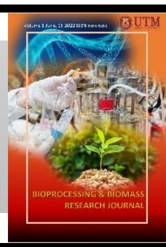
Bioprocessing and Biomass Technology

Journal homepage: https://bioprocessing.utm.my



Research Article

Comparison of Compressive Strength and Water Absorption Characteristics of Cement stabilized Earth Blocks Reinforced with Banana and Jute fibers

Akash Ray[a], Sajid Hossain[b*], Minhaj ul Islam[a], Rafia Islam[a], Anika Anjhum[a], Ishrat Jahan Shatu[a], S.M. Farhana Iqbal[a]

[a] *Department of Yarn Engineering, Bangladesh University of Textiles, Dhaka, Bangladesh.*
[b] *Department of Industrial & Production Engineering, Bangladesh University of Textiles, Dhaka, Bangladesh*

ARTICLE INFO

Article History:
Received 18 October 2024
Received in revised 28 November 2024
Accepted 2 December 2024
Available online 31 December 2024

Keywords:
Concrete material, environment friendly, mechanical characteristics, durable construction, water absorption, sand block materials.

ABSTRACT

This paper discusses the influence of textile fiber reinforcement with concrete materials for evaluating the mechanical property and water absorption of banana and jute fiber reinforced conventional sand block for calculating the suitability in affordable and environment friendly construction material production. The experimental design was completely randomized with three categories like treated earth block, untreated earth block and clay brick. The treated blocks were representing 47.4 MPa Compressive strength whereas an untreated block was represented as on average 14.2 MPa. Meanwhile, the untreated earth block result is 15.5% and clay brick result is 19.2% which is maximum for the water absorption test. It was identified from the study that the water absorption rate must remain below 22% to guarantee the material's longevity. This experimental work study was found that the comparison between blocks with no fiber reinforcement and blocks with banana and jute reinforcement which can include extra compressive strength and water absorbency as per Bangladesh Standards & Testing Institute (BSTI). It was found that the difference in properties of a block by adding banana and jute fibers in the conventional sand blocks. These efforts were necessary to ensure the environment friendly technology of textile reinforced concrete gets widely accepted for building affordable and durable constructions.

INTRODUCTION

The increasing demand for sustainable and affordable building materials has led to a growing interest in exploring alternative reinforcing materials. Natural fibers, such as banana and jute, offer promising options due to their abundance, renewability, bio-degradability, recyclability, and potential for improved material properties. Banana and jute fibers have excellent tensile properties, therefore it makes these fibers a good choice for being used in a composite concrete material. The main objective is to develop a durable, economical and eco-friendly composite reinforced concrete. Such composite concrete can be used in a lot of modern applications.

The objective of this research is to explore how the addition of banana and jute fibers to cement-stabilized soil blocks influences their ability to withstand compression and their tendency to absorb water. The study seeks to determine the effects of each type of fiber on the blocks' performance and identify which fiber offers the most substantial benefits. Composite materials are made from two key parts: one part (the reinforcement) adds strength and firmness, and the other part (the matrix) keeps everything together and spreads out any forces applied to it. The reinforcement part handles the heavy lifting, so to speak, while the matrix makes sure the reinforcement stays where it should. Even when combined, each part of a composite keeps its own unique properties. People have used composite materials in many ways throughout history. For example, in Africa and Asia, people have used jute, a

*Corresponding Author
E-mail address: sajidhossain.shipan@gmail.com
DOI address
ISBN/©UTM Penerbit Press. All rights reserved

plant with very strong fibers, to make ropes and cloth, and they've eaten the leaves as food (Mostafa & Uddin 2016).

Previous research has demonstrated the potential benefits of using natural fibers as reinforcement in various composite materials. However, limited studies have specifically focused on their application in cement-stabilized earth blocks (Raghavendra et al., 2013). This research contributes to the advancement of more sustainable and durable building solutions by examining how these fibers affect the mechanical properties and longevity of these blocks.

