



LOW-COST HOUSING MATERIALS AND CONSTRUCTION TECHNIQUES IN INDIA

Sakshi Himmatrao Mali¹, Aaksnsha Sunil Dange², Pooja Kiran Patil³, Samiksha Rajendra Pakhare⁴, Vaishnavi Dinkar Ganganmale⁵

^{1,2,3,4,5} D Y Patil technical campus talsande, Kolhapur.

Article Info

Article History:

Published: 30 Sept 2026

Publication Issue:

Volume 3, Issue 9
September-2026

Page Number:

629-639

Corresponding Author:

Sakshi Himmatrao Mali

Abstract:

Affordable housing in India requires construction systems that balance cost, structural performance, durability, environmental impact, construction speed and user acceptance. This research paper presents a comparative study of selected low-cost housing materials and construction techniques using published Indian case-study and research data as the evidence base. The study considers fly ash bricks, compressed stabilized earth blocks (CSEB), bamboo, agro-waste materials, recycled materials, lightweight blocks, ferrocement, rat-trap bond masonry, filler slabs, prefabrication and modular construction. A structured comparison framework was developed around four criteria: economic potential, resource and environmental potential, construction practicality, and performance or acceptance considerations. Published studies show that material-efficient construction can generate measurable savings in appropriate applications. A Bihar case study reported 26.11% construction-cost savings for rat-trap bond masonry and 22.68% for a filler roof slab compared with the conventional alternatives examined in that study. Other Indian studies have compared embodied energy and cost among masonry materials and have investigated waste-derived materials for economically weaker sections. The comparative analysis indicates that no single technology is universally the cheapest or most sustainable. Local material availability, transportation distance, climate, labour skills, structural requirements, building scale, maintenance and social acceptance strongly affect the final outcome. CSEB and bamboo show strong resource potential where local conditions are favourable, while rat-trap bond and filler slabs show strong component-level economic potential. Lightweight blocks and prefabricated systems can be attractive in projects with suitable supply chains. The study concludes that low-cost housing should be treated as a system-design problem rather than a simple material-substitution problem. Future research should combine structural testing, thermal performance, life-cycle cost, embodied carbon, durability and user satisfaction to create region-specific decision tools for affordable housing in India.

Keywords: Low-cost housing; affordable housing; CSEB; fly ash; bamboo; rat-trap bond; filler slab; prefabrication; embodied energy; sustainability; India

1. INTRODUCTION

India has a large and diverse housing requirement. The affordability of a house is influenced by land, labour, materials, transportation, services, design, finance and maintenance. For lower-income households, even a moderate increase in material or labour prices can make formal housing difficult to achieve. This has encouraged researchers, engineers and government institutions to investigate low-cost and resource-efficient construction technologies.

Low-cost housing should not be interpreted as housing of poor quality. The objective is to achieve required structural safety, durability, comfort and functionality with efficient use of materials and labour. Cost can be reduced by

optimizing building planning, reducing material wastage, using locally available resources, selecting appropriate wall and roof systems, adopting prefabrication and using industrial or agricultural by-products where technically suitable.

Srivastava and Kumar discussed low-cost housing technologies and emphasized resource management, local materials and construction methods that can reduce cost without compromising basic performance. Varun Raj et al. reviewed sustainable low-cost materials and techniques and highlighted bamboo, rice husk ash, agro-waste, industrial waste, precast systems and emerging technologies.

This research paper develops a comparative framework using published research. It is therefore a secondary-data research study. The authors do not claim to have performed new laboratory experiments. Instead, published experimental and case-study results are interpreted together to identify patterns, opportunities and limitations.

2. BACKGROUND AND NEED FOR LOW-COST HOUSING

Construction in India includes a wide range of technologies, from traditional masonry and reinforced concrete to prefabricated and industrialized systems. Conventional construction can be reliable but may require significant quantities of cement, steel, fired bricks, aggregates and labour. The environmental effects of these materials include energy use, emissions and extraction of natural resources.

At the same time, India generates substantial agricultural and industrial residues. Fly ash from thermal power generation, rice husk ash from agriculture, foundry sand from metal industries, coconut shell waste and construction and demolition waste have all been investigated for construction applications. Using waste as a raw material can potentially reduce disposal problems and demand for virgin resources.

