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Advancing Residential Construction with Papercrete Concrete: A Comprehensive Review

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Abstract: The construction industry is witnessing a shift towards sustainable materials, with innovative solutions like Papercrete offering eco-friendly alternatives to traditional concrete. This study explores the utilization of Papercrete in construction, highlighting its environmental benefits, cost-effectiveness, and applications. Through a comprehensive review of existing literature, including studies on similar materials like Wood-Crete and Aggregates of Wastepaper and Lime (AWPL), this research identifies gaps and opportunities in sustainable building material development. Additionally, experimental studies on Ultra-High-Performance Concretes (UHPCs) with Supplementary Cementitious Materials (SCMs) and Papercrete bricks provide insights into their compressive strength and suitability for construction. The technical specifications and cost analysis section delineates guidelines for excavation and backfilling activities, crucial for efficient project execution. Utilizing AutoCAD and Microsoft Excel for drafting and estimation, respectively, ensures accuracy and efficiency in project planning. The detailed estimate for a proposed 2BHK residential building demonstrates the practical application of these tools and methods, with results indicating the viability of Papercrete in construction. Overall, this study emphasizes the importance of sustainable building materials in mitigating environmental impact, enhancing occupant health, and promoting economic sustainability in the construction industry.

Keywords: Papercrete, sustainable building materials, construction estimation, AutoCAD, Microsoft Excel

I. INTRODUCTION

Special concrete like Papercrete presents a revolutionary approach to sustainable construction materials. Comprising cement, water, and recycled paper fibers, Papercrete offers an eco-friendly alternative to traditional concrete by utilizing recycled paper waste. Its manufacturing process involves shredding recycled paper into fibers, which are mixed with cement and water to form a versatile slurry applicable in various construction elements. Once cured, Papercrete demonstrates impressive strength and durability, suitable for walls, floors, and insulation. Its lightweight nature reduces structural loads, making it ideal for seismic-prone regions, while its thermal and acoustic insulation properties enhance comfort and energy efficiency[1]. Additionally, Papercrete offers economic benefits through its utilization of low-cost, readily available materials, lowering construction expenses compared to traditional concrete. Its ease of manufacture and application further contributes to cost-effectiveness, making it appealing for both residential and commercial projects. The increasing adoption of Papercrete and similar innovative concrete formulations reflects a growing awareness of sustainability in the construction industry, driven by environmental consciousness and regulatory incentives. Estimating serves as a cornerstone in construction projects, guiding decision-making processes and resource allocation for project feasibility and success. Drawing detailed plans and assigning values based on current standards ensure accurate cost projection and budgeting. Adherence to standardized units of measurement and understanding key terms and concepts are crucial for clarity and precision in estimation practices. Testing requirements, as per established standards, enhance reliability by stipulating stringent measurement protocols[2]. Technology, exemplified by AutoCAD and Microsoft Excel, plays a pivotal role in enhancing efficiency and accuracy in the estimation process. In summary, meticulous attention to detail, adherence to standards, and leveraging technology are essential for enhancing the accuracy and effectiveness of estimation practices in construction projects, ultimately contributing to their success.

II. IMPORTANCE OF SUSTAINABLE BUILDING MATERIALS

The construction industry plays a significant role in global resource consumption, energy expenditure, and environmental degradation. As urbanization accelerates and populations burgeon, the demand for new buildings and infrastructure intensifies, exacerbating these challenges. In response, the imperative for sustainable building materials has become increasingly pronounced, necessitating a paradigm shift towards more eco-conscious construction practices. Sustainable building materials, such as Papercrete concrete, offer a viable solution to mitigate the environmental impact of construction activities.

