Manufacturing of Stabilised Mud Blocks Reinforced with Jute fiber for Sustainable Construction

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Abstract

Stabilized mud blocks are increasingly recognized as eco-friendly alternatives to traditional bricks, offering reduced environmental impact through the use of locally available soil. This study evaluates the mechanical performance and durability of mud blocks reinforced with bidirectional jute fiber and stabilized with varying lime contents. The blocks were fabricated using a remote-operated compression device and tested for compressive strength, flexural tensile strength, and water absorption. Optimal results were observed at 8–10% lime content, with a 3-day compressive strength of 4.47 MPa, flexural tensile strength of 0.16 MPa, and 24-hour water absorption of 4.69%. The combination of lime and jute fiber notably improved strength, moisture resistance, and long-term durability. These findings support the adoption of fiber-reinforced, lime-stabilized mud blocks in sustainable construction practices.

Keywords: Stabilised mud blocks, jute fiber reinforcement, lime stabilization, compressive strength, flexural strength, water absorption, sustainable construction.

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1 Introduction

In the context of sustainable construction, compressed earth blocks (CEBs), rammed earth blocks, and mud blocks are gaining traction as eco-friendly alternatives to conventional materials. These methods utilize locally available soil and natural additives to minimize embodied energy, reduce carbon emissions, and lower construction costs. Mud blocks, in particular, eliminate the need for high-temperature firing, thereby significantly reducing energy consumption. Typically composed of soil, clay, and sand, they are stabilized using lime or cement and compacted into molds. Studies have also examined the effects of supplementary materials like fly ash and ground granulated blast furnace slag (GGBS) on the performance of lime-stabilized mud blocks [1]. This process lowers environmental impact, conserves natural resources, and supports local economies through decentralized production. Previous studies have explored stabilization techniques using microbial agents [2], hybrid mud-concrete compositions [3], and alternative binders such as alkali-activated industrial waste [4]. Kamal [5] emphasized the increasing adoption of compressed earth blocks as a sustainable alternative in low-energy construction.

The addition of natural fibers such as jute, coir, and palm has been shown to enhance mechanical performance by improving soil cohesion, tensile resistance, and crack control. fiber geometry, particularly the aspect ratio, has been shown to significantly influence the strength behavior of soil-based blocks [6]. These fibers also align with sustainability goals due to their biodegradability and availability. Polymeric fiber reinforcement has also been explored as an alternative, with promising mechanical outcomes [7], though natural fibers are generally preferred for their eco-compatibility. Alternative stabilization approaches using recycled aggregates, such as crushed brick waste, have also shown promising results in similar applications [8]. With rising demand for cost-effective and environmentally sound housing solutions, stabilized mud block technology presents a viable path for rural and urban development alike. Prakash et al. [9] have examined the viability of stabilized mud blocks in regional construction, supporting their relevance in affordable, resource-efficient housing. This study focuses on the manufacture and performance evaluation of jute fiber-reinforced mud blocks stabilized with lime, targeting improved compressive strength, flexural behavior, and moisture resistance.

2 Materials and Methods

2.1 Materials

Locally available soil was collected from a depth of 1 m in northern Hassan, Karnataka. Basic geotechnical tests were conducted as per IS 2720 to assess the suitability of the soil. The key properties are listed in Table 1.

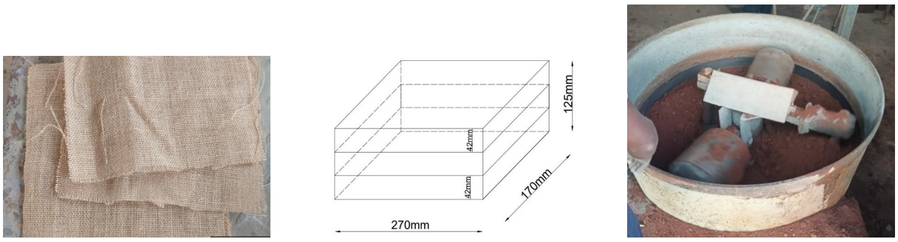
Table 1 Geotechnical properties of the soil

Property	**Value**
Specific gravity	2.59
Bulk density	2590 kg/m^3
Liquid limit	6.6%
Plastic limit	17.4%
Maximum dry density	1.76 g/cm^3

Soil type and composition are known to significantly influence block performance, as established by Mahendran and Vignesh [10], highlighting the importance of local soil characterization. Commercially available hydrated lime was used as a stabilizer at three dosage levels: 8%, 10%, and 12% by weight. Natural jute fibers (22 cm $\times$ 15 cm) were incorporated in two bidirectional layers per block, spaced 42 mm apart. These fibers provided tensile reinforcement and resistance to shrinkage cracks. Similar applications of natural and synthetic fibers have demonstrated improvements in strength, ductility, and durability of earth-based materials [11, 12].

2.2 Block Preparation

The dry mix of soil and lime was blended in a mechanical pan mixer, followed by the addition of 12% water. The mixture was placed into steel moulds (270 mm $\times$ 170 mm $\times$ 125 mm), with fiber mats inserted at specified depths. Blocks were compacted using a remote-operated hydraulic press exerting 3000 psi. After demoulding, they were cured for 7, 14, and 28 days under moist conditions. The effectiveness of compaction and curing has been shown to vary significantly with initial molding moisture content, as discussed by Kandasamy and Rachel [13], underscoring the need for consistent water control during fabrication.