Low-cost housing is also influenced by regional climate and local material availability. A material that is economical in one region may be expensive in another because of transportation. Similarly, an earthen technology can be highly attractive where suitable soil is available but less attractive where soil must be transported or extensively processed.

Thus, the need is not simply for a list of cheap materials. The need is for a method of selecting appropriate technologies based on cost, performance, availability, sustainability and constructability.

3. PROBLEM STATEMENT

The central problem addressed in this research is the difficulty of achieving affordable housing while maintaining structural safety, durability, thermal comfort, environmental responsibility and user acceptance. Many low-cost technologies are discussed individually in the literature, but their advantages and limitations are often reported using different criteria. A comparative framework is therefore needed to support technology screening.

4. AIM AND OBJECTIVES

Aim: To comparatively evaluate selected low-cost housing materials and construction techniques for Indian conditions using published research evidence and a structured performance framework.

Objectives:

1. Identify major low-cost materials relevant to Indian housing.
2. Compare selected wall, roof and construction systems.
3. Analyze published cost and material-saving results.
4. Examine environmental and embodied-energy considerations.
5. Study thermal, functional and social considerations.
6. Identify limitations and barriers to adoption.
7. Propose application-specific recommendations.

5. RESEARCH QUESTIONS

Which materials show strong potential for affordable housing in India?

Which construction techniques demonstrate measurable cost or material savings?

How do local availability and transportation influence technology selection?

What technical, environmental and social barriers limit adoption?

What research gaps should be addressed before large-scale implementation?

6. SCOPE OF THE STUDY

The study focuses on residential low-cost housing in India and considers materials and construction techniques that can influence walling, roofing, structural or prefabricated components. The study includes fly ash products, CSEB, bamboo, agro-waste, recycled materials, lightweight blocks, ferrocement, rat-trap bond, filler slabs, prefabrication and modular systems.

The research does not provide structural design calculations for a particular building and does not replace the requirements of applicable Indian Standards, building regulations or professional engineering design. It is intended as a comparative academic research study.

7. RESEARCH METHODOLOGY

7.1 Research Design

A comparative secondary-data research design was used. Published journal papers, conference papers and scholarly studies were treated as the evidence sources. The research process consisted of source identification, evidence extraction, technology classification, comparative analysis and interpretation.

7.2 Data Extraction

Information was extracted under five broad categories: material characteristics, reported cost effects, environmental/resource effects, construction practicality, and limitations. Numerical results were retained in their reported form because different studies use different years, locations, building sizes and cost assumptions.

7.3 Comparative Scoring

A qualitative five-point screening scale was developed. A score of 1 indicates low potential and 5 indicates high potential for the particular criterion. The scores are not laboratory measurements or official standards. They are an analytical synthesis of the reviewed evidence.

Criterion	Meaning	Indicators considered
Economic potential	Potential to reduce project cost	Material quantity, labour, construction time, transport
Resource/environmental	Potential to conserve resources	Waste utilization, renewable content, embodied energy
Practicality	Ease of implementation	Skills, equipment, production, logistics
Performance/acceptance	Suitability for users and buildings	Durability, comfort, safety, social acceptance

7.4 Limitations of Method

Published studies are not directly comparable in every respect. Costs change over time, and performance depends on material quality and construction practice. Consequently, this paper uses published numerical results as case-specific evidence and uses qualitative synthesis for broader comparison.

8. REVIEW OF EXISTING RESEARCH

8.1 Low-Cost Housing Techniques

Srivastava and Kumar examined methods of using low-cost housing techniques in India and described approaches based on efficient use of materials, local resources and alternative construction methods [1]. Their work illustrates that cost reduction can occur at the level of individual building components rather than requiring a completely different type of building.

8.2 Sustainable Materials

Varun Raj et al. reviewed low-cost materials and techniques and identified several waste and bio-based materials as potential inputs for sustainable construction [2]. Their discussion also includes precast construction and emerging digital fabrication technologies.

8.3 Rat-Trap Bond and Filler Roof Slab

Sinha et al. investigated rat-trap bond masonry and filler roof slab technology in Bihar. Their reported case results showed 26.11% cost savings for rat-trap bond masonry and 22.68% for the filler roof slab [3]. These results demonstrate how material-efficient component design can influence construction cost.

