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LOW-COST HOUSING MATERIALS AND CONSTRUCTION TECHNIQUES IN INDIA

Sakshi Himmatrao Mali[1], Aaksnsha Sunil Dange[2], Pooja Kiran Patil[3], Samiksha Rajendra Pakhare[4], Vaishnavi Dinkar Ganganmale[5]
[1,2,3,4,5] D.Y. Patil Technical Campus, Talsande.

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Corresponding Author:
Sakshi Himmatrao Mali

Abstract:

In India, building affordable homes needs systems that balance cost, how well the buildings hold up, how long they last, how much they affect the environment, how fast they can be built, and how people accept them. This paper compares different low-cost materials and methods used in Indian case studies and research.The materials and methods studied include fly ash bricks, compressed stabilized earth blocks (CSEB), bamboo, agro-waste, recycled materials, lightweight blocks, ferrocement, rat-trap bond masonry, filler slabs, prefabrication, and modular construction.The study uses a structured framework that looks at four main areas: how cost-effective the materials are, how they use resources and affect the environment, how practical they are to build, and how well they perform or are accepted by people. Research shows that using materials efficiently can save money in the right situations.A case study from Bihar found that using rat-trap bond masonry saved 26.11% on construction costs compared to traditional methods, and using a filler roof slab saved 22.68%.Other studies in India have compared the energy and cost of different masonry materials and looked at using waste materials for poorer communities.The analysis shows that no one material or method is always the cheapest or most sustainable. Factors like where the materials come from, how far they have to travel, the local climate, the skills of the workers, the building's design needs, its size, how much it needs maintenance, and how people feel about it all influence the final result.CSEB and bamboo are good options where local conditions support them, while rat-trap bond and filler slabs offer strong cost savings at the component level.Lightweight blocks and prefabricated systems can be good choices if there are reliable supply chains.The study concludes that building affordable housing is more about designing the whole system than just replacing one material with another.Future research should include testing how structures hold up, how well they keep the inside temperature steady, long-term costs, carbon emissions, how well they last, and how happy people are with them.This would help create tools that are specific to different regions in India for building affordable homes.

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

1. INTRODUCTION

India has a big and varied need for homes.The cost of buying a house depends on many things like land, workers, building materials, transport, services, design, money, and how well it is maintained.For families with less money, even a small increase in the price of materials or labor can make buying a house in a formal way very hard.Because of this, researchers, engineers, and government groups have looked into cheaper and more efficient ways to build homes.

Low-cost housing doesn't mean the house is bad quality.The goal is to make sure the home is safe, lasts long, is comfortable, and works well, but uses materials and labor efficiently.Costs can be cut down by planning the building well, reducing waste, using materials that are easily available nearby, choosing the right kinds of walls and roofs, using prefabricated parts, and using by-products from industries or farming when it makes sense.Srivastava and Kumar talked about low-cost housing techniques and focused on managing resources, using local materials, and building methods that can cut costs without lowering the performance of the home.

Varun Raj and others looked into sustainable low-cost materials and methods, and they mentioned things like bamboo, rice husk ash, agricultural waste, industrial waste, precast systems,and new technologies.This research paper creates a comparison based on published studies.So,this is a type of secondary data study.The authors don't claim tohave done new lab tests.Insteadthey look at published experiments and case studies to find patterns, chances, and challenges.

2. BACKGROUND AND NEED FOR LOW-COST HOUSING

In India, building methods range from traditional brick and concrete to prefabricated and industrialized systems.Traditional construction canbe trustworthy,butit uses a lot of cement, steel, fired bricks, aggregates,and workers.These materials cause environmental issues like using energy, creating emissions, and taking natural resources.At the same time, India produces a lot of agricultural and industrial waste.Things like fly ash from power plants, rice husk ash from farms, foundry sand from metal industries, coconut shells, and construction waste have all been studied for use in building.Using these wastes as raw materials can help reduce waste and the need for new resources.

