

A Study on Improving the Performance of Concrete Using Coconut Fibers

Aman Rehman^{1,*}, Shaifali Ruhil²

Abstract

This study aims to explore the incorporation of coconut fiber into M30-grade concrete and assess its impact on the strength characteristics. A literature review of different fibers is conducted highlighting the working parameters. This research explores the efficacy of employing coconut fibers as micro-reinforcement in concrete. The investigated properties encompass the compressive strength of the coconut fibers reinforced concrete (CFRC) at different percentages of fiber. The experiment involved high-strength concrete mixed with varying proportions (0%, 1%, 1.5%, and 2%) of coir fiber. The coconut fibers were obtained from the raw material by hand and cut to a length of 50mm, cement of OPC 53 grade and the maximum 20mm size of aggregate were used in this investigation. Concrete cubes of size 150 mm×150 mm×150 mm have been cast to take the compressive strength and the data indicates that the compressive strength of concrete rises with longer curing periods but declines with higher quantities of coconut fiber. The cured concrete was tested for compressive strength after 7, 14, and 28 days. This research is conducted to raise awareness within the field of Civil Engineering regarding the dual nature of coconut fiber as both a beneficial and potentially hazardous construction material.

Keywords: Coconut fiber, compressive Strength, M30 grade concrete, concrete cubes, OPC 53 grade cement, CFRC

INTRODUCTION

Concrete reinforced with coconut fibers is a sustainable alternative to traditional concrete incorporating natural fibers derived from coconut husks. These fibers, extracted from the outer shells of coconuts, are strong, lightweight, and readily available in regions where coconuts are cultivated. To enhance the tensile strength, compressive strength, and impact effect of the concrete, coconut fibers

were added. This coconut fiber can be applied to concrete, which is an important component of the construction industry. Normally, in regular reinforced concrete, we use steel bars that add weight as well as the cost of the concrete, which is not affordable to all leaders as well as city dwellers [1].

Figure 1 shows the coconut fiber, and Figure 2 shows the section of coconut.

Background

The construction industry is organized in two ways. The first is the development of construction techniques such as the use of automatic tools in buildings. The second advancement in high-

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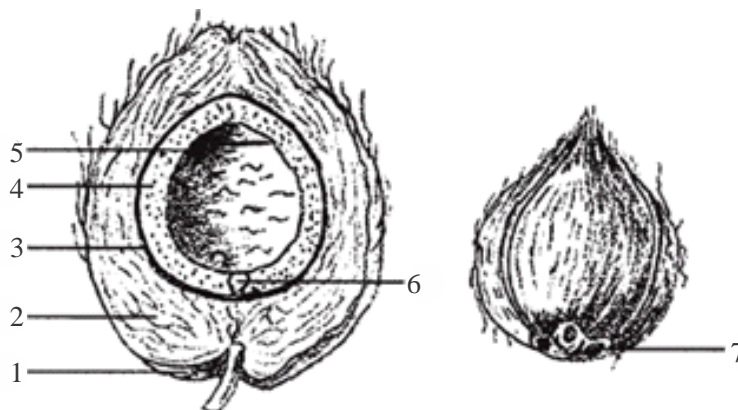
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performance structural materials is similar to the introduction of extreme-strength concrete. These high-performance materials, fiber-reinforcing cement (FRC), slowly obtain acceptance from civil engineers [3].



Figure 1. Coconut fiber [1].



Longitudinal section through a coconut (left) and plan view of stone (right)

- 1- Thin, yellow-brown, watertight outer skin (exocarp)
- 2- Thick, fibrous middle layer (coconut fiber, coir, mesocarp)
- 3- Hard inner layer, the stone (endocarp)
- 4- White, oily copra layer, 1-2 cm thick (solid endosperm)
- 5- Cavity filled with coconut milk (liquid endosperm)
- 6- Embryo
- 7- "Eyes" (3 germ pores set in pits)

Figure 2. Section of coconut [2].

Later, the search and development of fibers and matrix materials and manufacturing processes related to the building industry grew quickly. Their key advantages over other building materials include their high tensile strength-to-weight ratio, flexibility in shaping, and possible resilience to environmental factors, which could lead to reduced maintenance costs [3].