8.4 Earthen Construction and CSEB

Kulshreshtha et al. studied the potential and current status of earthen materials for low-cost housing in rural India. Their work indicates that technical suitability alone is insufficient; social image and user acceptance can strongly influence adoption [4]. Compressed stabilized earth blocks provide a more standardized form of earth construction when suitable soil and production quality are available.

8.5 Embodied Energy and Material Cost

Research on Indian residential buildings has compared embodied energy and construction cost for alternative masonry materials. Such studies demonstrate that the cheapest purchase price does not necessarily correspond to the lowest embodied energy. Material quantity, manufacturing process and building configuration all influence the result [5].

8.6 Waste-Derived Construction Materials

Arun et al. investigated EPS, coconut shell, foundry sand and fly ash as cost-effective material options for economically weaker sections [6]. Experimental research of this type is important because waste utilization must be supported by testing of strength, durability and other relevant properties.

8.7 Regional and Emerging Technologies

Recent work on Assam-type houses examines traditional materials such as bamboo, thatch and mud along with newer materials including CSEB, fly ash bricks, agro-waste products, ferrocement and hempcrete. The study also discusses prefabrication and 3D printing as emerging possibilities [7].

9. LOW-COST HOUSING MATERIALS

9.1 Fly Ash Bricks

Fly ash can be used in masonry products such as fly ash–lime–gypsum bricks. Singh and Garg investigated fly ash bricks and hollow blocks for low-cost housing [8]. Their use can help utilize industrial by-products and reduce reliance on some conventional masonry products. Quality depends on controlled proportioning, curing and manufacturing.

9.2 Compressed Stabilized Earth Blocks

CSEB is produced by compacting suitable soil, often with a stabilizer. Its major potential advantage is the possibility of using locally available soil, thereby reducing transportation. CSEB can also provide a consistent block form compared with loose earth construction. However, soil selection, moisture control, stabilization, compaction and curing must be carefully controlled.

9.3 Bamboo

Bamboo is a renewable, lightweight material that has long been used in several regions of India. It can be considered for structural frames, roofs, partitions and other components when species selection, treatment, connections, moisture protection and fire safety are appropriately addressed.

9.4 Rice Husk Ash and Agro-Waste

Agricultural residues such as rice husk ash can be incorporated into selected construction products. The main sustainability advantage is resource recovery. However, the properties of ash vary according to burning conditions and processing, so quality control is important.

9.5 Recycled and Industrial Waste

Foundry sand, coconut shell and construction waste have been investigated as alternative material inputs. The technical feasibility depends on particle characteristics, contamination, processing, proportioning and intended application.

9.6 Lightweight Blocks

AAC and other lightweight blocks can reduce wall dead load and can be installed quickly because of their larger unit dimensions. They may also influence thermal performance. However, manufacturing energy and transportation should be included when evaluating environmental performance.

9.7 Ferrocement

Ferrocement uses a relatively thin cementitious matrix reinforced with wire mesh. It can be useful for selected roofing and panel applications. Its suitability depends on crack control, workmanship, corrosion protection and exposure conditions.

10. LOW-COST CONSTRUCTION TECHNIQUES

10.1 Rat-Trap Bond Masonry

Rat-trap bond masonry places bricks on edge to create a cavity within the wall. Compared with a conventional arrangement, this can reduce the quantity of bricks and mortar while retaining a wall of comparable overall thickness. The cavity can also influence thermal behaviour. The Bihar study reported a 26.11% saving in the investigated application [3].

10.2 Filler Slab

A filler slab uses non-structural filler units in portions of a reinforced concrete slab where concrete is not required to carry the same structural role. This can reduce concrete quantity and dead load. The reported Bihar case showed 22.68% cost savings [3]. Structural design must determine the appropriate reinforcement and concrete arrangement.

10.3 Optimized Brickwork

Optimization of brick dimensions, bond pattern, wall thickness and openings can reduce material wastage. The key principle is to use material only where it contributes to structural or functional requirements.

10.4 Prefabrication

Prefabrication moves part of construction from the site to a controlled production environment. It can improve consistency, reduce site duration and reduce material wastage. However, transport, lifting, factory setup and standardization become important.

10.5 Modular Construction

Modular construction uses standardized building units that can be assembled rapidly. It is particularly suitable where repetition and scale justify manufacturing. Site access and transportation must be evaluated before adoption.

10.6 Precast Components

Precast wall panels, beams, slabs and other components can reduce on-site labour and construction duration. Quality control can be improved, but the economic benefit depends strongly on project scale and transportation.

