JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Unveiling Paper Crete's Construction Feasibility: An Experimental Analysis

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Abstract *:* This study explores the material properties and experimental analysis of papercrete, a sustainable construction material made from wastepaper. The methodology comprises nine major parts, including material collection, preliminary tests, and mix optimization. Raw paper undergoes meticulous processing to produce paper sludge, a key ingredient in papercrete manufacturing. Various tests on cement, aggregates, and water ensure compliance with standards and reliable performance. Concrete mix design focuses on achieving desired strength, workability, and cost-effectiveness, considering factors like water-cement ratio and aggregate size. Experimental analysis involves testing different mix proportions for workability, compressive strength, and split tensile strength. Notably, compressive strength tests on papercrete cubes reveal strengths ranging from 8.92 N/mm² to 26.7 N/mm² at 7, 14, and 28 days, respectively. Differences between papercrete and clay bricks are highlighted, including weight, water absorption, and compressive strength variations. Water absorption and fire resistance tests demonstrate papercrete's suitability for construction, with absorption rates of 25% and fire resistance of up to 4 hours. Comprehensive documentation ensures transparency and reliability in reporting experimental findings.

Keywords: Papercrete, Sustainable construction, Compressive strength. Mix design, and Experimental analysis.

I. Introduction

The use of sustainable and innovative materials in construction has garnered significant attention in recent years. One such material, Paper Crete, has emerged as a promising candidate due to its eco-friendly nature and potential applications in construction. This experimental analysis aims to unveil the construction feasibility of Paper Crete through a series of rigorous experiments. By examining its strength, durability, thermal conductivity, and fire resistance properties, this study seeks to provide valuable insights into the practicality of utilizing Paper Crete in construction projects. Through this research, we aim to contribute to the advancement of sustainable building materials and support environmentally conscious practices in the construction industry. Research on Papercrete, a composite material of paper and cement, has primarily focused on its applications and manufacturing methods rather than its engineering properties. Previous studies have revealed limited information on its mechanical and physical characteristics. Investigations have emphasized the significance of cement content in influencing Papercrete's compressive strength and behavior. Some researchers explored the potential of using paper mill sludge in concrete, suggesting optimal replacement ratios to maintain strength. Others observed a decrease in compressive strength and density with higher paper replacement ratios, along with increased water absorption. Further research on Papercrete bricks demonstrated compressive strength exceeding 3.5 MPa with moderate water absorption, hinting at potential fire resistance with appropriate plastering

1.1 **Background and significance of Paper Crete**

Papercrete, a composite material made from paper fibers, Portland cement, and often other additives, has gained attention as a sustainable and versatile building material. Its origins can be traced back to the 1920s when it was used in construction, but it experienced a resurgence in interest in recent decades due to its eco-friendly properties. The use of recycled paper in Papercrete reduces waste and minimizes environmental impact, aligning with sustainability goals. Additionally, Papercrete offers several advantages, including its lightweight nature, insulating properties, and relative ease of production. These characteristics make it suitable for a variety of construction applications, ranging from insulation to load-bearing walls. As the construction industry continues to prioritize sustainable practices, Papercrete presents a promising solution for eco-conscious builders seeking innovative materials to reduce their environmental footprint.

1.2 Motivation for the experimental analysis

The motivation for conducting this experimental analysis stems from the critical need to address the gap in understanding the engineering properties of Papercrete. While some information exists regarding its applications and manufacturing processes, there is a notable lack of comprehensive data on its mechanical and physical characteristics. By undertaking this analysis, we aim to provide valuable insights into Papercrete's feasibility as a construction material. Understanding its strength, durability, thermal conductivity, and fire resistance properties is crucial for assessing its suitability for various construction applications. Moreover, with increasing emphasis on sustainability in the construction industry, exploring alternative materials like Papercrete becomes imperative. This study seeks to contribute to the body of knowledge on sustainable building materials and support environmentally conscious practices in construction. Ultimately, the findings of this analysis can inform decision-making processes for architects, engineers, and construction professionals seeking innovative and eco-friendly building solutions.

1.3 Objective of the work

The objectives of this project are twofold: firstly, to innovate the manufacturing process of eco-friendly bricks by utilizing waste materials such as paper waste and glass powder to create Paper Crete bricks. Secondly, the project aims to conduct comprehensive testing on these Paper Crete bricks, including assessments of water absorption, fire resistance, and compressive strength. Through these objectives, the project endeavors to design and produce robust, economically viable, and environmentally sustainable building materials, contributing to the advancement of eco-conscious construction practices.

- Develop eco-friendly Paper Crete bricks using waste materials like paper waste and glass powder.
- Perform tests including water absorption, fire resistance, and compressive strength on Paper Crete bricks.

