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# Evaluation of the Flexural Performance of Concrete FC'25 with the Addition of Coconut Fiber

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## Abstract

With a target compressive strength of FC'25, this study investigates how adding coconut fiber affects the flexural performance of concrete. Assessing the improvement in concrete's flexural strength and durability when natural coconut fibers are used as reinforcement instead of synthetic fibers is the main goal. The availability, sustainability, and potential to enhance the mechanical qualities of concrete led to the selection of coconut fiber. Different percentages of coconut fibers (0.5%, 1%, and 1.5% by weight of cement) were added to concrete, and tests of durability and flexural strength were performed. After 28 days of curing, flexural tests were conducted on the concrete samples to ascertain their ultimate strength, modulus of rupture, and deflection. Consistency and mixing ease were the main criteria used to assess the mixes' workability. According to the results, adding coconut fibers to concrete greatly increased its flexural strength; the mix containing 1% coconut fibers improved the most when compared to the control sample. Higher fiber contents (1.5%), however, led to decreased strength because the mixture became more porous, weakening the concrete. Additionally, the study showed that coconut fiber increased concrete's resistance to cracking, which enhanced durability. The findings indicate that coconut fiber has potential as a concrete reinforcing material, providing a cost-effective and sustainable way to improve the mechanical properties of concrete structures, particularly in applications that call for greater flexural strength and crack resistance. The potential for improving fiber content and mix design for better performance in a range of environmental situations, as well as the long-term consequences and wider uses of coconut fiber-reinforced concrete in structural engineering, should all be investigated further.

**Keywords** : *coconut fiber, flexural strength, concrete, sustainability, durability, FC'25.*

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# I. INTRODUCTION

Concrete's strength, durability, and affordability make it the most used building material in the world. However, conventional concrete has drawbacks, especially when it comes to its low tensile strength and brittleness. In applications where the material is susceptible to bending, such as beams, slabs, and pavements, flexural strength, a crucial quality for concrete, is required. In order to improve concrete's performance and increase the lifespan of structures, researchers have been looking for ways to improve its mechanical qualities over time, particularly its flexibility and resistance to cracking.

One method that has been extensively researched to improve the mechanical qualities of concrete is the addition of fibers. The potential of several fiber types, including steel, glass, synthetic, and natural fibers, to enhance the performance of concrete has been investigated. Among these, natural fibers have drawn much interest because of their sustainability and environmental friendliness. The availability, high tensile strength, and durability of coconut fiber in particular have made it a potential material for reinforcing concrete. Furthermore, using natural fibers like coconut fiber supports the global movement for sustainable building materials (Abdalla et al., 2023; Singh et al., 2024).

A byproduct of the coconut industry, coconut fiber is mostly made from the husk. It is frequently seen as a waste product and is easily accessible in tropical areas. Nonetheless, its potential as a concrete reinforcing material is becoming more widely acknowledged. Numerous studies have shown that adding natural fibers, such as coconut, to concrete can increase its tensile and flexural strength, offering a sustainable substitute for synthetic fibers and lessening the impact of building materials on the environment (Zaid et al., 2025). Specifically, coconut fiber is a plentiful resource that does not require much energy to process, which makes it a desirable choice for environmentally friendly concrete reinforcement.

**Problem Statement**

One of concrete's main drawbacks in many structural applications is its vulnerability to cracking under flexural loads. Cracks can jeopardize structures' stability, resulting in maintenance problems, increased repair expenses, and, in extreme situations, structural failure. Fiber reinforcement in concrete has emerged as a workable way to lessen this issue. Fibers increase the material's ductility and lessen the chance of cracks by distributing the applied load more evenly.

Though numerous studies have examined how various fiber types affect concrete's flexural performance, little is known about the precise impacts of coconut fiber, especially in concrete with a compressive strength of FC'25. It is also unknown how much coconut fiber is the ideal amount to add to concrete without degrading its overall strength or workability. Using coconut fiber as a reinforcement material has shown mixed results in numerous studies; some have found advantages in mechanical qualities, while others have found that the excessive fiber content reduces strength (Ali et al., 2022). Therefore, in order to better understand concrete's potential and limitations as a reinforcement material, it is vital to look into how different coconut fiber contents affect the material's flexural performance.

