STUDY ON THE CHARACTERISTICS OF LATEX MODIFIED JUTE FIBRE INFUSED COMPRESSED STABILISED EARTH BLOCKS

Vinoth Kumar N[1], Dr D Elango[2], Dr L Devaraj Stephen[3], Abhimaneu S[4],Chinnadevan S[4], Nishanth K[4] , Sowmiya V [4],

[1] Assistant Professor , [2] Professor, [3] Associate Professor[3], Department of Civil Engineering, SRM Valliammai Engineering college ,Kattankulathur

[4] UG Student, Department of Civil Engineering, SRM Valliammai Engineering college ,Kattankulathur

Abstract-This study focuses on improving the properties of natural jute fibres for use in Compressed Stabilized Earth Blocks (CSEBs) through chemical and polymer surface treatments. The fibres were first treated with a 6% sodium hydroxide (NaOH) solution to remove impurities and enhance surface roughness for better bonding. This alkali treatment exposed hydroxyl groups, improving adhesion with soil and cement matrices. Subsequently, the fibres were coated with Styrene Butadiene Rubber (SBR) mixed with varnish in a 1:2 ratio and heated to 60°C for uniform dispersion. The SBR layer formed a protective film that reduced water absorption and biological decay. Treated fibres were analysed to confirm improved surface morphology and bonding characteristics. The combination of alkali and polymer treatment enhanced fibre durability, flexibility, and interfacial strength. This dual treatment approach significantly improved fibre–matrix compatibility. Overall, the modified jute fibres provide a sustainable and long-lasting reinforcement option for earthen construction materials.

KEYWORDS: Compressed Stabilized Earth Block (CSEB), Latex Modified polymer, Styrene Butadiene Rubber(SBR), Jute Fibre Reinforcement.

1.INTRODUCTION

The construction industry is widely recognized as one of the leading contributors to global carbon emissions and environmental degradation. This is primarily due to the massive consumption of energy-intensive materials such as cement, steel, and fired clay bricks. The manufacturing of these materials involves high-temperature processes, resulting in the release of significant amounts of greenhouse gases such as carbon dioxide (CO_2). As the world moves toward sustainable development goals, it has become imperative to identify and adopt construction materials that are both environmentally friendly and economically feasible. The alternative is the Compressed Stabilized Earth Block (CSEB), a green building material that offers both structural reliability and sustainability. CSEBs are produced by compacting a mixture of soil, stabilizers (such as cement or lime), and other additives under high pressure. Unlike conventional fired clay bricks, CSEBs do not require burning, which drastically reduces fuel consumption and emissions. Despite these advantages, conventional CSEBs often exhibit certain limitations, including low compressive strength, high water absorption, and reduced durability when exposed to moisture or extreme weather conditions. Therefore, improving the strength, water resistance, and long-term performance of CSEBs has become an important area of research in sustainable construction. To address these challenges, the present study investigates the incorporation of natural fibre reinforcement into CSEBs to enhance their mechanical and durability characteristics. Jute fibre, a and biodegradable material, has been chosen because it is abundantly available ,renewable, and cost-effective.

Natural jute fibre, derived from the Corchorus plant, is widely recognized for its eco-friendly and sustainable nature. However, in its untreated form, jute contains lignin, hemicellulose, and waxes that hinder effective bonding with the soil-cement matrix. To overcome this limitation, chemical and polymer treatments are applied to improve fibre surface roughness and adhesion properties. In this study, jute fibres are treated with Styrene Butadiene Rubber (SBR), a synthetic polymer known for its elasticity and durability. The SBR coating forms a thin film over the fibre surface, enhancing flexibility and bonding strength. Incorporating these treated fibres into Compressed Stabilized Earth Blocks (CSEBs) improves mechanical performance and moisture resistance. The modified blocks show reduced brittleness and better durability under stress. Microstructural analysis using SEM and XRD helps to evaluate the internal bonding and structural integrity. The study ultimately aims to develop an optimized CSEB mix with higher strength and lower water absorption. This sustainable approach contributes to low-cost and eco-friendly construction materials suitable for both rural and urban environments.

