

STUDY ON STRENGTH AND DURABILITY PROPERTIES OF FIBRE REINFORCED CONCRETE

Nagulamalyala Jyothsna¹, B V Rajiv Vinayak², Riyaz Syed³

¹M.Tech Scholar, ^{2,3}Assistant Professor

Department of Civil Engineering, Vaagdevi College of Engineering

Bollikunta, Warangal-506002, Telangana

Corresponding Email id: jyothsnanagulamalyala35@gmail.com

ABSTRACT

This M. Tech project focuses on investigating the strength and durability properties of fiber reinforced concrete (FRC). Fiber reinforced concrete is a composite material consisting of cement, aggregates, and discrete fibers. The addition of fibers, such as steel, polypropylene, or glass, enhances the mechanical properties and durability of concrete by controlling crack propagation and improving resistance to various loading conditions and environmental factors. This study aims to comprehensively evaluate the performance of FRC through experimental testing and analysis. Various parameters, including fiber type, fiber content, aspect ratio, and curing conditions, will be investigated to assess their influence on the strength and durability characteristics of FRC. The experimental program includes tests such as compressive strength, flexural strength, splitting tensile strength, and durability tests involving freeze thaw resistance, chloride penetration, and carbonation resistance. The results obtained from this study will provide valuable insights into the effectiveness of fiber reinforcement in enhancing the performance of concrete and contribute to

the optimization of FRC mix designs for practical applications in construction engineering.

1.1 Background and Motivation:

Concrete is one of the most widely used construction materials due to its versatility, durability, and cost-effectiveness. However, traditional concrete has inherent limitations, including low tensile strength and susceptibility to cracking under various loading conditions. These shortcomings can compromise the structural integrity and service life of concrete structures, leading to maintenance challenges and safety concerns.

Fiber reinforced concrete (FRC) has emerged as a promising solution to enhance the mechanical properties and durability of concrete. By incorporating discrete fibers into the concrete matrix, FRC exhibits improved crack resistance, ductility, and toughness compared to conventional concrete. Various types of fibers, including steel, polypropylene, and glass, have been extensively studied for their effectiveness in mitigating cracking and improving the overall performance of concrete.

1.2 Objectives of the study

To Investigate the Influence of Fiber Type:
Evaluate the effect of different types of fibers (e.g., steel, polypropylene, glass) on the mechanical

properties and durability of fiber reinforced concrete (FRC).

To Assess the Impact of Fiber Content: Determine the optimal fiber content range for enhancing the strength, ductility, and crack resistance of FRC while avoiding fiber clustering and workability issues.

To Study the Effect of Aspect Ratio: Analyze the influence of fiber aspect ratio (length to diameter ratio) on the performance of FRC in terms of crack control, flexural toughness, and post cracking behavior.

To Evaluate the Role of Curing Conditions: Investigate the importance of curing conditions (e.g., temperature, moisture, duration) on the development of strength and durability properties in FRC specimens.

To Characterize Mechanical Properties: Conduct comprehensive mechanical tests, including compressive strength, flexural strength, splitting tensile strength, and modulus of elasticity, to assess the structural performance of FRC.

To Assess Durability Performance: Perform durability tests, such as freeze thaw resistance, chloride penetration resistance, and carbonation resistance, to evaluate the long-term durability of FRC in harsh environmental conditions.

To Optimize Mix Design Parameters: Develop guidelines and recommendations for optimizing FRC mix designs based on the experimental findings and statistical analysis of the test results.

To Provide Practical Recommendations: Translate research findings into practical recommendations for engineers, designers, and construction professionals involved in the specification, design, and implementation of FRC in real-world applications.

To Contribute to Advancements in Construction Engineering: Contribute new knowledge and insights to the field of construction engineering by addressing critical challenges related to the development, characterization, and utilization of fibers in forced concrete materials.

1.3 Scope and Significance

1.3.1 Scope:

The scope of this study encompasses a comprehensive investigation into the strength and durability properties of fiber reinforced concrete (FRC) with a focus on understanding the influence of various parameters, including fiber type, fiber content, aspect ratio, and curing conditions. The experimental program will involve the preparation of FRC specimens using different combinations of materials and mix proportions, followed by mechanical testing and durability assessments. The study will include the following aspects:

Material Selection and Mix Design: Selection of suitable cementitious materials, aggregates, and fibers for the preparation of FRC mixtures. Optimization of mix proportions to achieve desired mechanical properties and durability characteristics.

