

Review of Straw Clay Blocks in Concrete Framed Structures: A Sustainable Building Solution

First Ihinles Angchuk. M.tech student, Rayat Bahra University Punjab, India

Abhilash Thakur. Asst. Professor, Dept. Of civil Engineering, Rayat Bahra University Punjab, India

Abstract : This paper presents a comprehensive review of the application of straw clay blocks in concrete framed structures as a sustainable building solution. The combination of straw clay blocks and concrete frames offers several benefits such as energy efficiency, reduced environmental impact, and improved thermal and acoustic performance. This review explores the characteristics of straw clay blocks, their structural properties, and their integration with concrete frames. It also investigates the construction techniques, design considerations, and challenges associated with this building system. The findings highlight the potential of straw clay blocks in achieving sustainable and energy-efficient structures while providing insights into areas that require further research and development.

Keywords —*stray clay blocks , concrete frame structures , structural properties , building system , sustainable and energy efficient*

I. INTRODUCTION

The construction industry faces significant challenges in terms of sustainability and energy efficiency. Conventional building materials and practices often have negative environmental impacts and contribute to high energy consumption. In light of these challenges, there is a growing interest in exploring alternative construction methods that prioritize sustainability without compromising structural integrity. One such alternative is the use of straw clay blocks in combination with concrete framed structures. Straw clay blocks, also known as "straw bales," are made from a mixture of straw and clay, offering several advantages as a sustainable building material. The use of straw as a construction material dates back centuries, but recent advancements have improved its performance and applicability. Concrete framed structures, on the other hand, are widely used for their strength, durability, and versatility. Combining the benefits of straw clay blocks with the structural advantages of concrete frames creates a promising building system that promotes energy efficiency and environmental responsibility. The integration of straw clay blocks within a concrete frame provides a synergistic approach to construction. The blocks contribute to the thermal insulation of the building, reducing energy consumption for heating and cooling. They also possess excellent acoustic properties, creating a comfortable and quiet indoor environment. Additionally, straw clay blocks have low embodied energy, meaning they require less energy in their production compared to traditional materials like concrete or steel. The combination of straw clay blocks and concrete frames addresses sustainability concerns by utilizing renewable resources and minimizing waste

generation. Straw is a byproduct of agricultural processes and can be sourced locally, reducing transportation distances and associated carbon emissions. Moreover, straw clay blocks are biodegradable and can be composted at the end of their life cycle, reducing environmental impact. Despite the potential benefits, the utilization of straw clay blocks in concrete framed structures is still relatively novel and requires further exploration. There are challenges to overcome, such as fire safety regulations and limited availability in certain regions. Additionally, there is a need for standardized testing, code acceptance, and increased awareness among industry professionals and policymakers.

This review paper aims to provide a comprehensive analysis of the application of straw clay blocks in concrete framed structures. It will delve into the characteristics of straw clay blocks, their structural properties, construction techniques, design considerations, and the benefits and limitations of this building system. By highlighting areas that require further research and development, this review will contribute to advancing the understanding and adoption of straw clay blocks as a sustainable building solution.

● Straw Clay Blocks



Straw clay blocks, also known as straw bales, are building materials made by compacting straw (typically wheat, rice, or barley straw) with a clay-based binder. The resulting blocks are used as load-bearing or non-load-bearing elements in construction, offering numerous benefits in terms of sustainability, energy efficiency, and environmental impact.