10.7 Passive Design and Material Efficiency

Building orientation, shading, natural ventilation, appropriate openings and roof design can reduce operational energy requirements. These measures are important because low-cost housing should address both construction cost and long-term comfort.

11. COMPARATIVE DATA ANALYSIS

The following table presents selected published results. The figures are case-specific and should not be treated as universal market prices.

Technology / source	Reported result	Interpretation
Filler slab [1]	Up to about 25% construction-cost reduction in reviewed applications	Potential roof-level economy when structurally appropriate
Rat-trap bond [3]	26.11% cost saving in Bihar case	Strong component-level economic potential
Filler roof slab [3]	22.68% cost saving in Bihar case	Reduced material use and dead load potential
CSEB [4]	Potential for rural low-cost housing; acceptance remains a challenge	Best suited where soil, skills and user acceptance are favourable
Masonry alternatives [5]	Embodied energy and cost vary among materials and building configurations	Life-cycle assessment is preferable to purchase-price comparison
Waste-derived materials [6]	EPS, coconut shell, foundry sand and fly ash investigated experimentally	Requires further field validation and durability assessment

Fly ash bricks [8]	Studied as low-cost masonry products	Potential industrial-waste utilization
--------------------	--------------------------------------	--

11.1 Qualitative Technology Screening

Technology	Economic	Resource/Environment	Practicality	Performance/Acceptance
Fly ash bricks	4/5	4/5	4/5	4/5
CSEB	5/5	5/5	3/5	3/5
Bamboo	4/5	5/5	3/5	3/5
Agro-waste	4/5	5/5	3/5	3/5
Lightweight blocks	4/5	3/5	5/5	4/5
Rat-trap bond	5/5	4/5	4/5	4/5
Filler slab	5/5	4/5	3/5	4/5
Prefabrication	4/5	3/5	5/5	4/5
Ferrocement	3/5	4/5	3/5	3/5

The screening indicates that rat-trap bond and filler slab have strong economic potential in suitable applications. CSEB and bamboo have strong resource potential but require careful attention to local conditions and acceptance. Lightweight and prefabricated systems have strong practicality where industrial supply chains are available.

11.2 Interpretation of Comparative Results

The results show why low-cost housing should be evaluated at the building-system level. A material with a low unit price may require more labour, transportation or maintenance. Conversely, a manufactured product with a higher purchase price may reduce construction time and labour. Therefore, cost should be measured across the complete construction process.

12. COST ANALYSIS

12.1 Material Cost

Material cost includes the purchase price of bricks, blocks, cement, steel, aggregates, timber, bamboo or other components. Local materials can provide an advantage when transportation is short. Waste-derived materials can also be economical when processing facilities are located near the construction site.

12.2 Labour Cost

A construction method that saves material but requires highly specialized labour may not be economical for a small rural project. Conversely, prefabrication can reduce site labour but may require factory labour and equipment. Labour productivity should therefore be considered together with material savings.

12.3 Transportation

Transportation can significantly affect the delivered cost of heavy construction materials. Local soil, bamboo or locally manufactured blocks may have an advantage over materials transported long distances. Prefabricated components also require transport planning because of their size and weight.

12.4 Life-Cycle Cost

Initial construction cost is only one part of affordability. Maintenance, repair, replacement and energy consumption over the service life can change the total cost. A durable but slightly more expensive component may be preferable to a cheaper component requiring frequent replacement.

13. ENVIRONMENTAL AND ENERGY ANALYSIS

13.1 Waste Utilization

The use of fly ash, rice husk ash, foundry sand, coconut shell and recycled construction materials can reduce demand for virgin resources when technically appropriate. It can also divert residues from disposal. However, waste processing itself consumes energy and therefore must be included in a complete environmental assessment.

13.2 Embodied Energy

Embodied energy includes energy associated with extraction, processing, manufacture and transportation of materials. Research on Indian houses has shown that embodied energy varies between masonry materials and building configurations [5]. This means that environmental comparison should consider the complete material quantity used in the building.

13.3 Embodied Carbon

Reducing cement-intensive materials, optimizing concrete quantities and using local or renewable materials can potentially reduce embodied carbon. However, carbon performance should be calculated using reliable life-cycle data rather than assumed solely from material type.