Experimental Testing: Mechanical tests, including compressive strength, flexural strength, splitting tensile strength, and modulus of elasticity, to evaluate the structural performance of FRC specimens. Durability tests, such as freeze thaw resistance, chloride penetration resistance, and carbonation resistance, to assess the long-term durability of FRC under harsh environmental conditions.

Microstructural Analysis: Microscopic examination and image analysis techniques to investigate the microstructural changes, fiber distribution, and interfacial bond characteristics in

FRC specimens. Statistical Analysis and Optimization: Statistical analysis of experimental data to identify significant factors affecting the strength and durability properties of FRC. Development of empirical models and optimization algorithms to optimize mix design parameters for enhanced FRC performance.

1.3.2 Significance:

Advancement of FRC Technology: The findings of this study will enhance our understanding of the mechanical behavior and durability performance of FRC, contributing to the advancement of FRC technology. **Optimization of Mix Designs:** Practical recommendations and guidelines derived from this research will aid engineers and construction professionals in optimizing FRC mix designs for specific applications, leading to improved structural performance and service life of concrete structures. **Sustainability and Resilience:** FRC offers potential benefits in terms of sustainability and resilience by reducing the need for conventional reinforcement, improving structural robustness, and enhancing durability against environmental factors. **Infrastructure Development:** The adoption of FRC in infrastructure projects can lead to the construction of more durable and resilient structures capable of withstanding dynamic loading and harsh environmental conditions, thereby promoting sustainable infrastructure development.

Literature Review

In their 2022 study, Biju C. Thomas and Y. Stalin Jose emphasize the prioritization of natural fibers due to their widespread availability. They specifically focus on SISAL Fiber (SF) as a substitute material for reinforcement. Through a detailed examination of the fibers' chemistry, physics, and structural characteristics, they uncover the robust structural potential of sisal fiber reinforced

composites in both urban and rural construction contexts. The study highlights the hazardous nature of steel materials to both human health and the environment, positioning SF as a safer alternative. Furthermore, the manufacturing process of SF is compared to that of artificial fibers and mineral asbestos, emphasizing its cost-effectiveness and environmental benefits. Overall, SF is recognized for its significant social and economic advantages, making it a promising choice for sustainable construction practices.

In their 2022 study, Biju Thomas and Y. Stalin Jose undertake a comprehensive survey to analyze the functionality of sisal fibers. They include several papers in this survey, each meticulously chosen for its relevance in assessing the properties and applications of sisal fibers. These selected papers undergo thorough examination based on the specific sisal and concrete ingredients utilized in various architectural projects. Additionally, the researchers provide an illustration showcasing sisal fiber compositions distinct from traditional concrete mixtures.

Furthermore, Thomas and Jose delve into the contributions of the chosen papers, analyzing their impact on tensile and compression strengths, along with their compositional percentages. Through this detailed analysis, they aim to elucidate the evolution of sisal fiber applications in concrete reinforcement and other construction-related fields. Overall, their study provides valuable insights into the diverse applications and advancements in sisal fiber technology, offering a comprehensive understanding of its potential in architectural and engineering contexts.

In their 2020 study, M.P. Iniya and K. Nirmalkumar delve into the application of sisal fibers as reinforcement within a cement-supported matrix. Their research aims to leverage the inherent

mechanical strength improvements offered by sisal fibers, a natural and sustainable alternative to traditional reinforcement materials. Throughout their investigation, they explore a range of sisal fiber concentrations in concrete, spanning from 0.1% to 2%, with fibers varying in length from 50mm to 60mm. To provide a comprehensive evaluation of their research, Iniya and Nirmalkumar detail the range of testing methodologies employed. These methodologies encompass various analyses, including compressive strength tests, flexural strength tests, tensile strength tests, and other pertinent assessments, offering a thorough examination of the concrete's mechanical behavior under different conditions. Overall, their study contributes valuable insights into the potential applications and performance attributes of sisal fiber-reinforced concrete within the realm of sustainable construction practices.

