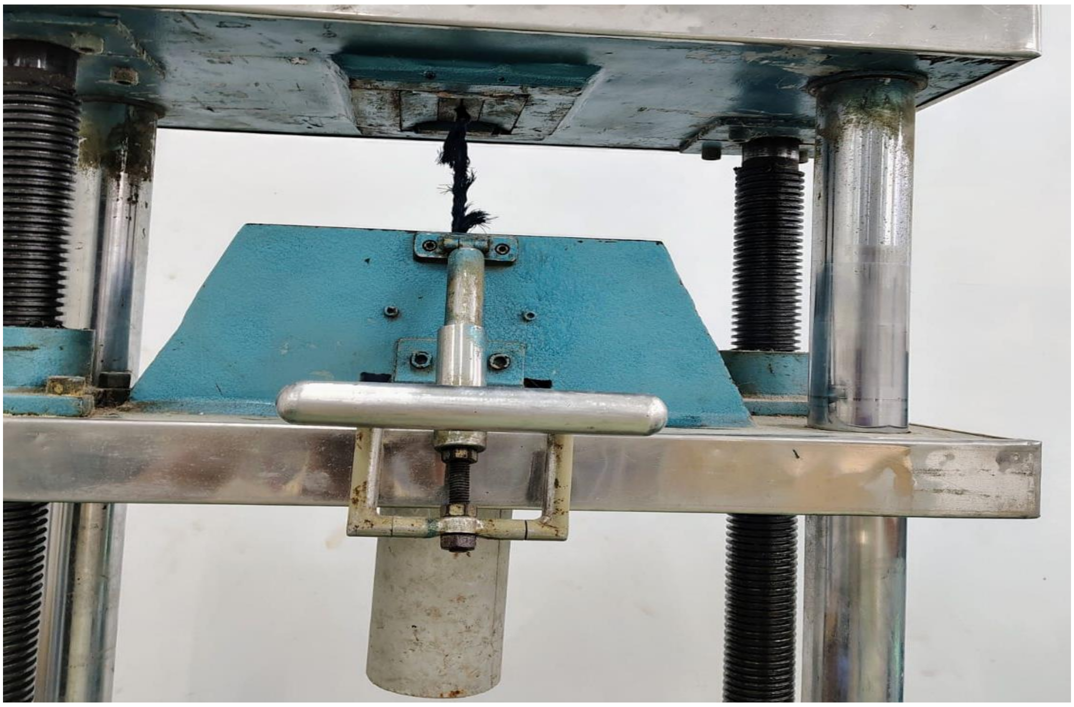

Figure 29: Pull-out test for cylinder cotton fiber

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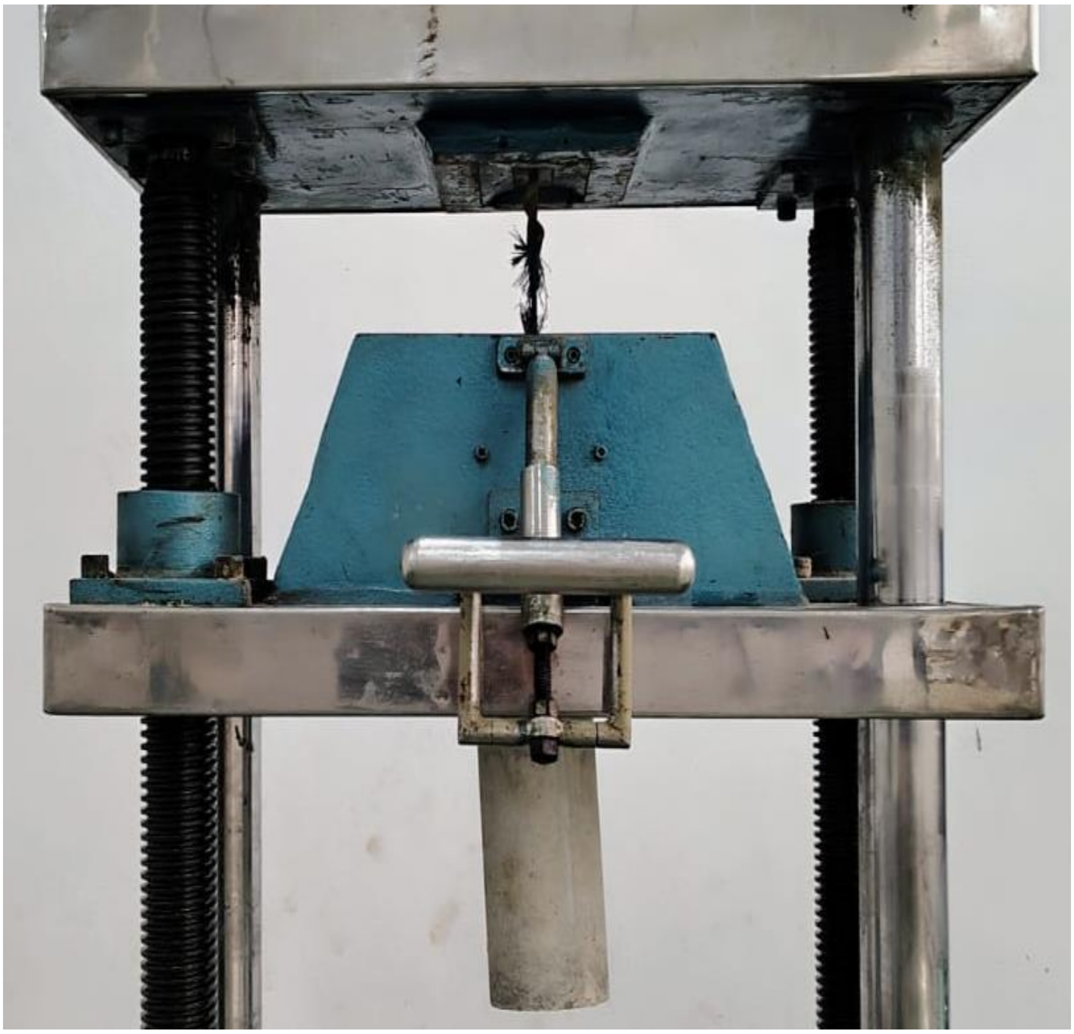

Figure 30: Pull-out test for chemically submerged cotton fiber cylinder

4.4 Beam result

Beams are prepared in 4 conditions. The deflection' f ' each has been governing, discuss replace Reinforced, what amount load and cost has decreased.