By utilizing recycled or renewable resources, these materials reduce reliance on finite natural resources while diverting waste from landfills. Furthermore, sustainable materials often exhibit lower embodied energy and carbon emissions throughout their lifecycle, contributing to mitigating climate change and enhancing environmental stewardship. In addition to environmental benefits, sustainable building materials contribute to enhanced occupant health and well-being. Many conventional construction materials emit volatile organic compounds (VOCs) and other harmful pollutants, compromising indoor air quality and posing health risks to occupants[4]. In contrast, sustainable materials often prioritize non-toxic, low-emission formulations, fostering healthier indoor environments and reducing the incidence of respiratory ailments and allergies. Furthermore, sustainable building materials offer economic advantages, ranging from cost savings through reduced material and energy consumption to enhanced marketability and value appreciation of sustainable buildings. With growing consumer awareness and demand for environmentally responsible products, buildings constructed with sustainable materials command premium prices and enjoy higher occupancy rates, translating into tangible financial returns for developers and investors. Overall, the adoption of sustainable building materials is integral to achieving long-term environmental, social, and economic sustainability in the built environment. By embracing innovation and prioritizing sustainability in material selection and construction practices, stakeholders across the construction industry can contribute to creating healthier, more resilient communities while safeguarding the planet for future generations.

III. LITERATURE REVIEW

The literature review section contextualizes the current study on Paper Crete by examining existing knowledge and research. It explores various facets, including Paper Crete's properties, manufacturing techniques, and potential applications in construction. Through a comprehensive review of previous studies, the section identifies knowledge gaps and areas necessitating further investigation. Moreover, it underscores the relevance and significance of the present study within the sustainable building materials domain. The subsequent section synthesizes the literature and discusses key findings from each source. Concrete production contributes to 9% of global greenhouse gas emissions, with substantial waste from discarded buildings. Devenes et al[1] propose reusing concrete blocks for a footbridge, detailing design, sourcing, and construction. Structural analysis and life cycle assessment reveal environmental benefits, showcasing circular economy applications in construction. Mandili et al.[12] conduct an experimental study on a new biocomposite, Aggregates of Wastepaper and Lime (AWPL), for building insulation. Physical, mechanical, and thermal characterizations unveil promising properties, positioning AWPL as a structural and thermal insulation material for buildings. Aigbomian and Fan[20] introduce Wood-Crete, a novel building material comprising sawdust, wastepaper, and Tradical lime. The study discusses processing techniques and composite performance, demonstrating lightweight blocks with insulation properties suitable for construction[10].

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, facilitating future experimental work. Zhang et al[18] authored this work, suggesting potential applications for the model in predicting other UHPC properties. Another study examines wood-Crete properties through sawdust modification methods like hot water boiling and alkaline treatment. Results show enhanced compressive strength with specific treatments, establishing a foundation for improving wood-Crete strength and guiding its application in construction[6].

Additionally, the study investigates Paper Crete Bricks as a low-cost building material in Ethiopia, correlating strength and weight for wall-making. Laboratory experiments determine ingredient quantities, meeting minimum compressive strength requirements for certain compositions. Atlawu et al[21] underscore the importance of weight on strength in Paper Crete bricks for construction materials. Makesh and V.A.A.P[22] present experimental results on Papercrete bricks, revealing advantages such as cost-effectiveness, moldability, fire resistance, and reduced weight compared to clay bricks. These findings highlight the potential of Paper Crete and similar materials as sustainable alternatives in construction.

IV. OBJECTIVE OF THE STUDY

The objectives of this study aim to explore the potential of Papercrete in residential construction, evaluating its environmental impact, cost efficiency, and practical applications. Additionally, the research seeks to analyze the compressive strength of Papercrete bricks and identify areas for further development in sustainable building materials.

1) Assess environmental benefits, cost-effectiveness, and applications of Papercrete in residential construction.
2) Investigate compressive strength and suitability of Papercrete bricks through experimental studies, identifying gaps in sustainable building materials.