14. THERMAL AND FUNCTIONAL PERFORMANCE

14.1 Thermal Comfort

Thermal comfort is important for affordable housing because occupants may have limited access to mechanical cooling. Wall and roof properties, shading, ventilation, orientation and window design work together. Rat-trap bond and earthen systems can provide useful thermal characteristics when appropriately designed.

14.2 Structural Safety

Cost reduction must never be achieved by removing essential structural elements. Alternative materials and systems require appropriate structural calculations, workmanship and compliance with relevant standards. Particular attention is needed in seismic, flood, cyclone and high-wind regions.

14.3 Moisture and Durability

Earth, bamboo and some waste-derived materials can be sensitive to moisture or biological deterioration if not protected. Plinth detailing, roof overhangs, drainage, surface treatment and material treatment can significantly influence service life.

15. SOCIAL AND PRACTICAL CONSIDERATIONS

15.1 User Acceptance

Technology adoption depends partly on how users perceive a material. Earthen construction can face a negative social image even when technical performance is acceptable [4]. Demonstration buildings, good finishes and evidence of durability can improve acceptance.

15.2 Skill Requirements

Rat-trap bond, CSEB and bamboo systems require trained workers. Poor workmanship can reduce the expected benefit and may create defects. Training and simple construction manuals can support wider adoption.

15.3 Local Employment

Local production of blocks and components can create employment and retain construction expenditure within the community. However, quality-control procedures are necessary to ensure that locally produced materials meet required specifications.

15.4 Institutional Support

Government agencies, research institutions and professional bodies can support technology dissemination through demonstration projects, training, technical guidelines and standards. Institutional confidence can make builders and households more willing to adopt alternatives.

16. APPLICATION-SPECIFIC RECOMMENDATIONS

Situation	Potential technologies	Main conditions
Rural area with suitable soil	CSEB, stabilized earth	Soil availability, moisture protection, trained labour
Region with bamboo resources	Treated bamboo	Treatment, connections, fire and moisture protection
Low-rise masonry housing	Rat-trap bond, fly ash bricks	Quality masonry and suitable structural design
Suitable reinforced-concrete roof	Filler slab	Structural design and correct filler placement
Urban repetitive housing	Precast/prefabrication, lightweight blocks	Supply chain, transport, scale
Waste-generating industrial region	Fly ash/foundry-sand products	Processing, testing and quality control

These recommendations are screening-level conclusions. Final technology selection should be based on site investigation, structural design, local cost data, applicable codes, material testing and qualified engineering review.

17. LIMITATIONS

This study is based on secondary published research rather than a new laboratory or field experiment. Therefore, the paper cannot claim original measured strength, thermal or durability values.

The reviewed studies use different locations, years, building sizes, material specifications and economic assumptions. Direct numerical comparison is therefore limited.

The qualitative scores were developed for academic comparison and have not been statistically validated. They should not be interpreted as official ratings.

Some emerging technologies have limited long-term field data in Indian conditions. Their inclusion in this study indicates research potential rather than guaranteed performance.

18. FUTURE RESEARCH

Future research should develop standardized Indian datasets for material cost, embodied energy, embodied carbon and service life. Such datasets would allow better comparison of technologies across states and climatic regions.

Long-term field monitoring should be conducted for CSEB, bamboo, fly ash products, recycled materials and prefabricated systems. Monitoring should include cracking, moisture, thermal comfort, biological deterioration and maintenance requirements.

Future experimental work should combine structural testing with life-cycle assessment. Small-scale wall and roof specimens could be constructed using two or more alternative systems and compared for strength, thermal response, material quantity, cost and environmental impact.

Digital technologies such as BIM, automated quantity estimation, modular design and 3D printing should be assessed using realistic Indian labour, transport and supply-chain conditions.

19. CONCLUSION

This research paper has comparatively examined low-cost housing materials and construction techniques relevant to India using published research as the evidence base. The study demonstrates that affordability is influenced by more than the unit price of a material. Material quantity, labour, transportation, construction time, maintenance, durability and environmental performance must be considered together.

Published evidence provides measurable support for selected techniques. In the Bihar case study reviewed in this paper, rat-trap bond masonry showed 26.11% construction-cost savings and filler roof slab construction showed 22.68% savings compared with the conventional alternatives examined [3]. Other research identifies potential in CSEB, fly ash products, bamboo, agro-waste, lightweight blocks and prefabricated systems.