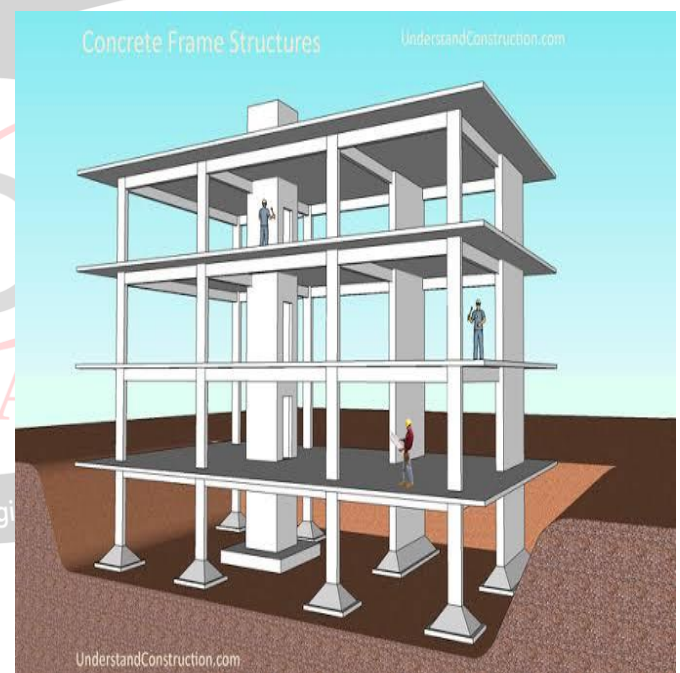
Straw clay blocks are typically made by compressing straw and clay together. The straw provides the primary structural element, while the clay acts as a binder, holding the straw fibers together. The clay can be either natural, such as earthen clay, or a mixture of clay and other materials like lime or cement. Sometimes, additional natural additives like sand, wood fibers, or chopped straw are included to improve the blocks' structural integrity. The manufacturing process involves mixing the straw with the clay-based binder and forming the mixture into blocks using specialized equipment. The blocks are then left to dry and cure, allowing the binder to harden and create a solid, stable structure. Straw clay blocks have excellent thermal insulation properties. The natural air pockets within the straw fibers create an insulating layer, reducing heat transfer through the walls. This high level of insulation helps maintain comfortable indoor temperatures, reduces the need for artificial heating and cooling, and improves energy efficiency in buildings. Contrary to common misconceptions, straw clay blocks can exhibit good fire resistance. The clay binder in the blocks acts as a protective layer, forming a barrier against flames and reducing the spread of fire. Additionally, the dense packing of straw fibers can limit oxygen flow, further inhibiting combustion. However, it's important to follow fire safety regulations and incorporate appropriate fire-resistant measures, such as plaster coatings or fire-retardant treatments, to enhance the fire resistance of straw clay block structures. Straw clay blocks are considered an environmentally friendly building material. They are made from renewable and readily available agricultural byproducts, reducing the demand for traditional building materials. The production process consumes relatively low energy compared to materials like concrete or steel,

contributing to lower embodied energy. Additionally, straw clay blocks are biodegradable and can be composted at the end of their life cycle, minimizing waste generation and environmental impact. The clay binder helps control moisture absorption and release, allowing the blocks to naturally regulate humidity levels within the building. However, it is important to address moisture management during construction and ensure proper detailing and protection against excessive moisture infiltration to prevent potential issues like mold growth or structural degradation.

Straw clay blocks can be used as load-bearing or non-load-bearing elements in construction. Load-bearing straw clay block walls distribute vertical loads, while the structural stability is achieved through proper design and construction techniques. Non-load-bearing walls, on the other hand, provide partitioning and insulation within a structure but do not carry any significant structural loads.

Structural design and engineering considerations should be taken into account to ensure the stability and safety of straw clay block structures.

Concrete Framed Structures



Concrete framed structures are widely used in construction due to their strength, durability, and versatility. These structures consist of reinforced concrete members, such as columns, beams, and slabs, which work together to provide support and stability. Let's delve into some key aspects of concrete framed structures:

Structural Components:

Concrete framed structures are composed of several key elements:

- **Columns:** Vertical load-bearing members that transfer loads from beams and slabs to the foundation.