In their 2019 project, Mr. Mithun K, R.M. Mahalinge Gowda, and H.S Suresh Chandra conducted a study to investigate the impact of treating sisal fibers with Na_2CO_3 over a five-day period on the strength properties of standard concrete. The research utilized IS10262-2009 standards to design M30 grade concrete mixes containing varying percentages of Na_2CO_3 -treated sisal fibers, including 0.5%, 1%, 1.5%, and 2%. Concrete specimens in the form of cubes and cylinders underwent testing at intervals of 7, 14, and 28 days post-curing to assess their strength metrics. Through experimental studies, the researchers determined that incorporating 1% of Na_2CO_3 -treated sisal fibers into M30 grade concrete yielded optimal results. This percentage of fiber addition was found to enhance the strength properties of the concrete mixture effectively. The research adhered to IS10262-2009 standards and focused on designing M30 grade concrete formulations with varying proportions of Na_2CO_3 -treated sisal fibers, ranging

from 0.5% to 2%. Concrete specimens, comprising cubes and cylinders, were subjected to rigorous testing at intervals of 7, 14, and 28 days post-curing to evaluate their strength parameters. Through meticulous experimental analyses, the researchers determined that the incorporation of 1% Na_2CO_3 -treated sisal fibers into M30 grade concrete exhibited the most favorable outcomes. This particular percentage of fiber addition demonstrated significant enhancements in the concrete's strength metrics, surpassing the performance of other fiber concentrations tested.

In their 2018 study, Venkateshwara and Kalaiyarrasi. A. R. R aimed to assess the influence of natural sisal fiber on concrete by partially substituting cement. In this investigation, sisal fiber underwent chemical processing for incorporation into concrete mixes. The study focused on evaluating various mechanical characteristics, including compressive strength, split tensile strength, and flexural strength of fiber-reinforced concrete. Different percentages of fiber, specifically 0.5%, 1%, and 1.5%, were utilized to replace cement by volume fraction. These concrete mixes were compared against normal M30 concrete, with sisal fiber possessing an aspect ratio of 1:20.

The results revealed notable enhancements in compressive strength at 28 days for the different fiber substitutions. Specifically, the compressive strength increased by 13.8%, 21%, and 16.3% for fiber replacements of 0.5%, 1%, and 1.5%, respectively, compared to normal concrete. Additionally, the first cracking load in flexure experienced significant increases of 12.5%, 27.5%, and 20% for fiber substitutions of 0.5%, 1%, and 1.5%, respectively. Moreover, there were substantial improvements in split tensile strength at 28 days, with increases of 24%, 56%, and 80% observed for fiber replacements

of 0.5%, 1%, and 1.5%, respectively, compared to normal concrete. Different volumes of sisal fiber, specifically 0.5%, 1%, and 1.5%, were utilized to replace cement in the concrete mixes. These fiber-reinforced concrete formulations were then compared against normal M30 concrete, with the sisal fibers possessing an aspect ratio of 1:20.

STUDY METHODOLOGY

It is a step by step process of a project. It represents the mechanism of the project tasks aligned in a suitable and sophisticated way. The following are the points to be followed:

- Selection of the title is to be done and the title should be finalized.
- Fixing of the problems statement is to be done.
- Literature survey is to be done with related topic.
- Procurement of materials is to be done.
- Preliminary test on the materials is to be done to determine its physical properties.
- Mix design should be done for appropriate grade of concrete.
- Casting and testing of trial cubes with the trial mix of concrete is to be done to obtain optimum dosage of Hybrid fibers.
- Casting of the test specimens is to be done with the optimum proportion of hybrid fibers.
- Curing of test specimens is to be done.
- Analysis of results and representation of the obtained results to be done in graphical form.
- Comparing the results.
- Displaying the results.

EXPERIMENTAL WORK

4.1 MATERIALS USED:

The materials used are:

- 53 grade Cement
- River sand
- Coarse aggregate
- Water
- Recycled coarse aggregate (demolition waste)
- Super plasticizer
- Sisal Fiber

4.1.1 Cement

In this project 53 grade ordinary Portland cement is used that is confirming to code IS: 10262-2013.

4.1.2 Fine Aggregate

In this project fine aggregate belongs to Zone -II was used which is confirming to the code IS: 383-2016. To fill the voids between the coarse, aggregate fine aggregate was used. In comparison with the coarse aggregate fine aggregate has more surface area.

4.1.3 Coarse Aggregate

Locally available coarse aggregate of nominal size 20mm is used in this project which is free from debris.

4.1.4 Water

For both mixing and curing portable water was used which is free from dirt particles.

4.1.5 Recycled Coarse Aggregate

In this project preparation of RCA was done by crushing the cubes which are procured from the concrete technology lab. We can collect RCA from different sources like demolition waste, construction and tested concrete specimens which are available within the concrete technology lab.