4.4.1 Pure concrete:

First condition: Pure concrete beam. Its load capacity is 10 kN and its deflection is 0.225 mm.

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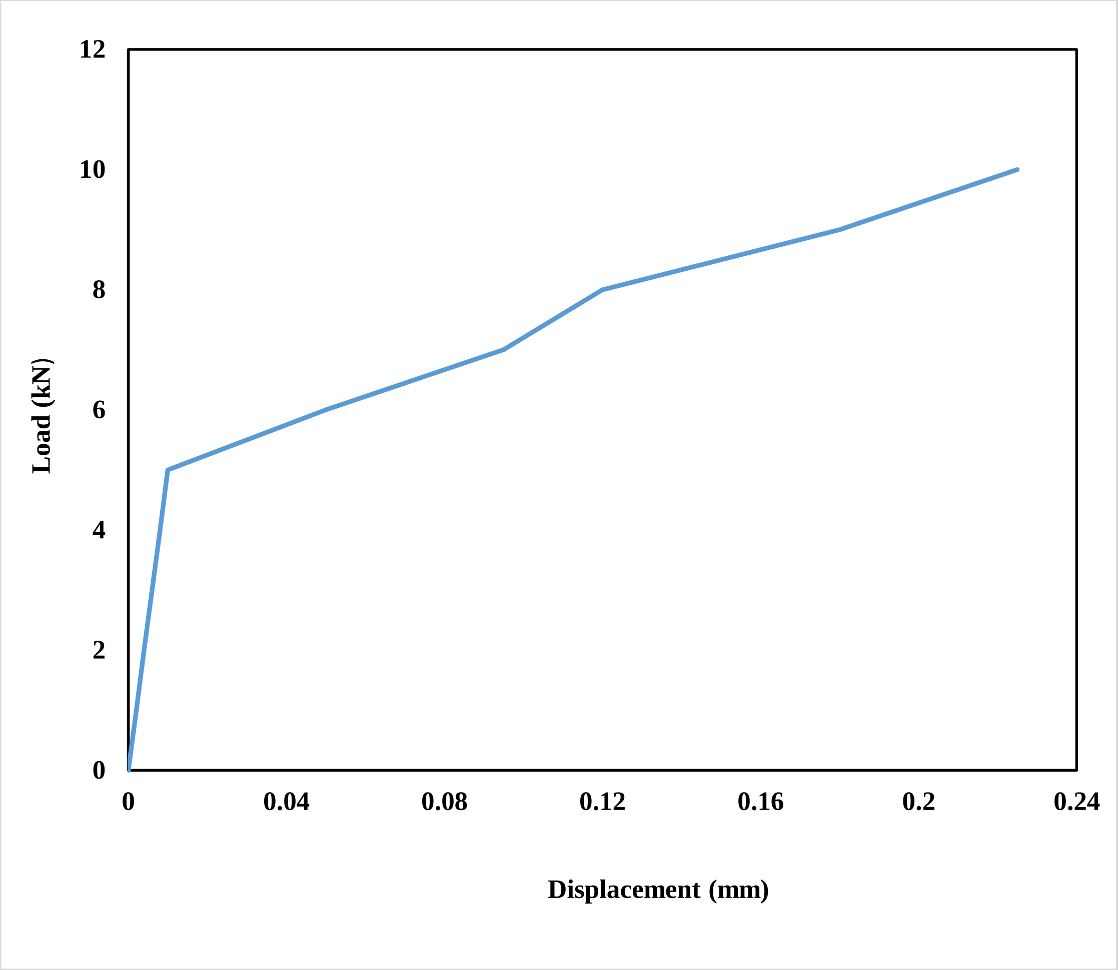

Figure 31: Load-displacement relation (for type 1 beam)

The graph demonstrates the correlation between load and displacement. Based on the provided information, the following is a breakdown of how displacement alters with changing load.

• Since the displacement starts zero to 0 mm so the load also starts zero to 0 kN.

• The displacement rises to 0.01 mm with a further rise in load to 5 kN.

• The displacement grows in step with the load as it continues to rise. As the load increases to 10 kN this pattern persists, leading to a displacement of 0.225 mm.

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4.4.2 Use 2-12 mm diameter bar reinforcement:

First condition: 2-12mm diameter bar reinforcement concrete beam. Its load capacity is 48kN and its deflection is 2.75mm.

