

# Corrosion Resistance of Reinforcing Steel in Concrete Using Natural Fibers Treated with Used Engine Oil

Ninad Teke.<sup>1</sup>, Tulasi Kavathekar<sup>2</sup>, Aary Gade<sup>3</sup>

<sup>1,2,3</sup> Diploma in civil engineering, Latthe education society's polytechnic, sangli,

## Abstract

Corrosion of reinforcing steel is a major cause of deterioration in reinforced concrete structures, leading to cracks, spalling, and reduced durability. This study presents an eco- friendly and low-cost approach to improve corrosion resistance by using natural fibers treated with used engine oil in concrete.

Locally available **coconut leaf fibers** were selected for their good tensile strength and low cost. The fibers were treated with used engine oil to reduce water absorption and degradation, forming a protective hydrophobic layer that limits moisture and chloride penetration.

Concrete mixes containing **0.2%** and **0.4%** of treated fibers were tested for **compressive strength**, and **electrochemical corrosion resistance**. Results showed that treated fibers improved steel–concrete bonding and significantly reduced corrosion rates without affecting strength.

This sustainable technique enhances concrete durability, promotes waste reuse, and offers a cost-effective alternative to chemical corrosion inhibitors.

**Keywords:** Corrosion, Coconut Leaf, Electrochemical

## 1. Introduction

Concrete is one of the most widely used construction materials in the construction industry due to its high compressive strength, durability, and versatility. When reinforced with steel, concrete gains the ability to resist tensile stresses, forming reinforced concrete (RC), which is extensively used in buildings, bridges, and other infrastructure projects. The highly alkaline environment of cement paste forms a protective passive oxide layer on the surface of reinforcing steel, which helps prevent corrosion under normal conditions.

However, environmental factors such as carbonation and the penetration of chloride ions can damage this passive layer. Once the protective layer is destroyed, corrosion of reinforcing steel begins. The corrosion products occupy a larger volume than the original steel, creating internal tensile stresses within the surrounding concrete. This results in cracking, spalling, and a reduction in the durability and service life of reinforced concrete structures.

To improve the performance and durability of concrete, researchers have explored the use of different types of fibers such as synthetic fibers, steel fibers, and natural fibers. Among these, natural fibers have gained significant attention due to their low cost, eco-friendly nature, availability, and good mechanical properties.

Coconut leaf fiber is a natural fiber that can be used in concrete to improve its mechanical properties and crack resistance. However, natural fibers are hydrophilic in nature and tend to absorb more water, which may affect their bonding with the cement matrix and reduce durability.

To overcome this limitation, surface treatment methods are adopted to reduce the water absorption capacity of fibers. In this study, **used engine oil (UEO)** is used as a treatment material for coconut leaf fibers. Used engine oil provides a hydrophobic coating that helps reduce moisture absorption and may improve durability.

The present study focuses on the use of **coconut leaf fibers treated with used engine oil in concrete**. The research evaluates the effect of treated fibers on the mechanical properties of concrete, particularly compressive strength, and also examines their potential to improve durability and corrosion resistance in reinforced concrete.

## 2. Literature survey

### 2.1 Alejandro Flores Nicolás et al. in their study (“Corrosion Resistance of Reinforcing Steel in Concrete Using Natural Fibers”)

investigated the performance of natural fibers in reinforced concrete after treating them with waste engine oil. The treatment enhanced the hydrophobicity of the fibers, preventing easy penetration of water and chlorides into the concrete matrix. As a result, the chloride ingress and carbonation process, which are the primary causes of corrosion in reinforcement, were significantly delayed. Experimental results indicated improved compressive and tensile strength along with enhanced durability properties. Microstructural analysis using SEM and XRD confirmed that treated fibers refined the pore structure, reduced crack propagation, and created a protective environment around the rebar. This helped in minimizing corrosion initiation and progression. Additionally, the use of waste engine oil addressed the problem of industrial waste management, making it a sustainable and low-cost alternative. Overall, the research concluded that treated natural fibers substantially increase the service life of reinforced concrete structures.

### 2.2 Gopu G. Naidu and S. A. Joseph in (“Corrosion Behavior of Fiber Reinforced Concrete—A Review”)

presented a detailed evaluation of fiber-reinforced concrete (FRC) in resisting corrosion. The study emphasized that natural and synthetic fibers improve crack resistance, reduce micro-crack propagation, and enhance toughness, indirectly reducing pathways for chloride penetration. It was also highlighted that incorporating supplementary materials such as silica fume and fly ash further reduces chloride ingress. The review confirmed that fibers provide effective crack bridging and arresting capacity, which minimizes water penetration into the concrete. However, the authors stressed that untreated fibers may absorb water and reduce durability; therefore, surface modification or oil treatment is crucial. The paper concluded that the combined use of fibers and mineral admixtures provides significant resistance against reinforcement corrosion.

### 2.3 Nabeel A. et al., in their study (“Effect of Corrosion on Bond Between Reinforcing Steel Bars and Fiber Reinforced Geopolymer Concrete”)

investigated geopolymer concrete with fiber reinforcement under accelerated corrosion conditions. The bond strength between rebar and concrete was tested using the pull-out method.

Results showed that while corrosion reduced bond strength, the presence of fibers mitigated this reduction by bridging cracks and holding the concrete matrix together. SEM analysis confirmed improved microstructure and reduced crack propagation. Compared to ordinary Portland cement (OPC) concrete, fiber-reinforced geopolymer concrete displayed superior corrosion resistance and durability, making it a potential alternative in aggressive environments.

#### **2.4 Pawar et al. (Waste Oil Treated Fibers in Marine Structures)**

Pawar and colleagues carried out detailed research on fiber-reinforced concrete for marine construction, where reinforcement corrosion occurs rapidly due to the presence of seawater, chloride ions, and sulfates. Their study explored whether natural fibers could enhance corrosion resistance in such aggressive environments. When untreated natural fibers were used, they tended to absorb moisture, which negatively affected the long-term durability of concrete. However, when the fibers were treated with waste engine oil, their water absorption capacity significantly reduced, making them more stable in saline conditions. These treated fibers also helped in bridging microcracks that typically form in concrete, thereby reducing the penetration of chlorides and water into the reinforcement zone. As a result, the onset of corrosion in reinforcing steel was considerably delayed. Experimental results indicated that the service life of concrete structures in marine environments could be extended by 20–30% with the use of waste oil-treated fibers. Furthermore, the concrete showed better crack resistance, reduced permeability, and lower maintenance requirements. This makes the approach highly beneficial for coastal and offshore structures such as jetties, ports, and bridges exposed to severe chloride attack..

