Enhancing Durability and Crack Resistance of Concrete using Coconut Fibre

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Publication Date: 2025/07/14

Abstract: The increasing demand for sustainable and eco-friendly construction materials has led to the exploration of natural fibers as reinforcement in concrete. This study investigates the potential of coconut fiber, a readily available agricultural waste product, in enhancing the mechanical properties of concrete. Coconut fiber, known for its high toughness, low density, and biodegradability, was incorporated into concrete mixes in varying percentages by weight of cement. Experimental results revealed that the addition of coconut fibers improved the tensile and flexural strength of concrete, while also enhancing crack resistance and durability. However, an optimal fiber content was identified, beyond which the workability and compressive strength began to decline due to fiber agglomeration and poor bonding. This research highlights the feasibility of using coconut fiber as a sustainable and cost-effective reinforcement material, promoting the development of greener construction practices without significantly compromising the performance of concrete.

Keywords: *Coconut Fibe, Eco-Friendly Construction Material, Biodegradability, Concrete.*

How to Cite: Vikash Kumar Gautam; Vansh Rathi; Nikita Gaur; Ankush Gupta; Aditya Raj; (2025). Enhancing Durability and Crack Resistance of Concrete using Coconut Fibre. *International Journal of Innovative Science and Research Technology,* (RISEM–2025), 150-153. https://doi.org/10.38124/ijisrt/25jun184

I. INTRODUCTION

This The use of natural fibres in construction materials has gained momentum in recent years due to growing concerns about sustainability, cost, and environmental impact. Among these, coconut fibre (commonly known as coir) stands out as an effective, renewable material with the potential to improve the performance of concrete. Coconut fibre is derived from the outer husk of the coconut and is primarily composed of lignin and cellulose, which give it high tensile strength and flexibility.Traditionally used in rope making, mats, brushes, and other products, coconut fibre is now being explored in civil engineering for its potential to reinforce concrete. It is biodegradable, abundant in tropical and subtropical regions, and has a low environmental impact compared to synthetic fibres. In concrete, the role of fibre reinforcement is to improve mechanical properties and crack resistance. Coconut fibres, due to their natural toughness and availability, are an economical and sustainable alternative to conventional fibres such as steel or polypropylene.The main objective of adding coconut fibre to concrete is to address its inherent weakness in tension and improve the material's toughness and ductility. This section sets the stage for understanding the significance of coconut fibre as a green additive in concrete mixes and explores its advantages over traditional reinforcement materials.

A. Mechanical Properties and Performance Enhancement

Concrete is a widely used construction material known for its high compressive strength but relatively low tensile and flexural strength. The addition of coconut fibre addresses this limitation by acting as a bridging material across cracks and improving the energy absorption capacity of the concrete.Tensile and Flexural Strength Improvement:

Coconut fibres help enhance the tensile and flexural properties of concrete by reducing the initiation and propagation of microcracks. When stress is applied, the fibres absorb some of the tension that would otherwise cause the matrix to fail. Studies have shown that the addition of 0.5% to 2% coconut fibre by weight of cement can significantly improve tensile strength. Beyond this percentage, however, the mix may become less workable and uniformity may decrease.

➢ *Crack Resistance and Ductility:*

One of the notable advantages of using coconut fibre is the improvement in the post-cracking behaviour of concrete. Fibre-reinforced concrete demonstrates greater energy.

B. Practical Considerations and Applications

For effective utilization of coconut fibre in concrete, several practical considerations must be addressed. These

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25jun184

include fibre preparation, mix design, workability, and site application.

- *Fibre Preparation and Treatment:*

Raw coconut fibres should be cleaned and, in some cases, treated with an alkaline solution (such as NaOH) to enhance bonding with the cement paste. Treatment reduces the natural oils and waxes that hinder proper adhesion, thereby improving the mechanical interlocking between fibre and matrix. Typical fibre lengths range from 30 mm to 50 mm, although shorter fibres may be used for better workability.

- *Mix Design and Workability:*

Adding fibres to a concrete mix can reduce its workability due to the increased surface area and fibre entanglement. To counter this, superplasticizers or water-reducing admixtures may be added. The optimal fibre content varies depending on the application, but a 1% addition by weight of cement is often cited as a balance between strength gain and workability.

II. LITERATURE REVIEW

A. According to [Banthia and Nandakumar (2003)],

Fibre reinforcement helps delay the formation of macro-cracks, reduces spalling, and enhances ductility. This mechanism results in significant improvement in post-crack load-carrying capacity and impact resistance. The presence of fibres does not drastically increase compressive strength; however, it plays a crucial role in improving tensile and flexural strength, which are the primary weaknesses of conventional concrete".

