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Experimental Study on Coconut Fiber Reinforced Stabilized Mud Blocks (CFR-SMBs)

Avinash Rot N[1], Rakshitha R [2], Sneha K [3], Ravi Kiran B [4]

[1]UG Student, Dept. of Civil Engineering, S J C Institute of Technology, Chikkaballapura Visvesvaraya Technological University, Belagavi Karnataka, India

[2]UG Student, Dept. of Civil Engineering, S J C Institute of Technology, Chikkaballapura Visvesvaraya Technological University, Belagavi Karnataka, India

[3]UG Student, Dept. of Civil Engineering, S J C Institute of Technology, Chikkaballapura Visvesvaraya Technological University, Belagavi Karnataka, India

[4]Assistant Professor, Dept. of Civil Engineering, S J C Institute of Technology, Chikkaballapura Visvesvaraya Technological University, Belagavi Karnataka, India

ABSTRACT:

The construction industry is increasingly seeking sustainable and cost-effective alternatives to traditional building materials. Stabilized Mud Blocks (SMBs) offer an eco-friendly solution, further enhanced by natural fiber reinforcement. This study investigates the mechanical and durability properties of coconut fiber reinforced stabilized mud blocks (CFR-SMBs), emphasizing their applicability in low- to medium-rise sustainable structures. A comprehensive experimental methodology was adopted, testing samples with varying fiber contents (0%–3%). Results showed a significant increase in compressive strength and water resistance with fiber addition, with optimal performance observed at 3% fiber content. CFR-SMBs thus present a promising material for affordable and environmentally conscious construction.

Keywords: Coconut Fiber, Stabilized Mud Blocks, Sustainable Construction, Compressive Strength, Water Absorption, Natural Fiber Reinforcement.

1. Introduction:

The need for sustainable alternatives has never been greater as the world's construction industry struggles with issues like resource depletion, climate change, and the environmental impact of traditional building materials. Despite their widespread use, traditional materials like concrete blocks and fired clay bricks require a lot of energy to manufacture and transport. These substances have a major impact on environmental deterioration and greenhouse gas emissions. Stabilized Mud Blocks (SMBs), on the other hand, provide a practical and environmentally responsible substitute. SMBs are economical and energy-efficient, made from soil that is readily available in the area and stabilized with a small amount of cement or lime. They adhere to the ideas of vernacular architecture and local resource use, and their production uses a lot less energy than fired bricks.

This study investigates the addition of coconut fibers to the block matrix in an attempt to enhance the mechanical performance and environmental appeal of SMBs. A plentiful and renewable agricultural by-product that is frequently thrown away as waste are coconut fibers. Reducing agricultural waste and improving material performance are two advantages of incorporating them into building materials. Coconut fibers are the perfect reinforcement for earthen blocks because of their high tensile strength, low density, and superior biodegradability.

The goal of the study is to create Coconut Fiber-Reinforced Stabilized Mud Blocks (CFR-SMBs) and evaluate their mechanical characteristics, including compressive strength, impact resistance, and crack resistance. The study examines how different fiber contents and stabilization methods affect the blocks' structural integrity and longevity through methodical experimental testing. According to preliminary results, adding coconut fibers to SMBs considerably increases their ductility and resilience without sacrificing their sustainability. These advancements are essential for encouraging the use of environmentally friendly materials in both structural and non-structural applications, especially in the low-cost and rural housing sectors.

In the end, CFR-SMBs are a combination of contemporary sustainable innovation and conventional building knowledge. This strategy supports circular economy principles while lowering construction costs and environmental impact by combining locally produced materials with renewable agricultural fibers. Natural fiber-reinforced earthen materials have the potential to help the construction industry achieve sustainable development goals, and the study's insights add to the expanding body of knowledge in green building technologies.

2.Objectives of the study:

1. To investigate the optimal proportion of Coconut Fibers for enhanced block performance.
2. The primary objective is to assess the effect of coconut fiber on the strength of mud blocks.
3. To evaluate the impact of Coconut Fibers on the Mechanical Properties of Stabilized Mud Blocks.