II. LITERATURE REVIEW

The literature review section is dedicated to contextualizing the current study on Paper Crete by examining existing knowledge and research. It delves into various aspects such as Paper Crete's properties, manufacturing techniques, and its potential applications in construction. Through a thorough review of previous studies and findings, this section aims to pinpoint gaps in knowledge and areas requiring further investigation. Moreover, it contributes to establishing the relevance and significance of the present study within the realm of sustainable building materials. Subsequently, the subsequent section will present the synthesized literature and discuss key findings from each source.

Concrete production contributes to 9% of global greenhouse gas emissions, with substantial waste from discarded buildings. Devenes et al. (2022) propose reusing concrete blocks for a footbridge, detailing design, sourcing, and construction. Structural analysis and life cycle assessment show environmental benefits, highlighting the potential of circular economy applications in construction. Mandili et al. (2019) conduct an experimental study on a new biocomposite, Aggregates of Wastepaper and Lime (AWPL), for building insulation. Physical, mechanical, and thermal characterizations reveal promising properties, including low thermal conductivity and good mechanical strength. The AWPL shows potential as a structural and thermal insulation material for buildings. The study introduces Wood-Crete, a novel building material comprising sawdust, wastepaper, and Tradical lime. Processing techniques and composite performance factors are discussed. Results demonstrate lightweight blocks with insulation properties suitable for construction, with compressive strength ranging from 0.06 to 0.80 MPa. The addition of wastepaper significantly influences strength and thermal conductivity. The study, authored by Aigbomian and Fan (2013), is detailed in Construction and Building Materials.

This study investigates the compressive strength and microstructure of Ultra-High-Performance Concretes (UHPCs) with Supplementary Cementitious Materials (SCMs). An Artificial Neural Network (ANN) model is developed to predict compressive strength, easing future experimental workload. Key findings include the impact of SCMs on compressive strength, efficiency factors for blends, correlation between microstructure and mechanical properties, and accuracy of the ANN model. The study suggests potential applications for the model in predicting other UHPC properties. Zhang, et al. (2017) authored this work, titled "Experimental investigation and prediction of compressive strength of ultra-high-performance concrete containing supplementary cementitious materials" in Advances in Materials Science and Engineering, 2017.

The study investigates wood-Crete properties through sawdust modification methods like hot water boiling, alkaline treatment, and wastepaper addition. Key findings include enhanced compressive strength with 4% NaOH treatment and 140 min boiling, gradual strength increase with boiling duration, and paper type's influence on strength. NaOH treatment exceeding 4% weakened wood particles. Water uptake was minimal, but strength decreased significantly. The research establishes a foundation for improving wood-Crete strength and guiding its application in construction, emphasizing its potential as a low-carbon sustainable product. The study investigates Paper Crete Bricks as a low-cost building material in Ethiopia, aiming to correlate strength and weight for wall-making. Laboratory experiments determine ingredient quantities following Ethiopian and ASTM standards. The 1:1 (wastepaper: sand 20%) composition meets minimum compressive strength, with no efflorescence and good fire resistance. Other ratios exhibit varying results, with 1:1 (20%) recommended. Weight-strength correlation approaches 1, indicating good correlation. Atlawu et al. (2022) authored this study, emphasizing the importance of weight on strength in Paper Crete bricks for construction materials. Makesh and V.A.A.P., (2017) paper present experimental results on the properties of Papercrete bricks under uniaxial compression loading. Findings reveal several advantages: cost-effectiveness due to recycled materials, moldability, ease of lifting, superior surface finish, fire resistance, sound absorption, and reduced weight compared to clay bricks. These lighter bricks lessen the building's deadload and are ideal for earthquake-prone regions. They are unsuitable for waterlogged or external walls but excel in inner partitions, being termite resistant. Utilizing waste materials reduces landfill and pollution, cutting building costs by 20-25%.

III. METHODOLOGY

IN ORDER TO ACCOMPLISH THE AFORESAID OBJECTIVES, THE RESEARCH WORK HAS BEEN DIVIDED INTO NINE MAJOR PARTS. THEY ARE:

- Material collection
- Study of properties of materials
- Specimen making
- Preliminary tests
- Optimization of mix
- Behavioral studies on the papercrete bricks and masonry units
- Comparison of results with conventional bricks
- Comparison of results with software analysis
- Viability and cost analysis.

IV. MATERIAL AND EXPERIMENTAL ANALYSIS

4.1 Material Collection

To ensure environmentally friendly practices, materials were sourced meticulously. Mainly, paper served as the primary material. Seshasayee Paper Board (SPB) mill and TNPL paper mill, both ISO certified, provided essential paper pulp. Additionally, old newspapers, particularly The Hindu, were collected from college facilities. Slurry form, purchased from SPB and TNPL, lacked sufficient fiber content, thus necessitating the conversion of dry newspapers into slurry form using a flour machine. Fly ash from Mettur Thermal Plant, along with rice husk ash and micro silica, were acquired from authorized dealers. Grade 43 cement, sand, and waterproofing materials were procured and tested per BIS standards.