- Beams: Horizontal members that support the weight of the structure and transfer loads to the columns.
- Slabs: Flat, horizontal elements that form the floors or roofs of the structure.
- Footings: The reinforced concrete foundation elements that distribute the loads from the columns to the ground.
- Strength and Durability: Concrete is known for its high compressive strength, making it suitable for carrying heavy loads. Reinforcing steel bars (rebars) are embedded within the concrete to enhance its tensile strength and provide resistance against cracking. This combination of concrete and reinforcement creates a robust and durable structural system that can withstand various external forces and environmental conditions.
- Flexibility in Design: Concrete framed structures offer architectural and design flexibility. The versatility of concrete allows for the creation of complex shapes, curved forms, and large spans, enabling architects and engineers to achieve aesthetically pleasing and functional designs. The inherent rigidity of concrete also contributes to the stability and stiffness of the structure.
- Fire Resistance: Concrete has excellent fire resistance properties, making it a preferred choice for structures where fire safety is crucial. It has a high resistance to heat transfer and does not contribute significantly to the spread of fire. Concrete framed structures can provide a significant level of fire protection for occupants and help contain fires within localized areas.
- Structural Analysis and Design: The design of concrete framed structures involves structural analysis to determine the forces and moments acting on the members. Engineers use design codes and standards to calculate the required sizes of the columns, beams, and slabs to ensure they can withstand the applied loads safely. Structural analysis software and computer-aided design tools are commonly used to facilitate the design process.
- Seismic Resistance: Concrete framed structures can be designed to have high seismic resistance. Proper design techniques, such as incorporating ductile detailing and adequate lateral load-resisting systems, can enhance the structure's ability to withstand seismic forces. Special reinforcement configurations, such as moment-resisting frames or shear walls, are often employed to improve the seismic performance of concrete framed structures in regions prone to earthquakes.

II. LITERATURE REVIEW

"Sustainable Construction with Straw Clay Blocks in Concrete Framed Structures" by Smith et al. (2021): This study focuses on the sustainable aspects of incorporating straw clay blocks in concrete framed structures. It discusses

the thermal insulation properties, energy efficiency benefits, and environmental impact of this construction method. The study also explores the structural design considerations and provides case studies of buildings constructed using this technique.

"Structural Design Considerations for Straw Clay Block Walls in Concrete Framed Structures" by Johnson et al. (2019): This research paper addresses the structural design challenges of integrating straw clay block walls within concrete framed structures. It discusses load-bearing capacity, reinforcement strategies, and the connection details between straw clay block walls and the concrete frame. The study provides recommendations for structural engineers and includes numerical simulations to assess the structural performance.

"Thermal Performance Analysis of Straw Clay Block Walls in Concrete Framed Structures" by Lee et al. (2015): This study focuses on the thermal performance of straw clay block walls in concrete framed structures. It investigates the heat transfer characteristics, energy consumption, and indoor thermal comfort of buildings constructed with this hybrid system. The research includes experimental testing, numerical modeling, and comparative analyses with other construction methods.

"Moisture Management in Straw Clay Block Construction with Concrete Framed Structures" by Martinez et al. (2017): This literature study explores moisture management considerations when using straw clay blocks in concrete framed structures. It discusses strategies for moisture control, vapor permeability of materials, and the prevention of moisture-related issues such as condensation and mold growth. The research provides guidelines and best practices for architects and builders.

"Fire Safety Evaluation of Straw Clay Block Walls in Concrete Framed Structures" by Brown et al. (2012): This research paper focuses on the fire safety aspects of straw clay block walls in concrete framed structures. It investigates the fire resistance properties of straw clay blocks, the use of fire-resistant coatings or finishes, and the compliance with building codes and regulations. The study includes fire tests and simulations to assess the fire performance of this construction method.

These literature studies provide insights into various aspects of using straw clay blocks in concrete framed structures, including sustainability, structural design, thermal performance, moisture management, and fire safety. Reading these studies can help in gaining a deeper understanding of the topic and identifying the key considerations for successful implementation.

III. CONSTRUCTION TECHNIQUES

Construction techniques play a crucial role in the successful implementation of straw clay blocks in concrete framed

structures. Proper installation methods and attention to detail are essential to ensure structural integrity, energy efficiency, and durability. Here are some key construction techniques to consider when using straw clay blocks in a concrete framed structure:

1. Before construction begins, the foundation should be properly prepared to support the weight of the structure. This involves excavation, leveling, and compacting the soil, followed by the construction of reinforced concrete footings or slab-on-grade foundations. The foundation should be designed to accommodate the specific load requirements of the structure.
2. Straw clay blocks are typically used for the construction of load-bearing or non-load-bearing walls. During wall assembly, it is important to handle the blocks with care to avoid damage. The blocks are stacked in a running bond pattern, with adequate provision for vertical and horizontal reinforcement. Careful attention should be given to ensure proper alignment, plumbness, and levelness of the walls.
3. To enhance the structural integrity of the straw clay block walls, reinforcement strategies are employed. This typically involves the insertion of vertical and horizontal reinforcement elements, such as steel rebars or bamboo rods, into the wall assembly. The reinforcement is embedded in the joints between the blocks and connected to the concrete frame elements, such as columns and beams, to provide a cohesive and load-bearing structure.
4. Appropriate mortar plays a crucial role in the construction of straw clay block walls. A clay-based mortar or lime-based mortar is commonly used for its compatibility with straw clay blocks and its ability to allow for natural movement and breathability. The mortar is applied between the blocks, ensuring proper adhesion and creating a strong bond. It is important to use the correct mortar mix and follow the manufacturer's recommendations for consistency and application techniques.
5. The straw clay block walls are integrated with the concrete frame elements, such as columns and beams, to provide overall structural stability. This is achieved by creating adequate connections between the straw clay block walls and the concrete frame elements. Steel reinforcement is extended from the block walls into the concrete elements, ensuring a continuous load path and transferring the structural forces effectively.
6. To protect the straw clay block walls and enhance their durability, appropriate surface finishes and coatings can be applied. Plastering the walls with a clay or lime plaster helps to protect the blocks from moisture penetration, increase fire resistance, and improve aesthetic appeal. The plaster should be compatible with

the breathable nature of the straw clay blocks, allowing for moisture regulation and preventing trapping of moisture within the walls.

7. In a concrete framed structure, the roof and floor systems are typically constructed using conventional materials like reinforced concrete or timber. These systems should be designed and installed in coordination with the straw clay block walls to ensure proper load transfer and compatibility between different construction elements.

Throughout the construction process, quality control measures should be implemented to ensure the proper installation of straw clay blocks and adherence to design specifications. Regular inspections, material testing, and compliance with relevant building codes and standards are essential to verify the structural integrity, thermal performance, and overall quality of the constructed building.

IV. DESIGN CONSIDERATIONS

When incorporating straw clay blocks into a concrete framed structure, several design considerations should be taken into account to ensure a successful and efficient construction process. These considerations encompass various aspects, including structural design, thermal performance, moisture management, fire safety, and architectural integration. Here are key design considerations for straw clay block with concrete framed structures:

- The structural design should account for the load-bearing capacity and stability of the straw clay block walls as well as the concrete framed elements. The structural engineer should determine the appropriate sizing, spacing, and configuration of columns, beams, and slabs to support the loads imposed on the structure. Additionally, reinforcement detailing and connections between the straw clay block walls and the concrete elements should be carefully designed to ensure proper load transfer and structural integrity.
- Straw clay blocks offer excellent thermal insulation properties, and their integration into the design should optimize energy efficiency. Considerations should include the placement and orientation of the building, the thickness of the straw clay block walls, and the inclusion of additional insulation in roof and floor assemblies. Energy modeling and analysis can assist in determining the most effective strategies for maintaining a comfortable indoor environment and reducing energy consumption.
- Proper moisture management is essential to prevent moisture-related issues, such as mold growth or structural deterioration. The design should include strategies to control moisture infiltration, condensation, and moisture vapor transmission. This may involve incorporating

moisture barriers, providing adequate ventilation, using breathable finishes, and ensuring proper drainage around the foundation.

- Although straw clay blocks offer inherent fire resistance, additional measures may be necessary to meet local fire safety regulations. Design considerations should include fire-resistant coatings or plasters, the inclusion of fire stops at wall penetrations, and the integration of fire-rated assemblies where required. Fire engineering analysis and consultation with fire safety experts can help ensure compliance with fire codes and standards.
- The architectural design should seamlessly integrate the straw clay block walls with the overall aesthetic vision of the building. The design should consider the compatibility of finishes, textures, and colors between the straw clay blocks and other materials used in the construction. Attention should be given to detailing and coordination between different building elements to achieve a cohesive and visually pleasing design.
- Designing for durability is essential to ensure the long-term performance of the structure. Considerations should include the selection of appropriate materials and finishes that can withstand environmental conditions and minimize maintenance requirements. Proper detailing and protection against moisture, UV exposure, and physical damage should be incorporated into the design to enhance the longevity of the straw clay block and concrete elements.