The most flexible natural fiber available is coconut fiber, which can be utilized as a cement reinforcement component. Because of its biodegradability, there will not be much impact on the environment. To create high-strength materials, this method also derives fibers that are left over from coir-based production facilities. Moreover, they are inexpensive, readily accessible, and non-abrasive.

Research is being conducted to determine whether coconut fiber ropes can be used as vertical reinforcements in interlocking constructions that do not require mortar. This is considered an affordable option for building earthquake-resistant houses [3].

Advantages of Coconut Fiber Concrete

1. Coconut fiber reinforcement improves the compressive strength of concrete owing to the bridging effect of fibers across cracks, which impedes crack propagation and increases the load-carrying capacity.
2. The addition of coconut fibers enhances the flexural strength of concrete, making it more resistant to bending and cracking when a load is applied.
3. Coconut fibers act as reinforcement elements, enhancing the tensile strength of concrete and reducing its susceptibility to cracking, particularly under tensile stress.
4. Coconut fibers help to control plastic shrinkage and reduce the formation of microcracks in concrete, thereby improving its resistance to cracking.
5. Coconut fiber comes from coconut husks, which is a natural result of harvesting coconuts.
6. The production of coconut fiber involves minimal energy consumption compared to synthetic reinforcement materials, making CFRC an environmentally friendly alternative.
7. Coconut fiber concrete maintains good workability, allowing for ease of placement and compaction during construction.

Disadvantages of Coconut Fiber Concrete

1. Achieving uniform dispersion of coconut fibers within a concrete matrix can be challenging. Improper mixing or inadequate distribution of fibers may lead to nonuniform properties and reduced reinforcement effectiveness.
2. Incorporating coconut fibers into concrete mixtures may affect the workability of the material. A high fiber content or improper fiber alignment can result in reduced workability, making it more difficult to place, compact, and finish concrete.
3. Coconut fibers have a low density, typical of different reinforcement materials. However, their addition to concrete mixtures may slightly increase the density of the resulting CFRC, which can affect the transportation, handling, and construction logistics.
4. Coconut fibers are amazing because they do not mind moisture and decay, but sometimes break down if they hang out too long in wet or tough weather.
5. Coconut fiber concrete is suitable for applications that require moderate to low load-bearing capacities.
6. The long-term performance and durability of coconut fiber concrete under different environmental and loading conditions are still being studied.

LITERATURE REVIEW

In this section, a review of the work done by various authors on different fibers is presented in Table 1.

Table 1. Review of summary on different fibers.

Ref. no.	Study title	Author(s) and year	Additives percentage	Additive material	Parameter worked on	Remark
[4]	Impact of fiber types on properties of concrete	Zhang et al. (2015)	Varies	Fiber	Compared effects of different fibers (e.g., steel, polypropylene, glass) on concrete properties.	Steel fibers enhance flexural and compressive strength, while polypropylene fibers improve toughness and crack resistance.
[5]	Enhancing concrete with natural fibers.	Kumar and Bhattacharyya (2016)	0.5–2.0	Jute fiber	Investigated jute fiber's influence on concrete strength,	Jute fiber improves tensile strength by up to 30% and enhances

