e-palli

INTERNATIONAL JOURNAL OF SUSTAINABLE RURAL DEVELOPMENT

GLOBAL FORUM FOR SUSTAINABLE RURAL DEVELOPMENT

Volume 1 Issue 2 (2024)

PUBLISHED BY: E-PALLI PUBLISHERS, DELAWARE, USA

GLOBAL FORUM FOR SUSTAINABLE RURAL DEVELOPMENT

Global Forum for
Sustainable Rural Development

International Journal of Sustainable Rural Development (IJSRD)

Volume 2 Issue 1, Year 2025
ISSN: 2998-9035 (Online)
DOI: https://doi.org/10.54536/ijsrd.v2i1.3577
https://journals.e-palli.com/home/index.php/ijsrd

Mechanical Properties and Performance Analysis of Natural Fiber Reinforced Concrete Using Jute and Coconut Fibers

Md. Liton Rabbani[1*], Md. Mohimin Islam[1], Md. Shakhawat Hossain[1], Azizul Hakim Tusar[1], Mohammed Atiqul Hasan[1]

Article Information

Received: August 19, 2024
Accepted: September 28, 2024
Published: March 03, 2025

Keywords

Coconut Fiber, Compressive Strength, Crack Resistance, Flexural Strength, Jute Fiber, Mechanical Properties, Microstructure, Natural Fiber-Reinforced Concrete, Split Tensile Strength, Workability

ABSTRACT

Concrete is one of the most widely used construction materials, but it lacks adequate tensile strength and strain capacity. The addition of fibers to concrete has been shown to improve these properties. This study investigates the use of jute fiber and coconut fiber. Two abundant natural fibers reinforcement in concrete. An experimental program was carried out to evaluate the mechanical properties of natural fiber-reinforced concrete (NFRC) of jute and coconut fibers. Compressive strength, split tensile strength, flexural strength. Additionally, the impact of these fibers on workability and microstructure of the concrete was examined. Jute and coconut fiber-reinforced concrete exhibited improved tensile and flexural properties compared to plain concrete, although compressive strength was slightly reduced. Fiber-reinforced concrete demonstrated improved ductility and crack resistance. Optimal fiber dosages were identified for achieving balanced strength and toughness properties. On the 28th day, the compressive strength, flexural strength, split tensile strength were respectively 2338 psi, 415.23 psi and 292.25psi for normal concrete , 2523 psi, 437.23psi and 315.375psi for coconut fiber concrete, and 2609 psi, 452.1397 psi and 326.125psi for jute fiber concrete. Microstructural analysis revealed that the natural fibers formed an effective bridging system across cracks and contributing to enhanced post-cracking behavior. The study demonstrates the potential of jute and coconut fibers as low-cost and environmentally friendly reinforcements for concrete, making them suitable for applications requiring improved tensile properties and crack resistance. Overall, this research contributes to the development of high-performance, eco-friendly, and cost-effective concrete materials by leveraging the unique properties of natural fibers. The findings have potential applications in infrastructure, construction, and other industries where enhanced durability and crack resistance are desired.

INTRODUCTION

Concrete has long been the cornerstone of modern construction, underpinning the world's infrastructure with its remarkable compressive strength and versatility. However, beneath its seemingly impenetrable facade lies a material vulnerable to tensile forces, susceptible to cracking, and associated with a significant environmental footprint. In response to the growing demand for sustainable building practices and the imperative to reduce the ecological burden of construction materials, the search for innovative solutions to enhance concrete's mechanical properties while minimizing its environmental impact has intensified.

Various types of fibers, encompassing both organic and inorganic varieties, find application in reinforcing concrete components. The selection of fibers for enhancing tensile strength in concrete is contingent upon several factors, including fiber surface characteristics, length, modulus of elasticity, and their composition. Furthermore, the extent to which these fibers influence concrete performance remains a subject of exploration.

Fibers are typically categorized into two main groups: metallic fibers and nonmetallic fibers. Metallic fibers are distinguished by their electrical conductivity, with steel fibers being the predominant example. In contrast, nonmetallic fibers encompass materials such as glass fibers, polypropylene fibers, carbon fibers, and others. Among these, steel fibers, glass fibers, polypropylene fibers, and carbon fibers have garnered significant research attention. However, they are associated with high costs, limited availability, and notably greater stiffness, which can adversely affect concrete workability. Consequently, recent studies have proposed the utilization of natural fibers as alternatives to metallic fibers.

Fiber-reinforced composites have gained considerable acceptance in structural applications. The technological characteristics and low cost make them attractive to the cement industry. Natural fiber-reinforced composites are known to be an advantageous alternative and less harmful to the environment since they come from plants (Achour, 2017).

These composites have advantages over synthetic fibers, such as glass fiber composites. Glass fibers require greater energy consumption for manufacturing. On the other hand, natural fibers have biodegradability, non-toxicity, easy availability, non-abrasiveness, low density, low cost, good specific strength, and great resistance to corrosion and fatigue. However, natural fibers also have disadvantages such as loss of workability, fiber degradation, and material heterogeneity (Ferreira, 2016; Fokam, n.d.).