Furthermore, this research highlights the potential of utilizing natural fibres and eco-friendly polymers to achieve sustainable development in the construction sector, thereby contributing to the global effort toward reducing carbon emissions and promoting green building technologies. The overall objective of this study is to develop a sustainable, low-cost, and high-performance CSEB suitable for modern construction while minimizing environmental impact. The integration of treated jute fibre and SBR with varnish not only strengthens the mechanical and durability properties but also promotes the use of renewable materials and waste reduction in the construction sector. By partially replacing cement with lime and eliminating the energy-intensive firing process, the carbon footprint of building materials can be greatly reduced.

2.Experimental Program

2.1. Materials and processing

Natural jute fibre, derived from the Corchorus plant, is a renewable and cost-effective material widely used in earthen construction. It possesses high tensile strength 442 MPa, a modulus of elasticity of 55.5 GPa, and a low density of 1.94 g/cm^3 . These properties make it suitable for reinforcing brittle Compressed Stabilized Earth Blocks (CSEBs). Its inclusion in the soil–cement–lime matrix improves the tensile, flexural, and impact strength of the blocks. Jute fibres control shrinkage and crack propagation by bridging micro-cracks and uniformly redistributing stresses within the matrix, thereby enhancing ductility and post-crack toughness. This reinforcement mechanism improves the structural reliability of CSEBs under different loading and environmental conditions. Moreover, jute fibres provide thermal insulation, contributing to energy efficiency and sustainability. To enhance fibre–matrix bonding, the fibres are treated with a 6% NaOH solution, which removes lignin, hemicellulose, and waxes while increasing surface roughness. This treatment exposes hydroxyl groups that improve interfacial adhesion with the soil–cement matrix. The treated fibres are then washed with distilled water and oven-dried at 60°C for 24 hours to maintain stable moisture content.

Fig No 2.1 Jute Fibre

2.2 STYRENE BUTADIENE RUBBER(SBR)

Styrene Butadiene Rubber (SBR) polymer was utilized to modify treated jute fibres, improving their flexibility, durability, and resistance to moisture. SBR, a synthetic polymer, provides excellent elasticity, adhesion, and chemical stability. In this study, the SBR was blended with varnish in a 1:2 ratio and stirred at 60°C to obtain a uniform dispersion. The polymer coating formed a continuous film over the fibre surface, enhancing its bonding with the soil–cement–lime matrix. This coating reduced water absorption by sealing micro voids and improved the fibre’s durability. Additionally, it acted as a protective layer against microbial degradation during curing and service life.

2.3 Jute Fibre Treatment

Natural jute fibres are emerging as eco-friendly substitutes for synthetic reinforcements due to their affordability, renewability, and low density. However, their high moisture absorption and the presence of lignin and hemicellulose reduce bonding and mechanical performance. This study focuses on alkali (mercerization) treatment to improve the tensile strength and surface properties of jute fibres, enhancing their suitability for engineering applications.

2.3.1 Characterization testing

1. Preparation of Sodium Hydroxide Solution

The chemical treatment required a Sodium Hydroxide NaOH solution. The intended concentration was 0.6% by weight. Crucially, the actual preparation involved dissolving 400 grams of NaOH pellets in 8 litres of water. This specific ratio resulted in a calculated working concentration of 5%. This significant increase in alkalinity relative to the target concentration is a critical procedural note, suggesting the experiment uses a more aggressive treatment which could lead to a greater degree of structural modification.

2. Fibre Treatment and Soaking

To analyze potential size effects, jute fibres of three distinct lengths 2cm,3cm and 4cm were selected for immersion. The fibres were submerged entirely in the prepared NaOH solution for a fixed duration of three hours. This soaking period was deemed sufficient to allow the OH to diffuse into the fibre structure and initiate the necessary chemical reactions.