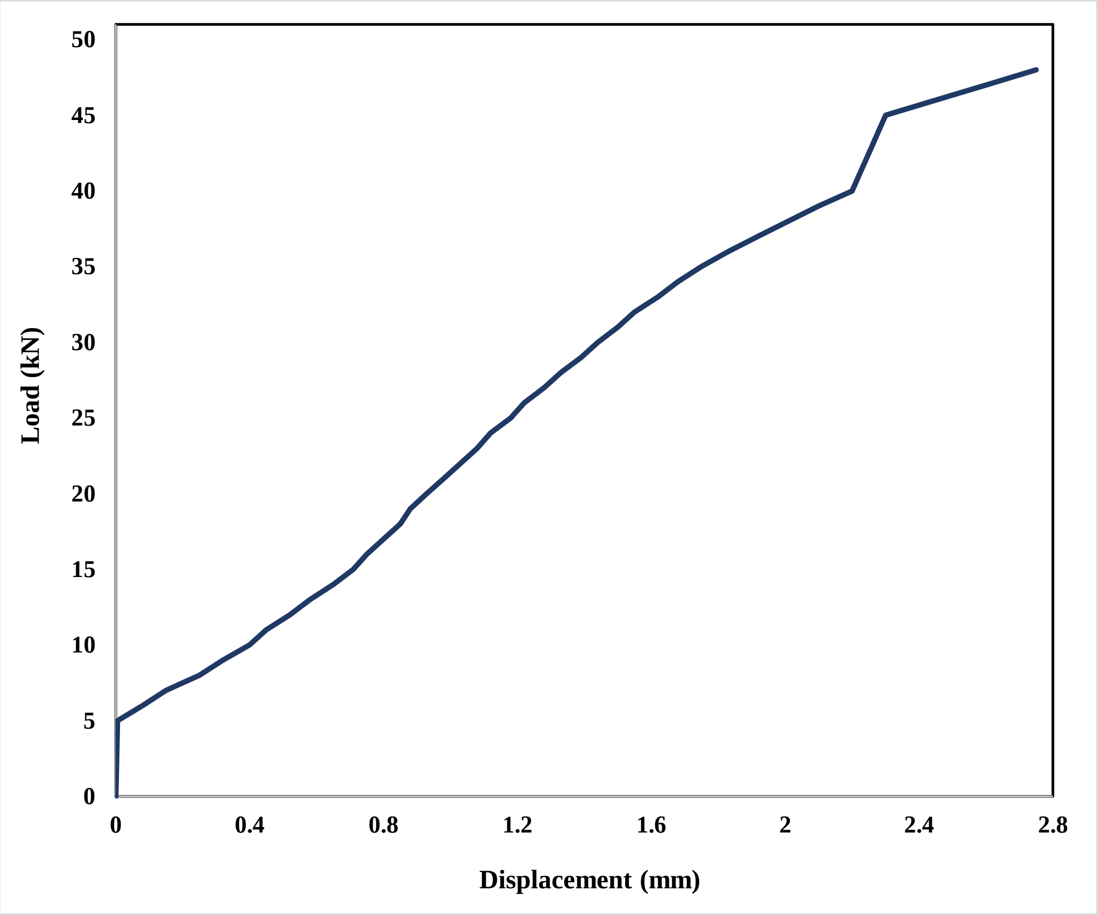

Figure 32: Load-displacement relation (for type 2 beam)

The graph demonstrates the correlation between load and displacement. Based on the provided information, the following is a breakdown of how displacement alters with changing load.

• Since the displacement starts zero to 0 mm so the load also starts zero to 0 kN.

• The displacement rises to 0.005 mm with a further rise in load to 5 kN.

• The displacement grows in step with the load as it continues to rise. As the load increases to 48 kN this pattern persists, leading to a displacement of 2.75 mm.

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4.4.3 Use 2-12mm diameter bar textile reinforced:

First condition: 2-12mm diameter bar recycle textile cotton fiber reinforcement concrete beam. Its load capacity is 20 kN and its deflection is 0.55 mm.

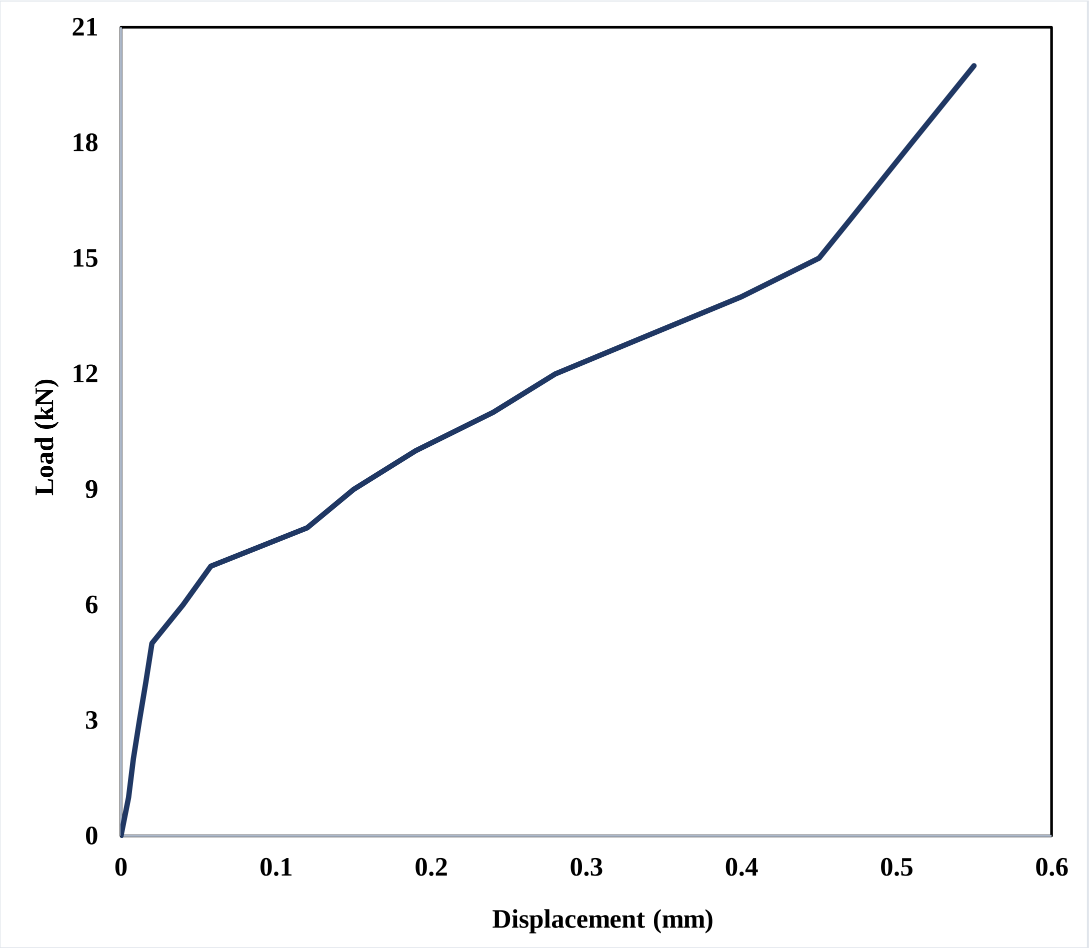

Figure 33: Load-displacement relation (for type 3 beam)

The graph demonstrates the correlation between load and displacement. Based on the provided information, the following is a breakdown of how displacement alters with changing load.

• Since the displacement starts zero to 0 mm so the load also starts zero to 0 kN.

• The displacement rises to 0.02 mm with a further rise in load to 5 kN.

• The displacement grows in step with the load as it continues to rise. As the load increases to 20 kN this pattern persists, leading to a displacement of 0.55 mm.

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4.4.4 Use 3-12mm diameter bar textile reinforced:

First condition: 3-12 mm dia. Bar recycle textile cotton fiber reinforcement concrete beam. Its load capacity is 15 kN and its deflection is 0.60 mm.