Ref. no.	Study title	Author(s) and year	Additives percentage	Additive material	Parameter worked on	Remark
					durability, and workability.	durability.
[6]	Sustainable concrete reinforced with fiber	Ganesan et al. 2017	0.5–3.0	Bagasse fiber	Explored the effects of bagasse fiber addition on fresh and hardened concrete properties.	Enhances compressive strength by 15%, and decreases water absorption by 20%.
[7]	Mechanical properties of concrete using PVA fiber	Wu et al. 2017	0.5–2.0	PVA fiber	Investigated the mechanical properties of concrete reinforced with polyvinyl alcohol (PVA) fibers.	Increases flexural strength by 20%, compressive strength by 15%, and reduces crack width by 40% in concrete.
[8]	Effects of hybrid fibers on concrete	Chen and Wang 2018	0.5–3.0	Hybrid fibers	Examined the combined effects of different fibers (e.g., steel and polypropylene) on concrete properties.	25% increase in tensile strength, 30% improvement in toughness, and better crack resistance in concrete.
[9]	Effects of fiber reinforcement on concrete	Smith et al. 2018	0.5–2.0	Steel fibers	Explored the impact of steel fibers on concrete strength, durability, and crack resistance.	Increase flexural and compressive strength by 15–25%, decrease crack width by 20–30%.
[10]	Performance evaluation of coconut hush ash in concrete	Kumar et al. 2018	1.0–3.0	Coconut husk ash	Impact of coconut husk ash as a cementitious material in fiber-reinforced concrete.	Increases compressive strength by 15–20%, decreases permeability by 20–25%.
[11]	Enhancing concrete performance with coconut fiber	Das et al. 2018	0.5–2.0	Coconut fiber	Addition of coconut fiber in concrete enhances compressive, tensile, and flexural strengths.	Improved compressive, tensile, and flexural strengths observed in CFRC.
[12]	Influence of additives on properties of concrete	Garcia et al. 2018	0.5–2.5	Graphene oxide	The impact of graphene oxide additives on mechanical properties and durability of concrete.	Increase compressive strength by 20–25%, reduce permeability by 25–30%, and enhance durability.
[13]	Influence of coir fiber on fresh concrete	Rahman et al. 2018	0.5–1.5	Coconut fiber	Investigated the impact of coconut fiber on fresh and hardened properties of concrete.	Enhances workability by 10%, compressive strength by 20%, and reduces cracking by 25%.
[14]	Performance evaluation of concrete using cellulose fibers	Martinez and Kim 2019	1.0–3.0	Cellulose fibers	Performance of concrete reinforced with cellulose fibers	Increase compressive strength by 15–20%, improve durability, and provide an eco-friendly

Ref. no.	Study title	Author(s) and year	Additives percentage	Additive material	Parameter worked on	Remark
					regarding strength and durability.	reinforcement solution.
[15]	Effects of bamboo fiber addition on concrete	Liu and Xing 2019	0.5–2.0	Bamboo fiber	Examined the influence of bamboo fiber on mechanical and durability properties of concrete.	Bamboo fiber addition increases flexural strength by 15%, splitting tensile strength by 10%, and reduces water absorption by 30%.
[16]	Effects of hybrid fiber reinforcement on concrete	Lee and Park 2019	1.0–2.5	Hybrid fibers	Explored the combined effects of steel and polypropylene fibers on various properties of concrete.	25–30% increase in flexural and compressive strengths and 30–35% reduction in crack width in concrete.
[17]	Enhancing concrete performance with polypropylene fibers	Patel and Gupta 2019	0.5–3.0	Polypropylene fibers	Investigated the influence of polypropylene fibers on fresh and hardened properties of concrete.	Improve workability by 10–15%, and decrease shrinkage by 20–25%.
[18]	Investigation on coconut fiber reinforced concrete	Pothiyappan et al. 2019	0.5–2.5	Coconut fiber	Coconut fiber reinforcement improves toughness and impact resistance in concrete.	CFRC exhibits increased toughness and impact resistance.
[19]	Durability studies on coconut fiber-reinforced concrete	Sujatha et al. 2020	1.0–3.0	Coconut fiber	Coconut fiber-reinforced concrete exhibits better resistance to chloride penetration and sulfate attack.	CFRC shows improved resistance against chloride penetration and sulfate attack.
[20]	Utilization of date palm fibers in concrete	Khan et al. 2020	0.5–3.0	Date palm fiber	Studied the effects of date palm fiber on fresh and hardened properties of concrete.	Date palm fiber improves workability by 12%, compressive strength by 18%, and decreases shrinkage crack.
[21]	Performance evaluation of concrete using polyethylene fiber	Li et al. 2021	2–3	Polyethylene fiber	Investigated the performance of concrete reinforced with polyethylene fibers.	Increases flexural strength by 25%, tensile strength by 20%, and reduces crack propagation by 35% in concrete.
[22]	Influence of hemp fibers on concrete	Sharma and Sharma 2022	0.5–2.5	Hemp fiber	Analyzed the influence of hemp fibers on mechanical and durability properties of concrete.	Increases compressive strength by 30%, flexural strength by 25%, and reduces permeability by 20%.

RESEARCH GAP

1. Long-term durability and mechanical properties of coconut fiber-reinforced concrete (CFRC) in varied environmental conditions.