Furthermore, although the effects of coconut fiber on compressive strength have been investigated, nothing is known about how it influences concrete's flexural strength and fracture resistance, particularly when using a typical mix like FC'25. An excellent choice for this kind of research is concrete with a compressive strength of FC'25, which is frequently utilized in medium-strength applications like sidewalks, pavements, and residential constructions. In certain applications, the inclusion of coconut fiber may increase the mix's flexibility, lessen cracking, and boost overall performance. The efficacy of this strategy has not yet been fully assessed, though, particularly when considering a popular concrete mix design.

**Research Objectives**

The main goal of this study is to assess the flexural performance of concrete FC'25 reinforced with coconut fiber. In particular, the study will concentrate on the following goals:

1. To assess how adding coconut fiber affects concrete FC'25's flexural strength, this will entail evaluating how various fiber content levels affect the concrete's resistance to bending, as demonstrated by the final flexural strength and modulus of rupture.
2. To examine the concrete reinforced with coconut fibers' workability and handling characteristics: Workability is a crucial consideration when assessing how simple it is to mix, pour, and finish concrete. The study will evaluate the impact of adding coconut fiber on the concrete mix's workability.
3. The best percentage of coconut fiber to add to concrete FC'25 will be determined by testing various fiber content percentages (such as

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0.5%, 1%, and 1.5%), which will improve the flexural performance of the concrete without sacrificing its strength and workability.

By offering a thorough assessment of the flexural performance of coconut fiber-reinforced concrete with a compressive strength of FC'25, this study seeks to close the gap in the body of literature. The findings of this study will provide important information about the possible employment of coconut fiber as a substitute reinforcement material in concrete, particularly in applications where fracture resistance and flexural strength are crucial. Furthermore, by encouraging the use of natural fibers in concrete to lessen the environmental impact of the construction sector, the findings will add to the expanding body of knowledge on sustainable building materials.

## II. BIBLIOGRAPHY

The need for more robust, environmentally friendly, and reasonably priced building materials has led to a sharp rise in research on fiber-reinforced concrete in recent years. Natural fibers, such as coconut fiber, have drawn much interest because of their accessibility, affordability, and sustainability. In a study by Vélez et al. (2022), it was demonstrated that adding coconut fiber up to 1% by weight of the concrete mix improved the mechanical qualities of the mixture, including compressive and tensile strength. Similar findings were made by Ullah et al. (2025), who discovered that coconut fiber reinforced concrete had improved post-crack behavior and fracture resistance, making it appropriate for applications needing durability.

Other research has brought attention to the difficulties in incorporating coconut fiber into concrete, namely with workability and the possibility of fiber clumping (Lejano et al., 2024). Furthermore, it has been demonstrated that a high fiber concentration reduces the strength of the concrete, presumably as a result of poor bonding between the fiber and the cement matrix and an increase in the mix's porosity. To optimize the advantages of utilizing coconut fiber without sacrificing the concrete's overall strength, the fiber content must be carefully controlled.

Results on coconut fiber's flexural strength have been inconsistent. While some studies imply that too much fiber can result in a reduction in strength due to the voids formed in the mix, others show that the fiber's ability to bridge cracks and distribute applied loads more uniformly increases flexural strength (Veerappan et al., 2024). (Aliha et al., 2022). Thus, the purpose of this study is to give a more thorough examination of the flexural performance of concrete FC'25 with coconut fiber added, providing important information on the ideal fiber content for improved concrete performance.

Adding coconut fiber to concrete has the potential to improve the material's mechanical qualities, especially its resistance to cracking and flexural strength. This study attempts to give a thorough grasp of the advantages and restrictions of utilizing coconut fiber in concrete by examining the impact of different coconut fiber contents on the flexural performance of concrete FC'25.

## III. METHODOLOGY

This section describes the research strategy and methodology used to assess the flexural performance of concrete FC'25 with coconut fiber added. As part of the study's experimental methodology, concrete samples reinforced with different amounts of coconut fiber are created, cured, and put through a battery of tests to determine their flexural strength and durability. Material preparation, mix design, sample preparation, experimental protocol, testing techniques, and data analysis are all included in the process.


**Figure 1. Flowchart Concrete Sample Preparation and Testing Process**

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**1. Materials**

Ordinary Portland Cement (OPC), fine and coarse aggregates (gravel and sand), water, and coconut fiber are the ingredients employed in this study. The specifications for creating concrete with a goal compressive strength of 25 MPa (FC'25) serve as the foundation for the design of the concrete mix. The following materials were used in the study:

- Cement: Ordinary Portland Cement (OPC) conforming to ASTM C150 standards.
- Fine Aggregate: Natural river sand with a maximum particle size of 4.75 mm, obtained from a local supplier.
- Coarse Aggregate: Crushed gravel with a maximum particle size of 19 mm.
- Water: Potable water is used for mixing and curing the concrete.
- Coconut Fiber: Natural coconut fibers obtained from a local source. The fibers are processed and chopped into uniform lengths of approximately 30 mm.

