iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 **Issue:** XI **Month of publication:** November 2025

DOI: https://doi.org/10.22214/ijraset.2025.75805

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue XI Nov 2025- Available at www.ijraset.com

Utilization of Waste Paper in Construction: A Review on Papercrete Bricks

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Abstract: ***The construction industry is currently at a critical juncture, facing the dual challenges of environmental degradation caused by conventional material production and the escalating crisis of solid waste management. "Papercrete," a composite building material comprising re-pulped waste paper, cement, sand, and water, presents a sustainable solution to these issues. This paper provides a detailed review of the state-of-the-art research on Papercrete, categorizing existing knowledge on mix designs, manufacturing methodologies, and engineering properties. The review highlights that while Papercrete significantly reduces the dead load of structures (by up to 40%) and offers superior thermal insulation compared to burnt clay bricks, it exhibits limitations in compressive strength and water impermeability. This paper critically analyzes these trade-offs and identifies Papercrete as a viable, low-cost material for non-load-bearing applications,***
Keywords: Papercrete, Solid Waste Management, Sustainable Construction, Thermal Insulation, Compressive Strength, Green Materials.

I. INTRODUCTION

Infrastructure development is a primary driver of economic growth, but it is also a major consumer of natural resources. The production of traditional Red Clay Bricks relies heavily on the excavation of fertile topsoil, leading to land degradation and soil erosion. Furthermore, the brick kiln industry is a significant contributor to greenhouse gas emissions, releasing tons of CO2 and particulate matter annually.

Concurrently, the generation of Municipal Solid Waste (MSW), particularly paper waste, is increasing. Although paper is recyclable, the cellulose fibers shorten with each recycling cycle, eventually becoming unfit for paper production. Diverting this "end-of-life" paper to the construction sector effectively locks carbon in building materials and reduces landfill burden.

Papercrete (Paper + Concrete) addresses these ecological concerns. It is a lightweight, cementitious composite that replaces the fine aggregate or filler material with waste paper pulp. This review paper consolidates findings from various researchers to evaluate whether Papercrete can serve as a standardized construction material in the modern civil engineering context.

II. COMPOSITION AND MANUFACTURING

Based on the composition and the ratio of ingredients, researchers have classified Papercrete into three distinct categories:

1) Papercrete: A mix containing Paper Pulp, Cement, and Sand. This is the most common form used for brick manufacturing due to its balance of strength and weight.
2) Fidobe (Fibrous Adobe): A mixture of Paper Pulp, Earth (Clay), and Water. This type does not use cement and relies on the clay for binding. It is eco-friendly but lacks water resistance.
3) Fibrous Concrete: Normal concrete (Cement + Sand + Aggregate) with a very small percentage (2-5%) of paper pulp added to reduce shrinkage cracks.

III. MANUFACTURING METHODOLOGY: A REVIEW

The manufacturing process of Papercrete is unique compared to standard concrete. A review of methodologies adopted by Chandurkar et al. (2007) and Suganya (2012) reveals a standardized four-step process:

A. Pulp Generation

The quality of Papercrete depends on the defibering of paper.

1) Soaking: Waste paper (newspapers, records, cardboard) is soaked in water for 3 to 4 days. This softens the lignin and breaks hydrogen bonds.
2) Agitation: Mechanical blending is required to turn the soaked paper into a consistent slurry (pulp). Unblended paper clumps can create weak spots in the brick.

B. Mix Proportioning

There is no IS Code for Papercrete mix design. However, literature suggests the following trends:

1) High Paper Content: Results in lighter bricks but drastically lower compressive strength.
2) High Sand Content: Increases strength but increases weight.
3) Optimum Ratio: Most researchers agree that a volumetric ratio of 1:1:0.5 (Paper: Sand: Cement) yields the best compromise for masonry units.

C. Casting and Compaction

Since Papercrete contains high water content, manual compaction in wooden or steel molds is standard. Hydraulic pressing is less common but can significantly increase density and strength.

D. Curing

Unlike concrete, which requires moisture retention, Papercrete requires **drying**. The bricks must be sun-dried to allow excess water to evaporate before standard water curing begins to hydrate the cement.