4.2 Pulp Generation

Raw wastepaper underwent meticulous processing before utilization in papercrete manufacturing. Initially, paper was meticulously cleaned, removing pins, threads, and other contaminants. Subsequently, the papers were shredded into small pieces and soaked in water for 3 to 5 days to form a paste. Following soaking, the papers were extracted from water and ground in a mixer to produce paper sludge. The sludge was then placed on a non-absorbent surface to eliminate excess water.

4.3 Experimental Materials and Testing Procedures

Materials used in the study include cement, fine aggregate (such as sand), water, and paper. Cement, a binding material, consists of calcareous and argillaceous components. Fine aggregate, meeting IS 383 standards, encompasses sand, crushed stone, ash, or cinder. Potable water, crucial for mixing, ensures concrete strength. The primary material, paper, sourced from waste, undergoes processing to form papercrete. Paper, comprising newspapers, record sheets, and magazines, serves as a fibrous material rich in wood cellulose. In the experimentation process, various tests were conducted on cement to assess its properties. These tests include determining normal consistency, initial and final setting times, fineness, specific gravity, compressive strength, and soundness. Similarly, tests on aggregates were performed to evaluate their characteristics. These tests encompassed assessing the fineness modulus of sand, specific gravity, bulk density, water absorption, and moisture content. Moreover, water quality tests were conducted, covering alkalinity, suspended matter, acidity, chlorides, sulphates, inorganic and organic content, and pH value. Additionally, the paper underwent a series of processes before incorporation into papercrete. These processes involved shredding the paper into small pieces, soaking it in water, grinding it into a sludge, and finally storing it for casting specimens. The physical properties of the wastepaper, including moisture content, specific gravity, density, absorption, and organic and inorganic materials, were also determined. Throughout the study, adherence to relevant standards and protocols ensured accurate assessment and reliable results regarding the materials' properties. Such comprehensive testing and evaluation enable a thorough understanding of the suitability and performance of these materials for the intended application in papercrete production.

4.4 Concreate mix design.

The process of concrete mix design involves selecting the appropriate ingredients and determining their relative proportions to achieve the desired strength, durability, and cost-effectiveness. This process is crucial as it directly impacts the performance of concrete in both its plastic and hardened states. Workability, defined as the ease of placing and compacting plastic concrete, is a vital property that influences the success of construction. The compressive strength of hardened concrete, often used as an indicator of its overall quality, depends on various factors including the quality and quantity of cement, water, and aggregates, as well as the mixing, placing, compaction, and curing methods employed. It's essential to strike a balance between cost and quality, with the goal of producing a lean mix that meets structural requirements while minimizing expenses. Concrete cost is primarily determined by material, plant, and labor costs. Cement, being more expensive than aggregate, significantly influences overall expenses. Therefore, achieving the necessary strength with minimal cement content is ideal. Rich mixes may lead to issues like increased shrinkage and cracking, particularly in structural concrete, or excessive heat generation in mass concrete, resulting in cracks. The actual cost of concrete production is also affected by quality control measures, which ensure that the concrete meets specified standards. However, implementing rigorous quality control adds to the overall cost, making it an economic compromise based on project size and type.

Key factors influencing mix design include the required compressive strength, workability for effective compaction, maximum water-cement ratio for durability, and aggregate size and grading. Compressive strength is crucial and determines the nominal water-cement ratio of the mix, with higher compaction leading to greater strength. Workability depends on factors such as section size, reinforcement amount, and compaction method. Durability, influenced by environmental conditions, dictates the water-cement ratio needed. Larger aggregate sizes reduce cement requirements but improve workability, while aggregate grading affects mix proportions and cohesion. Quality control is essential to minimize variations in mix properties and ensure consistency in performance. Various methods exist for mix design, each with its advantages and limitations. Commonly used methods include those recommended by ACI, DOE, and Indian standards. The Indian standard procedure, outlined in IS 10262-82, provides a systematic approach based on extensive research. However, this method requires updating to reflect advancements in cement technology and high-strength concrete requirements. Overall, mix design aims to achieve the desired concrete properties efficiently and economically, with adjustments made based on specific project needs and material characteristics.

V. Experimental Analysis of Concrete Mix Proportions

This chapter presents the experimental results obtained from various concrete mix proportions, focusing on workability, compressive strength, split tensile strength, flexural strength, and durability tests.