4. The study also explores the environmental benefits of using coconut fibers in construction.

3.Materials and methodology:

Soil: Collect local soil (red soil), ensuring it is free from impurities and large stones. The soil should be sieved to remove any unwanted particles. Perform tests on the soil to determine properties such as plasticity index, moisture content, and grain size distribution.
Cement: OPC 53 cement must meet IS:8112-1989 standards and have a minimum 28-day designed strength of 53 MPa. The experiment uses Birla cement, which has a specific gravity of 3.14.
Sand: One of the most often used fine aggregates in construction is sand. The material that makes it through a 4.75 mm sieve is known as fine aggregate. M-sand is used in this experiment. The fine aggregate's specific gravity is 2.68.
Coconut Fibre: Collect coconut husk from mature coconuts. The fibres should be cleaned, separated, and cut into appropriate lengths, typically between 10-30 cm. Check the moisture content and test its tensile strength.
Stabilizers: Choose appropriate stabilizers like cement. The stabilizer quantity typically varies depending on the soil type but is often around 5-10% of the total dry weight.
Water: Use clean, potable water for mixing the materials, ensuring it does not contain contaminants that could affect the setting and strength of the blocks.

4. Methodology:

The first step in assessing Coconut Fiber-Reinforced Stabilized Mud Blocks (CFR-SMBs) is gathering the necessary materials, which include soil that is readily available in the area, stabilizing agents like cement or lime, and coconut fibers that are obtained as an agricultural byproduct. Each of these components is essential to the blocks' overall functionality, and the strength, sustainability, and durability of the finished product are all directly impacted by the quality of each one. The raw materials are then put through tests to evaluate their chemical and physical characteristics. For example, coconut fibers are tested for tensile strength and length uniformity, and soil is tested for moisture content, plasticity, and grain size distribution. By ensuring that only appropriate materials are chosen, these tests offer a solid basis for creating blocks of superior quality.
After the materials are approved, the mix must be proportioned, thoroughly blended, and compacted into molds using either mechanical or manual techniques to improve density and remove air voids. After leveling, the molded blocks are placed aside to cure. For seven to fourteen days, they are kept in shady spots and given frequent waterings to ensure the stabilizers are properly hydrated. Following curing, tests are performed on the blocks to assess their load-bearing capacity, with a primary focus on compressive strength. This brings us to the results and discussions section, where test data is examined to determine how curing time and coconut fiber reinforcement affect block performance. Meaningful conclusions are drawn by interpreting trends, observations, and anomalies. The overall efficacy of CFR-SMBs is finally summed up in the conclusions section, which also highlights their potential as a structurally sound and sustainable substitute for traditional masonry units. Future research recommendations and possible uses in environmentally friendly construction are also included.

5. MIX PROPORTIONS

Table. 5.1 Mix proportions

Composition of materials in percentage (%)				
Materials	**Sample -1**	**Sample -2**	**Sample -3**	**Sample -4**
Soil	**70**	**69.9**	**69.8**	**68.7**
Sand	**20**	**20**	**20**	**20**
Cement	**10**	**10**	**10**	**10**
Coconut fibers	**00**	**1.0**	**2.0**	**3.0**

6. Experimental work:

A crucial step in the creation of Coconut Fiber-Reinforced Stabilized Mud Blocks (CFR-SMBs) is material mixing, which has a big impact on the final product's consistency and quality. The first step in the process is soil preparation, which involves sieving the soil to get rid of big debris or stones. In order to achieve a uniform block structure, it is essential to guarantee a consistent texture. After that, water is added to the soil to reach the ideal moisture content, which is necessary for compaction and workability and usually ranges between 12% and 16% by weight. The next step is to mix the soil with stabilizers like fly ash, lime, or Ordinary Portland Cement (OPC). The stabilizer improves the binding properties and increases the strength and durability of the block. It is typically added at a rate of about 10% of the dry weight of soil. At this point, making sure the soil and stabilizer are thoroughly and uniformly blended is the aim.

Coconut fibers are added to the soil-stabilizer mixture once it is prepared. To prevent clumping and guarantee uniform reinforcement throughout the matrix, these natural fibers, which are normally added at a volume percentage of the soil mix of 1-3 percent, must be dispersed equally. Coconut fibers are a good reinforcement material because of their high tensile strength, moderate elasticity, and biodegradability. Their addition improves the blocks' overall toughness, impact resistance, and crack resistance. Either careful manual blending or mechanical mixing is used to ensure an even spread when distributing these fibers. After that, water is gradually added to change the mixture's overall consistency. In order to prevent segregation and weak bonding within the block, the mix should be just moist enough for compaction but not so wet.