Low-cost housing is also affected by the local climate and the availability of materials.A material that is cheap in one area might be expensive in another because of transport costs.Likewise, earth-based techniques can be great where there's good soil, but not so good if the soil needs to be brought in or treated a lot. So, the need isn't just for cheap materials.The real need is for a way to choose the best building methods based on cost, how well they work, how easy they are to get, how sustainable they are, and how easy they are to build.

3. PROBLEM STATEMENT

This research looks at the challenge of making affordable homes while still making sure they are safe, durable, comfortable, kind to the environment, and accepted by people. Many low-cost building methods are discussed separately in the literature, but their pros and cons are often explained using different standards.That's why a comparison is needed to help choose the best methods.

4. AIM AND OBJECTIVES

Aim: To compare selected low-cost housing materials and building methods forIndia using published research and a structured way to evaluate performance.

Objectives:

1.Find the main low-cost materials used in Indian housing.

2.Compare different wall, roof, and construction systems.

3.Look at published results on cost savings and material use.

4.Study environmental and energy-related aspects.

5.Examine things like temperature control, functionality, and social factors.

6.Identify the problems and barriers in using these methods.

7.Suggest specific recommendations for different situations.

5. RESEARCH QUESTIONS

Which materials could be useful for building affordable homes in India?

Which construction methods save money or use fewer materials?

How do the availability and transport of materials affect the choice of technology?

What technical, environmental, and social issues stop people from using these methods?

What research areas are still unclear before we can use these methods on a large scale?

6. SCOPE OF THE STUDY

This study looks at low-cost housing in India and considers materials and techniques that can be used for walls, roofs, structural parts, or prefabricated components.It includes fly ash products, CSEB, bamboo, agro-waste, recycled materials, lightweight blocks, ferrocement, rat-trap bond, filler slabs, and prefabrication or modular systems.

The study does not provide specific structural designs for buildings and does not replace the requirements of Indian Standards, building rules,or professional engineering.It is meant to be a comparison-based academic research.

7.RESEARCH METHODOLOGY

7.1 Research Design

A comparative secondary data research method was used.Published journal articles, conference papers, and scholarly studies were the main sources of information.The process involved identifying sources, extracting evidence, classifying technologies, comparing them, and interpreting the results.

7.2 Data Extraction

Information was collected under five main categories: material features, cost effects, environmental and resource impacts, construction ease, and limitations.Numerical results were kept as they were because different studies used different years, locations, building sizes, and cost assumptions.

7.3 Comparative Scoring

A five-point scale was created for qualitative analysis. A score of 1 means low potential and 5 means high potential for a specific criterion.These scores are not lab results or official standards but are based on the analysis of the reviewed data.Criterion Meaning Indicators considered

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 entirely comparable because costs change over time, and performance depends on material quality and construction practices.Therefore, this paper uses published numerical results as case-specific evidence and uses qualitative synthesis for broader comparisons.

8.REVIEW OF EXISTING RESEARCH

8.1 Low-Cost Housing Techniques

Srivastava and Kumar looked at methods for low-cost housing in India, focusing on efficient use of materials, local resources, and construction approaches [1].Their work shows that cost savings can happen at the component level rather than requiring a completely new building type.

8.2 Sustainable Materials

Varun Raj and others reviewed low-cost materials and techniques, identifying several waste and biomass materials as potential options for sustainable construction [2].

Their discussion also covers precast construction and new digital fabrication methods.

8.3 Rat-Trap Bond and Filler Roof Slab

Sinha and others studied rat-trap bond masonry and filler roof slabs in Bihar.Their results showed 26.11% cost savings for rat-trap bond masonry and 22.68% for the filler roof slab [3].These results show how efficient design of building components can reduce costs.

8.4 Earthen Construction and CSEB

Kulshreshtha and others examined the potential and current state of earthen materials for low-cost housing in rural India [4].Their work shows that technical suitability alone isn't enough; social image and user acceptance can greatly affect adoption.Compressed stabilized earth blocks offer a more standardized form of earthen construction when suitable soil and production quality are available.