[1] Barishal Engineering College, University of Dhaka, Bangladesh
[*] Corresponding author's e-mail: liton.kce@bec.ac.bd

The cement composite reinforced with natural fibers can achieve mechanical characteristics superior to those of conventional materials already used in the industry. Fibers inhibit the initiation and propagation of cracks. They attenuate the progression of micro-cracks, thus preventing sudden rupture. As a result, the length of cracks in the hardened matrix is shorter, which considerably improves the impermeability and durability of composites exposed to the environment (Zhang, n.d.).

Natural fiber-reinforced concrete (NFRC) has emerged as a promising avenue in this quest for sustainable construction materials. NFRC integrates natural fibers, such as coconut fiber and jute fiber, into the concrete matrix, enhancing its tensile strength, toughness, and durability. These fibers, derived from renewable sources, offer a potential means to mitigate the reliance on conventional steel reinforcements and reduce the carbon footprint associated with concrete production.up to 70% can be saved in terms of energy usage for heating and cooling of buildings by using passive wall systems (Cabeza *et al*., 2010).

LITERATURE REVIEW

Fiber-Reinforced Concrete (FRC) is a composite material that incorporates short, discrete fibrous elements evenly distributed and randomly oriented within the matrix. This integration improves the structural performance of concrete. The roots of FRC technology trace back to ancient civilizations, where materials like mud reinforced with straw were employed in the construction of various structures, including houses, churches, mosques, and utensils (Barr, 1992).

In a study by Ed., Swamy *et al.* (1992), advancements in concrete reinforcement with fibers have been driven by the pursuit of enhancing physical and mechanical properties while optimizing production costs. Various types of fibers have been explored as constituents of concrete, including natural fibers, synthetic fibers, and ferro-cementitious fibers (Marikunte). Natural fiber-reinforced concrete, in particular, offers distinctive advantages, including economic benefits derived from energy-efficient production, environmental friendliness, a favorable strength-to-weight ratio, and superior insulation properties compared to conventional materials.

However, a subject of debate revolves around the biodegradable nature of natural fibers, which can potentially impact the long-term durability of concrete (Thomas). This durability concern does impose certain limitations on the applications of natural fiber-reinforced concrete, as engineering analyses dictate the extent to which it can be safely used in specific contexts.

In essence, while FRC holds significant promise in enhancing concrete's properties and cost-effectiveness, the choice of natural fibers as a reinforcement material comes with both advantages and considerations, particularly related to their biodegradability and its potential implications on concrete performance. These factors guide the engineering applications of natural fiber-reinforced concrete, striking a balance between its benefits and limitations.

Debnath *et al.* (2024) studied Properties Evaluation and Suitability Assessment for Construction Applications of Sand of Kirtankhola River in Bangladesh. This investigated that the availability of high-quality construction materials is a critical factor in ensuring the durability and structural integrity of construction projects (Debnath, 2024).

FRC is composed of two essential components: the matrix component, which represents the conventional concrete, and the fiber component. The composition of the concrete matrix component includes cement, aggregates, water, and, in certain instances, additives are introduced to address specific considerations. The proportions of these constituent materials are determined by various factors such as workability, strength, durability, and the cost implications of the final product (Nimityongskul).

Saifullah *et al.* (2024) studied on investigation the Use of Waste Glass and Waste Paper as an Alternative Construction Binding Material: An Approach towards Sustainable Environment. In this investigation waste glass and waste paper materials used as binding materials. This suggested that glass waste-reinforced concrete can serve as a sustainable alternative without compromising structural integrity, even in the long term (Saifullah, 2024).

Utsha *et al.* (2024) studied on Enhancing Recycled Concrete Performance by Using Chemical Activators. This investigation focus on recycled concrete performance when it was plain concrete and when it was with chemical activators. Also note that concrete with chemical activators gave better result (Utsha, 2024).

In a study by Majid Ali and Chouw (2012), the utility of fiber-reinforced concrete in various civil engineering applications was explored. This investigation encompassed a range of fibers, including steel, natural, and synthetic varieties, each contributing distinct properties to the concrete matrix. The study findings underscored the enhancement of structural integrity facilitated by fibrous materials. These insights guided our decision to employ readily available and cost-effective natural fibers. They also examined the feasibility of employing coconut-fiber ropes as vertical reinforcement in earthquake-prone regions for mortar-free, low-cost housing. Anchoring the rope within the foundation and top tie-beams was instrumental, and the bond between the rope and concrete played a pivotal role in structural stability. Notably, the tensile strength of the rope was found to be commendably high. To ensure structural safety, it was imperative that the rope tension generated during earthquake loading remained below both the pull-out force and the rope's tensile load. The study concluded that increased embedment length, rope diameter, cement content, and fiber content in the matrix positively influenced pull-out energy (Majid Ali, 2011).

Anthony Liu (2011) investigated the impact of fiber volume fraction through surface treatment with a wetting agent for coir mesh-reinforced mortar using non-woven coir mesh matting. A four-point bending test

Published by
E-Palli Publishers, Delaware, USA

was conducted, revealing that cementitious composites, reinforced by three layers of coir mesh with a low fiber content of 1.8%, yielded a remarkable 40% improvement in flexural strength compared to conventional concrete. These composites exhibited superior flexural toughness (25 times higher) and ductility (approximately 20 times higher). While static properties of coconut fiber-reinforced concrete (CFRC) were studied, dynamic properties remained unexplored. The study emphasized the need for comprehensive investigations, encompassing various fiber lengths and parameters, to derive reliable conclusions. Understanding both static and dynamic CFRC properties was deemed crucial for its potential application in earthquake-resistant, affordable housing (Nibasumba, 2011).