(a) Jute fiber mats (b) Mould and fiber layout (c) Mixing and compaction setup

Figure 1 Materials and manufacturing process

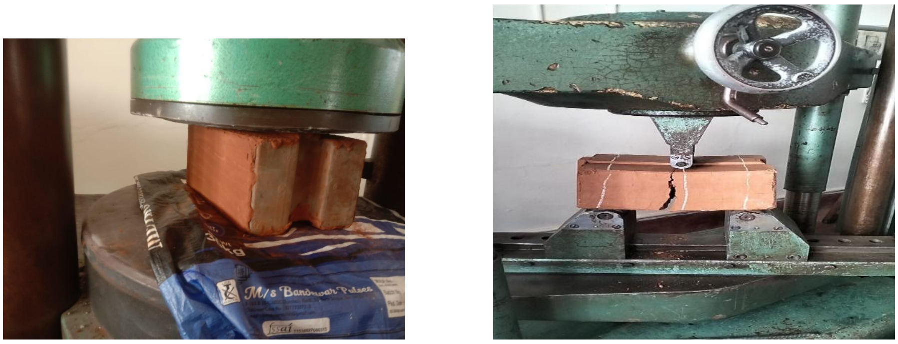
2.3 Testing Procedure

Three standard tests were conducted to assess the mechanical and durability properties of the stabilized mud blocks: compressive strength, flexural tensile strength, and water absorption. Compressive strength was evaluated using a Universal Testing Machine (UTM) following IS 3495 (Part 1):1992. Block samples were tested after 3 days of curing under both dry and wet conditions to assess strength retention under moisture exposure.

Flexural tensile strength was determined using a three-point bending setup in line with ASTM C1609. The modulus of rupture was calculated from bending loads recorded during testing, with results used to evaluate tensile resistance contributed by jute fiber reinforcement. Water absorption was measured after 24 hours of immersion, as per IS 3495 (Part 2):1976. The blocks were oven-dried, weighed, soaked in water, and reweighed to determine the percentage mass gain. All tests were conducted under controlled laboratory conditions with consistent moisture levels and specimen dimensions. Figure 2 shows a summary of the testing setups.

3 Results and Discussion

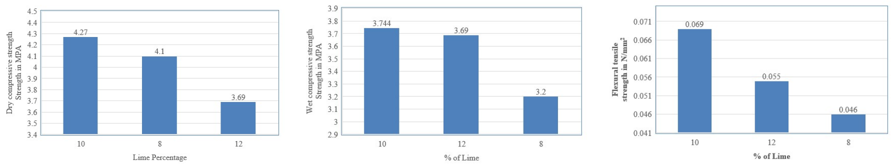
The compressive strength of the mud blocks increased with lime content up to 10%, after which a decline was observed. As shown in Figure 3(a), the highest dry compressive strength of 4.27 MPa was recorded at 10% lime, compared to 4.10 MPa at 8% and 3.69 MPa at 12%. A similar trend was observed under wet conditions, with a peak strength of 3.744 MPa at 10% lime, as shown in Figure 3(b). The results confirm that excessive lime content leads to over-stabilization, reducing cohesion and mechanical performance.



(a) Compressive testing (b) Flexural setup

Figure 2 Testing procedures for compressive strength and flexural tensile strength

Flexural tensile strength results (Figure 3(c)) showed a comparable trend. The inclusion of jute fibers, combined with lime stabilization, contributed to crack resistance and increased tensile capacity. The strength peaked at 0.069 N/mm^2 for 10% lime before declining to 0.055 N/mm^2 at 12%. This suggests that optimal tensile behavior is also achieved in the 8–10% lime range.



(a) Dry compressive strength (b) Wet compressive strength (c) Flexural tensile strength

Figure 3 Mechanical performance of mud blocks with varying lime content

Water absorption decreased with higher lime content, indicating improved matrix densification and reduced porosity due to pozzolanic reactions. The lowest absorption was recorded at 4.69% for 12% lime. While this suggests better moisture resistance at higher lime percentages, the corresponding loss in compressive and flexural strength supports 10% as the optimum content for balancing durability and mechanical integrity. Taallah and Guettala [14] similarly demonstrated that the combination of lime with natural fiber reinforcement enhances both mechanical strength and water resistance in compressed earth blocks.

These findings are consistent with the work of Arooz and Halwatura [3], who reported enhanced strength and durability in mud-concrete blocks with optimized stabilizer ratios. Ganesh et al. [11] also observed comparable improvements from fiber addition, reinforcing the effectiveness of natural fiber reinforcement in earthen construction.

4 Conclusion

This study demonstrated that jute fiber-reinforced mud blocks stabilized with lime offer improved mechanical strength and durability for sustainable construction. Optimal performance was observed at 10% lime content, yielding a dry compressive strength of 4.27 MPa, wet strength of 3.74 MPa, and flexural tensile strength of 0.069 N/mm^2. Water absorption was effectively reduced with increased lime, though mechanical properties declined beyond 10%. The integration of bidirectional jute fibers enhanced tensile resistance and crack control. These findings support the use of lime–fiber-stabilized mud blocks as viable, low-carbon alternatives in eco-conscious building applications. Future studies could explore long-term durability under varying climatic conditions and fiber orientation effects in scaled-up construction.

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Biography

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