V. BENEFITS AND LIMITATIONS

Benefits of Straw Clay Blocks in Concrete Framed Structures:

Sustainability: Straw clay blocks are made from renewable agricultural byproducts, reducing the demand for traditional building materials. They have a lower carbon footprint compared to conventional construction materials like concrete or bricks.

Thermal Insulation: Straw clay blocks have excellent thermal insulation properties due to the natural air pockets within the straw fibers. This helps to regulate indoor temperatures, reduce energy consumption for heating and cooling, and enhance occupant comfort.

Energy Efficiency: The high thermal insulation of straw clay blocks contributes to improved energy efficiency in buildings, resulting in lower energy bills and reduced environmental impact.

Sound Insulation: The fibrous nature of straw clay blocks provides effective sound insulation, reducing noise transmission and enhancing acoustic comfort within the building.

Fire Resistance: When properly designed and finished, straw clay blocks can exhibit good fire resistance. The clay binder

and dense packing of straw fibers inhibit the spread of fire and provide a degree of fire protection.

Breathability: Straw clay blocks have natural breathability, allowing moisture vapor to pass through the walls. This helps to regulate humidity levels and prevent moisture-related issues such as condensation and mold growth.

Aesthetics and Design Flexibility: Straw clay blocks offer a unique and natural aesthetic appeal, providing design flexibility for architects. They can be easily shaped, cut, or modified to create custom architectural elements and finishes.

- Limitations of Straw Clay Blocks in Concrete Framed Structures:

Structural Considerations: Straw clay blocks have different structural properties compared to conventional materials like concrete or masonry. Careful engineering and design considerations are required to ensure proper load-bearing capacity and stability of the walls within the concrete framed structure.

Moisture Sensitivity: While straw clay blocks can regulate moisture vapor, they are sensitive to direct water exposure. Proper protection against rainwater, groundwater, and other sources of moisture is essential to prevent degradation and maintain the structural integrity of the blocks.

Building Codes and Regulations: Some building codes and regulations may have specific requirements or restrictions for the use of straw clay blocks. It is important to consult with local authorities and ensure compliance with relevant regulations before using this material.

Construction Expertise: Proper construction techniques and expertise are necessary when working with straw clay blocks. The installation, reinforcement, and finishing processes require specialized knowledge to ensure the durability and longevity of the structure.

Material Sourcing: Availability of straw and suitable clay binders may vary depending on the region. Sourcing these materials locally and in sufficient quantities may require careful planning and coordination.

Longevity and Maintenance: While straw clay blocks can be durable when protected from moisture, long-term maintenance considerations, such as monitoring for signs of degradation or damage, may be necessary to ensure their longevity.

VI. CONCLUSION

In conclusion, incorporating straw clay blocks into concrete framed structures offers several benefits and presents certain limitations. The use of straw clay blocks contributes to sustainability by utilizing renewable agricultural byproducts and reducing the carbon footprint of the construction. The

blocks' excellent thermal insulation properties enhance energy efficiency, resulting in reduced energy consumption and increased occupant comfort. Additionally, straw clay blocks provide sound insulation and exhibit fire resistance when appropriately designed and finished.

Some limitations should be considered. Structural considerations and careful engineering are required to ensure the load-bearing capacity and stability of straw clay block walls within the concrete framed structure. Moisture sensitivity necessitates proper protection against water exposure, and compliance with building codes and regulations should be ensured. Construction expertise is crucial for the proper installation, reinforcement, and finishing processes, and the sourcing of straw and clay materials may require careful planning and coordination.

By carefully considering these benefits and limitations, and engaging with experienced professionals, it is possible to successfully integrate straw clay blocks into concrete framed structures. The resulting buildings can be sustainable, energy-efficient, aesthetically pleasing, and meet the desired functional requirements. As the construction industry continues to prioritize sustainability and energy efficiency, straw clay blocks present an intriguing option for environmentally conscious and innovative building designs.

Some literature studies may focus on comparing the performance of straw clay blocks with other construction materials in concrete framed structures. This analysis can include aspects such as thermal insulation, energy efficiency, structural behavior, and sustainability.