Nibasumba (2011) conducted third-point loading tests on concrete reinforced with coconut, sugarcane bagasse, and banana fibers to assess flexural strength, fracture toughness, and fracture energy. The study established that coconut fiber-reinforced concrete exhibited the highest fracture toughness and energy among natural fibers, with a corresponding increase in flexural strength of up to 25%. These superior properties of coconut fibers led to their selection as the reinforcement material in our project. The influence of coconut fiber content (ranging from 1% to 5%) at various fiber lengths (2.5 cm, 5 cm, and 7.5 cm) on concrete properties. Damping of coconut fiber-reinforced concrete beams was observed to increase with higher fiber content, with the best results achieved at a fiber length of 5 cm and a fiber content of 5%. This study informed our decision to incorporate 4%, 5%, and 6% coconut fiber by weight of cement in our research (Ferraz, 2013).

In a study by Ferraz *et al.* (2013), the physical, mechanical, and thermal properties of coir-based lightweight cement boards after 28 days of hydration. Factors such as fiber length, coir pre-treatment, and mixture ratio were considered. Boards composed of 5 cm long boiled and washed fibers, with an optimal cement: fiber: water weight ratio of 2:1:2, demonstrated the highest modulus of rupture and internal bond among the tested specimens. Furthermore, these boards exhibited lower thermal conductivity compared to other commercial flake board composites. Consequently, our research opted for 5 cm fiber length following appropriate fiber treatment to eliminate coir dust. The Shear behavior of reinforced concrete beams strengthened using different configurations and quantities of carbon fibers. The study demonstrated that carbon fiber reinforcement enhanced shear resistance and mitigated concrete spalling (DP, 1998).

Rabbani (2017) investigated on A study on low cost roof (Masonry Slab). This study focused on examine of masonry slab load carrying capacity and failure pattern. They observed combined failure both in joints and bricks module (ML, 2017).

Jute is a lignocellulosic fiber that comprises both textile and wood fibers, falling under the category of bast fibers extracted from the plant's skin or bast. Derived from the jute plant's bark, jute fiber consists of cellulose, hemicellulose, lignin, along with trace elements such as lipids, pectin, aqueous extract, and other minor constituents. The structural composition of jute fiber involves minuscule cellulose units enclosed and bound together by lignin and hemicellulose. Jute Fiber (JTF) boasts a higher cellulose content, contributing to its superior tensile strength. Consequently, it is anticipated that JTF will enhance the mechanical properties of concrete, particularly its tensile capacity. The fundamental structure of jute fiber consists of numerous cells composed of crystalline microfibrils primarily based on cellulose. These microfibrils are held together by amorphous lignin and hemicellulose, forming a multi-layer composite. The ratio of cellulose to lignin/hemicellulose and the arrangement of cellulose microfibrils within these cell walls can vary significantly (M, 2020).

Rabbani *et al.* (2021)studied on Experimental Investigation of Load Deflection Characteristics of Beam with Various End Conditions of Different Materials. This study focused on examining of Load Deflection Characteristics of Beam with Various End Conditions of Different Materials. The results indicated that every materials has deflection. By using various natural fiber the material can be resist this deflection. (Rabbani *et al.*, 2021)).

The investigation focused on the mixed-mode I/II fracture toughness of jute fiber-reinforced concrete, utilizing a substantial number of semi-circular bend (SCB) specimens with pre-existing cracks. The results revealed that specimens comprised of jute fiber-reinforced concrete exhibited significantly enhanced resistance to crack propagation when compared to those composed of plain concrete. Additionally, the study encompassed an examination of the compressive strength, splitting tensile strength, and flexural strength of the concrete mixes. The findings demonstrated that the incorporation of jute fibers led to notable improvements in compressive, splitting tensile, and flexural strength across the concrete materials. This enhancement in mechanical properties can be attributed to the inherent characteristics of jute fibers, which possess the capability to impede crack extension, mitigate stress concentration at crack tips, and decelerate crack growth rates (Razmi, 2017).

MATERIALS AND METHODS

Specimen Preparation

The preparation of concrete specimens for testing is a critical aspect of this research, ensuring the accuracy and reliability of subsequent assessments of mechanical properties. In this section, detail the specific procedures undertaken to create the concrete specimens containing coconut fiber and jute fiber as admixtures.

Materials Selection

Selecting the appropriate materials for our research on natural fiber-reinforced concrete (NFRC) with a focus on coconut fiber and jute fiber is a critical step in ensuring the accuracy and relevance of this study.

Published by
E-Palli Publishers, Delaware, USA

Cement
Type
Ordinary Portland Cement (OPC) was selected as the primary binding agent. OPC is widely used in concrete construction and serves as a standard reference point for evaluating the influence of natural fibers.

Aggregates
Fine Aggregate
We utilized locally sourced fine sand as the fine aggregate component in the concrete mix. This choice aligns with typical construction practices in the region.