8.5 Embodied Energy and Material Cost

Studies on Indian residential buildings have compared embodied energy and construction costs for alternative masonry materials.These studies show that the cheapest price doesn't always mean the lowest embodied energy.Material quantity, manufacturing process, and building layout all affect the outcome [5].

8.6 Waste-Derived Construction Materials

Arun and others looked at EPS, coconut shell, foundry sand, and fly ash as cost-effective options for low-income groups [6].Experimental research like this is important because using waste needs to be supported by testing strength, durability, and other relevant properties.

8.7 Regional and Emerging Technologies

Recent work on Assam-type houses examines traditional materials like bamboo, thatch, and mud, as well as newer materials like CSEB, fly ash bricks, agro-waste products, ferrocement, and hempcrete.The study also talks about prefabrication and 3D printing as future possibilities [7].

9.LOW-COST HOUSING MATERIALS

9.1 Fly Ash Bricks

Fly ash can be used to make masonry products like fly ash–lime–gypsum bricks.Singh and Garg studied fly ash bricks and hollow blocks for low-cost housing [8].Using these bricks helps make use of industrial by-products and reduces the need for some traditional masonry products.The quality of these bricks depends on controlling the mix, curing, and manufacturing process.

9.2 Compressed Stabilized Earth Blocks

CSEB is made by pressing suitable soil, often with a stabilizer.One big advantage is that it can use locally available soil, which reduces the need for transporting materials.CSEB can also make a more uniform block compared to loose earth construction.However, choosing the right soil, controlling moisture, stabilization, compaction, and curing are all important.

9.3 Bamboo

Bamboo is a renewable, lightweight material that has been used for a long time in parts of India.It can be used for structural frames, roofs, partitions, and other parts of a building if the right species are chosen, it is properly treated, connected, protected from moisture, and made safe from fire.

9.4 Rice Husk Ash and Agro-Waste

Agricultural waste like rice husk ash can be used in certain construction products.The main benefit for sustainability is recovering resources.However, the properties of the ash can change depending on how it is burned and processed, so it’s important to control quality.

9.5 Recycled and Industrial Waste

Materials like foundry sand, coconut shells, and construction waste have been studied as alternative materials.Whether they are useful depends on their particle size, contamination level, how they are processed, and what they are used for.

9.6 Lightweight Blocks

AAC and other lightweight blocks can reduce the weight of walls and can be installed quickly because they are larger.They may also affect how well a building keeps heat.However, when judging the environmental impact, it’s important to consider the energy used to make them and transport them.

9.7 Ferrocement

Ferrocement uses a thin layer of cement mixed with wire mesh.It can be useful for roofing and paneling.Its performance depends on how well it handles cracks, the skill of the workers, protection from corrosion, and the conditions it’s used in.

10.LOW-COST CONSTRUCTION TECHNIQUES

10.1 Rat-Trap Bond Masonry

Rat-trap bond masonry places bricks on their edges to create a hollow space inside the wall.Compared to a standard layout, this can use fewer bricks and mortar while keeping the wall thickness similar.The hollow space can also affect the building's ability to keep heat.A study in Bihar showed a 26.11% cost saving in the area studied [3].

10.2 Filler Slab

A filler slab uses non-structural filler units in parts of a reinforced concrete slab where concrete isn't needed for load-bearing.This can reduce the amount of concrete used and the weight of the structure.A case study in Bihar reported 22.68% cost savings [3].The structural design must decide the right reinforcement and concrete layout.

10.3 Optimized Brickwork

Improving the size of bricks, bond pattern, wall thickness, and placement of openings can reduce material waste.The main idea is to use materials only where they are necessary for structure or function.

10.4 Prefabrication

Prefabrication moves some construction work from the building site to a controlled factory environment.This can lead to more consistent results, less time on site, and less material waste.However, transporting the parts, lifting them, setting up the factory, and standardizing the process become important.