4.1.6 Super Plasticizer

In this project Forsook Conplast SP430 Superplasticizer was used. It is taken 1% by weight of cementitious material. In order to make the concrete better in workability superplasticizer was used.

4.1.7. Sisal fiber

Sisal fiber is a natural fiber derived from the leaves of the Agave sisal plant, which is native to Mexico but is now cultivated in many parts of the world, including Brazil, Tanzania, and Kenya. Here are some key points about sisal fiber:

4.1.7.1 Characteristics

1. Durability: Sisal fibers are known for their strength and durability. They have a high tensile strength, making them ideal for various applications.
2. Biodegradability: Being a natural fiber, sisal is biodegradable and environmentally friendly.
3. Texture: Sisal fibers are coarse and stiff, which makes them suitable for products that require a rough texture.
4. Color: The natural color of sisal is creamy white, but it can be dyed to various colors.

4.1.7.2 Applications

1. Rope and Twine: One of the primary uses of sisal fiber is in the production of ropes and twines, owing to its strength and durability.
2. Carpets and Rugs: Sisal is widely used in making carpets and rugs. Its natural appearance and durability make it a popular choice for floor coverings.
3. Agricultural Products: It is used in making agricultural baler twine, which is used for binding hay, straw, and other agricultural products.

4. Textiles: Sisal is also used in textiles for making bags, mats, and other similar products.

5. Paper Industry: Sisal pulp is used in the production of specialty papers.

6. Automotive Industry: Sisal fibers are used in the manufacturing of composite materials for the automotive industry, such as in car door panels and dashboards.

4.1.7.3 Environmental Impact

1. Sustainability: Sisal cultivation is considered sustainable. The plant requires minimal pesticides and fertilizers, and it can grow in arid environments where other crops might fail.

2. Renewable Resource: Sisal is a renewable resource, as the plant regenerates after the leaves are harvested.

4.1.7.4 Cultivation

1. Climate: Sisal grows best in warm climates and can tolerate arid conditions, which makes it suitable for regions with less rainfall.

2. Harvesting: The leaves are harvested by hand and then processed to extract the fibers. This involves decortication, where the leaves are crushed and beaten to separate the fibers from the fleshy tissue.

3. Processing: After decortication, the fibers are washed, dried, and brushed to remove any remaining impurities before they are bundled for sale.

4.1.7.5 Economic Importance

Sisal is an important crop in several developing countries, providing employment and income for farmers and workers involved in its cultivation and processing. The global demand for natural fibers, driven by an increased focus on sustainability and

eco-friendliness, has kept sisal as a relevant commodity in various industries.

MIX DESIGN

In this project concrete of grade M30 mix

is designed according to the code IS:10262-2019. The codal practice IS: 456-2000 has laid down the acceptance criteria for the quality of concrete. The mix proportions obtained for concrete of grade M30 are shown below.

Table 4.8: Mix proportions of concrete per m³

| Concrete Grade | 53 Grade Cement | Sand | Coarse aggregate | Water content |
|----------------|-----------------|--------|------------------|---------------|
| M30 | 328 kg | 695 kg | 1225 kg | 154 liters |
| Ratios | 1 | 2.11 | 3.73 | 0.47 |

4.2 SPECIMEN PREPARATION

Cube specimens of standard dimension of 150x150x150mm for compressive strength test and size of cylindrical specimens 300mm height and 150mm diameter for split tensile strength with mixture of different percentages of glass and polypropylene fibers (0%,0.2%,0.4%,0.6%,0.8%,1%) are prepared to determine the optimum proportion of Hybrid fibers. Cubes and Cylinders with the optimum dosage of hybrid fibers and with the different proportions of demolition waste (0%,10%,20%,30%,40%) were prepared to determine the optimum dosage of demolition waste replaced in the concrete. Prism of dimensions 700x150x100mm is adopted to find the flexural performance of hybrid fiber reinforced eco-friendly concrete.

4.3 CASTING AND CURING OF THE SPECIMENS

Specimens Casting can be done by removing the bolts of the molds and properly

cleaning them in order to prevent the mold from any debris. Bolts should be tightening in such a way that it should not be any seepage. A small layer of oil will be applied on all the sides of mold. After mixing the concrete, the concrete was poured in three layers and every layer should be given 25 blows with the tampering rod or compacted with a vibrator. Curing should be done after demolding of the specimen for 28 days.