Coarse Aggregate
Standard coarse aggregates, such as crushed stone or gravel, were incorporated based on local availability and typical concrete formulations.

Water
Source
Clean and potable water from a reliable source was employed for mixing and curing the concrete. Ensuring water quality is essential to prevent any contamination that could affect test results.

Natural Fibers
Coconut Fiber
Coconut fibers were selected due to their promising mechanical properties, renewability, and suitability for various applications. The inherent characteristics of coconut fibers make them an intriguing choice for concrete reinforcement. This fiber were cut n small size and treatment before used.

Figure 1: Preparation of Coconut Fiber

Jute Fiber
Jute fibers were chosen for their affordability, widespread availability, and eco-friendly attributes. Their biodegradability and desirable mechanical qualities make them an excellent candidate for comparison with coconut fibers. This fiber were also cut n small size and treatment before used.

Figure 2: Preparation of Jute Fiber

Mix Proportions (With Coconut Fiber)
- The mix design was M20 means 1:1.5:3 ratio of cement, sand and coarse aggregate.
- Fiber content was determined as one percentage of the total weight of cementitious materials.

Mixing Procedure
- We have done hand mixing method to do the manual concrete mixer to ensure thorough dispersion of fibers within the mix. For large work mixing machine can be used and it will gives better result.
- Mixing time and speed were carefully controlled to achieve uniform distribution.

Figure 3: Mixing of Ingredients

Specimen Molding
- Specimens were molded into two shapes which were cubes and cylinders as required for different mechanical tests.
- Two types of molds were selected based on the specific test parameters and dimensions. Dimension of cube mold is 4"x4"x4" and cylindrical mold is dia.4" and height 6"

Curing Specimen
- To facilitate proper curing, specimens were cured under controlled conditions, maintaining room temperature and humidity levels.
- Curing durations included 7 days, 14 days, 21 days and 28 days, allowing for assessment of strength development over time.

Published by
E-Palli Publishers, Delaware, USA

Labeling and Identification

• Each specimen was appropriately labeled, detailing critical information such as mix proportions, curing duration, and fiber content.

• Clear identification ensured accurate tracking and organization during testing.

Figure 4: Labeling and Identification of Sample

Sample Size and Replication

• To ensure the statistical significance of results, we replicated the specimen preparation process with multiple samples for each type of test.

• Sample size and replication were determined in accordance with established statistical principles.

Quality Control

• Rigorous quality control measures were implemented to minimize variability in specimen preparation.

• These measures included meticulous attention to detail in mixing, molding, and curing procedures.

This comprehensive specimen preparation protocol ensures the integrity and consistency of the concrete specimens used for subsequent mechanical testing, allowing for a thorough investigation into the mechanical properties and sustainable applications of natural fiber-reinforced concrete, specifically with coconut fiber and jute fiber admixtures.

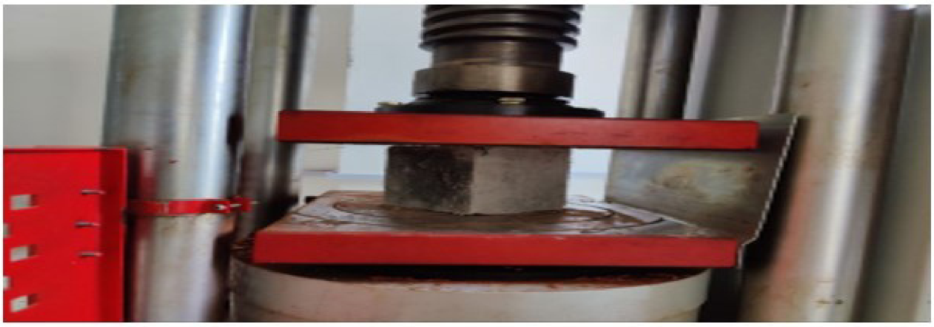

Figure 5: Testing of Sample

06 (a) 06 (b)

Figure 6: (a), (b), Failure Pattern of the Samples

RESULTS AND DISCUSSION

After the curing the specimens were tested carefully. The specimens were tested for compressive strength test, Flexural strength test and split tensile test. Details of the test results are given below in charts:

Compressive Strength Test Result

Flexural Strength Test Results

Split Tensile strength Test Results

From figure 7, 8, 9 and 10, when considering both cylindrical and cube it is worth highlighting that Coconut

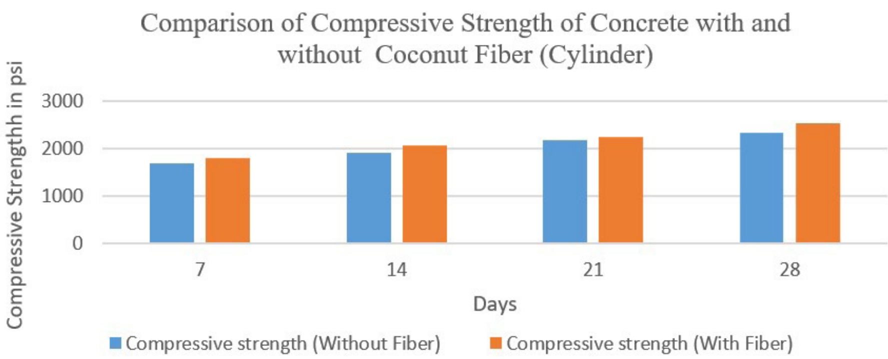

Figure 7: Comparison of Compressive Strength of Concrete with and without Coconut Fiber