10.5 Modular Construction

Modular construction uses standard building sections that can be put together quickly.It works well when there is a lot of repetition and a large scale.Before using this approach, it's important to check if site access and transportation are possible.

10.6 Precast Components

Precast wall panels, beams, slabs, and other parts can reduce on-site labor and construction time.Quality control can be better, but the cost benefits depend a lot on the size of the project and how far the parts need to be transported.

10.7 Passive Design and Material Efficiency

How a building is oriented, shaded, ventilated, and designed for natural airflow and roof shape can lower the energy needed to operate it.These aspects are important because low-cost housing should balance both construction costs and long-term comfort.

11.COMPARATIVE DATA ANALYSIS

The table below shows some published results.The numbers given are specific to each situation and shouldn't be used as general prices for the market.

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 Screenin

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 shows that rat-trap bond and filler slab have good economic value in the right uses. CSEB and bamboo have good resource benefits but need attention to local conditions and acceptance.Lightweight and prefabricated systems are practical when there are industrial supply chains available

11.2 Interpretation of Comparative Results

The results show why low-cost housing should be looked at as a whole building system.A material that's cheap per unit might need more workers, transport or maintenance.On the other hand, a product that's more expensive to buy might save time and work.So, cost should be considered for the whole building process.

12.COST ANALYSIS

12.1 Material Cost

The cost of materials includes the price paid for bricks, blocks, cement, steel, aggregates, timber, bamboo, or other parts used in construction. Using materials from nearby areas can be more cost-effective if they don't need to be transported far.Materials made from waste, like fly ash or crushed concrete, can also be cheaper if they are processed close to where the building is being constructed.

12.2 Labour Cost

Using a method that uses less material but needs highly skilled workers might not be cost-effective for a small project in a rural area. On the other hand, using prefabricated parts can lower the need for workers on-site, but it requires workers and equipment in a factory.It's important to think about how much work can be done by workers and how much material is saved together.

12.3 Transportation

How materials are transported can greatly influence the total cost of building.Materials that are made locally, like soil, bamboo, or locally produced blocks, may be more cost-effective than those that have to be transported over long distances.Prefabricated parts also need careful planning for transport because they can be large and heavy.

12.4 Life-Cycle Cost

The initial cost of building is just one part of the total cost.Other costs, like fixing problems, replacing parts, and using energy over the time the building is used, also add up.It's often better to spend a little more on a durable material that doesn’t need to be replaced often instead of a cheaper one that needs frequent repairs.

13.ENVIRONMENTAL AND ENERGY ANALYSIS

13.1 Waste Utilization

Using materials like fly ash, rice husk ash, foundry sand, coconut shell, or recycled construction waste can help reduce the need for new raw materials if the technology is appropriate.This can also help prevent waste from being dumped.However, processing these materials uses energy, so this should be considered in an overall environmental evaluation.

13.2 Embodied Energy

Embodied energy is the total energy used to extract, process, make, and move materials.Studies on Indian homes have found that the energy used varies depending on the type of masonry materials and how the building is designed.This means that when comparing the environmental impact of different materials, the total amount of material used in the building should be considered.

13.3 Embodied Carbon

Choosing materials that use less cement, using the right amount of concrete, and using local or renewable materials can help reduce the carbon impact.However, the carbon performance should be based on real data from full life-cycle studies, not just on the type of material.

14.THERMAL AND FUNCTIONAL PERFORMANCE

14.1 Thermal Comfort

Thermal comfort is especially important in affordable housing since people may not have access to air conditioning.Factors like the properties of walls and roofs, shading, ventilation, building orientation, and window design all work together.Techniques like the rat-trap bond or earthen systems can offer good thermal performance if they are designed properly.

14.2 Structural Safety

Cutting costs should never mean removing important structural parts. When using alternative materials or systems, it's necessary to make sure they are designed properly, built correctly, and meet the required standards.Special attention is especially needed in areas that are prone to earthquakes, floods, cyclones, or high winds.