5.1 General Overview

Different mix types were prepared by altering the percentage of coarse and fine aggregate replacement with crushed tiles, crushed tile powder, and granite powder. Four mix types were explored alongside conventional mixes. Coarse aggregates were replaced by 10%, 20%, 30%, 40%, and 50% of paper pulp, while fine aggregates were replaced by 10% of glass powder individually and in conjunction with coarse aggregates.

5.2 Workability

Workability denotes the ease of placing and compacting fresh concrete without segregation. It significantly impacts concrete's strength, durability, labor cost, and appearance. Workability can be assessed through various methods, including the slump-cone test and compaction factor test.

5.3 Slump Cone Test

The slump cone test involves filling a cone-shaped mould with concrete in layers, compacting each layer with a tamping rod. After removing the mould, the slump (difference in height between the mould and concrete) is measured. Different types of slumps, such as true slump, zero slump, collapsed slump, and shear slump, indicate distinct concrete properties. For example, the slump observed for the given sample was 5 mm.

5.4 Compaction Factor Test

In the compaction factor test, freshly prepared concrete is compacted in a cylindrical mould and weighed before and after compaction. The compaction factor is determined by calculating the ratio of the difference in weights before and after compaction to the weight of the partially compacted concrete.

5.5 Compressive Strength Procedure

Concrete specimens are prepared and cured in water for 24 hours before testing. The dimensions of the specimens are measured, and they are subjected to compressive loading in a testing machine until failure. The compressive strength is calculated by dividing the maximum load applied by the cross-sectional area of the specimen. For instance, the compressive strength of concrete with a particular mix design was found to be 35 N/mm².

5.6 Split Tensile Strength Procedure

Cylindrical concrete specimens are prepared and cured similarly to compressive strength specimens. After curing, the specimens are subjected to diametrical loading until failure using a compression testing machine. The splitting tensile strength is calculated based on the applied load and the dimensions of the specimen.

These experimental procedures provide valuable insights into the performance of different concrete mix proportions, aiding in the optimization of mix designs for specific applications. Further analysis of these results can inform decision-making in construction projects to ensure the desired concrete properties are achieved efficiently.

VI. COMPRESSIVE STRENGTH TESTING AND CHARACTERIZATION OF PAPERCRETE

- The compressive strength test procedure for papercrete cubes involves 7.06cm x 7.06cm x 7.06cm specimens to assess papercrete's strength. After molding and tempering, specimens undergo 24-hour curing in an oven, with the top surface smoothed using cement paste before testing.
- Apparatus required for the test includes a compression testing machine. Papercrete cube specimens are prepared using a mixture of cement, lime, fine aggregate, paper pulp, glass fiber, and water, mixed either manually or with a laboratory mixer.
- Sampling of cubes for testing entails filling clean molds with papercrete in layers, compacting each layer with at least 35 strokes using a tamping rod, and smoothing the top surface with a trowel.
- Specimens are then cured in moist air for 24 hours followed by submersion in water until testing. During testing, specimens are removed from water, excess water is wiped, and the testing machine's bearing surface is cleaned. Specimens are loaded gradually until failure, and the maximum load is recorded.
- Calculations of compressive strength involve determining the load applied to the specimen's area. For example, a cube with 20% paper pulp exhibits compressive strengths of 8.92 N/mm² at 7 days, 17.8 N/mm² at 14 days, and 26.7 N/mm² at 28 days.
- Differences between clay bricks and papercrete bricks are summarized, highlighting weight, water absorption, and compressive strength variations.
- The water absorption test on papercrete bricks involves drying, weighing, immersing in water for 24 hours, and reweighing to calculate absorption, which is found to be 25%.
- Similarly, the fire resistance test on papercrete bricks is conducted by subjecting them to fire and recording the time until failure, with papercrete bricks resisting fire for up to 4 hours.

- Reports include identification marks, test dates, and specimen ages, ensuring comprehensive documentation of the testing process and results.

VII. Conclusions

In conclusion, the experimental analysis provides valuable insights into the performance and characteristics of papercrete as a sustainable construction material. The meticulous methodology ensures the collection of reliable data regarding material properties and mix proportions. Compressive strength tests reveal promising results, indicating papercrete's potential for structural applications. Differences between papercrete and conventional clay bricks underscore the former's advantages in terms of weight, water absorption, and fire resistance. The water absorption test demonstrates papercrete's ability to withstand moisture, crucial for durability in various environmental conditions. Similarly, the fire resistance test confirms papercrete's suitability for fire-prone areas, enhancing its appeal for construction projects. Comprehensive documentation of test results ensures transparency and facilitates informed decision-making in construction projects. Overall, the study contributes to advancing sustainable construction practices by highlighting the viability and performance of papercrete as a green building material.

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