#### **2.5 Chavan & Salunkhe (Comparative Study of Treated and Untreated Fibers in RCC)**

Chavan and Salunkhe conducted a comparative study on the performance of reinforced cement concrete (RCC) when natural fibers were used in treated and untreated conditions. They observed that untreated fibers, though beneficial for crack control, tended to absorb moisture, which led to increased permeability and accelerated corrosion of embedded steel reinforcement. On the other hand, when the fibers were treated with used engine oil, their hydrophobic nature improved considerably, thereby reducing water absorption and restricting chloride ingress. The treated fibers enhanced the density of the concrete matrix, refined pore structures, and reduced capillary suction. As a result, the corrosion rate of steel reinforcement was significantly lowered compared to mixes containing untreated fibers. Additionally, mechanical properties such as compressive and flexural strength showed slight improvement with treated fibers due to better fiber–matrix bonding. The study concluded that waste oil-treated fibers not only improve the durability of RCC but also provide a cost-effective solution for increasing the service life of reinforced concrete structures, particularly in aggressive environmental conditions.

#### **Summary :-**

Studies show that natural fibers treated with waste engine oil greatly improve the corrosion resistance and durability of reinforced concrete. Treated fibers become hydrophobic, reducing water and chloride penetration, which delays corrosion and increases strength. Researchers such as Alejandro Flores Nicolás, Pawar, and Chavan found that treated fibers refine pore structures, reduce crack formation, and enhance bonding between concrete and steel. Compared to untreated

fibers, they provide better durability and lower corrosion rates, especially in marine and aggressive environments. Overall, oil-treated fibers offer an eco-friendly, low-cost, and sustainable solution to extend the service life of reinforced concrete structures.

### 3. Problem statement

Concrete is one of the most widely used construction materials, but its durability is significantly affected by the corrosion of reinforcing steel. Corrosion leads to cracking, spalling, and reduction in the strength and service life of structures. Conventional methods to control corrosion are often expensive and not environmentally friendly.

At the same time, natural fibers like coconut leaf fibers are abundantly available and low-cost, but their direct use in concrete is limited due to high water absorption and poor bonding with the cement matrix. This reduces the strength and durability of concrete.

Additionally, waste materials such as used engine oil create environmental pollution if not properly disposed of.

Therefore, there is a need to develop a sustainable and economical solution that:

- Improves corrosion resistance of reinforced concrete
- Enhances bonding and durability of natural fibers in concrete
- Utilizes waste materials effectively

This project aims to address these issues by using coconut leaf fibers treated with used engine oil in concrete and evaluating their effect on compressive strength and corrosion resistance.

### 4. Objectives

- 4.1) To process and treat coconut leaf natural fibers using used engine oil in order to reduce water absorption and enhance their durability and performance in concrete.
- 4.2) To prepare M20 grade concrete mixes by incorporating treated natural fibers at 0.2% and 0.4% by weight and compare them with conventional concrete.
- 4.3) To evaluate workability, mechanical strength, and electrochemical corrosion behaviour of M20 concrete with 0.2% and 0.4% treated fibers..
- 4.4) To investigate the effectiveness of natural fibers treated with used engine oil in reducing the corrosion rate of reinforcing steel in concrete.

### 5. Methodology

#### 5.1 Materials Used

In this study, concrete was prepared using **Portland Pozzolana Cement (PPC) – UltraTech** in accordance with relevant Indian Standard specifications. Natural river sand with a maximum particle size of **4.75 mm** was used as fine aggregate, while crushed gravel of nominal size **19 mm** was used as coarse aggregate. Clean potable water was used for mixing and curing of concrete.

Coconut leaf fibers were used as natural reinforcing material. The fibers were treated with **used engine oil (UEO)** to reduce water absorption and improve bonding with the cement matrix. Reinforcing steel bars were embedded in concrete specimens to evaluate corrosion resistance.

All experimental work was carried out at **Latthe Education Society's Polytechnic, Sangli**.

## 5.2 Fibers

Coconut leaf fibers were used as natural reinforcement in this study. These fibers were collected from locally available sources and cleaned thoroughly to remove dust and impurities. After cleaning, the fibers were air dried for **24–48 hours**.

The fibers were manually cut into uniform dimensions of approximately **10 mm length, 3–4 mm width, and 0.1 mm thickness** before mixing with concrete.

The density of coconut leaf fibers ranges from **0.85–1.44 g/cm<sup>3</sup>**.

## 5.3 Fiber Treatment

To improve durability and reduce water absorption, the coconut leaf fibers were treated using **used engine oil**. The fibers were immersed in filtered used engine oil, allowing the oil to penetrate the micro pores of the fibers and create a hydrophobic coating.

After soaking, the fibers were oven dried at **70°C for different durations (5, 15, 30 and 60 minutes)**. Water absorption tests were conducted to determine the optimum treatment duration. Based on the experimental results, **15 minutes drying time was selected as the optimum treatment period**.

Water absorption was calculated using:

$$\text{Water Absorption(\%)} = \frac{W_2 - W_1}{W_1} \times 100$$

Where

$W_1$  = Initial dry weight

$W_2$  = Final weight after immersion.

## 5.4 Concrete Preparation

Concrete of **M20 grade** was prepared for the experimental study. Three types of mixes were produced:

- **Control Mix (C)** – without fibers
- **CCF-02** – 0.2% coconut fibers

- **CCF-04** – 0.4% coconut fibers

The water–cement ratio was maintained at **0.50**. Concrete was mixed manually to ensure uniform distribution of fibers. Aggregates and cement were first dry mixed, followed by gradual addition of water. Treated fibers were then added slowly to avoid fiber clustering and to ensure uniform dispersion.

### **5.5 Casting of Specimens**

Concrete cube specimens of size **150 mm × 150 mm × 150 mm** were cast as per **IS 516:2018**.

For each mix, **7 specimens** were prepared:

- 3 specimens for **7-day compressive strength test**
- 3 specimens for **28-day compressive strength test**
- 1 specimen with embedded reinforcement for **corrosion testing**

Thus, a total of **21 specimens** were cast for the entire experimental program.

### **5.6 Curing of Specimens**

Concrete cubes for compressive strength tests were cured in **normal water** for **7 days and 28 & 42 days**.

Reinforced concrete specimens were cured in **saline water solution (35 g/L NaCl)** to simulate marine environmental conditions and accelerate corrosion of reinforcing steel.

### **5.7 Testing of Specimens**

#### **5.7.1 Compressive Strength Test**

The compressive strength test was conducted at **7 days and 28 days** according to **IS 516:2018** using a Compression Testing Machine (CTM).

The compressive strength was calculated using:

$$f_c = \frac{P}{A}$$

Where

$f_c$  = Compressive strength (N/mm<sup>2</sup>)

P = Maximum load applied (N)

A = Cross sectional area of specimen (mm<sup>2</sup>)

The average of three specimens was considered as the final compressive strength.