2. There may be existing research on the immediate effects of adding coconut fiber to concrete mixes, such as improvements in tensile strength or crack resistance, and there may be limited information on how CFRC performs over extended periods of time, especially in real-world applications where it is exposed to factors such as moisture and temperature variations.
3. Current research primarily focuses on short-term laboratory testing, which may not accurately reflect the complex interactions between the CFRC and the environment over extended periods.
4. Real-world applications expose concrete structures to various environmental factors, such as moisture, temperature fluctuations, chemical exposure, and mechanical loading, all of which can affect the structural integrity and durability of CFRC.
5. The lack of comprehensive studies examining the long-term behavior of CFRC poses challenges for engineers and construction professionals seeking to utilize this material in practical applications.
6. By filling this research gap, engineers and researchers can provide valuable insights into the long-term behavior, durability, and potential degradation mechanisms of CFRC.
7. This knowledge is crucial for optimizing the design and construction of sustainable concrete structures that meet the performance requirements and withstand environmental challenges throughout their service life.

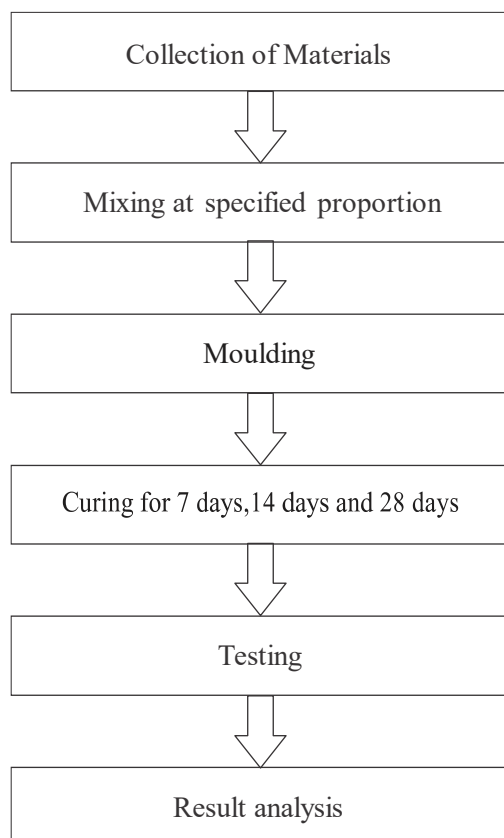


Figure 3. Methodology of Work in different environment conditions.

Figure 3 shows the process workflow: material collection, proportioning, molding, curing, testing, and analysis.

Material

Cement

Ordinary Portland cement (grade 53) was used in this experiment. A photograph of the cement bag is shown in Figure 4.



Figure 4. Cement.



Figure 5. Coarse aggregates.

Coarse Aggregate

Aggregates that are unable to pass through a 4.75 mm sieve yet only pass through an 80 mm sieve are called coarse aggregates. Cube specimens were made for the M30 mix employing aggregates of utmost sizes of 20 mm. The coarse aggregates are shown in Figure 5.

Fine Aggregates

An aggregate that passed 4.75 mm but did not pass through a 75-micron sieve is known as a fine aggregate. The fine aggregates are shown in Figure 6.

Water

The water available at the site followed the IS456–2000 code. It was used for the casting and curing of concrete.

Coconut Fiber

Coconut fibers of 1%, 1.5%, and 2% of the total volume of concrete were cut into lengths of 50 mm. The properties of the fibers are listed in Table 2.



Figure 6. Fine aggregates.

Table 2. Properties of fiber [2].

Properties	Values
Diameter	0.4 mm
Length	10 cm to 25 cm (commercially available)
Bulk Density	1.15 g/cc

TESTING PROCEDURE

Concrete specimens were prepared in the form of cubes to test the compressive strength of the concrete mix M30. Fibers were added at weights of 0, 1, 1.5, and 2% of the cement and allowed to cure for 7, 14, and 28 days. The aspect ratio of the fiber adopted was 50 mm in length and 0.4 mm in average diameter. Twelve cubes with dimensions of 150 mm × 150 mm × 150 mm were cast and tested after 7, 14, and 28 days.