The selection of coconut fibers was based on their sustainability, accessibility, and prior evidence of their beneficial effects on concrete's mechanical qualities. The fibers are a good substitute for synthetic fibers because they are non-toxic, biodegradable, and eco-friendly.

**2. Concrete Mix Design**

The concrete mix design is predicated on the FC'25 objective compressive strength, which is frequently utilized in structural applications. For concrete with a goal strength of 25 MPa, the mix proportion was established using the traditional method. The following is the mix design:

**Table 1. Material Requirements For 1 M³ Concrete Fc'25**

| Material | Quantity (per m³) |
|---|---|
| Cement | 350 kg/m³ |
| Fine Aggregate | 750 kg/m³ |
| Coarse Aggregate | 1200 kg/m³ |
| Water | 175 liters/m³ (water-cement ratio of 0.5) |

*Source : Analysis Results*

For the experimental setup, coconut fiber was added to the mix in different volume fractions: 0.5%, 1%, and 1.5% by weight of the cement component. These fiber contents were chosen based on earlier research showing the best fiber addition for enhancing concrete qualities without sacrificing the mixture's workability and strength. To provide a baseline for comparison, a control mix devoid of coconut fiber was also made.

**3. Sample Preparation**

The preparation of the concrete samples involved the following steps:

1. Fiber Preparation: The coconut fibers were obtained, washed to remove any dirt, and dried under the sun to eliminate moisture. The fibers were chopped into 30 mm lengths to ensure uniformity in size for consistent distribution in the concrete mix.
2. Mixing Process: The mixing process was done using a mechanical concrete mixer. First, the cement, fine aggregate, and coarse aggregate were thoroughly mixed. Then, the coconut fibers were added to the dry mix, followed by the addition of water. The fibers were evenly distributed throughout the mixture to avoid clumping. The water-cement ratio was maintained constant at 0.5 for all mixes.
3. Molding: After the mixing process, the concrete was poured into standard molds (150 mm x 150 mm x 150 mm for cubes and 150 mm x 150 mm x 600 mm for beams) and compacted to remove air bubbles. The molds were vibrated for 1-2 minutes to ensure proper compaction and to prevent voids within the mixture. The prepared samples were covered with plastic sheets to prevent moisture loss during the curing process.
4. Curing: The concrete samples were cured for 28 days in a controlled environment with a relative humidity of 95% and a temperature of 23 ± 2°C. The samples were immersed in water for the entire curing period to ensure proper hydration of the cement and prevent premature drying of the concrete.

**4. Experimental Procedure**

Concrete samples with different coconut fiber contents, 0.5%, 1%, and 1.5% by weight of cement, are prepared as part of the experimental process and put through a battery of tests to assess their durability, workability, and flexural performance. The assessment of fracture resistance, modulus of rupture, and flexural strength is the main focus. These tests include visual examination to assess fracture formation, a slump test to indicate workability, and the 2-point bending test to determine flexural strength. Tests for water permeability and compressive strength are also carried out to give further information about the fiber-reinforced concrete samples' overall performance.

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### 4.1. Workability Test

The slump test, which gives an indicator of the consistency and ease of handling of the concrete, was used to assess the workability of the fresh concrete mixtures. ASTM C143 was followed for conducting the test. S slump values were noted for every batch to evaluate the impact of adding coconut fiber on the concrete's workability.

### 4.2. Flexural Strength Test

In compliance with ASTM C293, a typical 2-point bending test was used to determine the concrete samples' flexural strength. The steps are as follows:

- Apparatus: The flexural strength test was conducted using a universal testing machine (UTM) with a load capacity sufficient for the samples.
- Test Setup: A concrete beam with dimensions of 150 mm x 150 mm x 600 mm was placed on the UTM, supported at two points. A load was applied at the midpoint of the beam until failure occurred.
- Test Procedure: The test was performed at a loading rate of 2 kN/min. The applied load was recorded at the point of failure, and the flexural strength was calculated using the following formula:

$$f_r = \frac{P \cdot L}{b \cdot h^2}$$

Where:

- $f_r$ is the flexural strength (MPa),
- $P$ is the applied load at failure (N),
- $L$ is the span length (mm),
- $b$ is the width of the beam (mm),
- $h$ is the height of the beam (mm).