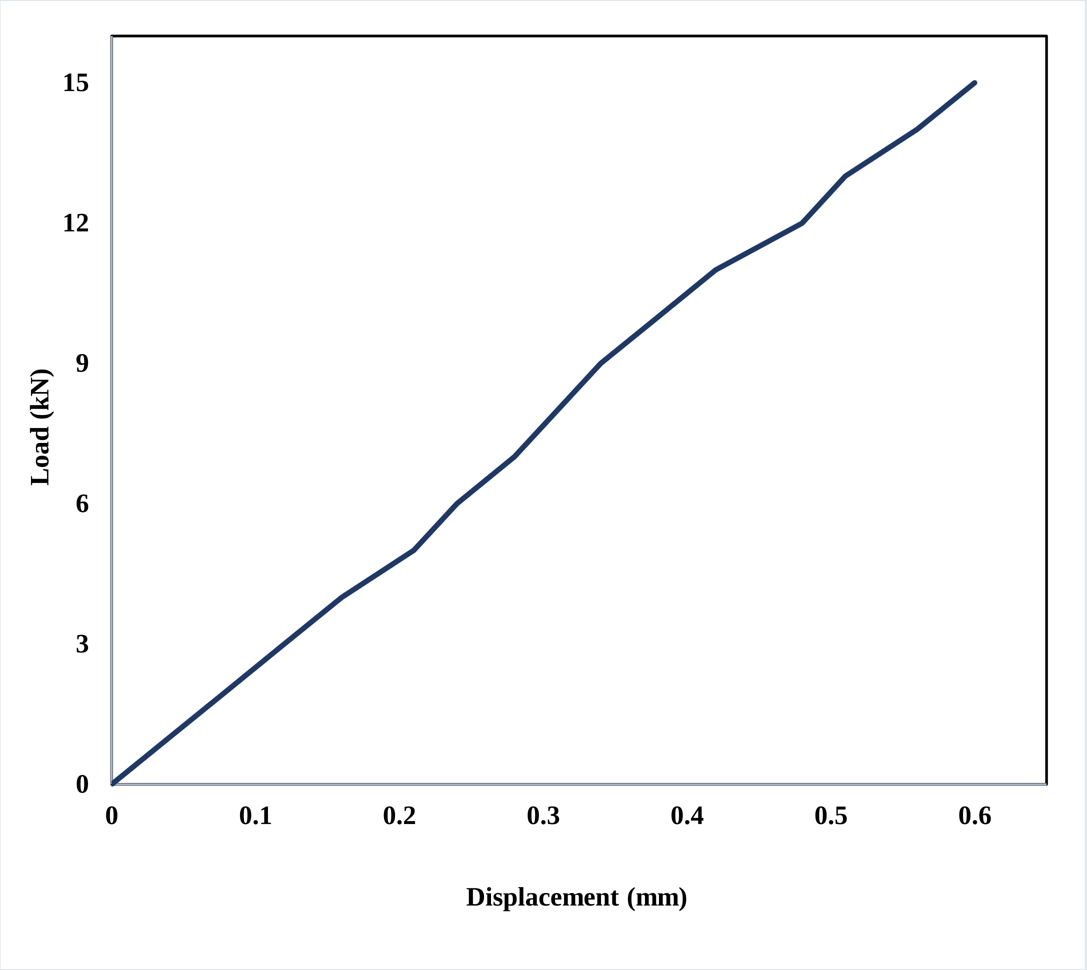

Figure 34: Load-displacement relation (for type 4 beam)

The graph demonstrates the correlation between load and displacement. Based on the provided information, the following is a breakdown of how displacement alters with changing load.

• Since the displacement starts zero to 0 mm so the load also starts zero to 0 kN.

• The displacement rises to 205 mm with a further rise in load to 5 kN.

• The displacement grows in step with the load as it continues to rise. As the load increases to 15 kN this pattern persists, leading to a displacement of 0.60 mm.

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4.4.5 Comparison of load capacity:

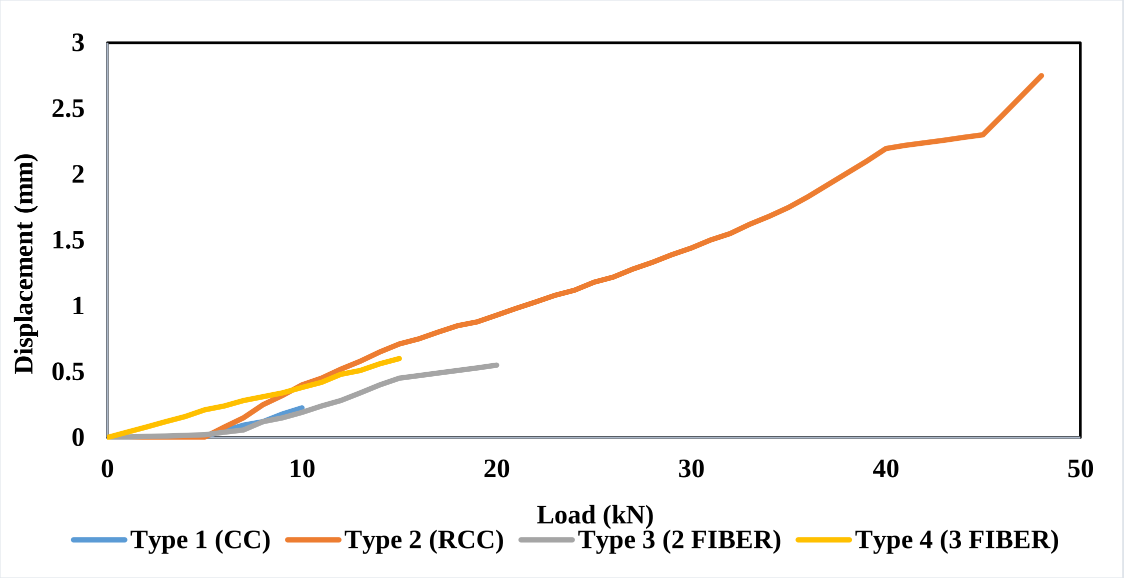

Figure 35: Load-displacement relation (for combined)

Maximum load and maximum deflection are found in type-2 beam, Load 48 kN, and deflection 2.78 mm. The lowest load and deflection are found in type-1 beam, Load 10 kN, and deflection of 0.225 mm.