The first step in the molding process is to prepare the molds by cleaning them and using a release agent, like oil or grease, to help remove the blocks without damaging them. Although they can be altered depending on the intended use, standard block dimensions, such as 230 mm × 190 mm × 100 mm, are commonly used. Layers of the carefully prepared and evenly mixed material are poured into these molds, and either mechanically or manually, the material is compacted completely. The strength and durability of the block are directly impacted by compaction, which is an essential step in removing air voids and ensuring maximum density. The coconut fibers will be firmly embedded and the mixture will solidify into a single, cohesive unit if the compaction is done correctly. After being filled and compacted, the blocks are allowed to set before curing starts, and the top surface of the mold is leveled with a trowel to guarantee uniformity.

Experimental results:

6.1 Test results (7 days)

Table 6.1: 7 days Compressive strength of Sample 1

	Sample 1 (without fibers)	
Sl. No.	**Dimensions (mm)**	**Compressive strength N/mm2**
1	**230 X 190 X 100**	**2.56**
2	**230 X 190 X 100**	**1.83**
3	**230 X 190 X 100**	**2.42**
	Average	**2.27**

Table 6.2: 7 days Compressive strength of Sample 2

	Sample 2 (with 1% fibers)	
Sl. No.	**Dimensions(mm)**	**Compressive strength N/mm2**
1	**230 X 190 X 100**	**4.39**
2	**230 X 190 X 100**	**3.89**
3	**230 X 190 X 100**	**4.21**
	Average	**4.16**

Table 6.3: 7 days Compressive strength of Sample 3

	Sample 3 (with 2% fibers)	
Sl. No.	**Dimensions**	**Compressive strength N/mm2**
1	**230 X 190 X 100**	**4.48**
2	**230 X 190 X 100**	**4.62**
3	**230 X 190 X 100**	**4.53**
Average		**4.54**

Table 6.4: 7 days Compressive strength of Sample 4

	Sample 4 (with 3% fibers)	
Sl. No.	**Dimensions**	**Compressive strength N/mm2**
1	**230 X 190 X 100**	**4.85**
2	**230 X 190 X 100**	**4.89**
3	**230 X 190 X 100**	**4.98**
Average		**4.90**

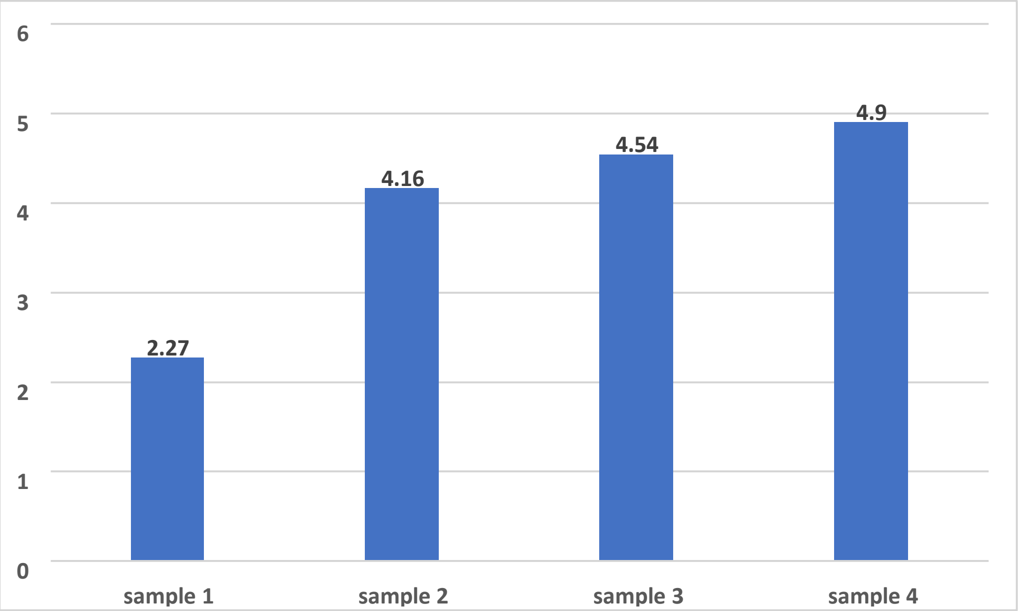

Figure 6.2: Graphical representation for 7 days dry compression test

6.2 Test results (14 day's)

Table 6.5: 14 days Compressive strength of Sample 1

	Sample 1 (without fibers)	
Sl. No.	**Dimensions**	**Compressive strength N/mm2**
1	**230 X 190 X 100**	**7.64**
2	**230 X 190 X 100**	**7.68**
3	**230 X 190 X 100**	**9.06**
	Average	**8.12**

