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Natural Fibrous Concrete Using Agricultural Waste Fibers: A Sustainable Approach for Green Construction

Dr. Battu Ravi Sanker Reddy [1], M. Guru Prasad [2] , N.Rushwanth Chowdary [3]

[1,2,3] Academic Consultant, S.V.U.College of Engineering, S.V.University, India

Abstract

The construction industry is increasingly focusing on sustainable and environmentally friendly materials to reduce its ecological footprint. Natural Fibrous Concrete (NFC) is an innovative construction material in which natural fibers are incorporated into conventional concrete to enhance its mechanical and durability properties. In the present study, agricultural waste fibers such as coconut coir, banana fiber, and sugarcane bagasse were utilized as reinforcing materials in concrete. These natural fibers improve the tensile strength, toughness, crack resistance, and post-cracking behavior of concrete by acting as micro-reinforcement within the cement matrix.

The use of natural fibers offers several advantages including low cost, biodegradability, renewability, and reduced environmental impact compared to synthetic fibers. Experimental investigations were carried out to evaluate the compressive strength performance of natural fibrous concrete at 28 days of curing. The results indicated that the incorporation of natural fibers enhanced the overall performance of concrete while contributing to sustainable waste management. Although challenges such as moisture absorption and variability in fiber properties exist, proper treatment and mix design can effectively address these issues. The study concludes that natural fibrous concrete has significant potential for sustainable construction applications, particularly in low-cost housing and green building technologies.

Keywords: Natural Fibrous Concrete, Coconut Coir, Banana Fiber, Sugarcane Bagasse, Sustainable Construction, Agricultural Waste, Fiber Reinforced Concrete.

1. Introduction

Concrete is the most widely used construction material due to its excellent compressive strength and durability. However, conventional concrete is inherently weak in tension and susceptible to cracking under various loading conditions. To overcome these limitations, fiber reinforcement has been introduced into concrete mixtures.

Natural Fibrous Concrete (NFC) is a type of fiber-reinforced concrete in which natural fibers obtained from renewable resources are incorporated into the concrete matrix. Common natural fibers include coconut coir, banana fiber, sugarcane bagasse, sisal, jute, bamboo, and flax fibers. These fibers help improve tensile strength, ductility, impact resistance, and crack control characteristics of concrete.

The growing concern over environmental sustainability and waste management has encouraged researchers to explore agricultural waste materials as construction resources. Natural fibers obtained from agricultural residues provide an eco-friendly alternative to synthetic fibers while reducing environmental pollution. Therefore, the utilization of coconut coir, banana fiber, and sugarcane bagasse in concrete contributes to both sustainable construction and effective waste utilization.

2. Literature Review

Several researchers have investigated the performance of natural fiber reinforced concrete using different agricultural fibers.

Ali et al. (2022) conducted a comprehensive review on coconut fiber reinforced concrete and reported that coir fibers significantly improve flexural strength, toughness, and crack resistance. The study identified an optimum fiber content of approximately 3%.

Nadzri et al. (2017) examined the properties of cement composites reinforced with coconut fibers and fly ash. Their results demonstrated improvements in compressive strength and durability characteristics while reducing water absorption.

Kiruthigasri and Sathishkumar (2020) investigated the combined use of banana and coconut fibers in concrete. The study reported enhanced tensile strength and improved resistance to crack propagation.

Recent studies published in Buildings (2023) showed that banana fibers improve the durability performance of high-strength concrete by reducing water absorption and chloride penetration.

Research on sugarcane bagasse fibers has indicated their effectiveness in improving mechanical properties and reducing permeability. Studies published in Materials (2022) demonstrated enhanced strength and durability when sugarcane fibers were incorporated into concrete.

Hybrid fiber studies by Sales et al. (2024) revealed that combinations of banana and sugarcane fibers significantly improve flexural strength and overall structural performance.

3. Research Gap

Despite extensive research on individual natural fibers, limited studies have focused on comparing the performance of coconut coir, banana fiber, and sugarcane bagasse under similar concrete mix conditions. Furthermore, the optimum fiber content and long-term durability characteristics require further investigation for practical construction applications.