14.3 Moisture and Durability

Materials like earth, bamboo, and some waste-based products can be affected by moisture or damage from living things if they are not protected.Details like the base of the building, roof overhangs, drainage, surface treatments, and material treatments can all help make the building last longer.

15.SOCIAL AND PRACTICAL CONSIDERATIONS

15.1 User Acceptance

People's willingness to use a new material depends in part on how they see it.Earthen construction, for example, can be looked down on even if it performs well technically [4].Showing buildings that work, having good finishes, and proving the durability of the materials can help people feel more comfortable using them.

15.2 Skill Requirements

Techniques like the rat-trap bond, compressed stabilized earth blocks (CSEB), and bamboo systems need trained workers. Poor work can reduce the benefits and cause problems.Training and simple manuals can encourage more people to use these methods.

15.3 Local Employment

Making blocks or parts locally can create jobs and keep money in the community.However, it's important to have quality checks to make sure the locally made materials meet the required standards.

15.4 Institutional Support

Government agencies, research institutions, and professional groups can help spread new building technologies through demonstration projects, training, guidelines, and standards.When institutions support a new technology, builders and homeowners are more likely to try it out.

16.APPLICATION-SPECIFIC RECOMMENDATIONS

Situation Potential Technologies Main Conditions Rural area with suitable soil CSEB, stabilized earth Soil availability, moisture protection, trained labor 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 are general suggestions.The final choice of technology should be based on site inspection, structural design, local costs, building codes, material testing, and a proper engineering review.

17.LIMITATIONS

This study is based on existing research rather than new experiments. Because of this, the paper cannot claim original measurements for strength, thermal comfort, or durability.

The studies reviewed were done in different places, at different times, with different building sizes, materials, and economic assumptions. Direct numerical comparisons are therefore limited.

The qualitative scores are meant for academic comparison and have not been statistically validated. They should not be considered as official ratings. Some new technologies have limited long-term field data in Indian conditions. Their inclusion in this study shows research potential rather than guaranteed performance.

18.FUTURE SCOPE

Future research should create standardized Indian datasets for material cost, embodied energy, embodied carbon, and service life. These datasets would help compare technologies better across different states and climates.

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

Future experiments should combine structural testing with life-cycle assessment. Small-scale wall and roof samples made using two or more alternative systems could be tested for strength, thermal response, material use, cost, and environmental impact. Digital tools like BIM, automated quantity estimation, modular design, and 3D printing should be evaluated under realistic Indian conditions, including labour, transport, and supply chain factors.

19. CONCLUSION

This research paper looks at affordable building materials and methods for housing in India, based on published studies.

It shows that the cost of building isn't just about how much each material costs.You also need to consider how much material is used, the labor involved, transportation, how long it takes to build, how much maintenance is needed, how long the building lasts, and how it affects the environment.

Published studies back up some of the methods discussed. In a study of Bihar, rat-trap bond masonry saved 26.11% on construction costs, and filler roof slabs saved 22.68% compared to traditional methods [3].Other studies show promise with CSEB, fly ash products, bamboo, agro-waste, lightweight blocks, and prefabricated systems.

The framework used in this research suggests that rat-trap bond and filler slabs are good choices for low-rise buildings where skilled workers and proper design are available. CSEB and bamboo could be great options in places where local materials and good environmental conditions are present.Lightweight blocks and prefabricated systems might be ideal for projects that have strong industrial supply chains.

The main takeaway is that there's no single cheapest or best way to build affordable housing. The best solution depends on the region and factors like climate, availability of materials, transportation, design needs, skills, durability, maintenance, and how much people accept the solution.Affordable housing should be seen as a full design and building strategy that keeps costs down without cutting corners on safety, quality, or long-term performance

Academic integrity note: Numerical results are presented as findings extracted from cited published studies. The comparative scores are the student researchers’ analytical synthesis.No laboratory experiment or field survey is claimed to have been conducted by the five authors.

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