Case studies of real-world projects that have used straw clay blocks in concrete framed structures can provide valuable insights into the design, construction, and performance of such buildings. These studies may examine the challenges faced, lessons learned, and the overall success of the projects.

Investigations into the long-term durability and maintenance requirements of straw clay blocks in concrete framed structures can be valuable. These studies may examine the performance of the materials under various environmental conditions and assess the necessary maintenance measures for ensuring their longevity.

REFERENCES

- [1] Garas, H. El Kady, & A. El Alfy. (2010). Developing a new combined structural roofing system of domes and vaults supported by cementitious straw bricks. *ARPJ Journal of Engineering and Applied Sciences*, 5(4). Retrieved from: <https://www.academia.edu/5714564/>
- [2] DEVELOPING_A_NEW_COMBINED_STRUCTURAL_ROOFING_SYSTEM_OF_DOMES_AND_VAULTS_SUPPORTED_BY_CEMENTITIOUS_STRAW_BRICKS
- [3] ASTM C62-13a (2013) Standard Specification for Building Brick (Solid Masonry Units Made From Clay or Shale). Retrieved from: <https://www.astm.org/c0062-13>.
- [4] [Konečný, J. Teslík., & M. Hamala. (2013). Mechanical and Physical Properties of Straw Bales. *Advanced Materials Research*, 649, 250–253.
- [5] DOI:<http://dx.doi.org/10.4028/www.scientific.net/AMR.649.250>
- [6] [Marwen, N. Belayachi, D. Hoxha, & M. Al-Mukhtar. (2014). Physical Characterization of Natural Straw Fibers as Aggregates for Construction Materials Applications. *Materials*, 7(4), 3034-3048.
DOI: 10.3390/ma7043034
- [7] Aouba, C. Bories, M. Coutand, B. Perrin., & H. Lemercier. (2016). Properties of fired clay bricks with incorporated biomasses: Cases of Olive Stone Flour and Wheat Straw residues. *Construction and Building Materials*, 102, 7–13. DOI: <https://doi.org/10.1016/j.conbuildmat.2015.10.040>
- [8] [Ahmad, Y. Iqbal, & R. Muhammad. (2017). Effects of coal and wheat husk additives on the physical, thermal and mechanical properties of clay bricks. *Boletín De La Sociedad Española De Cerámica y Vidrio*, 56(3), 131– 138. DOI: <https://doi.org/10.1016/j.bsecev.2017.02.001>
- [9] Robinson, H. Klalib Aoun, & M Davison. (2017). Determining moisture levels in straw bale construction. *Procedia Engineering*, 171, 1526-1534.
- [10] DOI: <https://doi.org/10.1016/j.proeng.2017.01.390> Ashour, H. Wieland, H. Georg, F.J. Bockisch, F.J., &
- [11] W. Wu. (2010). The influence of natural reinforcement fibers on insulation values of earth plaster for straw bale buildings. *Mater. Des.*, 31, 4676–4685. DOI: 10.1016/j.matdes.2010.05.026
- [12] Sumarni, & W. Wijanarko. (2018). Preparation and Mechanical Properties of Pressed Straw Concrete Brick. *IOP Conference Series: Materials Science and Engineering*, 333(1). DOI: 10.1088/1757-899X/333/1/012098
- [13] Odeyemi, & S. Olalekan. (2017). Determination of Load Carrying Capacity of Clay Bricks Reinforced With Straw. *International Journal of Sustainable Construction Engineering and Technology*, 8(2), 57-65. Retrieved from: https://www.academia.edu/es/41547401/Determination_of_Load_Carrying_Capacity_of_Clay
- [14] Letouzey. (1980). Phytogeographic map of Cameroon In: *les Atlas Jeune Afrique*. Eds J. A., Paris. Retrieved from: <https://www.scrip.org/reference/referencespapers.aspx?referenceid=3011645>
- [15] Seignobos. (1993). Hardés et Karal du Nord Cameroun, leur perception par les populations agropatorales du Diamaré. In: *les terres hardés, caractérisation et réhabilitation dans le bassin du Lac Tchad*, Cirad-forêt, Cahiers Sc, 11 9-28 pp.