3. Washing and Drying

Following the alkaline treatment, the fibres must be thoroughly washed to neutralize any residual alkali and stop the reaction. The final step involved conditioning the fibres by oven-drying them at a constant temperature of 60 degrees for 24 hours. This ensures all absorbed and residual moisture is completely removed, resulting in a stable, oven-dry state ready for accurate characterization and mechanical testing.

2.3.2 Outcomes

The enhanced performance of the jute fibres is rooted in the chemical mechanism of the alkali treatment:

1.Hemicellulose and Lignin Removal

The strong alkaline solution causes a process of hydrolysis, effectively dissolving and removing a substantial portion of the non-cellulosic matrix components (hemicellulose and lignin). These amorphous substances typically bind the cellulose microfibrils and contribute to the fibre's weakness and instability. Their removal purifies the fibre, leaving a higher concentration of the stronger crystalline cellulose.

2.Improved Interfacial Bonding

The removal of surface waxes and cementing materials creates a rougher fibre surface texture. This etching is highly beneficial as it increases the surface area for mechanical interlocking and improves the chemical accessibility of the cellulose hydroxyl groups, leading to stronger adhesion when the fibres are combined with a polymer matrix.

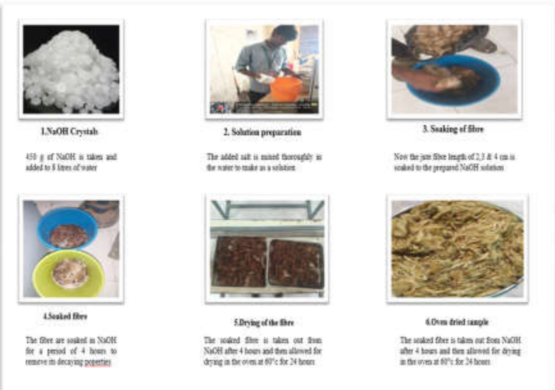


Fig No 2.3.2 NaOH Treatment Process

2.3 PREPERATION OF SBR POLYMER

2.3.1 SBR impregnation of jute fibre

This method is particularly relevant in the fields of material science, polymer engineering, and textile technology, where natural fibers are modified to improve their compatibility with synthetic matrices. The process involves four key stages: cutting, soaking, drying, and preparation of the SBR solution.

1. Slitting of Jute Fibers

The first step in the process involves cutting jute fibers into short and uniform lengths. This is a crucial preparatory step that ensures consistency in fiber treatment. Uniform fiber length facilitates even distribution and coating during the soaking phase, which is essential for achieving homogenous polymer absorption. Short fibers also improve the ease of handling and mixing, especially when incorporated into composite materials or used in reinforced structures.

2. Preparation of SBR Solution

In this method, undiluted Styrene Butadiene Rubber (SBR) is used directly without any dilution. SBR is a synthetic rubber known for its excellent abrasion resistance, flexibility, and bonding properties. Using it in its pure form ensures maximum polymer concentration, which enhances the bonding efficiency between the jute fibers and the rubber matrix. This decision to avoid dilution is strategic, as it allows for deeper penetration and stronger adhesion of the polymer onto the fiber surface.

A. **3. Soaking Process**

Once the fibers are cut and the SBR solution is prepared, the jute fibers are immersed completely in the undiluted SBR solution. The soaking duration is maintained for 24 hours, which is a significant period that allows for deep absorption of the polymer into the fiber structure. This prolonged exposure ensures that the SBR molecules have sufficient time to diffuse into the porous structure of the jute, thereby enhancing the mechanical interlocking and chemical bonding potential. The soaking process is a critical phase that determines the quality and durability of the final treated fiber.