4.4.6 Comparison with another fiber:

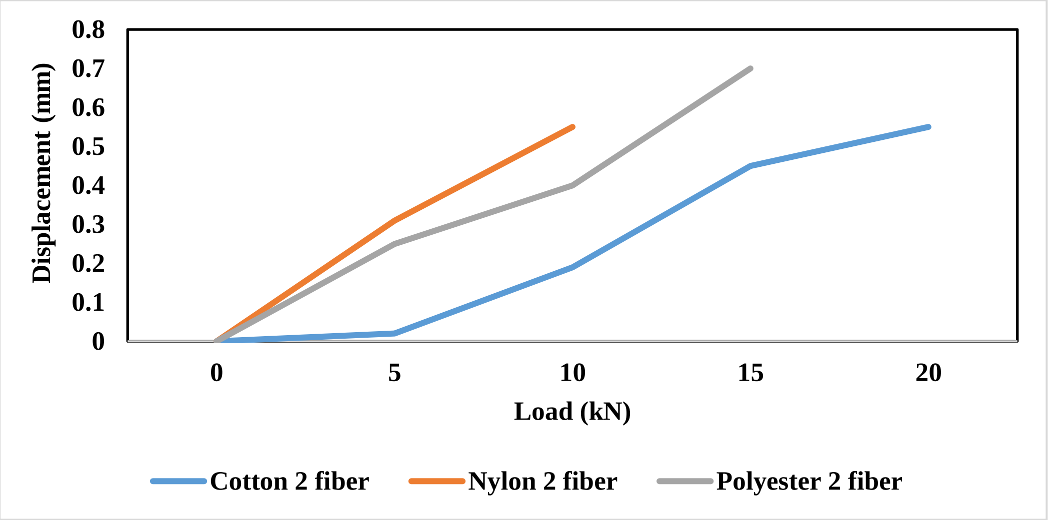

Figure 36: Comparison with other samples 2 fiber beam

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- Cotton fiber beam load capacity is 50% more than Nylon fiber beam,
- Cotton fiber beam load capacity is 75% more than polyester fiber beam.

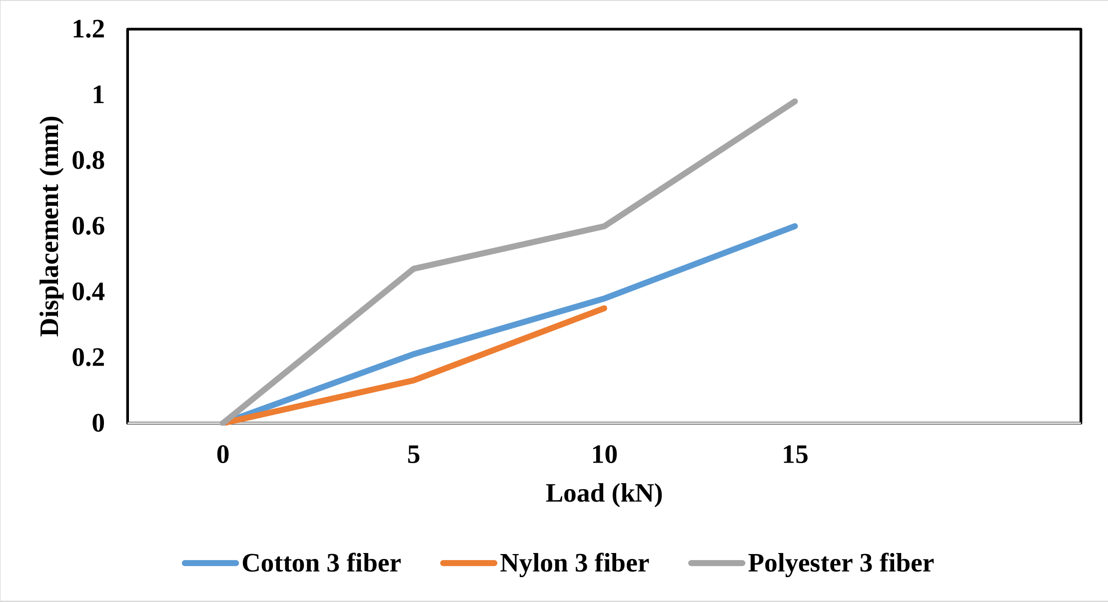

Figure 37: Comparison with other samples 3 fiber beam

- Cotton fiber beam load capacity is 66.67% more than Nylon fiber beam,
- Cotton fiber beam load capacity is Similar to polyester fiber beam.

Table 3: Comparison with other samples

Sample	Ultimate Load (kN) & Maximum Deflection (mm)		Failure mode	Comments
	2 Fiber	3 Fiber		
Cotton	Load-20 kN & Deflection-0.55 mm.	Load-15 kN & Deflection-0.60 mm.	Flexure failure	Better than nylon & polyester fiber.
Nylon	Load-10 kN & Deflection-0.55 mm.	Load-10 kN & Deflection-0.35 mm.	Flexure failure	Lowest load capacity.
Polyester	Load-15 kN & Deflection-0.70 mm.	Load-15 kN & Deflection-0.98 mm.	Flexure failure	Better than nylon fiber.

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4.5 Failure pattern

Failure modes in reinforced concrete beams are classified into two major types: flexural failure and shear failure. The former occurs when the imposed load exceeds the flexural capacity of the materials of the beam, while the latter occurs due to a deficiency in shear resistance between different materials of the beam. All beams of this study occurred at flexural failure.

Figure 38: Failure pattern (for type 1 beam)

Figure 39: Failure pattern (for type 1 beam)

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Figure 40: Failure pattern (for type 2 beam)

Figure 41: Failure pattern (for type 2 beam)

Figure 42: Failure pattern (for type 3 beam)

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Figure 43: Failure pattern (for type 3 beam)

Figure 44: Failure pattern (for type 4 beam)

Figure 45: Failure pattern (for type 4 beam)

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4.6 Cost analysis

Four different types of beams have been constructed. It has pure concrete for the first beam. The second bean is a 2-12 mm dia. bar bottom reinforced concrete beam. The third beam is made of 2-12 mm diameter. The bar bottom recycled cotton fiber reinforced concrete (RCFRC) beam, while the fourth beam is made of 3-12 mm dia. Bar bottom recycle textile cotton fiber reinforced concrete beam. Because there is less reinforcement in the third and fourth beams, the price is likewise lower.