### 5.7.2 Half-Cell Potential Test

The **Half-Cell Open Circuit Potential (HCP)** test was conducted to evaluate the probability of corrosion of reinforcing steel. The potential difference between the embedded steel and a **Copper/Copper Sulphate reference electrode** was measured using a digital multimeter. The obtained values were interpreted according to **ASTM C876**.

### 5.7.3 Gravimetric Method

The **gravimetric (weight loss) method** was used to determine the corrosion rate of reinforcing steel. Steel bars were extracted from the concrete specimens after exposure to saline water and cleaned properly.

Weight loss was calculated as:

$$\text{Weight Loss} = W_1 - W_2$$

Where

$W_1$  = Initial weight of steel bar

$W_2$  = Final weight after exposure.

The corrosion rate was then determined using standard corrosion rate equations.

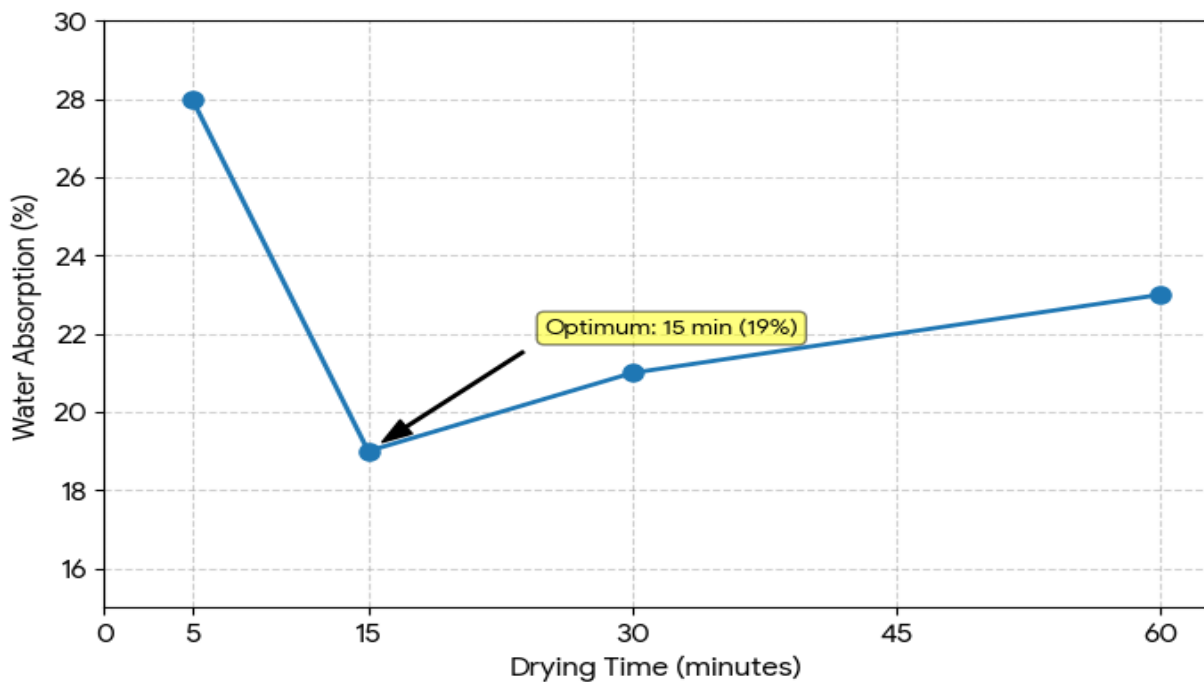
## 6. Result and discussion

### WATER ABSORPTION TEST

#### Experimental Results

**TABLE 1 : WATER ABSORPTION TEST RESULTS**

Drying Time (min)	Dry Weight $W_1$ (g)	Wet Weight $W_2$ (g)	Water Absorption (%)
5 min	10.00	12.80	28.00
15 min	10.00	11.90	19.00
30 min	10.00	12.10	21.00
60 min	10.00	12.30	23.00

**FIGURE 1: WATER ABSORPTION VS DRYING TIME****Graph Analysis**

- Trend: The curve shows a sharp initial decrease in absorption, followed by a gradual rise after the 15-minute mark.
- Optimum Point: The lowest point on the graph occurs at 15 minutes.
- Conclusion: Drying beyond 15 minutes is counterproductive, as it likely damages the fiber structure, causing absorption to increase again.

**Interpretation of Results**

The experimental results clearly indicate that the water absorption of oil-treated coconut leaf fibers is significantly influenced by the duration of oven drying. Among all the samples tested, the fibers dried for 15 minutes exhibited the lowest water absorption value of approximately 19%, which is considerably lower compared to other drying durations.

At 5 minutes of drying, the fibers were not completely free from internal moisture. As a result, the presence of residual moisture reduced the effectiveness of oil coating and allowed more water to be absorbed during immersion, leading to a higher absorption value of about 28%.

When the drying time was increased to 15 minutes, sufficient removal of internal moisture was achieved. This condition allowed the oil treatment to form a uniform and effective hydrophobic layer over the fiber surface. Consequently, the penetration of water into the fiber structure was minimized, resulting in the lowest observed water absorption.

However, further increase in drying time to 30 minutes and 60 minutes did not lead to additional improvement. Instead, a slight increase in water absorption was observed. This behavior may be attributed to:

- Over-drying of fibers, leading to stiffness and brittleness
- Formation of micro-cracks or surface irregularities
- Reduction in the effectiveness of oil coating due to changes in fiber structure

These factors can create pathways for water ingress, thereby slightly increasing the absorption capacity.

## Effect of Oil Treatment

The use of used engine oil as a treatment material plays a crucial role in reducing water absorption. The oil acts as a water-repellent (hydrophobic) coating, which:

- Blocks the natural pores of the fibers
- Reduces capillary suction
- Limits moisture penetration

The effectiveness of this treatment is maximum at the optimum drying condition of 15 minutes, where both moisture removal and coating efficiency are well balanced.

## SLUMP CONE TEST –

### Introduction

The slump cone test was conducted to determine the **workability and consistency** of fresh concrete mixes with and without coconut leaf fibers. The test was performed in accordance with **Bureau of Indian Standards guidelines (IS 1199: Methods of Sampling and Analysis of Concrete)**.