2.3.1 Fibre immersed in SBR solution

B. **4. Drying Stage**

After the soaking period, the treated jute fibers are air-dried. Drying serves two main purposes: it removes excess SBR from the fiber surface and fixes the polymer coating onto the fiber. Air drying is preferred over mechanical or heat drying methods to preserve the natural integrity of the jute fibers and avoid thermal degradation.

2.4 MORPHOLOGICAL ANALYSIS

2.4.1MICROSTRUCTURAL ANALYSIS OF RAW JUTE FIBRE

Microstructural Analysis of Raw Jute Fibre refers to the detailed examination of the internal structure, surface morphology, and physical characteristics of untreated jute fibres at microscopic levels. This analysis helps in understanding the fibre's texture, composition, and bonding behavior when used as reinforcement in composite materials.

Fig No 2.4.1 Various section images of raw jute fibre under SEM

The image reveals a fibrous texture characteristic of natural fibers such as jute, consisting of long, parallel fibrils with visible grooves and ridges that represent the inherent cellulose-based microstructure. The surface morphology appears uneven and layered, with flake-like or plate-like deposits distributed along the fibers—likely microfibrils, cell wall fragments, or surface impurities. Certain regions exhibit. At 1000× magnification (scale bar: 50 µm), the jute fibers display diameters in the tens of micrometers range, typical of natural jute. The surface shows microfibrils, cell wall fragments, and impurities, with regions of roughness and adhesion between fibril bundles, indicating minimal or no treatment. White patches likely represent residual lignin, wax, or dirt. Comparative analysis with treated samples (e.g., Raw Jute_2.tif, Raw Jute_3.tif) can reveal differences in surface cleanliness and fibril separation.

2.5 STRUCTURAL ANALYSIS OF RAW JUTE FIBRE

Structural Analysis of Raw Jute Fibre refers to the investigation of the physical, chemical, and mechanical structure of untreated jute fibres to understand their composition, arrangement, and performance in composite applications. This analysis focuses on examining how the internal and external structure of the fibre contributes to its strength, flexibility, and bonding capability with other materials.

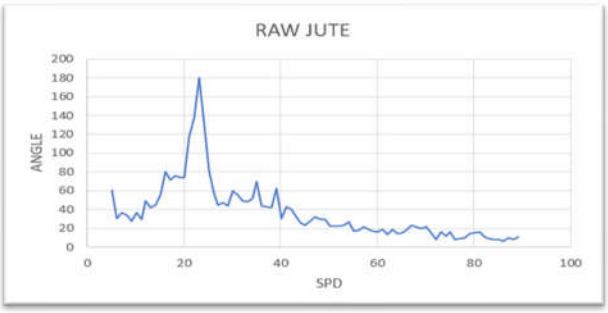
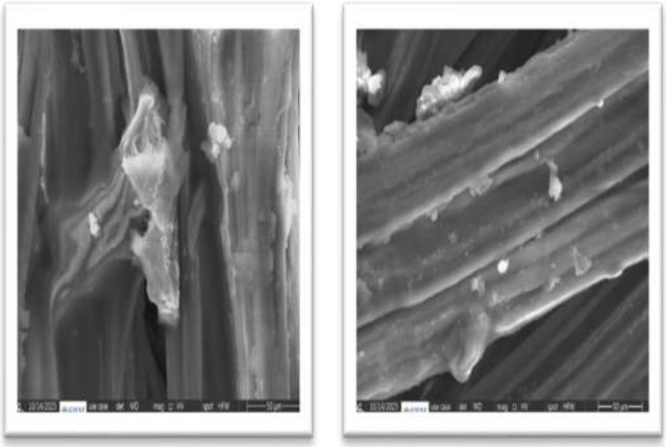


Fig No 2.4.1 Angle VS SPD

graph of ANGLE versus SPD for the raw jute sample shows an initial irregular pattern that gradually stabilizes. At low SPD (0–10), ANGLE fluctuates between 30° and 60°, indicating surface irregularities. A sharp peak near 180° appears at SPD ≈ 20, reflecting strong surface interaction. Afterward, ANGLE drops below 60° and shows minor fluctuations between 40°–80° up to SPD = 50.Beyond SPD = 50, ANGLE stabilizes between 10°–25°, showing consistent behavior.