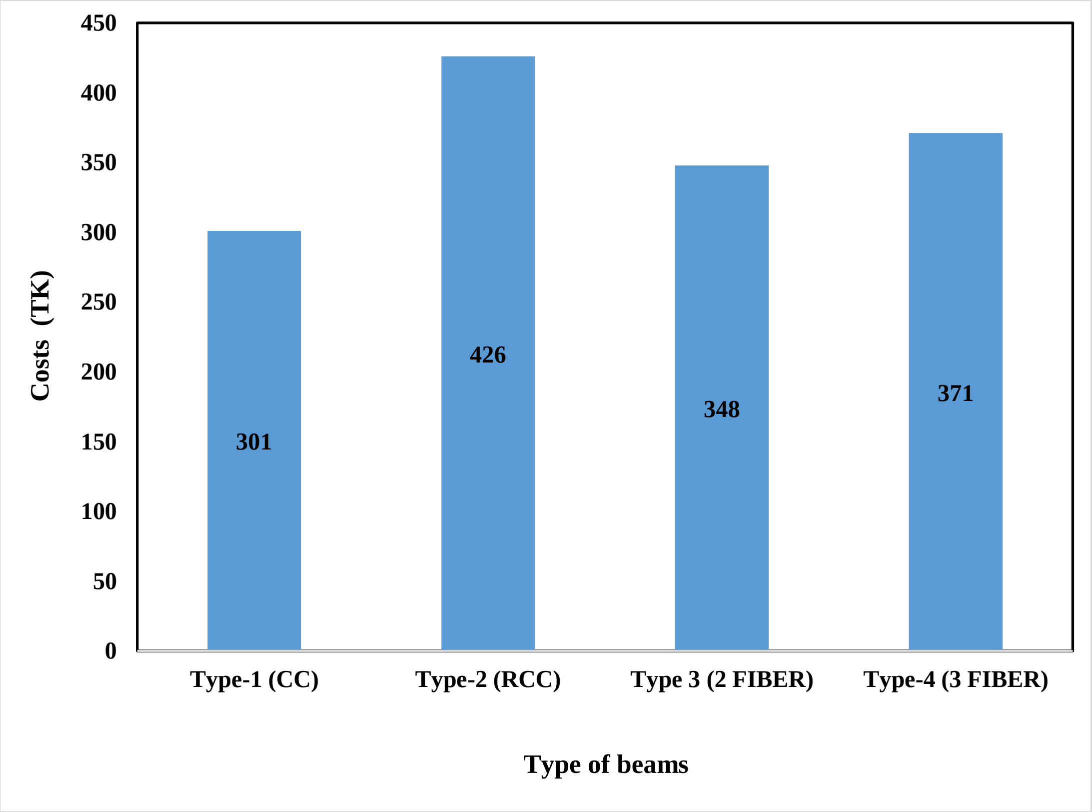

Figure 46: Cost analysis (per beam)

Type-1 beam cost 115.62% less than Type-3 beam, but Type-2 beam cost more than 81.69%. Type-1 beam cost 123.26% less than Type-4 beam, but Type-2 beam cost more than 87.09.33%. Type-4 Beam costs 106.61% more than Type-3 Beam. With the increase of textile reinforcement, the amount of cost is reduced. Therefore, where the amount of load is very low, it can convert the reinforcement into textile reinforcement and use it.

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4.7 Discussion

In this study, 4 different beams are made. Loads and deflections are compared with 2-12 mm diameter reinforcement concrete beams. Discussing how much and where recycled textile cotton fiber reinforcement can be used for 2-12 mm and 3-12 mm diameter bars, and how much is usable. Coarse aggregate, fine aggregate, cement reinforcement, and water are used as materials for making the beam. As a fine aggregate, selected sand with an FM of 1.6, and as a coarse aggregate, selected stone with a unit weight of 1680kg/m^3. The coarse aggregate has an absorption of 0.5 per cent and a bulk dry specific gravity of 2.68. Reinforcement is replaced by textile cotton fibers, selected Textile cotton Fibers with an Elongation Length of 75.67 mm as a Textile Reinforcement. The textile cotton fibers with an elongation length of 153.67 mm, 127.33mm, and 158.33mm after curing in Sodium chloride (NaCl) chemical for 7 days, 14 days, and 28 days as textile reinforcement. The textile cotton fibers with an elongation length of 161.33 mm, 159.67 mm, and 154 mm after curing in Magnesium sulfate ($MgSO_4$) chemical for 7 days, 14 days, and 28 days as textile reinforcement. The textile cotton fibers with an elongation length of 122.33 mm, 72 mm, and 90 mm after curing in Calcium carbonate ($CaCO_3$) chemical for 7 days, 14 days and 28 days as textile reinforcement. The textile cotton fibers with an elongation length of 45.67 mm, 24.33mm, and 45.67 mm after curing in Sulfuric acid (H_2SO_4) chemical for 7 days , 14 days, and 28 days as textile reinforcement. The elongation of the textile cotton fiber pull-out test was found to be 49.53 mm in length under a tensile load. After curing in NaCl chemical for 28 days, the elongation of the textile cotton fiber pull-out test was found to be 158 mm in length under a tensile load. After curing in $CaCO_3$ chemical for 28 days, the elongation of the textile cotton fiber pull-out test was found to be 00 mm in length under a tensile load. After curing in H_2SO_4 chemical for 28 days, the elongation of the textile cotton fiber pull-out test was found to be 75 mm in length under a tensile load. After curing in $MgSO_4$ chemical for 28 days, the elongation of the textile cotton fiber pull-out test was found to be 109 mm in length under a tensile load. The elongation of the textile cotton fiber heat pull-out test was found to be 29.33 mm in length under a tensile load. The main objective of this study is to replace reinforcement with textile cotton fiber. So, four separate beams are designed. Type 1, pure concrete with a load capacity of 10 kN and deflection of 0.225 mm. Type 2 is a 2-12 mm diameter reinforced concrete beam, its load capacity is 48 kN, and its deflection is 2.75 mm. Type 3 is 2-12 mm diameter textile cotton fibers Reinforced concrete beam is Which load capacity 20 kN and deflection 0.55 mm. Type 4 is 3-12 mm diameter Textile cotton fibers Reinforced concrete beam. Its load capacity is 15 kN and deflection is 0.60 mm. Type 3 beams can carry much less load than type 2 beams so type 3 beams cannot be used where type 2 beams are to be used. However, this type 3 beam can be used where

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there is less load and no live load. Which is almost close to type 3 and type 4 beam. So, where type 3 beam is to used type 2 can be used. In reinforced concrete beams, failure can happen in two main ways: through flexural failure or shear failure. Flexural failure takes place when the load on the beam becomes too much for its materials to handle, causing the beam to bend and ultimately fail. Shear failure, on the other hand, occurs when there isn't enough resistance between the materials of the beam to prevent them from sliding past each other. In this particular study, all the beams failed due to flexural failure, meaning the load exceeded what the beam's structure could withstand in terms of bending. In comparison with other samples 2 cotton fiber beam load capacity is 50% more than the nylon fiber beam. So cotton fiber is better than nylon fiber. In comparison with other samples 2 cotton fiber beam load capacity is 75% more than the polyester fiber beam. So cotton fiber is better than polyester fiber. In comparison with other samples 3 cotton fiber beam load capacity is 66.67% more than the nylon fiber beam. So cotton fiber is better than nylon fiber. In comparison with other samples 3 cotton fiber beam load capacity is similar to the polyester fiber beam. Polyester fiber is better than nylon fiber. The lowest load capacity to nylon fiber.