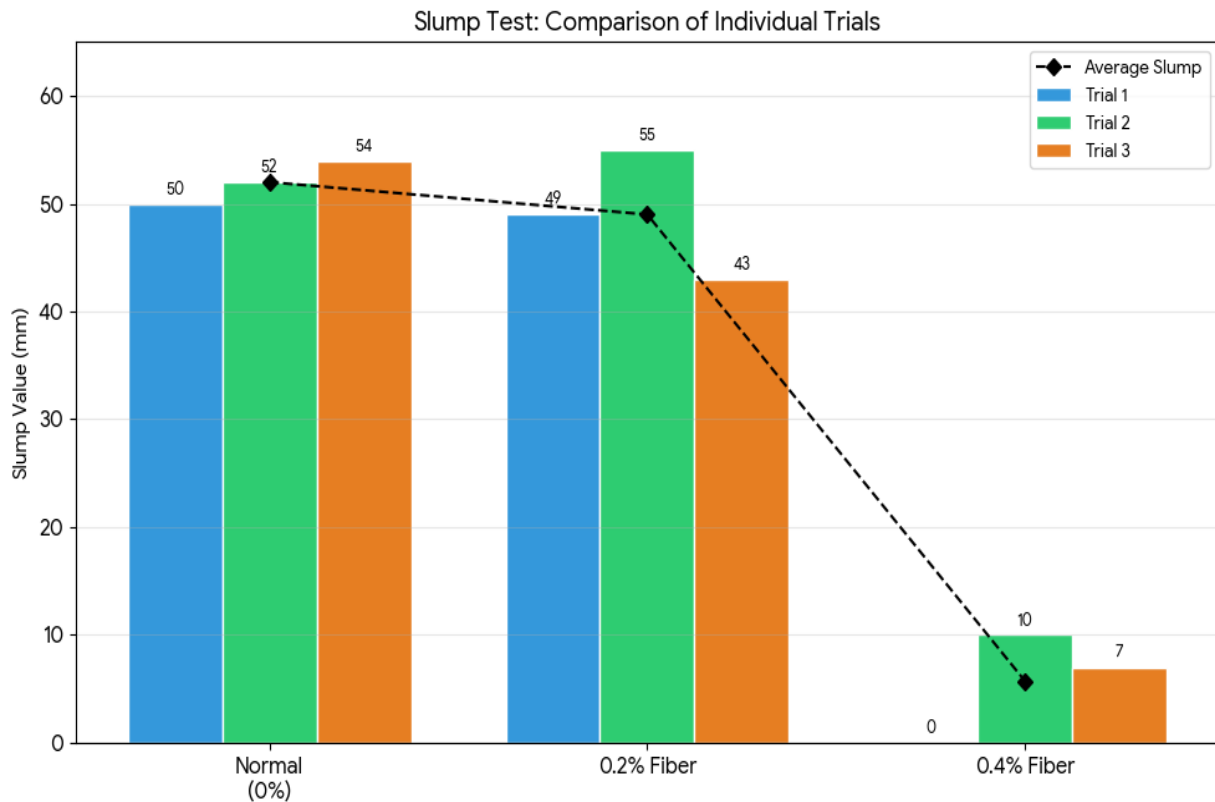
Workability is an important property of fresh concrete, as it affects **mixing, placing, compaction, and finishing** of concrete.

### Experimental Results

The test was conducted three times for each mix proportion to ensure reliability and minimize experimental error.

**Table2: Slump Values for Different Mixes**

Mix Type	Trial 1 (mm)	Trial 2 (mm)	Trial 3 (mm)	Average Slump (mm)
Normal Concrete	50	52	54	52
0.2% Coconut Leaf Fiber Concrete	49	55	43	49
0.4% Coconut Leaf Fiber Concrete	0	10	7	5.7



**FIGURE 2: SLUMP TEST RESULT GRAPH**

## Discussion of Results

### Normal Concrete

- The slump values obtained (50 mm, 52 mm, and 54 mm) fall under the category of **medium workability**.
- The average slump of **52 mm** indicates that the concrete is suitable for:
  - Reinforced concrete works
  - Beams, slabs, and columns with normal reinforcement
- The variation between trials is very small ( $\pm 2$  mm), which shows:
  - Good **uniformity of mix**
  - Proper **water-cement ratio control**
- The slump shape observed was likely a **true slump**, indicating proper cohesion and no segregation.

### Concrete with 0.2% Coconut Leaf Fibers

- The slump values (49 mm, 55 mm, and 43 mm) show **slight variation**, with an average of **49 mm**.
- Compared to normal concrete:
  - There is a **slight reduction in workability**
  - However, the mix still falls under **medium workability**
- The variation in readings is due to:

- **Non-uniform distribution of fibers**
- Random orientation of fibers affecting flow
- Fibers tend to:
  - **Absorb part of the mixing water**
  - Increase **internal friction**
- Despite this, at **0.2% fiber content**, the effect on workability is minimal, and the concrete remains: Easy to place, Easy to compact

### Concrete with 0.4% Coconut Leaf Fibers

- The slump values (0 mm, 10 mm, and 7 mm) indicate **very low workability**, with an average of **5.7 mm**.
- A slump value close to zero represents a **very stiff and harsh mix**.
- This drastic reduction in workability is due to:
  - **High fiber content**, which increases internal resistance
  - **Water absorption by fibers**, reducing free water available for lubrication
  - **Interlocking of fibers**, restricting movement of aggregates
- Problems observed in such mixes:
  - Difficulty in **placing and compaction**
  - Increased chances of **honeycombing**
  - Poor surface finish
- The slump type may approach a **zero slump**, indicating that the concrete does not flow under its own weight.

### Comparative Analysis

- As fiber content increases from **0% to 0.4%**, there is a **significant decrease in slump value**.
- Relationship observed:
  - **0% Fiber** → **Good workability**
  - **0.2% Fiber** → **Slight reduction**
  - **0.4% Fiber** → **Severe reduction**
- This shows that **workability is inversely proportional to fiber content**.
- The reduction trend is mainly due to:
  - Increased **surface area of fibers**
  - Higher **water demand**