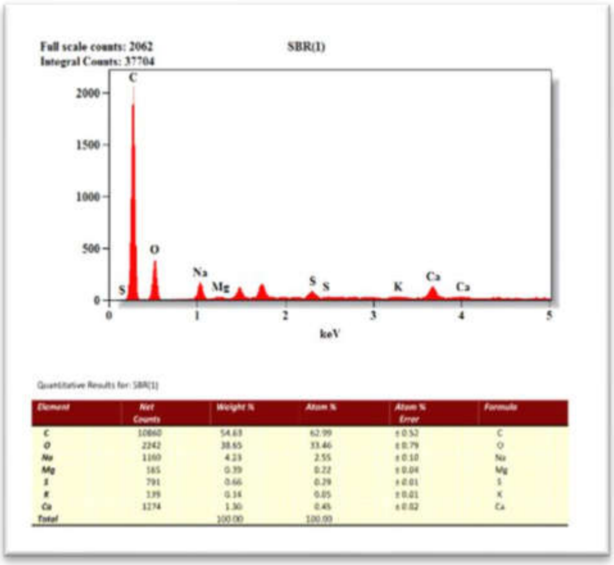
2.6 Morphological Analysis of SBR on jute fibre

Morphological Analysis of SBR with varnish on Jute Fibre refers to the detailed examination of the surface structure and physical appearance of jute fibres after being coated or treated with Styrene–Butadiene Rubber and varnish. This analysis aims to understand how the SBR modifies the fibre surface, enhances bonding characteristics, and improves durability when used in composite materials.



2.6 Various section images of SBR treated jute fibre under SEM

The graph depicting the variation of ANGLE with SPD for the RAW JUTE sample exhibits a clear transition from high initial variability to gradual stabilization. The xaxis (SPD) spans from 0 to 100, while the y-axis (ANGLE) ranges from 0 to 200 degrees. At low SPD values (approximately 0–10), the ANGLE fluctuates between 30° and 60°, reflecting minor irregularities in the surface structure and fiber alignment. A distinct sharp peak appears around SPD = 20, where the ANGLE rises abruptly to nearly 180°, indicating a strong response or interaction of the material—likely due to the natural roughness and non-uniform surface texture of raw jute fibers. Following this significant peak, the ANGLE decreases sharply to below 60°, suggesting that the material stabilizes rapidly after the disturbance.



Element	Net Counts	Weight %	Atom %	Atom % Error	Formula
C	10860	54.63	62.99	± 0.52	C
O	2242	38.65	33.46	± 0.79	O
Na	1160	4.23	2.55	± 0.10	Na
Mg	165	0.39	0.22	± 0.04	Mg
S	791	0.66	0.29	± 0.01	S
K	139	0.16	0.05	± 0.01	K
Ca	1274	1.30	0.45	± 0.02	Ca
Total		100.00	100.00		

Fig no 2.5 SEM analysis of SBR

The EDS spectrum of the SBR (Styrene-Butadiene Rubber) sample reveals its elemental composition, providing insight into the material's chemical structure and processing characteristics. The x-axis represents the X-ray energy (keV), while the y-axis corresponds to the intensity or counts of detected X-rays. The most prominent peak corresponds to Carbon (C), showing exceptionally high counts—consistent with the polymeric nature of SBR. Quantitatively, carbon constitutes 54.63% by weight and 62.99% by atomic percentage, confirming its role as the primary structural element of the rubber matrix The second major element is Oxygen (O), comprising 38.43% by weight and 35.23% by atomic percentage, which suggests the presence of oxygen-containing functional groups or surface oxidation due to environmental exposure. In addition to these dominant elements, minor peaks for Sodium (Na), Magnesium (Mg), Sulphur (S), Potassium (K), and Calcium (Ca) are also observed. Among these, Sulphur (S) appears at 2.66% by weight, confirming its role in the vulcanization process—a key step that enhances the strength, elasticity, and durability of rubber materials. Sodium (Na) and Magnesium (Mg) occur in trace amounts (less than 1%), likely originating from fillers, stabilizers, or processing residues. Meanwhile, Potassium (K) (1.26%) and Calcium (Ca) (1.36%) may derive from additives, pigments, or curing agents introduced during rubber formulation.