The comparative framework developed in this research suggests that rat-trap bond and filler slab can be strong choices for suitable low-rise applications where trained labour and appropriate structural design are available. CSEB and bamboo can provide strong resource advantages where local materials and suitable environmental protection exist. Lightweight blocks and prefabricated systems can be attractive for projects with appropriate industrial supply chains.

The major conclusion is that there is no universally cheapest or best low-cost housing technology. The appropriate solution is region-specific and should be selected after considering climate, material availability, transportation, structural requirements, skills, durability, maintenance and user acceptance. Low-cost housing should therefore be understood as an integrated design and construction strategy that aims to achieve affordability without compromising safety, quality or long-term performance.

References

- [1] M. Srivastava and V. Kumar, "The methods of using low cost housing techniques in India," *Journal of Building Engineering*, vol. 15, pp. 102–108, 2018, doi: 10.1016/j.job.2017.11.001.
- [2] P. Varun Raj, P. Surya Teja, K. Sai Siddhartha, and J. S. Kalyana Rama, "Housing with low-cost materials and techniques for a sustainable construction in India—A review," *Materials Today: Proceedings*, vol. 43, pp. 1850–1855, 2021, doi: 10.1016/j.matpr.2020.10.816.

- [3] S. Sinha, S. Mishra, P. Kumar, and S. Saurabh, “Sustainable Low-Cost Housing using Cost Effective Construction Technology ‘Rat Trap Bond Masonry’ and ‘Filler Roof Slab’ in Bihar,” *International Journal of Engineering Research and Technology*, vol. 13, no. 7, pp. 1780–1785, 2020, doi: 10.37624/IJERT/13.7.2020.1780-1785.
- [4] Y. Kulshreshtha, N. Mota, K. Jagadish, et al., “The potential and current status of earthen material for low-cost housing in rural India,” *Construction and Building Materials*, vol. 247, 118615, 2020, doi: 10.1016/j.conbuildmat.2020.118615.
- [5] “Effect of construction materials on embodied energy and cost of buildings—A case study of residential houses in India up to 60 m² of plinth area,” *Energy and Buildings*, 2014.
- [6] M. Arun, K. Baskar, B. S. Geethapriya, M. Jayabarathi, and R. Angayarkanni, “Affordable housing: Cost effective construction materials for economically weaker section,” *Materials Today: Proceedings*, vol. 45, pp. 7838–7844, 2021, doi: 10.1016/j.matpr.2020.12.265.
- [7] “Sustainable solutions for low-cost building: Material innovations for Assam-type house in North-East India,” *Case Studies in Construction Materials*, vol. 22, e04461, 2025, doi: 10.1016/j.cscm.2025.e04461.
- [8] S. Singh and A. K. Garg, “A perspective study on fly ash–lime–gypsum bricks and hollow blocks for low cost housing development,” *Construction and Building Materials*, vol. 16, no. 8, pp. 519–525, 2002, doi: 10.1016/S0950-0618(02)00034-X.
- [9] N. Sengupta, “Evaluation of Appropriateness of Rat-trap Bond Wall and Filler Slab Roof in housing sector in India,” *PREPARE@u*, 2019, doi: 10.36375/prepare_u.a16.
- [10] V. N. Nanyam et al., “Implementation of precast technology in India—opportunities and challenges,” *Procedia Engineering*, 2017.
- [11] V. Puri and P. Chakraborty, “A review of low cost housing technologies in India,” in *Advances in Structural Engineering*, 2015, doi: 10.1007/978-81-322-2187-6_150.
- [12] S. N. Joglekar et al., “Sustainability assessment of brick work for low-cost housing: A comparison between waste-based bricks and burnt clay bricks,” *Sustainable Cities and Society*, 2018.
- [13] “Cost Effective Construction for Low Income Earners with MRTB and MFS,” scholarly study reporting material savings for modified rat-trap bond and modified filler slab systems.
- [14] S. Chowdhury and S. Roy, “Prospects of low cost housing in India,” *Geomaterials*, vol. 3, no. 2, pp. 60–65, 2013.
- [15] “Review on comparative study of diverse wall materials for affordable housing,” *Materials Today: Proceedings*, 2023.
- [16] “Sustainable and affordable prefab housing systems with minimal whole life energy use,” scholarly research on prefabricated housing systems, 2020.