- Increased **mix cohesion and stiffness**

## COMPRESSIVE STRENGTH TEST

### Introduction

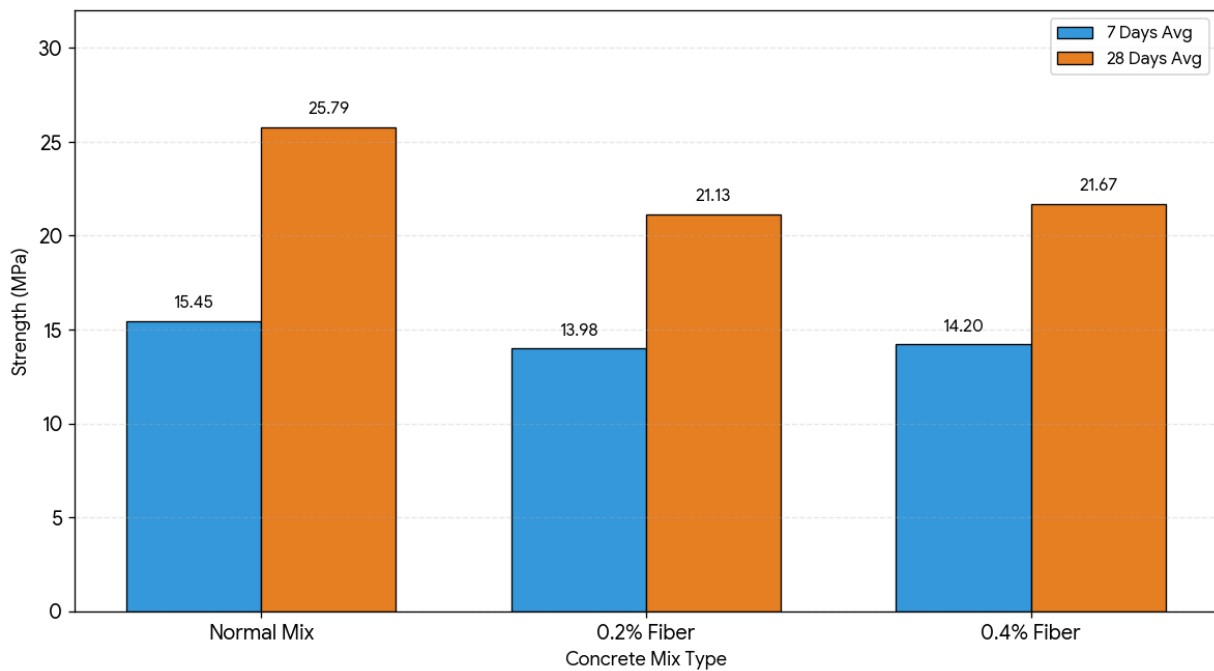
The compressive strength test was carried out on concrete specimens of M20 grade to evaluate the effect of coconut leaf fibers on strength characteristics. The test was conducted at curing ages of **7 days and 28 days** as per standard practice, and all results are expressed in **N/mm<sup>2</sup>**.

### Experimental Results

The detailed results obtained from the compression testing machine are presented below:

Table3 : Compressive Strength Results (N/mm <sup>2</sup> )								
Mix Type	7 Days				28 Days			
	Trial 1	Trial 2	Trial 3	Avg.	Trial 1	Trial 2	Trial 3	Avg.
Normal Mix	16	15	15.36	<b>15.45</b>	23.92	26.48	26.97	<b>25.79</b>
0.2% Fiber Mix	14.45	13.4	14.1	<b>13.98</b>	21.08	20.95	21.37	<b>21.13</b>
0.4% Fiber Mix	14.5	13.4	14.7	<b>14.20</b>	21.8	21.06	22.16	<b>21.67</b>

Compressive Strength Analysis



**FIGURE 3: COMPRESSIVE STRENGTH ANALYSIS**

### compressive strength graph analysis :

- Positive Strength Gain: All mixes show a healthy 60–65% increase in strength from 7 to 28 days, confirming effective hydration.

- **Fiber Reduction:** Adding coconut fibers caused an initial 16–18% drop in compressive strength compared to the Normal Mix (25.79 MPa).
- **Optimal Fiber Content:** The 0.4% mix (21.67 MPa) slightly outperformed the 0.2% mix, suggesting it is the more effective dosage for mechanical performance.
- **Improved Consistency:** Fiber-reinforced trials showed less variation than the normal mix, indicating a more stable internal matrix despite the lower peak strength.

### **Detailed Discussion**

#### **Strength Development with Age**

It is observed that compressive strength increases from 7 days to 28 days for all mixes. This is due to the continuous hydration of cement, which leads to the formation of additional calcium silicate hydrate (C-S-H) gel, improving the overall strength of concrete.

- Normal mix: Increased from **15.45 to 25.79 N/mm<sup>2</sup>** (~67% gain)
- 0.2% fiber mix: Increased from **13.98 to 21.13 N/mm<sup>2</sup>** (~51% gain)
- 0.4% fiber mix: Increased from **14.20 to 21.67 N/mm<sup>2</sup>** (~52% gain)

This confirms that all mixes follow the normal strength gain pattern.

#### **Comparison of Normal and Fiber Reinforced Concrete**

The normal concrete mix shows the highest compressive strength at both curing periods. When coconut leaf fibers are added:

- At **0.2% fiber content**, there is a noticeable reduction in strength:
  - Around **9–10% lower at 7 days**
  - Around **18% lower at 28 days**
- At **0.4% fiber content**, strength is slightly higher than 0.2% mix:
  - Improvement of about **1–2% compared to 0.2% mix**
  - Still lower than normal concrete by **15–16%**

#### **Effect of Fiber Content**

The results show that increasing fiber content from 0.2% to 0.4% leads to a slight improvement in compressive strength, but it does not reach the strength of normal concrete.

This indicates:

- Low fiber content may not be sufficient to enhance bonding.
- Slight increase in fiber content improves load distribution but also introduces some negative effects.

#### **Engineering Interpretation**

Although compressive strength decreases with fiber addition, fiber-reinforced concrete offers other advantages:

- Improved **crack resistance**
- Increased **impact resistance**

- Enhanced **durability performance**

Thus, coconut leaf fibers may be more beneficial in applications where tensile behavior and crack control are important rather than compressive strength.

#### HALF-CELL OPEN CIRCUIT POTENTIAL (HCP) TEST

##### Introduction

The Half-Cell Open Circuit Potential (HCP) test is a non-destructive electrochemical method used to assess the **probability of corrosion of reinforcing steel in concrete**. The test measures the electrical potential difference between embedded steel reinforcement and a standard reference electrode (usually Cu/CuSO<sub>4</sub>).

More negative potential values indicate a **higher likelihood of corrosion activity**, while less negative values indicate that the steel is in a **passive and protected condition**.

##### Experimental Results

The measured HCP values for different concrete mixes are given below:

###### (a) Normal Mix Concrete

**TABLE 4: NORMAL MIX CONCRETE**

Specimen No.	Potential (mV)
1	-212.09
2	-235.10
3	-226.60
4	-205.80
5	-198.70

**Average Value = -215.66 Mv**

###### (b) 0.2% Fiber Mix Concrete

**TABLE 5: 0.2% FIBER MIX CONCRETE**

Specimen No.	Potential (mV)
1	-178.60
2	-165.70
3	-146.60
4	-146.10
5	-172.10

**Average Value = -161.82 mV**

###### (c) 0.4% Fiber Mix Concrete

**TABLE 6: 0.4% FIBER MIX CONCRETE**

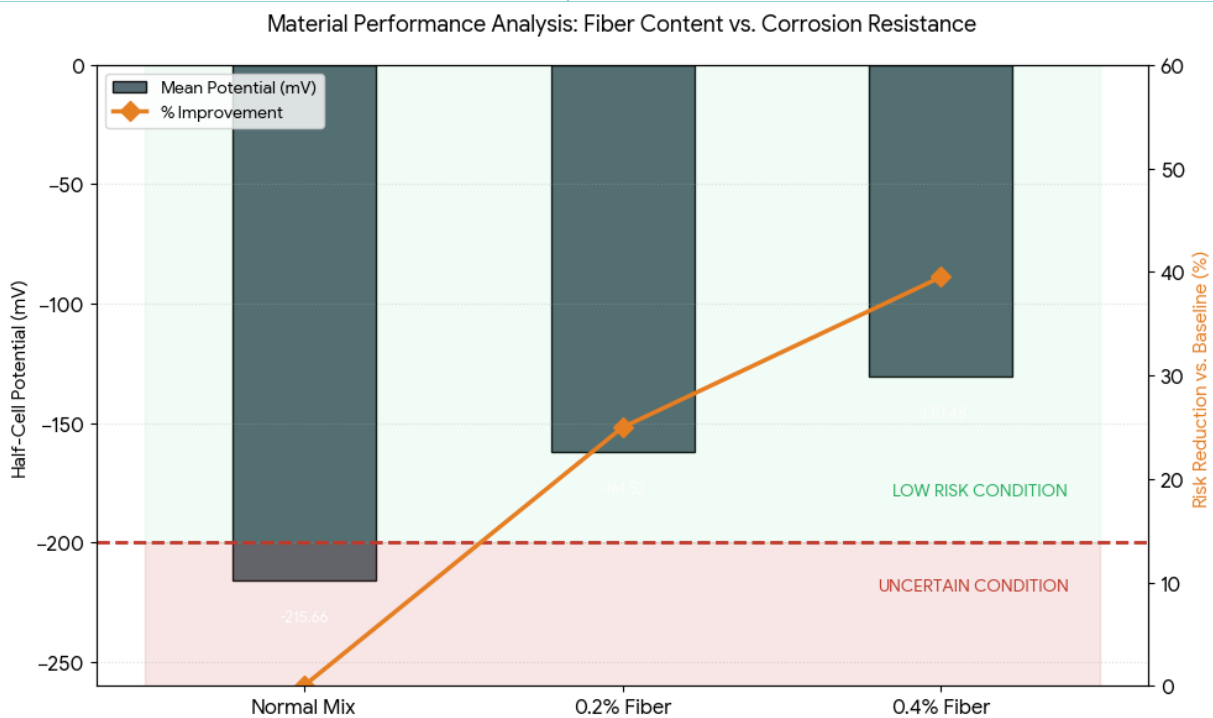
Specimen No.	Potential (mV)
--------------	----------------

1	-149.60
2	-124.60
3	-156.20
4	-109.10
5	-112.90

Average Value = -130.48 mV

### 8.4.3. Interpretation as per Standard Guidelines (ASTM C876)

TABLE 7: Interpretation as per Standard Guidelines (ASTM C876)	
Potential Range (mV)	Corrosion Probability
Greater than -200 mV	90% probability of <b>no corrosion</b>
Between -200 mV and -350 mV	<b>Uncertain condition</b>
Less than -350 mV	90% probability of <b>active corrosion</b>



**FIGURE 4: MATERIAL PERFORMANCE ANALYSIS**

### Performance Analysis

The Half-Cell Potential test measures the electrical potential of reinforcing steel to estimate the probability of active corrosion.

#### 1. Baseline Analysis (Normal Mix)

- Average Potential: -215.66mV

- Compliance Status: This value falls below the -200 mV threshold. According to ASTM C876, this mix is in the Uncertain Condition (Red Zone), where corrosion probability is roughly 50%

## 2. Impact of 0.2% Fiber Reinforcement

- Average Potential: -161.82 mV
- Improvement: A 25.0% reduction in negative potential compared to the baseline.
- Risk Mitigation: The potential successfully shifted into the Low Risk Condition (< 10% corrosion probability), proving that even a low dose of fiber significantly protects the reinforcement.

## 3. Impact of 0.4% Fiber Reinforcement

- Average Potential: -130.48 mV
- Improvement: A total 39.5% reduction compared to the baseline.
- Engineering Conclusion: While 0.2% fiber is sufficient to move the material into the "Low Risk" zone, the 0.4% mix provides a 31.3mV additional safety margin, making it the superior choice for high-durability environments.

### Engineering Summary

**TABLE 8 :RISK REDUCTION**

Mix Type	Potential (mV)	Risk Status (ASTM C876)	% Risk Reduction
Normal Mix	-215.66	● Uncertain	0%
0.2% Fiber	-161.82	□ Low Risk	25.0%
0.4% Fiber	-130.48	□ Low Risk	39.5%

Conclusion: The addition of fiber reinforcement effectively "lifts" the electrical potential out of the Uncertain Condition and into a stable, Low Risk state. The trend is linear, suggesting that higher fiber content directly correlates with enhanced corrosion resistance.

### Detailed Discussion

#### Normal Mix Concrete

- The average potential value is **-215.66 mV**, which falls in the **uncertain corrosion range**.
- Most readings are close to or more negative than **-200 mV**, indicating that corrosion **may initiate or already be present in some areas**.
- The absence of fibers results in:
  - Higher permeability
  - Increased micro-cracking
  - Easier ingress of moisture, oxygen, and chloride ions This leads to a **higher risk of corrosion of reinforcement steel**.

## 0.2% Fiber Mix Concrete

- The average potential value is **-161.82 mV**, which lies in the **low corrosion probability range**.
- All readings are significantly **less negative than the normal mix**, showing clear improvement.

### Reason for Improvement:

- Addition of oil-treated coconut leaf fibers:
  - Reduces shrinkage cracks
  - Improves concrete density
  - Blocks capillary pores
  - Limits chloride penetration

This results in a **more protective environment around the steel**, reducing corrosion chances

## 0.4% Fiber Mix Concrete

- The average potential value is **-130.48 mV**, indicating a **very low probability of corrosion**.
- This mix shows the **least negative potential values**, meaning:
  - Steel is in a **highly passive condition**

## 5. Comparative Analysis

TABLE 9: COMPARATIVE ANALYSIS

Mix Type	Average Potential (mV)	Corrosion Condition
Normal Mix	-215.66	Uncertain / Higher Risk
0.2% Fiber Mix	-161.82	Low Risk
0.4% Fiber Mix	-130.48	Very Low Risk

### Trend Observed:

- As fiber content increases:
  - Potential values become **less negative**
  - Corrosion probability **decreases**

This clearly indicates that **fiber addition improves durability and corrosion resistance**.

## 6. Engineering Significance

- Corrosion of reinforcement is one of the **major causes of concrete deterioration**.
- The use of **oil-treated natural fibers**:
  - Enhances durability
  - Extends service life of structures

- Provides a **cost-effective and eco-friendly solution**

### GRAVIMETRIC METHOD (WEIGHT LOSS METHOD)

#### Experimental Details

In the present study, each concrete specimen consisted of:

- 4 reinforcement steel bars
- Diameter of each bar = 6 mm (0.6 cm)
- Length of each bar = 15 cm

After exposure to a corrosive environment:

- Specimens were broken carefully
- Steel bars were extracted
- Cleaned to remove corrosion products
- Dried thoroughly
- Weighed using a digital balance

The initial weight ( $W_1$ ) and final weight ( $W_2$ ) were recorded.