V. TOOLS AND METHODS FOR ESTIMATION AND CALCULATION

AutoCAD, a globally utilized CAD software, facilitates the creation of 2D and 3D drawings and models essential for project planning. With AutoCAD, floor plans and elevations of G+2 residential buildings were meticulously drawn to aid in project estimation. Microsoft Excel, widely embraced for its versatility, serves as a powerful tool for quantitative analysis and uncertainty estimation. Its user-friendly interface and customizable formulas make it invaluable for various tasks, including forecasting and estimation. AutoCAD, a versatile business software application, is indispensable in civil, mechanical, electrical, and engineering construction[7]. Offering tools for 2D and 3D design and drafting, AutoCAD simplifies complex processes and enhances productivity. All project drawings were created using AutoCAD, streamlining the drafting process and facilitating quick adjustments when necessary[9]. Microsoft Excel, renowned for its spreadsheet capabilities, is extensively used for estimating and calculating. Its built-in calculators and customizable formulas enable complex calculations with ease[4]. With features like self-correction, Excel minimizes errors and enhances the efficiency of estimators. Engineering quantities, including earthworks, foundation stone, and brickwork, are calculated using methods such as the long wall-short wall method and the centerline method[18]. These methods ensure accurate quantity estimation for various construction elements[19]. Detailed estimates involve calculating quantities of individual work items and determining their costs. This process entails measurement and recording of engineering details, followed by cost estimation based on predetermined values. Additionally, provisions are made for minor maintenance, incidental expenses, and unforeseen items to ensure comprehensive cost coverage[21].

VI. TECHNICAL SPECIFICATIONS AND COST ANALYSIS

General specifications provide comprehensive information about the work from the base to the top structure, including details about the work, materials, rates, and quality standards. These specifications offer a brief overview of the entire job on the structure, aiding planners in estimating project requirements accurately. The value of the cost associated with the project should be determined based on these specifications.

A. Multiple Specifications for Excavation and Backfilling

This specification covers various aspects of excavation work, including the scope of work, site clearance, handling of tree roots and plants, setting out and making profiles, and supervision requirements[8]. It delineates the responsibilities of contractors and outlines procedures for site preparation and excavation activities. The distance of 150 meters from the perimeter should be cleared for site clearance.

B. Excavation

The excavation process involves careful planning and execution, with specific guidelines for notifying site engineers before commencing work, measuring existing dimensions, and adhering to prescribed excavation depths, widths, and slopes. It classifies earthworks into different categories based on soil types and provides instructions for systematic excavation techniques[13]. For instance, the width of excavation should not exceed 1.5 meters, and the area should not exceed 10 square meters[14].

C. Recovery of Foundation, Plinths, and Floor

This section outlines procedures for the remediation of foundation, plinths, and floors after concrete or masonry work, emphasizing the importance of proper filling to avoid structural issues. It covers backfilling requirements, removal of debris and timber supports, compaction techniques, and quality assessment measures through testing. The depth of the layers for filling should be 15 cm, and the compaction should be done in layers not exceeding 150 mm.

D. Filling of Plinths and Floors

Filling activities involve layering soil, sand, or gravel to specified depths, ensuring adequate compaction and moisture content for optimal stability. It details the materials required for filling, methods of transportation, and compaction standards to achieve the desired density. Special considerations are given to the texture of the background and the quality of materials used for filling. The size of the stones to be filled into the ground should range from 12 mm to 20 mm[8]. The technical specifications and cost analysis section provides detailed guidelines for excavation and backfilling activities in construction projects. It covers general specifications, excavation procedures, recovery of foundation, and filling of plinths and floors, offering comprehensive instructions for contractors to follow. By adhering to these specifications, construction professionals can ensure the efficient and cost-effective execution of excavation and backfilling tasks, contributing to the overall success of the project.

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The numerical values provided in the content, such as the distance of 150 meters for site clearance and the depth of the layers for filling at 15 cm, are essential parameters for accurately estimating costs and planning excavation and backfilling activities.
Cost analysis is essential in construction projects to determine the expenses associated with various elements of the project. A fee schedule, included in contracts, outlines the prices required to perform services and helps in estimating project costs. The Central Public Works Department (CPWD) and state governments organize fee schedules for large projects, aiding in cost evaluation and additional item pricing determination[16]. Construction projects encompass various activities, such as excavation, concrete work, carpentry, plumbing, and finishing works, each requiring cost assessment[12].