4.4 TESTING OF THE SPECIMENS

Testing is to be done to know the concrete behavior. Compressive strength test, split tensile test, Flexural strength test are performed after the various specimens are casted and cured for the age of 28 days.

4.5 COMPRESSIVE STRENGTH TEST

According to the code IS:516-1959, the cubical specimens were fabricated with the size 150x150x150mm and tested after 28 days

of the water curing. The surface water and the debris present on the cubes has wiped out and the trimming of the edges were done by removing excess layers from it. After drying of the cubes, it should be taken for testing. The bearing surfaces of the testing machine were wiped neatly then the cubes were made to be in contact with the compression platens. The movable plates shall be rotated gently in order to maintain the uniform seating of cube. The load should keep slowly and constantly until the failure occurs after achieving the ultimate strength. The testing was performed under 100T compression testing machine. The compressive strength of the cubes was defined by ratio of maximum load to cross-section area. Mean of the three specimens for each was done to get the ultimate compressive strength of the

Where,

$$f_{ck} = \frac{2P}{\pi LD} \quad \text{N/mm}^2$$

f_{ck} = split tensile
 P = max. load obtained
 L = cylinder length
 D = cylinder diameter

4.7 FLEXURAL STRENGTH TEST

$$R = PL/bd^2 \quad \text{Here,}$$

| | | |
|---|---|--------------------|
| R | = | modulus of rupture |
| P | = | peak load |
| L | = | specimen span |
| b | = | breadth of sample |
| d | = | sample depth |

4.8 CONCRETE DURABILITY TESTS

4.8.1 Permeability test

Evaluates how well concrete resists water penetration under hydrostatic pressure. This is considered the primary test for concrete that's subject to hydrostatic pressure.

cube.

4.6. SPLIT TENSILE STRENGTH TEST

According to the codal provision of IS:5816-1999, the cylindrical specimens shall be 150mm in diameter and 300mm long. The mechanism for casting, curing, and testing of these specimens with respect to the sampling of materials is same to that of compressive strength test. Any compression machine of reliable type with sufficient capacity can be used for split tensile strength of a cylinder. Load is applied slowly and repeatedly. For obtaining the cylindrical specimen's tensile strength, mean of the cylindrical specimens is done for different proportions. The split tensile strength of the cylinder is formulated below.

Flexural strength is additionally referred to as modulus of rupture or bends strength or transverse rupture strength. Beam of size 700x150x100mm were casted and cured in curing tank for 28 days. After 28 days of curing, specimens are dried in the sun and markings are done. Center making for the specimens were done. The beam setup is for two-point loading that is simply supported.

1. Three specimen of concrete each of 200mm diameter and 120mm height are cast.

2. After 24 hours, the middle portion of 100mm diameter is roughened and the remaining portion is sealed with cement paste.

3. The specimen are cured for 28 days and then water pressure is applied on the middle-roughened portion so that water can penetrate inside the concrete. The water pressure is maintained as given below:

- 1 bar (1kg/cm²) for 48 hours.
- 3 bars for next 24 hours.
- 7 bars for next 24 hours.

4. After this, the specimen is split to know the penetration of water. The specimen is split in compression machine by applying concentrated load at two diagonally opposite points slightly away from central axis. The average of three maximum values of penetration is calculated. The depth of penetration of water should not be more than 25mm otherwise the specimen is considered to be failed in permeability test.

Permeability of concrete can be minimized by adopting low water-content ratio, ensuring proper compaction and curing of concrete as shown in the table below.

Table: 4.9 Water cement ration on concrete

4.9 Durability tests

4.9.1 Acid attack test

The concrete specimens of dimensions 150 x 150 x 150 mm for 1% dosages of sisal fibers and conventional concrete of 0% sisal fiber were casted, cured for 28 days and dried and weighed. The specimens were immersed in 5% Sulphuric acid (H₂SO₄) of pH 0.3 for a period of 56 days. The resistance of concrete to acid attack was found by

calculating the % loss of weight of specimen and the % loss of compressive strength on immersing concrete cube in acid water. For this test, totally 6cubes were casted. From that, 3 cubes are of 1% SFRC and 3 cubes are conventional concrete of 0% sisal fiber. 6.2.2 Sulphate attack test the concrete specimens of dimensions 150 x 150 x 150 mm for 1% dosages of sisal fibers and conventional concrete of 0% sisal fiber were casted, cured for 28 days and dried and weighed.