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CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The study on the sustainable potential of recycled textile cotton fiber reinforced concrete (RTCFRC) beams highlights the promising role of recycled fibers in promoting sustainable construction practices. The incorporation of recycled cotton fibers, sourced from textile waste, in concrete beams presents a viable solution to two critical environmental issues:

The excessive waste generated by the textile industry and the high carbon footprint associated with conventional concrete production. The potential of textile-reinforced concrete as a sustainable building material is discussed. And how much load and deflection can be achieved by replacing steel with textile reinforced, and where it can be used is discussed. Comparing the load and deflection of a steel beam with replacement. And to discuss the susceptibility of textile cotton fiber to chemicals inside the concrete beam.

However, despite the potential environmental benefits, several challenges must be addressed to maximize their effectiveness and sustainability. The most critical challenge lies in the weak bonding between recycled cotton fibers and the concrete matrix, which limits the fibers' reinforcing capacity and reduces the overall structural performance. The hydrophilic nature of cotton fibers, potential degradation over time, and inconsistent fiber quality further hinder the durability and long-term viability of RCFRC beams. Additionally, the effect of recycled fibers on workability and the fiber distribution within the concrete mix can lead to uneven performance. To fully realize the sustainable potential of RCFRC beams, it is essential to improve fiber-concrete bonding through surface treatments, optimize fiber content and distribution, and explore potential chemical modifications to enhance durability. Addressing these issues can lead to better performance, making RCFRC beams a viable option for more eco-friendly and resilient construction practices.

The textile cotton fibers with an elongation length of 153.67 mm, 127.33mm, and 158.33mm after curing in Sodium chloride (NaCl) chemical for 7 days, 14 days, and 28 days as textile reinforcement. The textile cotton fibers with an elongation length of 161.33 mm, 159.67 mm, and 154 mm after curing in Magnesium sulfate ($MgSO_4$) chemical for 7 days, 14 days, and 28 days as textile reinforcement. The textile cotton fibers with an elongation length of 122.33 mm, 72 mm, and 90 mm after curing in

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Calcium carbonate ($CaCO_3$) chemical for 7 days, 14 days and 28 days as textile reinforcement. The textile cotton fibers with an elongation length of 45.67 mm, 24.33mm, and 45.67 mm after curing in Sulfuric acid (H_2SO_4) chemical for 7 days , 14 days, and 28 days as textile reinforcement.

The elongation of the textile cotton fiber pull-out test was found to be 49.53 mm in length under a tensile load. After curing in NaCl chemical for 28 days, the elongation of the textile cotton fiber pull-out test was found to be 158 mm in length under a tensile load. After curing in $CaCO_3$ chemical for 28 days, the elongation of the textile cotton fiber pull-out test was found to be 00 mm in length under a tensile load. After curing in H_2SO_4 chemical for 28 days, the elongation of the textile cotton fiber pull-out test was found to be 75 mm in length under a tensile load. After curing in $MgSO_4$ chemical for 28 days, the elongation of the textile cotton fiber pull-out test was found to be 109 mm in length under a tensile load. The elongation of the textile cotton fiber heat pull-out test was found to be 29.33 mm in length under a tensile load.

Discussing where replace may be utilized there are four distinct beams constructed. Type 1 is made pure concrete beam, has a 15 kN load capacity and a 0.225 mm deflection. Type 2 is 2-12 mm diameter reinforced beam; it has a 48 kN load capacity and a 2.75 mm deflection. Type 3 is 2-12 mm diameter textile cotton fibers reinforced beam, it has a 20 kN load capacity and a 0.70 mm deflection. Type 4 is 3-12 mm diameter textile cotton fibers reinforced beam, it has a 15 kN load capacity and a 0.60 mm deflection. Type 3 beams can carry much less load than type 2 beams so type 3 beams cannot be used where type 2 beams are to be used. However, this type 3 beam can be used where there is less load and no live load. There are two categories of failure mechanisms in reinforced concrete beams.

Type-1 beam cost 115.62% less than Type-3 beam, but Type-2 beam cost more than 81.69%. Type-1 beam cost 123.26% less than Type -4 beam, but Type -2 beam cost more than 87.09%. Type -4 Beam costs 106.61% more than Type-3 Beam. With the increase of textile reinforcement, the amount of cost is reduced. Therefore, where the amount of load is very low, it can convert the reinforcement into textile reinforcement and use it.

Further research is needed to evaluate the long-term performance, durability, and scalability of RTCFRC beams under various environmental conditions and load scenarios.

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5.2 Recommendations

The strength of the textile cotton fiber reinforced beam in the future, utilize to another fiber's reinforcement. A better outcome can be obtained by combining or rolling twisting more or more textile reinforcements. The fire test protective to in concrete for cotton fiber reinforced concrete beam. On this more study is required. For longer-lasting textile reinforcing, bitumen or other chemicals can be utilized. Improved outcomes are thus possible. The amount of fine aggregate, can be reduced by using cotton fiber with fine aggregate. Future textile reinforcing designs will require more study to be more advanced and sustainable.

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APPENDIX

Table 4: Load-displacement (for pour concrete)

Load (kN)	Displacement (mm)	Load (kN)	Displacement (mm)
0	0	6	0.05
1	0.002	7	0.095
2	0.004	8	0.12
3	0.006	9	0.18
4	0.008	10	0.225
5	0.01		

Table 5: Load-displacement (for steel)

Load (kN)	Displacement (mm)	Load (kN)	Displacement (mm)	Load (kN)	Displacement (mm)
0	0	17	0.80	34	1.68
1	0.001	18	0.85	35	1.745
2	0.002	19	0.88	36	1.83
3	0.003	20	0.93	37	1.92
4	0.004	21	0.98	38	2.01
5	0.005	22	1.03	39	2.1
6	0.08	23	1.08	40	2.195
7	0.15	24	1.12	41	2.22
8	0.25	25	1.18	42	2.24
9	0.32	26	1.22	43	2.26
10	0.4	27	1.28	44	2.28
11	0.45	28	1.33	45	2.3
12	0.52	29	1.39	46	2.45
13	0.58	30	1.44	47	2.6
14	0.65	31	1.5	48	2.75
15	0.71	32	1.55		
16	0.75	33	1.62		