To address the research question, this study will involve the fabrication of cement-stabilized earth blocks with varying proportions of banana and jute fibers. The compressive strength and water absorption of these blocks will be evaluated through standardized laboratory testing procedures. The findings will be analyzed to determine the optimal fiber type and dosage for achieving desired mechanical properties and resistance to moisture penetration. By comparing the performance of banana and jute fiber-reinforced blocks to control samples without fibers, this study will provide valuable insights into the potential advantages and limitations of using natural fibers as reinforcing agents in cement-stabilized earth blocks. The results may inform future research and practical applications in the construction industry (Ahmad et al., 2022).

MATERIALS AND METHOD

Materials

Materials that were used to make the block include- sand, cement, banana and jute fibers in different proportions and water was used to prepare the mixture of sand cement. Jute and banana fibers were collected from different sources. The jute and banana fibers were used in combination with each other because of the similarities in their mechanical properties and chemical composition.

Jute Fiber

Jute fibers (*Corchorus capsularies*) are derived from annual plants and are abundant in nature. Jute fibres have excellent mechanical qualities which are appropriate for using them as the reinforcing materials in bionic and laminated composites. The structural qualities of jute fabric reinforced composites are almost similar to the commercial materials despite of having a relatively cheap cost. Jute fibre has very high specific characteristics, lower at cost, easily available, and environmental friendly composite and a natural fibre which is also bio-degradable.

Banana Fiber

Banana Fiber is a type of leaf fiber. *Musa paradisiaca* and *Musaulugurensis* are cultivated mostly as some kinds of banana plants. Banana is an Arabic word which means “finger”. Banana fibres that are obtained from the banana plants are usually of low quality because of the separation process of the fiber bundles is done manually (Selsiadevi et al., 2018). The tables below show the chemical composition, physical and mechanical properties of jute and banana fibers which shows some similarities to be used in combination. The main constituent of plant fibers is cellulose followed by hemi-celluloses, lignin and pectin respectively. Cellulose acts as a reinforcing chemical for lignin, hemicellulose and pectin. These when used in combination make plant fibers exhibit the characteristics of a composite material (Pitimaneeyakul, 2009). **Table 1** and **Table 2** shows the chemical composition and physical properties of jute and banana fibers, respectively.

Table 1 Chemical composition of jute and banana fibers

Fiber Type	Hemicellulose (%)	Cellulose (%)	Lignin (%)	Pectin (%)
Jute	12-20	51-84	5-13	0.2
Banana	6-19	60-65	5-10	3-5

Table 2 Physical properties of jute and banana fibers

Fiber Type	D	L	Aspect Ratio (l/d)	Bulk Density (kg/m^3)	Moist. Regain (%)
Jute	15.9-20.7	1.5-120	157	1300-1500	13.75
Banana	-	2-10	-	1300-1350	13

D= Diameter (mm); L= Length (mm); Moist= Moisture

Table 3 Mechanical properties of jute and banana fiber

Fiber Type	Tensile Strength (MPa)	Specific Tensile Strength (GPa)	Young’s Modulus (GPa)	Specific Young’s Modulus (GPa)	Failure Strain (%)
Jute	200-450	140-320	20-55	14-39	2-3
Banana	529-914	392-677	27-32	20-24	1-3

Cellulose

Cellulose (**Figure 1**) is glucan polymer of D-glucopyranose that are linked together by β-(1-4)-glucosidic bonds. The building block for cellulose is the cellobiose as the repeating unit in the chemical composition of cellulose is two sugar units (Mostafa & Uddin, 2016).

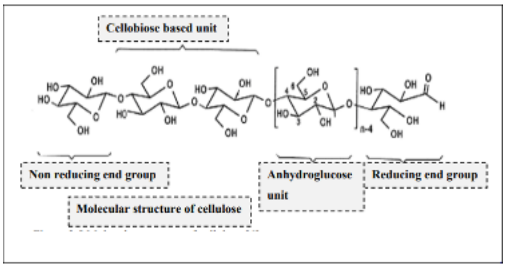


Figure 1 Cellulose structure

Hemicelluloses

Hemicelluloses (**Figure 2**) are branched and shorter in length than cellulose. They usually consist of one repeating sugar unit linked β.