IV. CRITICAL REVIEW OF PROPERTIES

A. Compressive Strength and Failure Mechanism

- Strength Range: Literature reports compressive strengths ranging from 2.5 MPa to 5.0 MPa. This classifies Papercrete as a non-load-bearing material suitable for partition walls (comparable to Class 3.5 clay bricks).
- Failure Mode: Fuller (2006) highlighted a key advantage: Ductility. While concrete fails suddenly (brittle failure), Papercrete compresses like wood. The fibers bridge micro-cracks, preventing catastrophic shattering. This property makes it safer for seismic zones.

B. Water Absorption and Durability

This is the primary drawback identified in all studies.

- Mechanism: Cellulose fibers are hydrophilic (water-loving). They act like microscopic sponges.
- Data: Water absorption rates are typically 20% - 35%, far exceeding the 20% limit for standard bricks.
- Consequence: When wet, Papercrete bricks can lose 30-40% of their strength. However, studies show they regain this strength upon drying. This necessitates the use of external plaster or waterproofing agents for durability.

C. Thermal and Acoustic Insulation

- Thermal: Due to the air pockets trapped within the paper fibers, Papercrete has a high R-value (Thermal Resistance). Buildings made of Papercrete remain cooler in summer and warmer in winter, reducing HVAC energy costs.
- Acoustic: The porous structure creates an effective sound barrier, making it ideal for auditoriums and shared partition walls.

D. Fire Resistance

Contrary to popular belief, Papercrete is fire-resistant. The cement coating around each fiber prevents oxygen from reaching the paper, causing it to smolder rather than burn with an open flame.

V. COMPARISON WITH CONVENTIONAL MATERIALS

The following table summarizes t he comparative analysis derived from literature:

Parameter	Red Clay Brick	Flyash Brick	Papercrete Brick
Primary Material	Top Soil	Fly Ash (Waste)	Waste Paper
Density (kg/m3)	1800 - 2000	1600 - 1800	1000 - 1200

Strength (MPa)	3.5 - 10.0	5.0 - 10.0	2.5 - 4.5
Water Absorption	10 - 15%	10 - 20%	20 - 35%
Nature	Brittle	Brittle	Ductile
Cost	High	Moderate	Low

VI. CHALLENGES AND FUTURE SCOPE

While Papercrete is promising, several challenges hinder widespread commercial adoption:

1) Lack of Standardization: There are no specific IS Codes or ASTM standards for Papercrete mix designs, making engineers hesitant to specify it in drawings.

2) Mechanization: Current production is largely manual. Developing industrial machinery for pulping and block-making is essential for scalability.

3) Durability Enhancements: Future research should focus on incorporating Nano-Silica or Latex polymers to reduce water absorption to below 15%.

VII. CONCLUSION

The review of existing literature confirms that Papercrete is a viable, eco-friendly alternative construction material. Its primary advantages lie in its lightweight nature, thermal insulation, and waste utilization potential. While it cannot replace reinforced concrete for load-bearing columns, it is an excellent substitute for burnt clay bricks in partition walls and infill panels. Adopting Papercrete would not only reduce the cost of construction but also contribute significantly to solving the global waste paper disposal crisis.