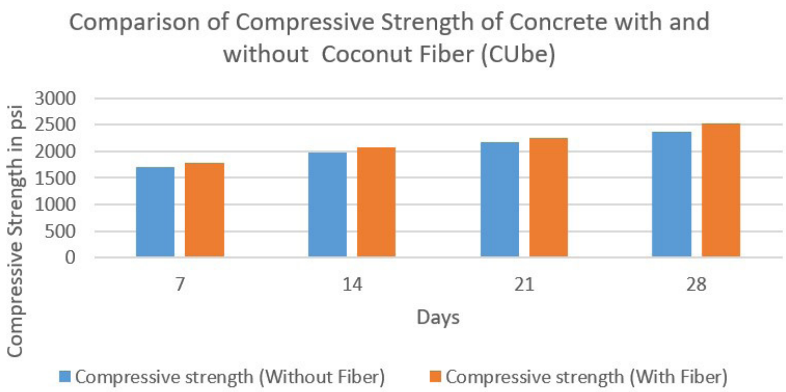

Figure 8: Comparison of Compressive Strength of Concrete with and without Coconut Fiber

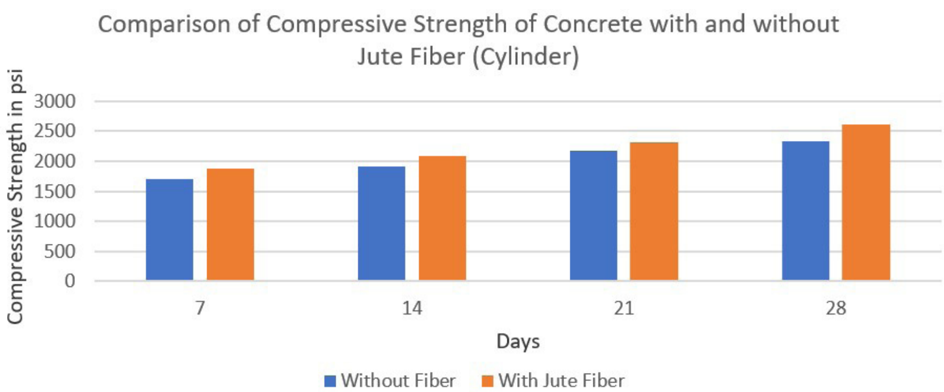

Figure 9: Comparison of Compressive Strength of Concrete with and without Jute Fiber

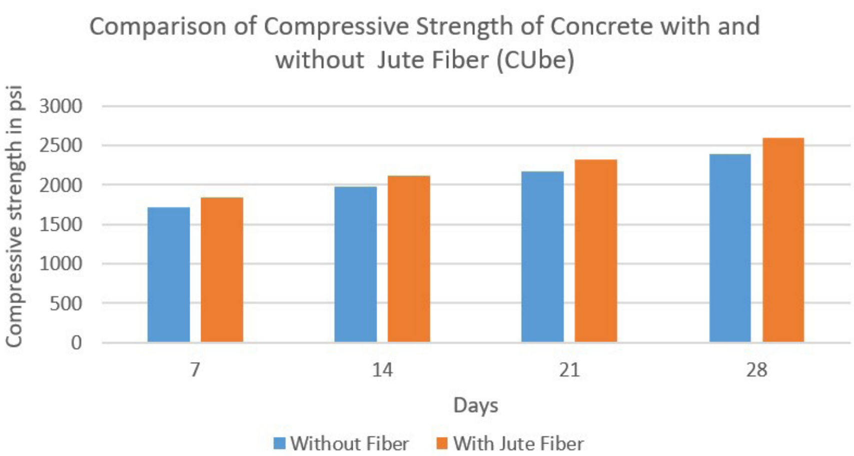

Figure 10: Comparison of Compressive Strength of Concrete with and without Jute Fiber

Published by
E-Palli Publishers, Delaware, USA

and Jute fiber concrete exhibited superior compressive

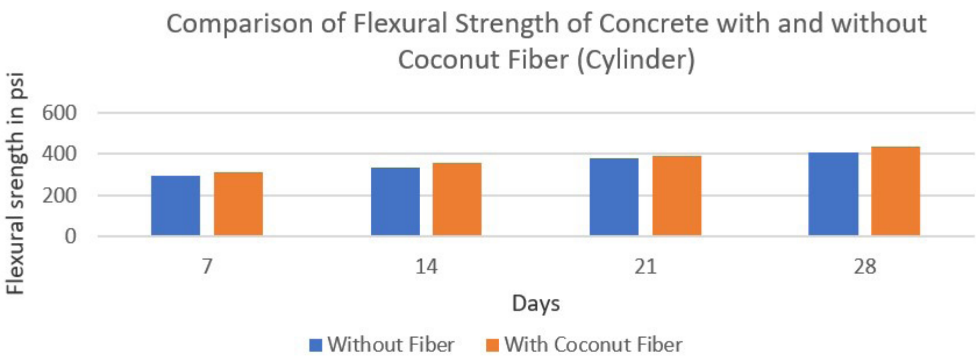

Figure 11: Comparison of Flexural Strength of Concrete with and without Coconut Fiber