C. 2.7 Structural analysis of SBR on jute fibre

Structural Analysis of SBR on Jute Fibre refers to the investigation of the internal and molecular interactions that occur when Styrene–Butadiene Rubber with varnish is coated onto natural jute fibres. The aim is to understand how the SBR layer modifies the fibre's structural composition, chemical bonding, and mechanical characteristics, thereby improving its performance as a reinforcement material in composites

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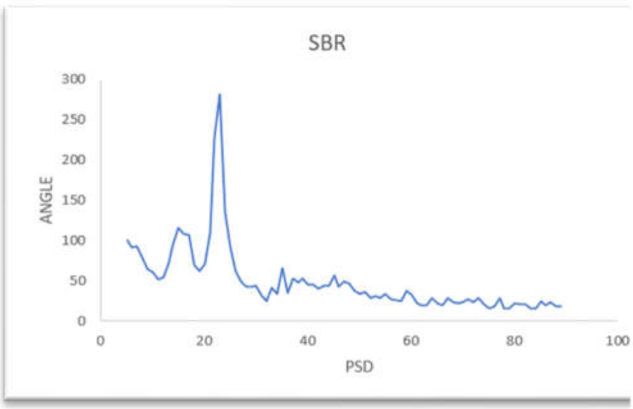

II. FIG NO 2.7 ANGLE VS SPD

The graph illustrating the relationship between PSD (Particle Size Distribution) and ANGLE for the SBR (Styrene-Butadiene Rubber) sample demonstrates a clear transition from strong initial fluctuations to gradual stabilization as particle size increases. The x-axis (PSD) ranges from 0 to 100, while the y-axis (ANGLE) spans from 0 to 300 degrees. At low PSD values (approximately 0–10), the ANGLE begins at a moderately high range of 80–100°, suggesting an irregular surface structure or enhanced reflection due to uneven particle distribution. Between PSD = 10 and 25, the ANGLE exhibits pronounced fluctuations, culminating in a sharp peak near 300°, which represents the maximum angular response in the graph. This intense peak likely corresponds to dense polymer clustering or localized agglomeration, phenomena typical of SBR owing to its viscoelastic nature and tendency for uneven dispersion.

CONCLUSION

The SBR with varnish treated fibers exhibited reduced oxygen levels, indicating a transformation from a hydrophilic to a more hydrophobic surface. This reduction in hydroxyl (-OH) groups enhances impregnation density and moisture resistance, improving durability and fiber matrix bonding in composites. Microstructural images further revealed that the SBR with varnish effectively filled surface voids and microcracks, ensuring better encapsulation and polymer penetration. SBR with varnish enabled even dispersion and spreading of polymer particles. XRD patterns also showed minor decreases in cellulose crystalline peak intensity, suggesting partial coating penetration and the formation of an amorphous polymer layer, which improves flexibility and mechanical interlocking with binders. This investigation demonstrates that SBR with varnish provides a uniform, hydrophobic, and chemically stable impregnation, enhancing resistance to moisture and degradation. These properties make SBR with varnish preferred for jute fibers used in Compressed Stabilized Earth Blocks (CSEBs), ensuring stronger fiber–matrix bonding, reduced water absorption, and longer service life. Future work will focus on manufacturing of CSEB with SBR with varnish –modified jute fibre to evaluate their mechanical strength, water absorption, and long-term durability for sustainable construction applications. hydrophilic jute surface.

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