B. [Paramasivam et al. (1984)]

The observed that untreated coconut fibre contributed to minor improvements in compressive strength, but when the fibres were pre-treated using alkali solutions, the compressive strength increased significantly, indicating better fibre-matrix bonding.

C. Tensile and Flexural Strength

Several studies highlight substantial improvements in tensile and flexural properties of concrete due to the incorporation of coconut fibres. [Olanipekun et al. (2006)] demonstrated that concrete containing 1.2% coir fibre exhibited a 35% increase in splitting tensile strength. Flexural strength tests conducted by [Swamy and Lankard (1974)] showed a similar trend, where fibre inclusion delayed the first crack and allowed the concrete to sustain higher loads post-cracking.

D. Impact Resistance

Impact resistance is another area where CFRC outperforms conventional concrete. [Manoharan et al. (2017)] conducted drop-weight impact tests and concluded that coconut fibre enhances the impact toughness of concrete by increasing its energy absorption capability.

E. Shrinkage and Crack Resistance

[Civil Engineering Research Foundation (2005)] states that shrinkage cracks are one of the most common durability issues in concrete. Fibre inclusion helps mitigate shrinkage-induced cracks by resisting tensile stresses during the curing process. Coconut fibre, due to its elasticity and anchoring behavior within the cement matrix, is effective in reducing both plastic and drying shrinkage.

III. METHODOLOGY

Concrete is one of the most widely used construction materials due to its versatility and durability. However, it exhibits brittleness and low tensile strength. To address these shortcomings and improve its mechanical properties, researchers and engineers have explored various reinforcements. This study focuses on the utilization of natural coconut fibres as a sustainable and eco-friendly additive to enhance the compressive strength of M30 grade concrete. The chapter aims to provide a comprehensive analysis of the methodologies adopted, materials used, and the results obtained during the experimental investigation.

A. Materials and Properties

- *Cement*

Ordinary Portland Cement (OPC) of 43 grade, conforming to IS 8112:2013, was used in the mix. It was free from lumps and stored in a dry place.

- *Fine Aggregates*

River sand conforming to Zone II grading of IS:383-1970 was used as the fine aggregate. The sand was sieved, cleaned, and tested for silt content and moisture.

- *Coarse Aggregates*

Coarse aggregates used were angular crushed stones with a maximum size of 20 mm. The aggregates were tested for specific gravity, water absorption, and impact value.

- *Water*

Clean and potable water was used for both mixing and curing purposes. The water satisfied the requirements of IS:456-2000.

- *Coconut Fibre*

Coconut fibres were sourced from local suppliers, cleaned to remove any husk or dust, and cut into 30 mm lengths. The fibres were soaked in water for 24 hours before use to improve their bonding with cement.

Fig 1 Coarse Aggregate: Crushed granite, 20 mm size

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25jun184

Fig 2 Casting of specimen

IV. RESULT AND DISCUSSION

After The incorporation of natural fibres into concrete mixtures has gained attention as a sustainable and economical alternative to synthetic fibres. Coconut fibre, in particular, due to its abundance, renewability, and mechanical properties, has been explored for its potential to enhance concrete strength. In this study, coconut fibre was added to the concrete mix in varying percentages (0%, 0.5%, 1%, 1.5%, and 2% by weight of cement), and the resulting compressive, tensile, and flexural strengths were evaluated and compared with the control mix (0% fibre).

A. Compressive Strength

The compressive strength of the concrete was measured at 7, 14, and 28 days for all mixes. The results indicated that the addition of coconut fibre had a notable impact on the compressive strength. The control specimen (0% fibre) exhibited a 28-day compressive strength of 32.5 MPa. When 0.5% fibre was introduced, the strength increased to 33.8 MPa, showing a moderate enhancement. At 1% fibre content, the compressive strength peaked at 35.4 MPa, suggesting that the optimal fibre content lies near this concentration. This improvement is attributed to the ability of coconut fibre to bridge microcracks, delay crack propagation, and enhance the post-cracking behavior of the concrete matrix. However, beyond 1.5% fibre content, the compressive strength began to decline. At 2% fibre, the strength dropped to 31.2 MPa. This reduction can be attributed to poor fibre dispersion, fibre agglomeration, and increased air voids, which compromise the homogeneity of the mix.

B. Split Tensile Strength

The split tensile strength results mirrored the trend observed in compressive strength. The control sample showed a tensile strength of 2.8 MPa. At 0.5% and 1% fibre content, the tensile strength increased to 3.1 MPa and 3.5 MPa, respectively. The maximum increase (approximately 25%) was observed at 1% fibre content. Coconut fibres acted as micro-reinforcements, bridging cracks under tensile stress and enhancing the ductility of the material. The fibres delayed the growth of cracks and increased the energy absorption capacity of concrete. Beyond 1.5%, however, a slight reduction was noticed (3.0 MPa at 2%), again likely due to poor fibre distribution and clumping, which adversely affected the bonding between the fibre and the cement matrix.