### 4.3. Compressive Strength Test

Compressive strength tests were conducted on concrete cubes (150 mm x 150 mm x 150 mm) following ASTM C39 to supplement the flexural strength results. The cubes were tested at 28 days of curing to determine the impact of coconut fiber on the compressive strength of the concrete.

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

Where:

- $fc$ is the compressive strength (MPa),
- $P$ is the maximum load applied at failure (N),
- $A$ is the cross-sectional area of the concrete cube (mm²).

## IV. RESULTS AND DISCUSSION

### 4.1. Workability Test

According to ASTM C143, the slump test was used to assess the workability of fresh concrete mixes. By measuring the vertical settling of a conical mold after it is removed, the slump test assesses the concrete mixture's consistency and manageability. The more workable the mix, the easier it is to handle and pour the concrete; the greater the slump value. Lower slump values, on the other hand, indicate that the mix is more rigid and challenging to deal with. This test is crucial to making sure the concrete is consistent with placement and finishing. The slump values for each mix, including different percentages of coconut fiber (0%, 0.5%, 1%, and 1.5% by weight of cement), were noted in this investigation.

**Table 2. Slump Test Results for Concrete Mixes with Coconut Fiber**

| Fiber Content (%) | Slump (mm) |
|---|---|
| 0% (control) | 110 |
| 0,5% | 90 |
| 1,0% | 85 |
| 1,5% | 80 |

*Source : Analysis Results*

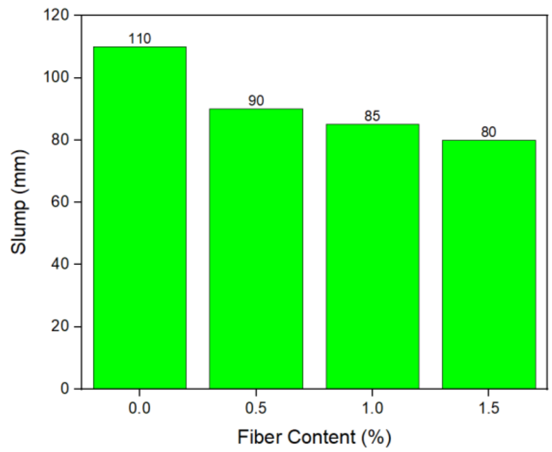


**Figure 2. Slump Test Results for Concrete Mixes with Varying Coconut Fiber Content**

The findings show how the inclusion of coconut fiber impacts the workability of concrete. The addition

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of coconut fibers is anticipated to affect the mix's flowability and water retention because the fibers can absorb water and change the behavior of the paste.

The slump value of the control mix, which is devoid of coconut fiber, was 110 mm. This figure indicates that the mix has the proper fluidity for common building applications since it falls within the normal range for workable concrete. The control mix's constancy made handling, placing, and finishing simple. This offers a starting point for evaluating the effects of varying coconut fiber concentrations on the concrete's workability. Relatively mild slump values are appropriate for general construction uses, offering sufficient workability for standard applications, per investigations by Tahir et al. (2022) and Kong et al. (2023). Similar studies assess the effects of fiber additives on the workability of concrete using the slump value of control mixtures (Yun et al, 2022; Abdelrazik et al., 2022; Bahmani et al., 2025).

The droop of the 0.5% coconut fiber concrete mix was 90 mm, marginally less than that of the control mix. This suggests that the inclusion of coconut fibers has somewhat decreased workability. Because the fibers are absorbent, they probably retained some of the water in the mixture, making it stiffer. Nonetheless, the mix remained manageable and pourable, and the slump value is still within the permissible range for typical concrete workability. These findings are corroborated by research by Wei et al. (2024) and Ortega-Lopez et al. (2021), which found that modest fiber levels, such as 0.5%, result in little slump reduction, preserving the mix's workability.

With a slump value of 85 mm, the mixture containing 1% coconut fiber demonstrated an even greater reduction. This suggests that the concrete has stiffened in comparison to the 0.5% coconut fiber mix and the control. The fiber content decreases the overall fluidity of the mixture because the coconut fibers absorb more water as the fiber level rises. The convenience of putting and completing the concrete may be impacted by this shift in uniformity, particularly in large-scale applications where workability is essential. Similar results were found by Haily et al. (2023) and Hamada et al. (2023), who concluded that a 1% fiber content in concrete may considerably lower the slump value, especially because of the natural fibers' absorption qualities.