Table 6.6: 14 days Compressive strength of Sample 2

	Sample 2 (with 1% fibers)	
Sl. No.	**Dimensions**	**Compressive strength N/mm2**
1	**230 X 190 X 100**	**10.11**
2	**230 X 190 X 100**	**10.43**
3	**230 X 190 X 100**	**10.25**
	Average	**10.26**

Table 6.7: 14 days Compressive strength of Sample 3

	Sample 3 (with 2% fibers)	
Sl. No.	**Dimensions**	**Compressive strength N/mm2**
1	**230 X 190 X 100**	**10.61**
2	**230 X 190 X 100**	**10.48**
3	**230 X 190 X 100**	**10.70**
	Average	**10.59**

Table 6.8: 14 days Compressive strength of Sample 4

	Sample 4 (with 3% fibers)	
Sl. No.	**Dimensions**	**Compressive strength N/mm2**
1	**230 X 190 X 100**	**11.16**
2	**230 X 190 X 100**	**11.12**
3	**230 X 190 X 100**	**10.93**
	Average	**11.07**

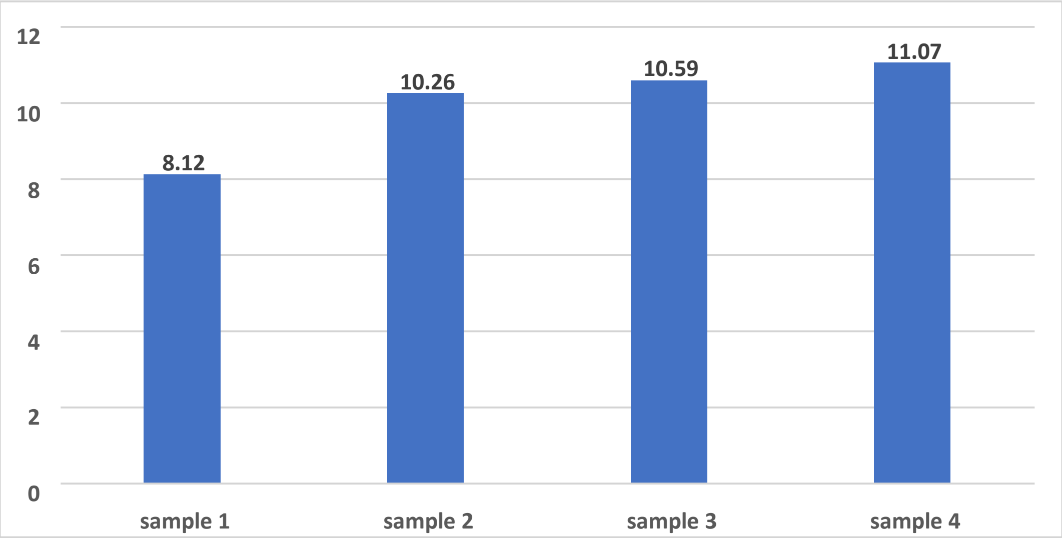

Figure 6.3: Graphical representation for 14 days dry compression test

6.3 WET COMPRESSION TEST

Table 6.9: Wet Compressive strength of Sample 1

	Coconut fibers - 0%	
SL. No.	**Dimensions (mm)**	**Compressive strength (N/mm2)**
1	**230 X 190 X 100**	**2.17**
2	**230 X 190 X 100**	**1.85**
3	**230 X 190 X 100**	**2.10**
	Average	**2.04**

Table 6.10: Wet Compressive strength of Sample 2

Coconut fibers - 1%		
SL. No.	**Dimensions (mm)**	**Compressive strength (N/mm2)**
1	230 X 190 X 100	4.00
2	230 X 190 X 100	2.47
3	230 X 190 X 100	3.93
	Average	**3.47**

Table 6.11: Wet Compressive strength of Sample 3

Coconut fibers – 2%		
SL. No.	**Dimensions (mm)**	**Compressive strength (N/mm2)**
1	230 X 190 X 100	4.46
2	230 X 190 X 100	3.98
3	230 X 190 X 100	4.23
	Average	**4.22**

Table 6.12: Wet Compressive strength of Sample 4

Coconut fibers – 3%		
SL. No.	**Dimensions (mm)**	**Compressive strength (N/mm2)**
1	230 X 190 X 100	4.48
2	230 X 190 X 100	4.12
3	230 X 190 X 100	4.28
	Average	**4.29**