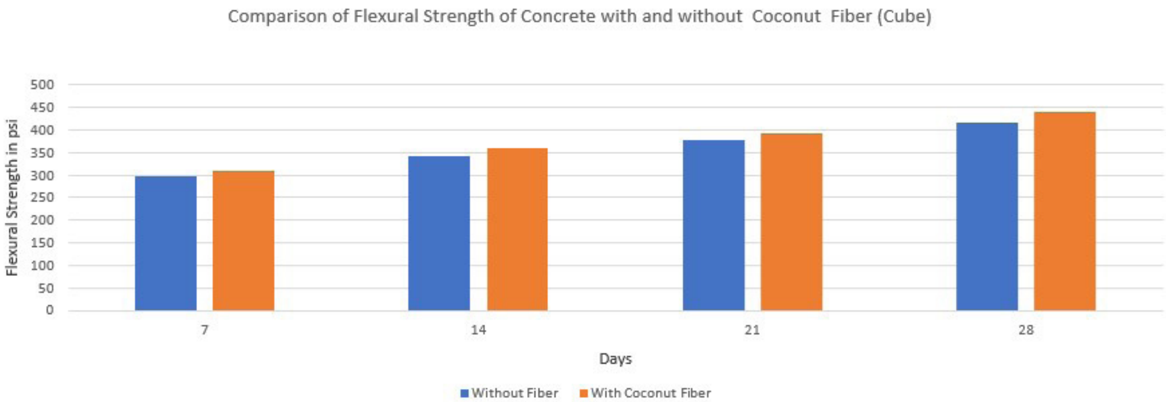

Figure 12: Comparison of Flexural Strength of Concrete with and without Coconut Fiber

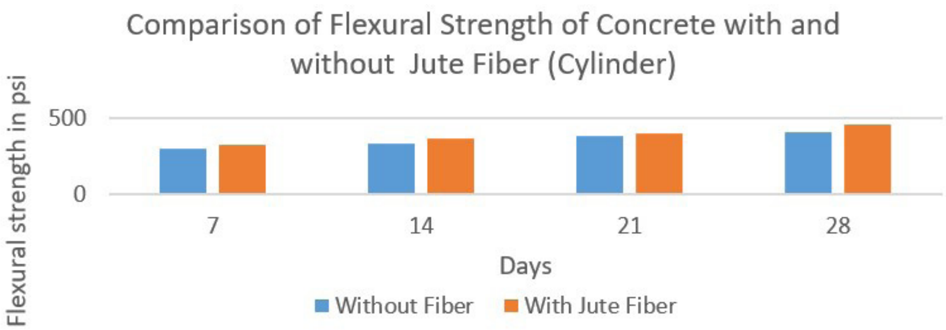

Figure 13: Comparison of Flexural Strength of Concrete with and without Jute Fiber (Cylinder)

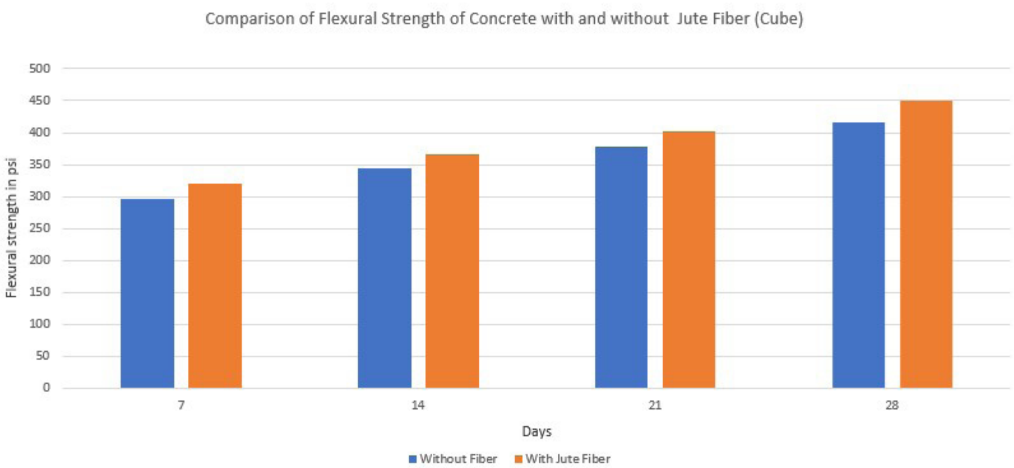

Figure 14: Comparison of Flexural Strength of Concrete with and without Jute Fiber (Cube)

Published by
E-Palli Publishers, Delaware, USA

performance compared to conventional concrete in all assessments. Also from figure 11, 12, 13, and 14, when considering both cylindrical and cube it is worth highlighting that Coconut and Jute fiber concrete exhibited superior flexural performance compared to conventional concrete in all assessments. And lastly for split tensile strength test, from figure 15,16,17 and 18 show that fiber concrete exibit superior performance in 7 days, 14 days, 21 days and 28 days