The combination with the lowest slump value (80 mm) had the largest percentage of coconut fiber (1.5%). The fibers' higher absorption of water is the cause of this notable decrease in workability, which makes the combination stiffer and less workable. This consistency of concrete could make it difficult to handle, pour, and finish, and it might need more water or admixtures to make it more workable. Although the mix is still practical, its decreased slump value suggests that it must be handled carefully to prevent problems during construction. This is consistent with the findings of Akeed et al. (2022), who found that adding 1.5% natural fibers to concrete considerably decreased its workability and necessitated modifying the mix design for large-scale applications.

### 4.2. Flexural Strength Test Results

According to ASTM C293, the conventional 2-point bending test was used to determine the flexural strength of the concrete samples. After 28 days of curing, the concrete beams were put to the test. The beams (150 mm x 150 mm x 600 mm) were placed on the Universal Testing Machine (UTM) with two points of support as part of the test arrangement. Each beam was subjected to a load at its halfway point until it failed. Table 3. displays the flexural strength values for the concrete mixtures with different coconut fiber contents.

**Table 3. Flexural Strength Results for Concrete Mixes with Varying Coconut Fiber Content (28 Days)**

| Fiber Content (%) | Flexural Strength (MPa) |
|---|---|
| 0% (control) | 5,33 |
| 0,5% | 5,00 |
| 1,0% | 4,67 |
| 1,5% | 4,42 |

*Source : Analysis Results*

The flexural strength test findings show that as the percentage of coconut fiber increases, the flexural strength decreases. As anticipated for a concrete mix with a target compressive strength of FC'25, the control mix, which contained no coconut fiber, achieved the maximum flexural strength of 5.33 MPa. The flexural strength gradually dropped when more coconut fiber was added to the mixture; the 1.5% coconut fiber mix had the lowest flexural strength, 4.42 MPa. The behavior of the fiber in the mix is responsible for this reduction in flexural strength. Although the addition of coconut fibers improves fracture resistance, it also increases the concrete's porosity, which may make it less resilient to bending

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strains. The fibers' greater absorption of water may also weaken their bond with the cement paste, which would further diminish their strength. These results are in line with earlier research on the use of natural fibers in concrete, which shows that. In contrast, fibers may improve toughness and resistance to cracking; they can also decrease other mechanical qualities like flexural strength.

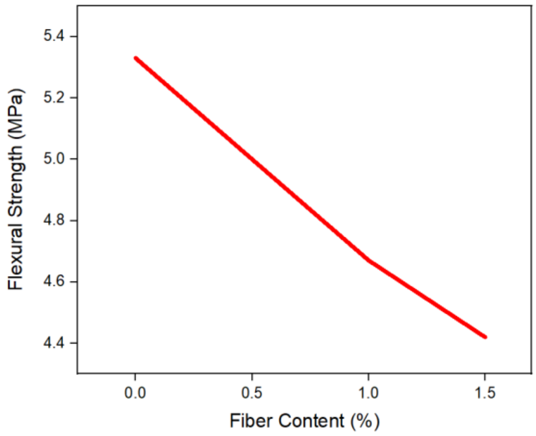


**Figure 3. Effect of Coconut Fiber Content on Flexural Strength of Concrete**

According to Yuan et al. (2022) and Gong et al. (2022), the addition of fibers may reduce the concrete's resistance to bending, which would lower its flexural strength, especially at higher fiber levels. This is explained by the fibers' propensity to break up the concrete matrix's homogeneity, which could result in weak spots and an unequal distribution of stress. As a result, although fibers might enhance some mechanical qualities, excessive usage of them could reduce concrete's ability to withstand bending.

### 4.3. Compressive Strength Test

Concrete cubes measuring 150 mm by 150 mm by 150 mm were subjected to compressive strength tests in accordance with ASTM C39. After 28 days of curing, the cubes were tested to determine the compressive strength of concrete mixtures containing varying amounts of coconut fiber. Table 4. displays the test results, which show how the fiber content affects the strength of the concrete.

**Table 4. Compressive Strength Results for Concrete Mixes with Varying Coconut Fiber Content (28 Days)**

| Fiber Content (%) | Compressive Strength (MPa) |
|---|---|
| 0% (control) | 25,33 |
| 0,5% | 24,67 |
| 1,0% | 24,00 |
| 1,5% | 23,33 |

*Source : Analysis Results*

The compressive strength test findings show that when the amount of coconut fiber increases, the compressive strength somewhat decreases. The goal compressive strength of FC'25 was met by the control mix (0% coconut fiber), which had a compressive strength of 25.33 MPa. The combination's compressive strength somewhat dropped as coconut fiber was added; the 1.5% coconut fiber mix had the lowest compressive strength, measuring 23.33 MPa.