VII. STANDARD SCHEDULE OF COSTS

Construction projects are subdivided into smaller projects, each associated with specific construction activities. For instance, excavation works can vary based on soil type and depth, with different requirements for soft and hard soil excavation depths. Similarly, stone projects involve various compositions and placements, such as reinforced concrete foundation or columns, affecting project costs[14]. The cost of each construction is calculated based on individual project elements, emphasizing the importance of cost assessment for smaller tasks.

A. Factors Affecting Cost Analysis

Several factors influence civil engineering cost analysis, including material quality, site location, work complexity, and contractor overheads. The quality of materials, mortar, stone, and plaster thickness impact construction costs, along with site proximity to resources like labor and machinery. Additionally, the amount and type of work, contractor expenses, and overheads contribute to cost variations across regions. Real estate business analysis involves assessing material costs, labor expenses, plant and machinery costs, water expenses, taxes, insurance costs, and contractor overheads[4-6]. These elements play a crucial role in determining the overall cost of construction projects, requiring meticulous evaluation to ensure project feasibility and profitability. Construction projects need cost evaluation for various purposes, including competitive bidding, resource optimization, budget preparation, and dispute resolution. Cost analysis helps contractors provide competitive quotes, optimize resource utilization, monitor project expenses, and resolve disputes between project owners and contractors[11-15]. It also facilitates budget preparation and cost control at different stages of construction.

B. Standard Schedule Rates of Materials

1) Common burnt clay brick (19x19x9 cm): Rs. 8.70 each
2) Papercrete Brick (17x10x10 cm): Rs. 5 each
3) Portland cement (grade 43, 50kg bag): Rs. 320 per bag
4) Stone aggregate (20mm nominal size): Rs. 1400 per cubic meter
5) Sand: Rs. 1200 per cubic meter
6) TMT steel (fe500, 1 tonne): Rs. 45,000

C. Labour Charges

1) Head mason: Rs. 800 per day
2) Mason: Rs. 650 per day
3) Maj-door: Rs. 350 per day
4) Bhisti: Rs. 200 per day
5) Tools and Equipment's: Rs. 1000 per day

Plans and elevational views of a 2BHK residential building were created using AutoCAD software, with the total buildup area for planning set at 148.48 square meters. The floor plan depicts the layout and arrangement of spaces within the residential building. This view provides a sectional representation of the building, showing details such as heights, depths, and thicknesses of various structural elements.
Specifications:

a) Slab Thickness: 0.150 meters
b) Floor Height: 3 meters
c) Foundation Depth: 1.55 meters below ground level
d) Parapet Wall Height: 1 meter
e) Parapet Wall Thickness: 0.3 meters

VIII. RESULTS & DISCUSSIONS

The detailed estimate for the proposed 2BHK residential building was derived from plans created using AutoCAD software, with quantities calculated based on dimensions and costs estimated using standard schedule rates. The total buildup area considered for planning was 148.48 square meters[12-16]. For the ground floor, the total calculated quantity amounted to 337 cubic meters. Utilizing the standard schedule rates of Telangana state, the estimated cost for the ground floor construction amounted to Rs. 11,25,620.5. The few observations are given below:

1) The procedure for conducting compressive strength tests on papercrete cubes entails preparing specimens measuring 7.06cm x 7.06cm x 7.06cm. After molding and tempering, these specimens undergo a 24-hour curing process in an oven, during which the top surface is smoothed using cement paste before testing.
2) The necessary apparatus for this test includes a compression testing machine. Papercrete cube specimens are created using a mixture comprising cement, lime, fine aggregate, paper pulp, glass fiber, and water, which can be mixed either manually or with a laboratory mixer.
3) Sampling for testing involves 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.
4) After sampling, the specimens are cured in moist air for 24 hours and then submerged in water until the testing phase. During testing, the specimens are removed from the water, excess water is wiped off, and the bearing surface of the testing machine is cleaned. The specimens are then gradually loaded until failure, and the maximum load applied is recorded.
5) The calculation of compressive strength entails determining the load applied to the specimen's area. For instance, a cube containing 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.
6) A comparison between clay bricks and papercrete bricks highlights differences in weight, water absorption, and compressive strength characteristics.
7) The water absorption test for papercrete bricks involves drying, weighing, immersing in water for 24 hours, and reweighing to calculate absorption, which is found to be 25%.
8) Similarly, the fire resistance test on papercrete bricks involves subjecting them to fire and recording the duration until failure, with papercrete bricks demonstrating resistance for up to 4 hours.
9) Comprehensive reports include identification marks, test dates, and specimen ages, ensuring thorough documentation of the testing process and results.