Once more, Jute Fibre concrete demonstrated its remarkable performance advantage over conventional concrete. Additionally, Coconut fibre concrete exhibited enhanced ductility

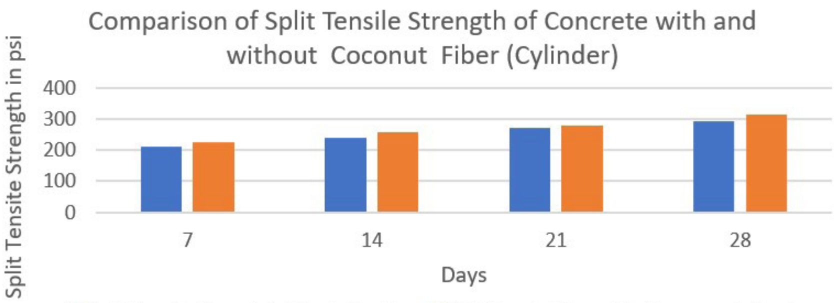

Figure 15: Comparison of Split Tensile Strength of Concrete with and without Coconut Fiber

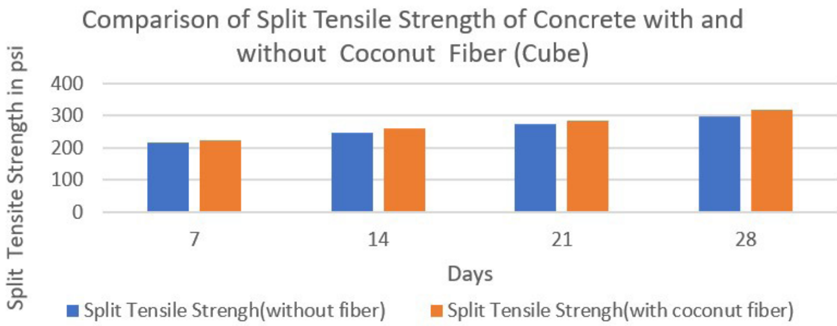

Figure 16: Comparison of Split Tensile Strength of Concrete with and without Coconut Fiber

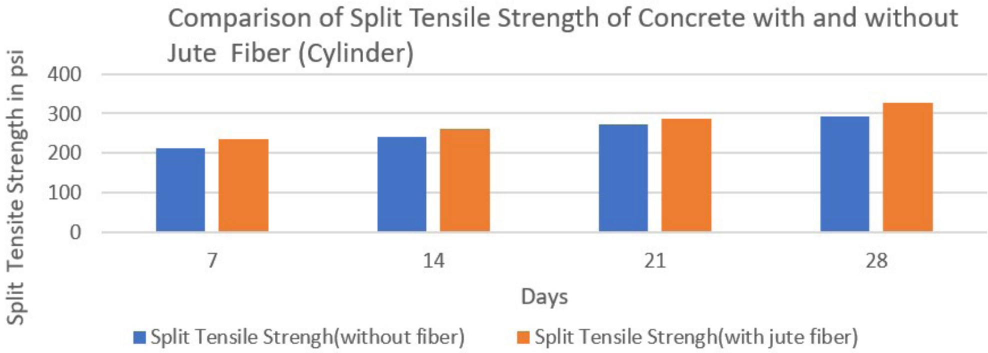

Figure 17: Comparison of Split Tensile Strength of Concrete with and without Jute Fiber

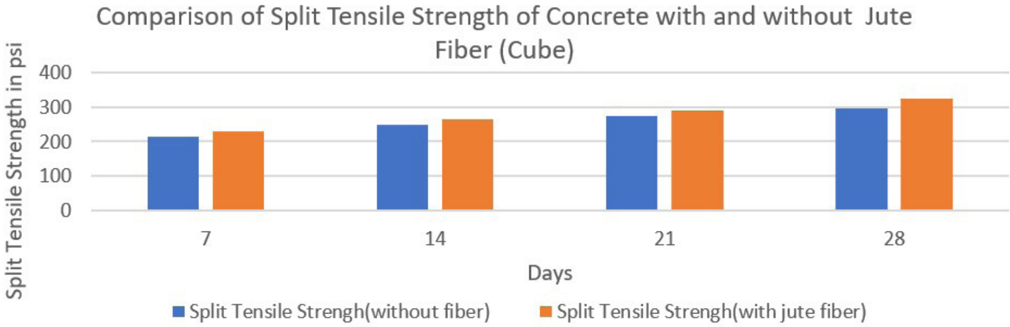

Figure 18: Comparison of Split Tensile Strength of Concrete with and without Jute Fiber

Published by
E-Palli Publishers, Delaware, USA

CONCLUSIONS

The results demonstrated that the addition of jute and coconut fibers improved several key properties of concrete. The compressive strength, tensile strength, and flexural strength were enhanced by the fiber reinforcement with jute fibers providing greater strength improvements than coconut fibers. The fibers also increased the toughness and ductility of the concrete by bridging micro-cracks.

In terms of durability, the NFRC specimens exhibited better resistance to water absorption which can improve more by using dam proof chemical. Natural fibers acted as barriers against the ingress of harmful substances and mitigated degradation from environmental attacks.