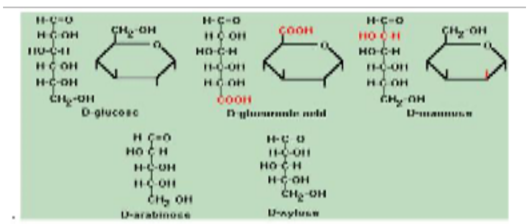


Figure 2 Hemicellulose structure

Lignin

Lignin (**Figure 3**) is a class of complex organic polymers. All plant lignin consist of three basic building blocks which are guaiacyl, syringyl and p-hydroxy phenyl moieties even though there are also some other aromatic type units existing in many different types of plants.

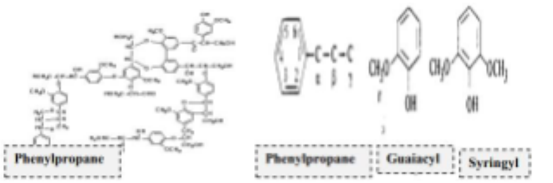


Figure 3 Lignin structure

Cement

Cement is constituent which solidifies individually, and it binds additional materials together while solidifying. Cement contains various chemical components (**Table 4**) (Indira et al., 2013).

Table 4 Basic properties of cement

No.	Basic Test	Values
1	Fineness Modulus	5%
2	Specific Gravity	3.11
3	Standard Consistency	31%
4	Initial Setting Time	35mins
5	Final Setting Time	550mins

Sand

Sand was used as the base material to make the block. Completely dried sand was used. **Table 5** shows the basic properties of sand (Gopakumar & Rajesh, 2016).

Table 5 Basic properties of sand

No.	Basic Test	Values
1	Specific Gravity	2.63
2	D10 (mm)	0.47
3	Coefficient of Uniformity	2.55
4	Coefficient of Curvature	0.87
5	Degree of Roundness of Particles	Angular

Specimen Preparation

A block was made with oakwood to provide the structure of the block to be made. The size of the block was 190*90*60 mm (**Figure 4**).

Figure 4 Sample of specimen

Materials used for each sample preparation included 850 g of sand, 450 g of cement, 250 ml of water, and 32 g of fibers (16 g of banana fiber and 16 g of jute fiber). The fibers were cut into dimensions of 20 cm in length and 9 cm in width. Each fiber layer contained 8 g of fibers, and four individual layers were used in the sample preparation.

The measured quantities of sand and cement were placed into a bowl and mixed by hand. Water (250 ml) was then added to the sand-cement mixture to form a homogeneous mixture. The mixture was divided into five equal portions. One portion was spread evenly in the specimen mold, creating the base layer. A fiber layer (8 g of fibers) was placed on top of the sand-cement mixture. Another portion of the sand-cement mixture was spread to cover the fiber layer. This process was repeated for each subsequent layer, alternating between sand-cement and fiber layers, until the final layer of the sand-cement mixture was placed on top.

Once the layers were assembled, the block was kept inside the mold and covered with a polythene bag to prevent exposure to direct sunlight and wind. The sample was left to set at room temperature for 24 hours. After 24 hours, the block (**Figure 5**) was carefully removed from the mold and left to dry at room temperature, away from sunlight and wind. This procedure was repeated for each sample to ensure consistency.

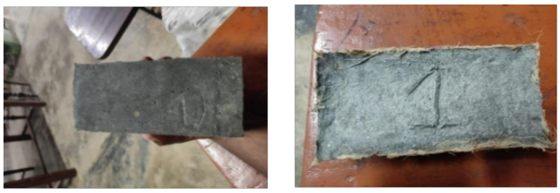


Figure 5 Earth block (Final product)

RESULTS AND DISCUSSION

In this section, results of compressive strength in MPa and water absorption % are shown and discussed detailed. The performance of the earth block is compared with clay brick and earth block (untreated fiber).