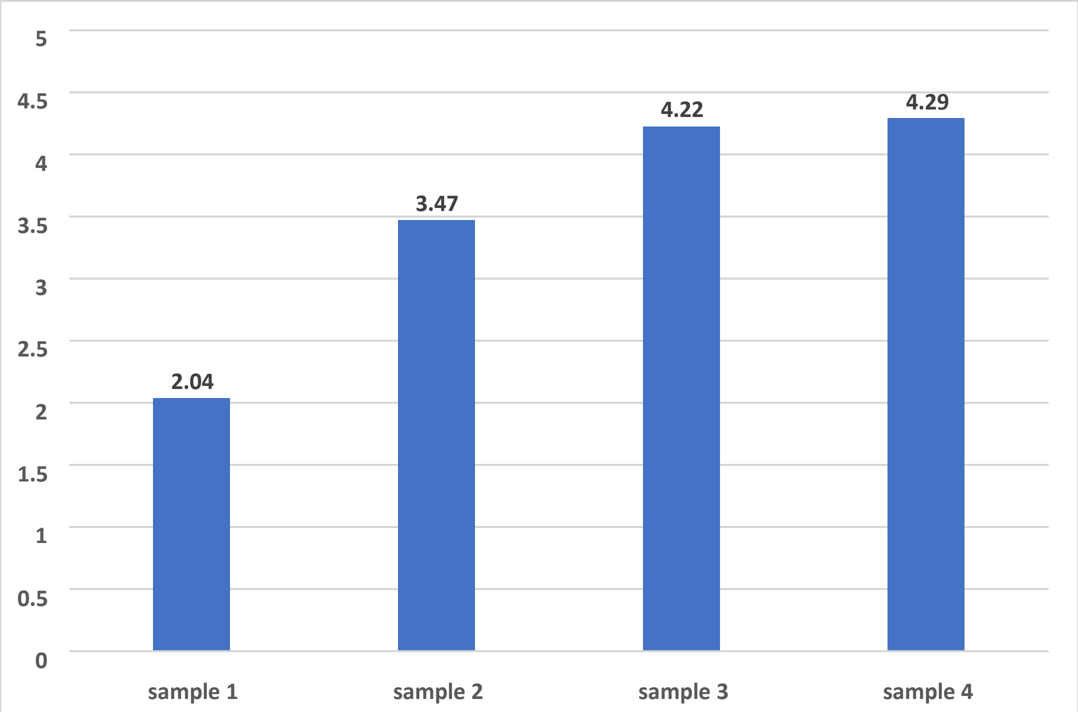

Figure 6.4: Graphical representation for wet compression test

6.4 Water Absorption:

Test: Immersion test

Purpose: Measures how much water the blocks absorb, which can affect their durability and resistance to weathering.

Table 6.13: Water Absorption test

SL. NO.	CF= 0%	CF= 1%	CF= 2%	CF= 3%
1	**12.59**	**15.78**	**17.00**	**17.68**
2	**10.77**	**18.45**	**18.21**	**16.24**
3	**13.17**	**13.54**	**16.53**	**17.48**
Average	**12.17**	**15.92**	**17.25**	**17.13**