While the fibers slightly reduced the workability of fresh concrete, the impacts were within acceptable limits for typical construction practices when using appropriate fiber contents and proper mixing procedures.

This research validates the viability of utilizing jute and coconut fibers as affordable and sustainable reinforcements in concrete. The NFRC composites demonstrated improved mechanical performance and durability characteristics. Making them promising materials compare to plain concrete.

Further research is recommended to optimize fiber types and concrete mixture designs for specific applications and to investigate long-term performance under different exposure conditions.

REFERENCES

Achour, A. G. F. (2017). Properties of cementitious mortars reinforced with natural fibers. *Journal of Adhesion Science and Technology, 31*(17), 1938–1962. https://doi.org/10.1080/01694243.2017.1290572

Barr, B. I. (1992). Fibre reinforced concrete: Where do we go from here? In R. N. Swamy (Ed.), *Proceedings of the Fourth RILEM International Symposium on Fibre Reinforced Cement and Concrete* (pp. 3–11). E and FN Spon.

Debnath, T. R. (2024). Properties Evaluation and Suitability Assessment for Construction Applications of Sand of Kirtankhola River in Bangladesh. *American Journal of Geospatial Technology, 3*(1), 91–100. https://doi.org/https://doi.org/10.54536/ajgt.v3i1.3178

DP, C. (1998). Introduction, chemistry, and preparatory processes of jute. *Colourage, 5,* 23–35.

Ferreira, T. R. M., & D. F. (2016, November). Mechanical properties evaluation of glass fiber and hollow glass bubble reinforced polyamide 6 composites. In *Proceedings of the 22nd CBECIMat* (pp. 6–10). Natal, Brasil.

Fokam, C. B., & T. E. (2020). Cement mortar reinforced with palm nut natural fibers: Study of the mechanical properties. *Revue des Composites et des Matériaux Avancés, 30,* 9–13. https://doi.org/10.18280/rcma.300102

Mark, H. F., & E. (1986). *Encyclopedia of polymer science and engineering* (2nd ed., Vol. 6). John Wiley & Sons.

Ferraz, J. M., & A. S. (2013). Effect of coir fiber treatment and coir-fiber ratio on properties of cement bonded composites. *BioResources, 6*(3), 3481–3492.

Cabeza, L. F., Castell, A., Medrano, M., Martorell, I., Pérez, G., & Fernández, I. (2010). Experimental study on the performance of insulation materials in Mediterranean construction. *Energy and Buildings, 42*(5), 630–636. https://doi.org/10.1016/j.enbuild.200

M, C. N. (2020). *Tribology of natural fiber polymer composites.* Woodhead Publishing.

Asim, M., *et al.* (2020). Comparative experimental investigation of natural fibers reinforced lightweight concrete as thermally efficient building materials. *Journal of Building Engineering, 31,* 101411. https://doi.org/10.1016/j.jobe.2020.101411

Ali, M. (2011). Mechanical and dynamic properties of coconut fiber reinforced concrete. *Construction and Building Materials, 30,* 814–825.

Marikunte, P. S. (1992). Long-term durability and moisture sensitivity of cellulose fiber reinforced cement composites. In R. N. Swamy (Ed.), *Proceedings of the Fourth RILEM International Symposium on Fibre Reinforced Cement and Concrete* (pp. 1). E and FN Spon.

ML, R. (2017). A study on low-cost roof (masonry slab). *American Journal of Engineering Research, 6*(3), 32–36.

Nimityongskul, B. C. (1992). Mechanical properties of sisal fiber mortar composites containing rice husk ash. In R. N. Swamy (Ed.), *Proceedings of the Fourth RILEM International Symposium on Fibre Reinforced Cement and Concrete* (pp. 1056–1072). E and FN Spon.

Nibasumba, P., & L. X. (2011). Recent developments in fibre reinforced concrete and their effect on concrete columns analysis. *Construction and Building Materials, 18*(7), 549–558.

Rabbani, M. L., Saifullah, M., Hasan, M., & Rahman, A. (2021). Experimental investigation of load deflection characteristics of beams with various end conditions of different materials. *International Journal of Innovative Science and Research Technology, 6*(12). Retrieved from https://www.ijisrt.com

Razmi, A., & H. (2017). On the mixed mode I/II fracture properties of jute fiber-reinforced concrete. *Construction and Building Materials, 148,* 512–520.

Saifullah, M. H. (2024). Investigation the Use of Waste Glass and Waste Paper as an Alternative Construction Binding Material: An Approach Towards Sustainable Environment. *American Journal of Environmental Economics, 3*(1), 116–129. https://doi.org/https://doi.org/10.54536/ajee.v3i1.3266

Thomas, G. S. (1966). *Fibre reinforced materials.* Elsevier Publishing Co. Ltd.

Utsha, T. D. (2024). Enhancing Recycled Concrete Performance by Using Chemical Activators. *American Journal of Innovation in Science and Engineering, 3*(3), 19–30. https://doi.org/https://doi.org/10.54536/ajise.v3i3.2497

Zhang, P., & Y. Y. (2020). Fracture models and effect of fibers on fracture properties of cementitious composites: A review. *Materials, 13,* 5495. https://doi.org/10.3390/ma13235495

Published by
E-Palli Publishers, Delaware, USA