Strength Analysis

Compressive strength analysis of earth block

In this **Figure 5** shows that, earth block is compared to the clay brick and earth block (untreated). With our methodology, earth block (treated) results is 47.4 MPa (Experiment Done by the Bangladesh Standards and Testing Institution-BSTI). On the other hand, clay brick results is only 14.2 MPa and earth block (untreated) results is also 14.2 MPa. Here earth block (treated) results is maximum. So earth block (treated) provide a durable and robust foundation for buildings, bridges, and other structures (Kumar & Rajesh, 2016).

We can also compare to the other earth block which is it find the results the greatest compressive strength was attained with a compaction force of 1.96 kN, with values above the required 2 MPa for non-structural applications (González-López et al., 2018). On the other hand we also get to the compare another earth block were the compressed stabilized earth blocks (CSEBs) reached a maximum dry compressive strength of 8.1 MPa (Bailly et al., 2024). According to studies, cement-stabilized blocks have a higher compressive strength, with values ranging from 2.42 MPa to

11.84 MPa depending on cement concentration (6% to 16%) and compaction force (Elahi et al., 2020).

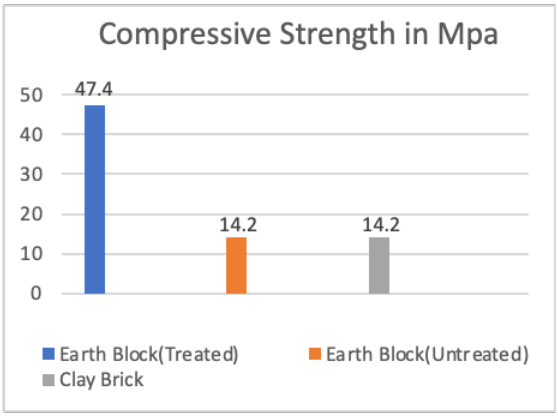


Figure 5 Compressive strength

Water Absorption Percentage analysis

Treated Earth Block

In this **Figure 6** shows that, earth block is compared to the clay brick and earth block (untreated). With our methodology, earth block (treated) results is only 14.1% (Experiment Done by the Bangladesh Standards and Testing Institution-BSTI as shown in **Table 6**). On the other hand Untreated earth block results is 15.5% and clay brick results is 19.2% which is maximum (Raghavendra et al., 2013). Meanwhile treated earth block is minimum. The water absorption rate must remain below 22% to guarantee the material's longevity. Excessive water absorption can cause the material to take in moisture from the environment, resulting in structural deterioration and a diminished lifespan.

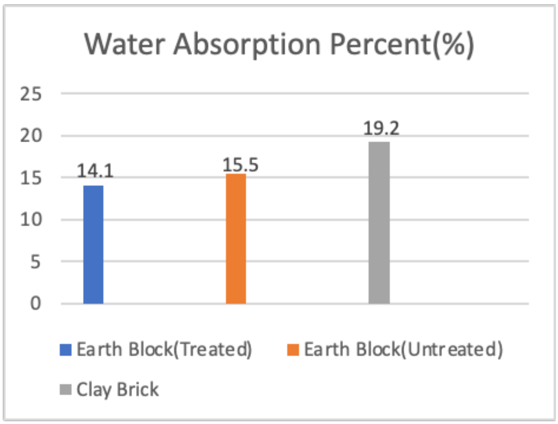


Figure 6 Water absorption

Table 6 Standards used for results and discussion analysis

Test method used	As per BDS 208:2022

Compressive strength and water absorption tests were essentially carried out on the cement stabilized reinforced earth blocks to evaluate their durability and suitability as building materials. The blocks' compressive strength is substantially higher than that of the clay brick, earth block (untreated) and its water absorption % is likewise lower than that of the clay brick, earth block (untreated) which is fairly excellent (Ugwuishiwu et al., 2013).