Weight loss was calculated for each bar and average values were determined.

#### Formula Used

(a) Weight Loss

$$W = W_1 - W_2$$

Where:

- $W_1$  = Initial weight (g)
- $W_2$  = Final weight (g)

(b) Corrosion Rate

$$\text{Corrosion Rate} = \frac{87.6 \times W}{D \times A \times T}$$

Where:

- $W$  = Weight loss (mg)
- $D$  = Density of steel = 7.85 g/cm<sup>3</sup>
- $A$  = Surface area (cm<sup>2</sup>)
- $T$  = Exposure time = 720 hours

#### Surface Area Calculation

Given:

- Diameter ( $d$ ) = 0.6 cm

- Length (L) = 15 cm

$$A = \pi dL = 3.14 \times 0.6 \times 15 = 28.26 \text{ cm}^2$$

Surface area of one bar = 28.26 cm<sup>2</sup>

### Experimental Results (Updated Data)

#### (a) Normal Mix Concrete

TABLE NO 10 : NORMAL MIX CONCRETE			
Bar No.	Initial (g)	Final (g)	Weight Loss (g)
1	33.63	32.6	1.00
2	34.17	33.16	1.005
3	33.59	32.59	1.00
4	37.94	36.94	1.00

**Average Weight Loss ≈ 1.00 g per bar**

#### (b) 0.2% Fiber Mix Concrete

TABLE NO 11 : 0.2% FIBER MIX			
Bar No.	Initial (g)	Final (g)	Weight Loss (g)
1	31.23	30.42	0.80
2	33.96	33.16	0.80
3	32.70	31.9	0.80
4	35.42	34.6	0.80

**Average Weight Loss ≈ 0.80 g per bar**

#### (c) 0.4% Fiber Mix Concrete

TABLE NO 21 : 0.4% FIBER MIX

TABLE NO 12 : 0.4% FIBER MIX			
Bar No.	Initial (g)	Final (g)	Weight Loss (g)
1	34.46	34.1	0.30
2	32.9	32.658	0.30
3	34.15	33.8	0.30
4	33.0	32.7	0.30

**Average Weight Loss ≈ 0.30 g per bar**

**Sample Calculation**

For Normal Mix – Bar 1:

Step 1: Weight Loss

$$W = 33.63 - 32.63 = 1.00 \text{ g} = 1000 \text{ mg}$$

Step 2: Corrosion Rate

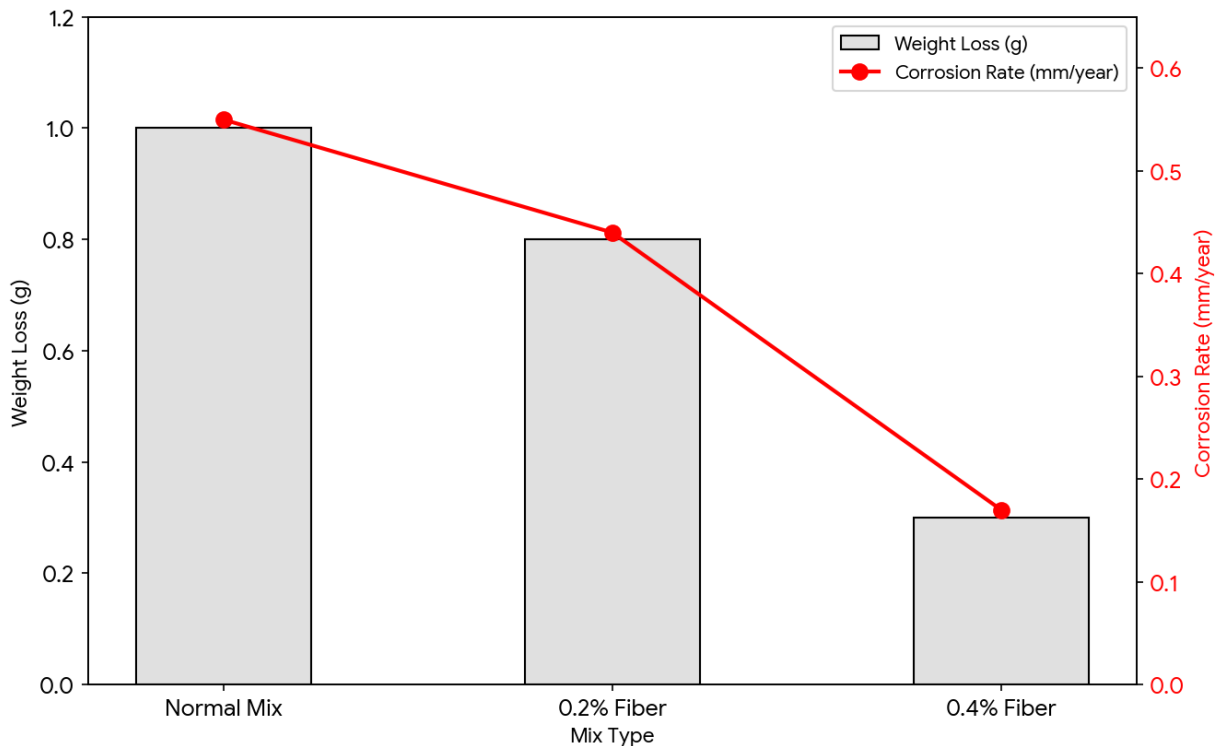
$$\text{Corrosion Rate} = \frac{87.6 \times 1000}{7.85 \times 28.26 \times 720} \approx 0.55 \text{ mm/year}$$

8.5.6 Summary of Results

TABLE 13: SUMMARY OF WEIGHT LOSS TEST RESULTS

Mix Type	Avg Weight Loss (g/bar)	Corrosion Rate (mm/year)
Normal Mix	1.00	0.55
0.2% Fiber Mix	0.80	0.44
0.4% Fiber Mix	0.30	0.17

Combined: Weight Loss vs Corrosion Rate



**FIGURE 5: WEIGHT LOSS VS CORROSION RATE**

8.5.7 Detailed Discussion

Normal Mix Concrete

- Shows highest weight loss (1.00 g)
- Highest corrosion rate
- Indicates severe corrosion condition

Reasons:

- High permeability
- Micro-cracks formation
- Easy ingress of chlorides and moisture

→ Leads to rapid corrosion of reinforcement steel

0.2% Fiber Mix Concrete

- Weight loss reduced to 0.80 g
- Corrosion rate decreases moderately

Reasons:

- Fibers reduce cracking
- Improve internal structure
- Lower permeability

→ Provides moderate corrosion resistance

0.4% Fiber Mix Concrete

- Lowest weight loss (0.30 g)
- Lowest corrosion rate

Reasons:

- Effective crack bridging
- Dense concrete matrix
- Strong barrier against corrosive agents

→ Steel remains in passive/protected condition

Comparative Analysis

- Increase in fiber content → Decrease in weight loss
- Decrease in weight loss → Lower corrosion rate

✓ Clear trend: Higher fiber content improves durability

Engineering Significance

Corrosion causes:

- Reduction in steel cross-section
- Loss of bond strength
- Structural deterioration

Use of oil-treated coconut leaf fibers:

- Improves durability
- Reduces corrosion

- Enhances service life

## **7. conclusion**

The experimental investigation on “Corrosion Resistance of Reinforcing Steel in Concrete Using Natural Fibers Treated with Used Engine Oil” leads to the following conclusions based on different tests:

### **7.1 Water Absorption Characteristics**

Oil-treated coconut leaf fibers dried for 15 minutes show the lowest water absorption. Lower water absorption helps in reducing moisture penetration into concrete and improves the durability of reinforced concrete.