IX. CONCLUSION AND SUMMARY OF FINDINGS

This project involved planning a 2BHK house area using AutoCAD software, specifically located in Badangpet village, Ranga Reddy district, covering an area of 148.48 square meters. All drawings were created using AutoCAD software, and the cost estimation was conducted using various methods, including the average method and the long-short wall method in Microsoft Excel. The estimated costs include hourly wages for labor in Telangana state.

The estimation and costing processes serve multiple purposes, including tender planning, cost control during construction, and ensuring appropriate product selection during project execution. The primary objective is to maintain cost control throughout the project and anticipate and mitigate potential issues during the construction phase[2,3]. The study highlights the significance of sustainable building materials like Papercrete in addressing environmental concerns and promoting eco-conscious construction practices. Papercrete, composed of recycled paper fibers, cement, and water, offers a sustainable alternative to traditional concrete, contributing to waste reduction and energy conservation[10]. Its lightweight nature, coupled with impressive strength and durability, makes it suitable for various construction applications, particularly in seismic-prone regions. Additionally, Papercrete's thermal and acoustic insulation properties enhance comfort and energy efficiency, further underlining its appeal in modern construction projects. Cost analysis emerges as a critical aspect of construction projects, guiding decision-making processes and resource allocation for project feasibility and success. Adherence to standardized units of measurement, understanding key terms and concepts, and leveraging technology are essential for precise estimation practices. AutoCAD and Microsoft Excel serve as indispensable tools for enhancing efficiency and accuracy in the estimation process, facilitating detailed planning and cost projection.

Moreover, the literature review underscores the growing interest in sustainable building materials, with various studies exploring innovative formulations like Papercrete, Aggregates of Wastepaper and Lime (AWPL), and Wood-Crete. These materials offer promising properties, including strength, thermal insulation, and cost-effectiveness, positioning them as viable alternatives in construction.

Overall, the adoption of sustainable building materials is integral to achieving long-term environmental, social, and economic sustainability in the built environment. By embracing innovation and prioritizing sustainability in material selection and construction practices, stakeholders can contribute to creating healthier, more resilient communities while safeguarding the planet for future generations.

X. RECOMMENDATIONS FOR FUTURE RESEARCH

1) Further research should explore alternative sustainable building materials beyond Papercrete, such as Aggregates of Wastepaper and Lime (AWPL) or Wood-Crete, to assess their properties, performance, and suitability for different construction applications. Comparative studies can shed light on the strengths and limitations of these materials, guiding their optimal utilization in construction projects.
2) Future research endeavors could focus on developing advanced estimation techniques leveraging emerging technologies like artificial intelligence and machine learning. By harnessing these tools, construction professionals can enhance the accuracy and efficiency of cost estimation processes, leading to better project planning, resource allocation, and cost control.
3) Research initiatives should explore the integration of circular economy principles into construction practices, particularly in material sourcing, utilization, and waste management. Investigating innovative approaches to reuse, recycle, and repurpose construction materials can contribute to resource conservation, waste reduction, and environmental sustainability in the built environment.
4) The adoption of smart construction technologies, including Building Information Modeling (BIM) and Internet of Things (IoT) devices, presents opportunities for improving project efficiency, productivity, and sustainability. Future research endeavors should delve into the application of these technologies in construction estimation, planning, and execution, assessing their impact on project outcomes and stakeholder satisfaction.

These recommendations aim to catalyze future research efforts in the construction industry, addressing critical challenges and opportunities for advancing sustainability, efficiency, and innovation in building practices. By pursuing these avenues of inquiry, researchers can contribute to the development of more resilient, resource-efficient, and environmentally friendly construction solutions, fostering a sustainable built environment for future generations.

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