CONCLUSION

Since the beginning of the project, banana fibers and Jute fibers, which come from the banana tree and jute tree, have been taken into consideration. It is commonly known that the plant is typically discarded in the environment or used as food for cattle, thus making useable fiber from a banana tree would be a noteworthy achievement. It was believed that the related product included as much banana fiber and jute fiber as possible. We can try to our level best to produce a product which have more compressive strength and water absorption rather than other related products. As the banana and jute fiber was purchased in long-staple form, so it was required to be cut and made suitable for processing manually since there was no automatic cutter in the lab. Lots of difficulties were faced in cutting the fiber as there was not any fiber-cutting machinery facilities. We use our end products as a building walls structures, concreate blocks, stairs and handrails, Patios, and decorative purpose.

Acknowledgement

The authors recognize Bangladesh Standards and Testing Institution (BSTI) for giving cooperation and full of support in this research activity. The authors are highly delighted to express our regards & gratitude and wish to thank the Department of Yarn Engineering and Department of Industrial and Production Engineering. Finally authors acknowledge the Bangladesh University of Textiles (BUTEX).

References

Ahmad, J., Arbili, M. M., Majdi, A., Althoey, F., Farouk Deifalla, A., & Rahmawati, C. 2022. Performance of Concrete Reinforced with Jute Fibers (Natural Fibers): A Review. Journal of Engineered Fibers and Fabrics, 17, 15589250221121871.

Bailly, G. C., El Mendili, Y., Konin, A., & Khoury, E. 2024. Advancing Earth-Based Construction: A Comprehensive Review of Stabilization and Reinforcement Techniques for Adobe and Compressed Earth Blocks. Eng, 5(2), 750-783.

Elahi, T. E., Shahriar, A. R., Islam, M. S., Mehzabin, F., & Mumtaz, N. 2020. Suitability of Fly Ash and Cement for Fabrication of Compressed Stabilized Earth Blocks. Construction and Building Materials, 263, 120935.

González-López, J. R., Juárez-Alvarado, C. A., Ayub-Francis, B., & Mendoza-Rangel, J. M. 2018. Compaction effect on the Compressive Strength and Durability of Stabilized Earth Blocks. Construction and Building Materials, 163, 179-188.

Gopakumar, R., & Rajesh, R. 2016. Development, Processing and Characterisation of Natural Rubber-Banana Fibre Composite. Cellulose, *63*, 64.

Indira, K. N., Parameswaranpillai, J., & Thomas, S. 2013. Mechanical Properties and Failure Topography of Banana Fiber PF Macrocomposites Fabricated by RTM and CM Techniques. International Scholarly Research Notices, 2013(1), 936048.

Kumar, R. G., & Rajesh, D. R. 2016. A Study on the Abrasion Resistance, Compressive Strength and Hardness of Banana–fibre Reinforced Natural Rubber Composites. International Journal of Advanced Research in Engineering and Technology, *7*(3), 42-55.

Mostafa, M., & Uddin, N. 2016. Experimental Analysis of Compressed Earth Block (CEB) with Banana Fibers

Resisting Flexural and Compression Forces. Case Studies in Construction Materials, 5, 53-63.
Pitimaneeyakul, U. 2009. Banana fiber: Environmental Friendly Fabric. In Proceedings of the environmental engineering association *of* Thailand (Vol. 5).
Raghavendra, S., Shetty, P. B., & Mukunda, P. G. 2013. Mechanical Properties of Short Banana Fiber Reinforced Natural Rubber Composites. http://13.232.72.61:8080/jspui/handle/123456789/388
Selsiadevi, S., Selescadevi, S., & Varshini, V. 2018. Earth Building Blocks Reinforced with Jute and Banana Fiber. International Journal of Engineering Research & Technology, *6*, 1-4.
Ugwuishiwu, B. O., Mama, B. O., & Okoye, N. M. 2013. Effects of natural fiber reinforcement on water absorption of compressed stabilized earth blocks. International Journal of Science and Research, *2*, 165-167.