4.9.2 Chloride attack test

The concrete specimens of dimensions 150 x 150 x 150 mm for 1% dosages of sisal fibers and conventional concrete of 0% sisal fiber were casted, cured for 28 days and dried and weighed. The specimens were immersed in Sodium Chloride (NaCl) solution for a period of 56 days. The resistance of concrete to Chloride attack was found by calculating the % loss of weight of specimen and the % loss of compressive strength on immersing concrete cubes in Chloride solution. For this test, totally 6cubes were casted. From that, 3 cubes are of 1% SFRC and 3 cubes are conventional concrete of 0% sisal fiber. 6.2.4

4.9.3 Water absorption test

The cubes of size 150 x150 x 150 mm were casted and tested after 28 days curing. The specimens were taken out and oven dried at a temperature of 100°C to 110°C for not less than 24 hours. Each specimen removed from the oven was cooled to 20°C to 25°C using dry air and the dry weight was determined. Then the specimens were immersed in water.

RESULTS AND DISCUSSION

5.1 Experimental Results

Table 5.3: Split Tensile Strength

| S.NO | Type of fiber used | Percentage (%) of fiber added | M30 Split Tensile in N/mm ² |
|------|--------------------|-------------------------------|--|
| | | | 28 days |
| 1. | Sisal fiber | 0 | 3.12 |
| 2. | Sisal fiber | 0.5 | 3.75 |
| 3. | Sisal fiber | 1 | 4.88 |
| 4. | Sisal fiber | 1.5 | 5.23 |
| 5. | Sisal fiber | 2 | 5.98 |

5.2 Durability tests results**5.2.1 Acid attack test**

From the results of acid attack test, loss in weight of cube specimen after immersion in Sulphuric acid

solution and loss in compressive strength of cube specimen after immersion in Sulphuric acid solution of concrete can be represented in table given below.

Table 5.4: Loss in weight after immersion in H₂SO₄ solution of M30 grade concrete

| Percentage of sisal fiber | % Mass reduction | |
|---------------------------|-------------------------------------|---|
| | Initial weight after 28 days curing | Final weight after 56 days immersing in H ₂ SO ₄ solution |
| B0 - 0% SF | 7.82 | 6.56 |
| B2 - 1% SFs | 8.73 | 7.49 |

Table 5.5: Loss in strength after immersion in H₂SO₄ solution of M30 grade concrete

| Percentage of sisal fiber | Strength reduction |
|---------------------------|--------------------|
|---------------------------|--------------------|

| | 28 th day compressive strength | 56 th day compressive strength |
|------------|---|---|
| B0 - 0% SF | 33.75 | 25.56 |
| B2 - 1% SF | 43.99 | 36.39 |

5.2.2 Sulphate attack test

From the results of Sulphate attack test, loss in weight of cube specimen after immersion in Sodium sulphate solution and loss in compressive strength of cube

specimen after immersion in Sodium sulphate solution of concrete can be represented in table given below.

Table 5.6: Loss in weight after immersion in Na₂SO₄ solution of M30 grade concrete

| Percentage of sisal fiber | % Mass reduction | |
|---------------------------|-------------------------------------|---|
| | Initial weight after 28 days curing | Final weight after 56 days immersing in H ₂ SO ₄ solution |
| B0 - 0% SF | 7.68 | 6.85 |
| B2 - 1% SF | 8.49 | 7.72 |

Table 5.7: Loss in strength after immersion in Na₂SO₄ solution of M30 grade concrete

| Percentage of sisal fiber | Strength reduction | |
|---------------------------|---|---|
| | 28 th day compressive strength | 56 th day compressive strength |
| B0 - 0% SF | 33.75 | 24.68 |
| B2 - 1% SF | 43.99 | 35.45 |

5.2.3 Chloride attack test

From the results of Chloride attack test, loss in weight of cube specimen after immersion in Sodium chloride solution and loss in compressive strength of cube specimen after immersion in Sodium chloride solution of concrete can be represented in table given below.