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BIOGRAPHIES

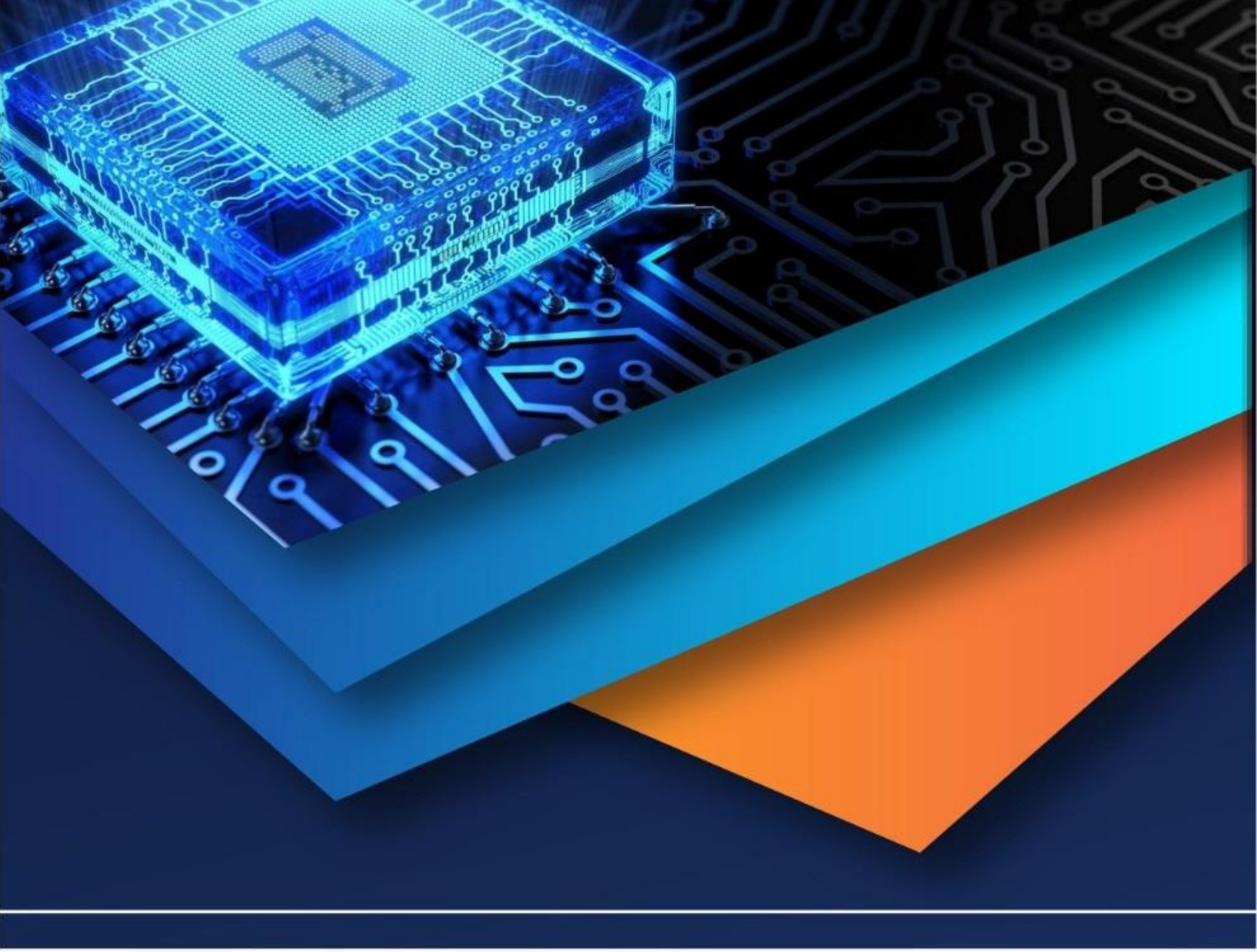
Chaitali Meshram
Ms. Chaitali Meshram is a final-year undergraduate student pursuing a Bachelor of Technology in Civil Engineering at J D College of Engineering & Management, Nagpur. Her research interests include sustainable construction materials and green building technologies. She played a pivotal role in the literature review and data analysis for this project, focusing on the environmental impact assessment of waste paper recycling in masonry.

Tuhin Mandal
Mr. Tuhin Mandal is currently pursuing his B.Tech in Civil Engineering from J D College of Engineering & Management, Nagpur. He is an active member of the Civil Engineering Student Association. For this research, he was responsible for the site execution, including the procurement of raw materials, mix design optimization, and overseeing the manufacturing process of the Papercrete bricks.

Shlok Rambhad
Mr. Shlok Rambhad is a final-year Civil Engineering student at J D College of Engineering & Management, Nagpur. His academic focus lies in structural engineering and concrete technology. In this project, he handled the laboratory experimentation phase, conducting rigorous compressive strength and water absorption tests according to IS codes to validate the engineering properties of the samples.

Ved Bisen
Mr. Ved Bisen is pursuing a Bachelor of Technology in Civil Engineering at J D College of Engineering & Management, Nagpur. He has a keen interest in construction management and cost estimation. His contribution to this paper includes the detailed cost analysis, comparing the economic feasibility of Papercrete against conventional materials, and analyzing the weight reduction benefits for high-rise structures.

Prof. Archana Mahajan
Prof. Archana Mahajan is an Assistant Professor in the Department of Civil Engineering at J D College of Engineering & Management, Nagpur. She holds a Master's degree in Civil Engineering and has extensive experience in teaching and research. Her areas of expertise include Concrete Technology, Sustainable Building Materials, and Structural Analysis. She guided this project, providing technical mentorship on mix design and standardized testing protocols.



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