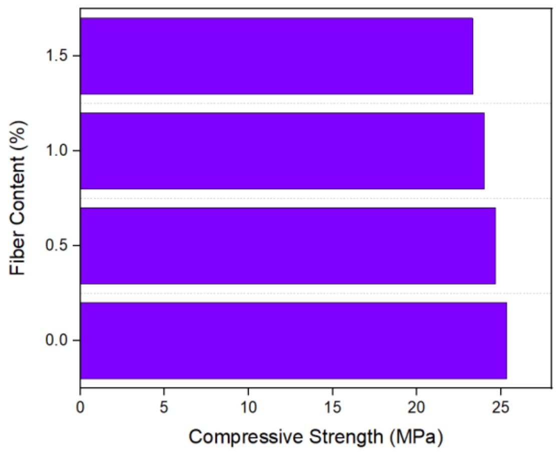


**Figure 4. Effect of Coconut Fiber Content on Compressive Strength of Concrete**

The increased porosity and water absorption brought about by the coconut fibers are probably the cause of this decline in concrete strength. The addition of natural fibers to the mixture may cause voids to form in the concrete, increasing its porosity. A larger ability to absorb water may result from this increased porosity, which could erode the link between the aggregates and cement paste. As a result, the concrete structure's overall strength and durability are diminished.

Furthermore, the material's integrity may be further jeopardized if the coconut fibers themselves do not adhere to the cement matrix. These results are consistent with other research that examined the effects of adding natural fibers to concrete, including hemp, jute, and coconut. According to research, these

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fibers' inherent qualities can have a negative impact on compressive and flexural strength, even though they can improve other qualities like impact resistance and thermal insulation.

These effects should be taken into account when developing concrete mixtures for particular uses, particularly when high-strength or long-lasting constructions are the goal. To balance the advantages and disadvantages of employing natural fibers in concrete, rigorous assessment and optimization of the fiber content and mix proportions are necessary.

Raabe et al. (2022) and Lilargem et al. (2022) claim that because natural fibers are porous and interfere with the cement hydration process, adding them, especially in larger quantities, often results in a reduction in compressive strength. Studies by Jamshaid et al. (2022) and Abedi et al. (2022) corroborate this, showing a similar pattern in which the addition of natural fibers decreased the concrete's compressive strength.

## V. CONCLUSIONS AND SUGGESTIONS

### 5.1 Conclusion

This study examines how adding coconut fiber to concrete affects its mechanical qualities, with a particular emphasis on workability, flexural strength, and compressive strength. The experimental test results indicate that adding coconut fiber to concrete mixtures reduces their workability, flexural strength, and compressive strength, especially as the fiber concentration rises.

The addition of coconut fiber reduced the concrete's workability. With a slump of 110 mm, the fiber-free control mix demonstrated satisfactory workability. The slump values gradually dropped to 90 mm, 85 mm, and 80 mm, respectively, as the fiber content rose to 0.5%, 1%, and 1.5%. The water-absorbing qualities of coconut fibers are responsible for this decrease in workability; they draw moisture from the mixture and produce stiffer, more difficult-to-handle combinations.

According to the flexural strength test, the control mix had the highest flexural strength of 5.33 MPa, while the mixes including coconut fiber gradually lost strength. At 4.42 MPa, the 1.5% coconut fiber blend had the lowest flexural strength. This drop is probably the result of the fibers' increased porosity and water absorption, which made the link between them and the cement paste weaker.

Likewise, as the fiber content increased, the concrete's compressive strength declined. The 1.5% coconut fiber blend had the lowest compressive strength, at 23.33 MPa, whereas the control mix had the highest, at 25.33 MPa. This decrease is explained by the natural fibers' increased porosity and interference with cement hydration, which compromised the concrete's overall structure.

### 5.2 Suggestions

The researcher makes the following suggestions in light of the current findings:

1. Future studies should investigate how varied water-to-cement ratios impact the workability, strength, and overall performance of coconut fiber-reinforced concrete while keeping the same components
2. To have a better understanding of the factors influencing the rise or decrease in flexural strength, more testing on the concrete's microstructure is advised.

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