### **7.2 Workability (Slump Cone Test)**

The slump test results show that the addition of coconut leaf fibers reduces the workability of concrete due to internal friction and fiber interlocking. The 0.2% fiber content provides optimum workability, while 0.4% fiber content makes the mix relatively stiff.

### **7.3 Compressive Strength**

The results indicate that normal concrete achieves the highest compressive strength and satisfies the M20 grade requirement. The addition of fibers slightly reduces compressive strength, but the 0.4% fiber mix performs better than the 0.2% fiber mix.

### **7.4 Corrosion Resistance (Half-Cell Potential Method)**

The Half-Cell Potential test results show that normal concrete has a higher probability of corrosion. The addition of fibers improves corrosion resistance, and the 0.4% fiber mix provides the maximum corrosion protection.

### **7.5 Corrosion Resistance (Gravimetric Method)**

Gravimetric test results indicate that normal concrete shows the highest weight loss, which means higher corrosion. The 0.2% fiber mix shows improved performance, while the 0.4% fiber mix gives the best corrosion resistance.

## **Final Overall Conclusion**

It can be finally concluded that the incorporation of **used oil-treated coconut leaf fibers** in concrete effectively enhances the **corrosion resistance of reinforcing steel**, as confirmed by both Half-Cell Potential and Gravimetric methods.

Although there is a reduction in compressive strength and workability at higher fiber content, the **0.4% fiber mix provides the best corrosion protection**, making it highly suitable for structures where **durability and resistance to corrosion are more critical than strength**.

This method offers an **eco-friendly, economical, and sustainable solution** for improving the service life of reinforced concrete structures.

## 8. References

### 8.1) Research papers

1. Alejandro Flores Nicolás et al. (2024)  
Corrosion Resistance using Natural Fibers  
<https://civilejournal.org/index.php/cej/article/view/4894>
2. Gopu G. Naidu & S. A. Joseph (2022)  
Corrosion Behavior of FRC – Review  
<https://www.ijسات.org/papers/2025/4/9185.pdf>
3. Nabeel A. et al. (2022)  
Corrosion Effect on Fiber Reinforced Geopolymer Concrete  
<https://www.sciencedirect.com>
4. Pawar et al. (2022)  
Waste Oil Treated Fibers in Marine Concrete  
<https://scholar.google.com>
5. Chavan & Salunkhe (2021)  
Treated vs Untreated Fibers in RCC  
<https://www.ijert.org>
6. Natural Fiber Cement Composite Study (2022)  
<https://www.nature.com/articles/s41598-022-25085-6>
7. Natural Fiber Reinforced Concrete Review (2025)  
<https://www.sciencedirect.com/science/article/pii/S0926669025020679>
8. Bond Behaviour of Treated Natural Fibre in Concrete (2022)  
<https://www.scientific.net/NHC.34.37>
9. Recycled Textile Fibers in Structural Concrete (2025)  
<https://link.springer.com/article/10.1007/s44416-025-00029-1>
10. Chemically Treated Natural Fibers in Concrete (2025)  
<https://www.nature.com/articles/s41598-025-21957-9>

### 8.2) IS CODES (RELEVANT TO YOUR PROJECT)

1. Bureau of Indian Standards (2000)  
IS 456:2000 – Plain and Reinforced Concrete (Durability & corrosion provisions)  
<https://www.bis.gov.in>
2. Bureau of Indian Standards (2019)  
IS 10262:2019 – Concrete Mix Design  
<https://www.bis.gov.in>

3. Bureau of Indian Standards (1959)  
IS 516:1959 – Compressive Strength Test  
<https://www.bis.gov.in>
4. Bureau of Indian Standards (1959)  
IS 1199:1959 – Slump Test (Workability)  
<https://www.bis.gov.in>
5. Bureau of Indian Standards (2013)  
IS 12269:2013 – Cement Specification (OPC reference)  
<https://www.bis.gov.in>
6. Bureau of Indian Standards (1989)  
IS 8112:1989 – PPC Cement (used in your project)  
<https://www.bis.gov.in>

#### ASTM STANDARD

11. ASTM International  
ASTM C876 – Half-Cell Potential Test for Corrosion of Reinforcing Steel  
<https://www.astm.org>
12. ASTM International  
ASTM G262 – Practice for Detecting Susceptibility to Intergranular Attack in Stainless Steel  
<https://www.astm.org>

#### 8.3) OTHER REFERENCES

1. ScienceDirect  
Research papers on fiber reinforced concrete & corrosion  
<https://www.sciencedirect.com>
2. Springer  
Concrete durability and corrosion studies  
<https://link.springer.com>
3. ResearchGate  
Natural fiber concrete & corrosion research papers  
<https://www.researchgate.net>
4. Google Scholar  
Search engine for journals & thesis  
<https://scholar.google.com>
6. Taylor & Francis  
Advanced research on construction materials  
<https://www.tandfonline.com>
7. ASCE Library  
Journal of Materials in Civil Engineering  
<https://ascelibrary.org>



9. Civil Engineering Portal  
Practical articles on concrete tests & materials  
<https://www.engineeringcivil.com>
10. The Constructor  
Concrete technology, tests & procedures  
<https://theconstructor.org>
11. YouTube  
Half Cell Potential Test (ASTM C876) – Procedure & Explanation  
<https://www.youtube.com>
12. YouTube  
Slump Cone Test of Concrete – Practical Demonstration  
<https://www.youtube.com>
13. YouTube  
Compressive Strength Test of Concrete Cubes  
<https://www.youtube.com>
14. National Programme on Technology Enhanced Learning  
Concrete Technology Lectures (Corrosion & Durability)  
<https://nptel.ac.in>
15. Coursera  
Construction Materials & Concrete Durability Course  
<https://www.coursera.org>
16. American Concrete Institute  
Concrete Durability & Corrosion Resources  
<https://www.concrete.org>