EXPERIMENTAL TEST

Compressive Strength Test

Concrete cubes of 150 mm × 150 mm × 150 mm were cast with varying percentages of fibers (1.5%, 1.5%, and 2%) by cement weight. The samples were cured in water for 7, 14, and 28 days, and the testing was coordinated. Three specimens were poured per percentile of fiber per day of curing.

A compression test machine was used in this study. The compression test machine is illustrated in Figure 7.

$$F=P/A$$

F: is the compressive strength in Mega Pascal

P: is the maximum load applied in Newton

A: is the cross-section area in mm²

RESULT

Results of the examination of the compressive strength of concrete pieces. It was observed that 1% and 1.5% of fibers by weight of cement increased the compressive strength compared to traditional concrete, while 2% of fibers by weight of cement decreased the compressive strength. The 1% and 1.5% fibers increased by 4.5% and 9.1%, respectively, after 28 d of healing. 2% of the fibers lowered the strength by 2.1%. Table 3 presents the comparative analysis chart for 0%, 1%, 1.5%, and 2% fibers and their compressive strength values. A bar chart of the compressive strength at different curing times is shown in Figure 8.



Figure 7. Compression test machine.

Table 3. Comparative analysis.

S.N.	Percentage of fiber	Compressive strength-7 days of curing (N/mm ²)	Compressive strength - 14 days of curing (N/mm ²)	Compressive strength-28 days of curing (N/mm ²)	Reference [2] Compressive strength-28 days of curing (N/mm ²)	Percentage improvement
1	0%	24.1	30.6	32.5	32.4	0.3%
2	1%	25.2	32	34	33.8	0.5%
3	1.5%	26	33.5	35.6	35.4	0.5%
4	2%	23.5	30.5	31.8	31.6	0.6%

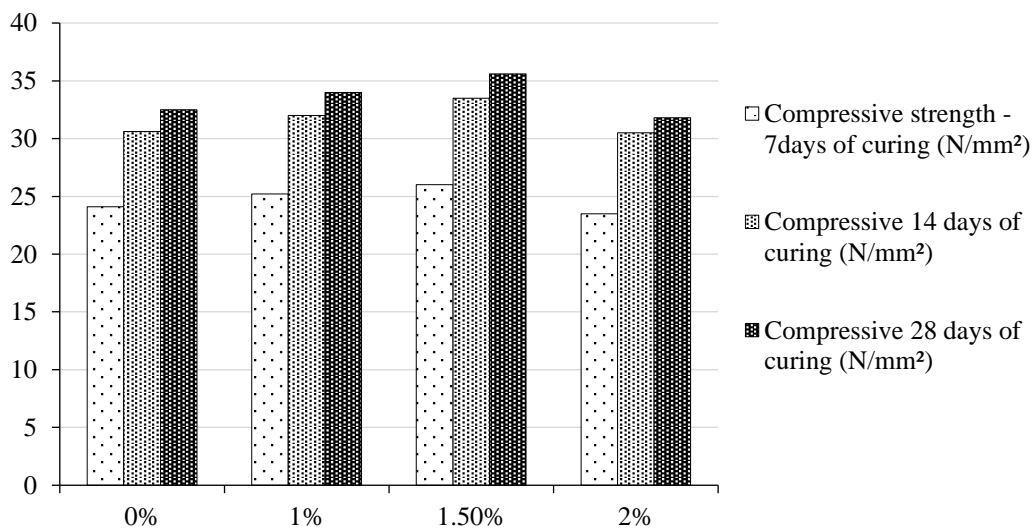


Figure 8. Compressive strength at different days of curing.

CONCLUSION

Because coconut fibers have better properties than normal fibers, they were used in the concrete in this study. This study examined coconut fiber concrete with varying percentages of fibers by cement

weight, and the test findings are presented. When compared to regular concrete, the M30 grade concrete with 1% and 1.5% fibers by weight of cement showed increased strength.

1. While 1.5% fiber yields superior results, 1% fiber also increases the concrete's total strength.
2. Concrete loses compressive strength when there is 2% fiber by weight of cement.
3. The compressive strength was improved by 0.5% and 0.5% with 1% and 1.5% fiber, respectively, with reference [2].

Conflict of Interest

Authors have no conflict of interest.

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