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Table 6: Load-displacement (for 2-12mm cotton fiber reinforced)

Load (kN)	Displacement (mm)	Load (kN)	Displacement (mm)
0	0	11	0.24
1	0.005	12	0.28
2	0.008	13	0.34
3	0.012	14	0.4
4	0.016	15	0.45
5	0.02	16	0.47
6	0.051	17	0.49
7	0.058	18	0.51
8	0.12	19	0.53
9	0.15	20	0.55
10	0.19		

Table 7: Load-displacement (for 3-12mm cotton fiber reinforced)

Load (kN)	Displacement (mm)	Load (kN)	Displacement (mm)
0	0	8	0.31
1	0.04	9	0.34
2	0.08	10	0.38
3	0.12	11	0.42
4	0.16	12	0.48
5	0.21	13	0.51
6	0.24	14	0.56
7	0.28	15	0.6

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Table 8: Load-displacement (for combine)

Load (kN)	Displacement (mm) Type – 1	Displacement (mm) Type - 2	Displacement (mm) Type - 3	Displacement (mm) Type - 4
0	0	0	0	0
1	0.002	0.001	0.005	0.04
2	0.004	0.002	0.008	0.08
3	0.006	0.003	0.012	0.12
4	0.008	0.004	0.016	0.16
5	0.01	0.005	0.02	0.21
6	0.05	0.08	0.04	0.24
7	0.095	0.15	0.058	0.28
8	0.12	0.25	0.12	0.31
9	0.18	0.32	0.15	0.34
10	0.225	0.4	0.19	0.38
11		0.45	0.24	0.42
12		0.52	0.28	0.48
13		0.58	0.34	0.51
14		0.65	0.4	0.56
15		0.71	0.45	0.6
16		0.75	0.47	
17		0.80	0.49	
18		0.85	0.51	
19		0.88	0.53	
20		0.93	0.55	
21		0.98		
22		1.03		
23		1.08		
24		1.12		
25		1.18		
26		1.22		
27		1.28		
28		1.33		
29		1.39		
30		1.44		
31		1.5		
32		1.55		
33		1.62		

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34		1.68		
35		1.745		
36		1.83		
37		1.92		
38		2.01		
39		2.1		
40		2.195		
41		2.22		
42		2.24		
43		2.26		
44		2.28		
45		2.3		
46		2.45		
47		2.6		
48		2.75		

Table 9: Tensile test for normal cotton fiber

Sl. No.	Original length (mm)	Final length (mm)	Distance (mm)	Elongation (mm)
1	500	590	90	75.67
2	448	510	62	
3	475	550	75	

Table 10: Fine aggregate F.M. value determination

Sieve No.	Weight of Retain (gm)	Percent (%) of Retain	Cumulative % Retain	Percent (%) Finer	Fineness Modulus
#4	0.0	0	0	100	F.M.= $\frac{159.6}{100}$ =1.596
#8	1.5	0.3	0.3	99.7	
#16	1.5	0.3	0.6	99.4	
#30	8.0	1.6	2.2	97.8	
#50	307.0	61.4	63.6	36.4	
#100	146.5	29.3	92.9	7.1	
Pan	35.5	-	-	0	
Total	500		159.6		

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Table 11: Coarse aggregate F.M. value test

Sieve No. (mm)	Weight of Retain (gm)	Percent(%) of Retain	Cumulative % Retain	Percent (%) Finer	Fineness Modulus
37.5	0	0	0	100	F.M.= $\frac{302.72}{100}$ =3.03
25	18	3.6	3.6	96.4	
19.5	114.5	22.9	26.5	73.5	
12.5	240.5	48.1	74.6	25.4	
6.3	118.7	23.74	98.34	1.66	
2.36	6.7	1.34	99.68	0.32	
Pan	1.6	0.32	-	0	
Total	500		302.72		

Table 12: Tensile test for chemically submerged cotton fiber after 7 days

Chemical	Sl. No.	Original length (mm)	Final length (mm)	Elongation (mm)	Ave. Elongation (mm)
NaCl	1	585	748	163	153.67
	2	515	672	157	
	3	572	713	141	
$MgSO_4$	1	512	674	162	161.33
	2	507	663	156	
	3	518	684	166	
$CaCO_3$	1	510	660	150	122.33
	2	593	700	107	
	3	540	650	110	
H_2SO_4	1	463	510	47	36
	2	474	498	24	
	3	410	447	37	

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Table 13: Tensile test for chemically submerged cotton fiber after 14 days

Chemical	Sl. No.	Original length (mm)	Final length (mm)	Elongation (mm)	Ave. Elongation (mm)
NaCl	1	530	670	140	127.33
	2	527	650	123	
	3	510	629	119	
$MgSO_4$	1	478	631	153	159.67
	2	490	651	161	
	3	510	675	165	
$CaCO_3$	1	497	565	68	72
	2	600	675	75	
	3	590	663	73	
H_2SO_4	1	580	603	23	24.33
	2	520	550	30	
	3	570	590	20	

Table 14: Tensile test for chemically submerged cotton fiber after 28 days

Chemical	Sl. No.	Original length (mm)	Final length (mm)	Elongation (mm)	Ave. Elongation (mm)
NaCl	1	489	629	140	158.33
	2	430	598	168	
	3	450	617	167	

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$MgSO_4$	1	523	678	155	154
	2	433	580	147	
	3	480	640	160	
$CaCO_3$	1	600	710	110	90
	2	610	690	80	
	3	550	630	80	
H_2SO_4	1	500	565	65	45.67
	2	500	529	29	
	3	502	545	43	

Table 15: Pull-out test of cotton fiber

SI. No.	Original length (mm)	Final length (mm)	Elongation (mm)	Ave. Elongation (mm)
1	340	430	90	49.33
2	335	360	25	
3	372	405	33	

Table 16: Pull-out test for chemical cotton fiber -28 days

SI. No.	Chemical	Original length (mm)	Final length (mm)	Elongation (mm)
1	NaCl	387	545	158
2	$MgSO_4$	420	529	109
3	$CaCO_3$	-	-	-
4	H_2SO_4	390	465	75

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Table 17: Pull-out test for fair effaced (cotton fiber at 200°C – 1 hour)

SI. No.	Original length (mm)	Final length (mm)	Elongation (mm)	Ave. Elongation (mm)
1	400	436	36	29.33
2	486	515	29	
3	457	480	23	

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