Table 5.8: Loss in weight after immersion in NaCl solution of M30 grade concrete

| Percentage of sisal fiber | % Mass reduction | |
|---------------------------|-------------------------------------|---|
| | Initial weight after 28 days curing | Final weight after 56 days immersing in H ₂ SO ₄ solution |
| B0 - 0% SF | 7.51 | 6.70 |
| B2 - 1% SF | 8.53 | 7.83 |

Table 5.9: Loss in strength after immersion in NaCl solution of M30 grade concrete

| Percentage of sisal fiber | Strength reduction | |
|---------------------------|---|------------------------------|
| | 28 th day compressive strength | 56thday compressive strength |
| B0 - 0% SF | 33.75 | 26.73 |
| B2 - 1% SF | 43.99 | 35.51 |

5.2.4 Water absorption test

5.10: The water absorption test result of concrete can be represented in a table given below

| Mix | Sample 1 | | Sample 2 | | Sample 3 | |
|-----|-------------|-----------|-------------|-----------|------------|-----------|
| | Initial(kg) | Final(kg) | Initial(kg) | Final(kg) | Intial(kg) | Final(kg) |
| B0 | 8.63 | 8.37 | 8.86 | 8.56 | 8.86 | 8.56 |
| B1 | 8.84 | 8.49 | 9.37 | 9.02 | 9.37 | 9.02 |

CONCLUSION

6.1 Summary of findings

- Adding fibers to concrete significantly improves its compressive strength, with the best results at a fiber content of 1% across all tested concrete grades.
- Higher concrete grades result in stronger compressive strength, showing that concrete grade plays an important role in the strength of sisal fiber-reinforced concrete.
- For all grades tested, the tensile strength increased as the fiber content increased, indicating better ductility (flexibility).
- The flexural strength (resistance to bending) also improved as more fibers were added, making the concrete better at handling bending forces.
- The minimal cracking observed in the specimens suggests that the fibers effectively enhanced the concrete's resistance to cracking.

On studying the SFRC with varying percentages of adding sisal fibers by weight of cement, it can be concluded that,

- The addition of sisal fiber into the concrete significantly increases the strength properties of the concrete.
- . It was observed that the addition of fibers increased the compressive strength of concrete for varying dosages of 0.5%, 1%, 1.5% and 2% and was found to be 18%, 35%, 24% and 7% more than that of conventional concrete of 0% sisal fiber. The maximum percentage increase in compressive strength was achieved at 1% of fiber dosage.
- . It was observed that the addition of fibers increased the split tensile strength of concrete for varying dosages of 0.5%, 1%, 1.5% and 2% and was found to be 54%, 89%, 68% and 18% more than that of conventional concrete of 0% sisal fiber. The maximum percentage increase in split tensile strength was achieved at 1% of fiber dosage.
- . SFRC is more resistant to acid attack, sulphate attack, and chloride attack when compared to conventional concrete of 0% sisal fiber. In all cases the maximum resistance was observed in case of SFRC with 1% of fiber dosage.

- . s It was also observed that water absorption value increases in 1% of fiber dosage than conventional concrete of 0% sisal fiber in each grade of concrete. It reveals that the fiber added into the

7. References

- [1] L. Jin, R. Zhang, G. Dou, J. Xu, X. Du, “Experimental and numerical study of reinforced concrete beams with steel fibers subjected to impact loading,” *Int. J. Damage Mech.* 27 (7) (2018) 1058–1083, <https://doi.org/10.1177/1056789517721616>.
- [2] S.G. Pande, A. M. Makarande, Effect of rice husk ash on concrete, *Int. J. Eng. Res. Afr.* 3 (1) (2013) 1718–1723.
- [3] P. Chavan, S. Rao, Utilization of waste PET bottle fibers in concrete as an Innovation in building materials— [A review paper], *Int. J. Eng. Res.* 5 (1) (2016) 304–307, <https://doi.org/10.17950/ijer/v5is1/072>.
- [4] I. Netinger Grubešsa, B. Markovi'c, A. Gojevi'c, J. Brdari'c, Effect of hemp fibers on fire resistance of concrete, *Constr. Build. Mater.* 184 (Sep. 2018) 473–484, <https://doi.org/10.1016/j.conbuildmat.2018.07.014>.
- [5] K. Senthilkumar, et al., Mechanical properties evaluation of sisal fibre reinforced polymer composites: a review, *Constr. Build. Mater.* 174 (Jun. 2018) 713–729, <https://doi.org/10.1016/j.conbuildmat.2018.04.143>.
- [6] J. Wei, C. Meyer, Improving degradation resistance of sisal fiber in concrete through fiber surface treatment, *Appl. Surf. Sci.* 289 (Jan. 2014) 511–523, <https://doi.org/10.1016/j.apsusc.2013.11.024>.