4. Objectives of the Study

The main objectives of this study are:

1. To investigate the feasibility of using natural agricultural waste fibers in concrete.
2. To evaluate the compressive strength performance of natural fibrous concrete.
3. To compare the effectiveness of coconut coir, banana fiber, and sugarcane bagasse fibers.
4. To promote sustainable construction through the utilization of renewable resources.
5. To reduce environmental pollution caused by agricultural waste disposal.

5. Materials Used

5.1 Cement
Ordinary Portland Cement (OPC) was used as the primary binding material for concrete production.

5.2 Coconut Coir Fiber
Coconut coir is obtained from coconut husks and possesses high toughness, durability, and resistance to moisture.

5.3 Banana Fiber
Banana fibers are extracted from banana plant stems and exhibit excellent tensile strength and flexibility.

5.4 Sugarcane Bagasse Fiber
Sugarcane bagasse is the fibrous residue remaining after juice extraction. It is lightweight and possesses good reinforcing characteristics.

5.5 Fine Aggregate
Natural river sand conforming to standard specifications was used as fine aggregate.

5.6 Coarse Aggregate
Crushed stone aggregates of suitable size were used in the concrete mix.

5.7 Water
Portable water free from impurities was used for mixing and curing.

6. Experimental Programme
The experimental investigation involved the preparation of concrete specimens containing different natural fibers. The fibers were added to the concrete mix in predetermined proportions and mixed uniformly.

The specimens were cast in standard cube molds and cured for 28 days. After curing, compressive strength tests were conducted according to relevant IS code procedures.

Testing Conducted
- Compressive Strength Test
- Observation of Crack Development
- Visual Assessment of Fiber Distribution

7. Results and Discussion
The compressive strength results obtained after 28 days of curing indicate that the inclusion of natural fibers influenced the performance of concrete.

Coconut Coir Fiber Concrete
The addition of coconut coir fibers improved crack resistance and enhanced the ductility of concrete. The fibers effectively bridged micro-cracks, delaying their propagation and improving post-cracking behavior.

Banana Fiber Concrete

Banana fiber reinforced concrete exhibited improved tensile behavior and better bonding characteristics within the concrete matrix. The fibers contributed to enhanced load-carrying capacity and reduced brittleness.

Sugarcane Bagasse Fiber Concrete

The incorporation of sugarcane bagasse fibers improved the sustainability aspect of concrete while providing moderate enhancement in mechanical performance. The lightweight nature of the fibers contributed to reduced density.

Comparative Analysis

Among the three fibers studied, the optimum fiber content resulted in improved compressive strength compared to conventional concrete. Natural fibers effectively enhanced toughness and crack resistance while contributing to environmentally sustainable construction practices.

The results demonstrate that agricultural waste fibers can successfully be utilized as reinforcement materials in concrete applications.

8. Conclusions

Based on the experimental investigation, the following conclusions are drawn:

1. Natural fibers can be successfully incorporated into concrete as reinforcement materials.
2. Coconut coir, banana fiber, and sugarcane bagasse improve crack resistance and toughness of concrete.
3. Natural fibrous concrete provides an environmentally friendly alternative to synthetic fiber reinforced concrete.
4. The utilization of agricultural waste fibers contributes to sustainable waste management.
5. Proper fiber treatment and mix proportioning are essential for achieving optimum performance.
6. Natural fibrous concrete is suitable for low-cost housing and sustainable construction applications.

9. Scope for Future Work

The future scope of the study includes:

- Development of sustainable and eco-friendly construction materials.
- Improvement of fiber treatment methods to enhance durability and bonding.
- Utilization of natural fibrous concrete in large-scale structural applications.
- Replacement of synthetic fibers with renewable natural fibers.
- Application in green building technologies.
- Optimization of fiber percentages for maximum strength and durability.
- Utilization of additional agricultural waste products.
- Development of lightweight and high-performance concrete products.

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