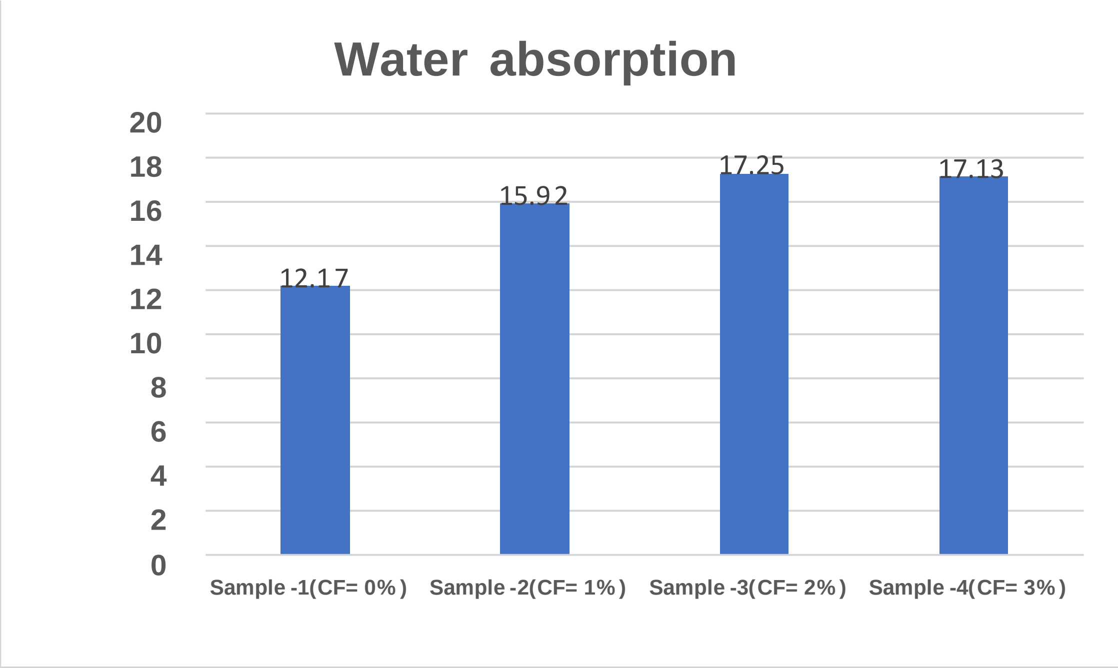

Figure 6.5: Graphical representation for water absorption test

The results of the water absorption test and the dry and wet compressive strength tests unequivocally show how the addition of coconut fiber (CF) affects the functionality of compressed fiber-reinforced stabilized mud blocks (CFR-SMB). Compressive strength rose steadily with increasing fiber content in dry conditions, rising from 2.27 N/mm² in the control sample (0% CF) to 4.90 N/mm² at 3% CF for 7-day samples and from 8.12 N/mm² to 11.07 N/mm² for 14-day samples. A similar pattern was seen in wet compressive strength, which increased from 2.04 N/mm² (0% CF) to 4.29 N/mm² (3% CF), suggesting that fiber reinforcement improves structural integrity even in damp environments. The water absorption test did show a trade-off, though, as the fiber content increased the blocks' water absorption capacity from an average of 12.17% (0% CF) to 17.25% and 17.13% for 2% and 3% CF, respectively. This implies that although coconut fibers greatly increase strength, they also increase porosity and moisture intake, which could affect durability over time when exposed to water if improperly sealed or treated.

7.Observations and discussions

The test results demonstrate that the performance of stabilized mud blocks (SMBs) was significantly impacted by the addition of coconut fibers. Every percentage of fiber added resulted in a steady increase in compressive strength. For example, the 7-day strength of the fiber-free plain blocks was only 2.27 N/mm², but when 3% fibers were added, the strength increased to 4.90 N/mm², more than doubling. The strength peaked at 11.07 N/mm² for the 3% fiber sample and 8.12 N/mm² for the control, following a similar pattern in the 14-day results.

The fiber-reinforced blocks outperformed even in damp conditions. The 3% fiber block demonstrated significantly greater water resistance, achieving 4.29 N/mm², compared to the control sample's average of 2.04 N/mm². This implies that the fibers aid in binding the mixture, minimizing the strength loss that occurs when the blocks are exposed to moisture.

There was a minor drawback, though, in that water absorption tended to rise with fiber content. At 17.25%, the 2% fiber block had the highest average absorption, which, if left unchecked, could be problematic for long-term use. Interestingly, there was not much of a performance difference between 2% and 3% fiber content, suggesting that 2% may be the ideal amount to balance strength and water absorption.

Overall, the findings imply that the addition of coconut fibers, particularly at a rate of about 2%, can greatly increase the structural strength and longevity of SMBs, making them more dependable for environmentally friendly building, especially in locations that are subject to moisture exposure.

8. Conclusions

- Coconut Fiber Reinforced Stabilized Mud Blocks (CFR-SMBs) are a practical and environmentally responsible substitute for traditional building materials, according to the study.
- The blocks' durability, moisture resistance, and compressive strength are all increased by the addition of coconut fibers.
- A fiber content of 2–3% is ideal because it strikes a balance between water absorption and mechanical strength.
- CFR-SMBs are particularly well-suited for cost-effective construction, rural housing, and low- to medium-rise buildings.
- Utilizing locally accessible resources, like cement, red soil, and agricultural coconut fibers, maintains production's affordability and sustainability.
- By lowering construction waste and minimizing environmental impact, these blocks help achieve sustainable development goals.
- For high-rise or heavy-load-bearing applications, where conventional materials like concrete are still preferred, CFR-SMBs are not the best option.
- Compared to fired bricks and concrete blocks, they require less energy to produce, which lowers carbon emissions.
- The experiment demonstrates the viability and advantages in performance of adding natural fiber reinforcements to earthen building materials.
- All things considered, the study promotes the broader use of CFR-SMBs in green building techniques and establishes the framework for additional investigation and improvement.

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