C. Flexural Strength

The flexural strength of coconut fibre-reinforced concrete also showed improvement over the control specimen. At 1% fibre addition, the flexural strength increased from 4.1 MPa (control)to 5.0 MPa, highlighting the significant role of fibres in resisting bending stress. The improvement was due to the fibre’s ability to absorb tensile stress developed on the tension side of the concrete beam. This suggests better load transfer and distribution under flexural loads. However, at 2% fibre content, the flexural strength reduced slightly to 4.3 MPa, indicating that excessive fibre may negatively influence the workability and consistency of the mix.

D. Workability and Density

The slump test results showed that the workability decreased with an increase in fibre content. While the control mix had a slump of 75 mm, the slump reduced to 40 mm at 2% fibre content. This is due to the high-water absorption and surface area of coconut fibres, which demand more water for lubrication and lead to a drier mix. Therefore, mix design adjustments or the use of plasticizers may be necessary at higher fibre contents to maintain workability. In terms of density, a marginal reduction was observed with increasing fibre content due to the lightweight nature of coconut fibres. This slight decrease may contribute positively to the development of lightweight structural elements.

E. Durability Observations

Preliminary durability tests, including water absorption and surface resistance, indicated a slightly higher porosity at fibre contents above 1.5%. The increased void content may accelerate water ingress if not properly managed. However, up to 1%, the effect on durability was negligible, indicating good potential for moderate fibre usage without compromising long-term performance.

F. Summary of Findings

- Optimum Fibre Content: The study identifies 1% coconut fibre by weight of cement as the optimum content for maximum improvement in mechanical properties.
- Compressive Strength: Increased by approximately 9% at 1% fibre.
- Tensile Strength: Improved by up to 25%, demonstrating enhanced crack resistance.
- Flexural Strength: Increased by over 20%, confirming better ductility.
- Workability: Decreased with increased fibre; adjustments in mix design are necessary for high fibre content.
- Durability: Acceptable up to 1.5%; beyond that, porositymay increase.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25jun184

V. CONCLUSION

The use of natural fibres in concrete has gained significant attention in recent years due to growing concerns about sustainability, environmental impact, and the need for improved material performance. Among various natural fibres, coconut fibre also known as coir has emerged as a promising material for reinforcing concrete. This study highlights the effectiveness of coconut fibre in enhancing the strength and durability of concrete, offering numerous mechanical and environmental benefits.

The addition of coconut fibre to concrete has been shown to significantly improve its tensile and flexural strength. This is particularly important in minimizing the formation and propagation of microcracks, which are common in plain concrete due to its inherently low tensile strength. Coconut fibre acts as a bridging material within the concrete matrix, helping to distribute loads more evenly and absorb energy during impact, which leads to increased toughness and better crack resistance. These improvements contribute to the overall structural integrity of concrete, especially in load-bearing and dynamic applications.

Furthermore, coconut fibre enhances the ductility of concrete, allowing it to deform more before failure a critical property in regions prone to seismic activity or where flexibility is required. In addition to mechanical performance, the use of coconut fibre offers practical and environmental advantages. It is a low-cost, biodegradable, and renewable resource that can be sourced from agricultural waste, especially in tropical countries where coconut production is high. This not only reduces the environmental burden associated with concrete production but also adds value to what would otherwise be discarded as waste.

The integration of coconut fibre in concrete also leads to improvements in thermal and acoustic insulation, broadening its application in both structural and non-structural elements. Its lightweight nature helps reduce the overall dead load on structures, potentially lowering construction costs and improving ease of handling during the building process.

In conclusion, coconut fibre is a viable and sustainable material for enhancing the strength and performance of concrete. It addresses both engineering and environmental concerns by improving concrete's mechanical properties while promoting the use of eco-friendly, waste-derived materials. Future research and development can further optimize the mix design and fibre treatment methods to fully harness the potential of coconut fibre in modern construction.

ACKNOWLEDGMENT

The authors would like to express their sincere gratitude to **IIMT College of Polytechnic, Greater Noida** for providing the necessary facilities and support to carry out this research work. We also acknowledge the valuable guidance and encouragement from the faculty members of the **Civil Engineering Department** throughout the duration of the study.

Special thanks to the our HOD (Rajiv R Singh) & laboratory staff for their assistance in material testing and data collection. The constructive feedback received from peers and reviewers has significantly improved the quality of this manuscript.

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