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Low Cost Housing in India: A Review of Sustainable Materials and Construction Methods

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Abstract:

India faces a significant housing shortage, with an estimated urban housing deficit of over 18 million units. Low-cost housing has emerged as a critical area of research and practice, aiming to provide affordable, durable, and sustainable shelter to economically weaker sections and low-income groups. This review paper examines the various sustainable materials and construction methods employed in low-cost housing across India. The study evaluates traditional materials such as stone, brick, timber, and bamboo alongside modern alternatives including fly ash bricks, autoclaved aerated concrete (AAC) blocks, compressed earth blocks (CEB), geopolymer concrete, prefabricated panels, and recycled construction and agricultural waste materials such as rice husk ash and sugarcane bagasse ash. Construction methods reviewed include filler slab technology, precast and prefabricated construction, 3D printing, and incremental housing approaches. The paper also discusses the role of government initiatives such as Pradhan Mantri Awas Yojana (PMAY), the Global Housing Technology Challenge (GHTC-India), and the Building Materials and Technology Promotion Council (BMTPC) in promoting affordable housing. The findings indicate that strategic selection of locally available materials, combined with modern construction techniques, can reduce housing construction costs by 20-40% while maintaining structural integrity and durability.

Keywords: bamboo reinforcement, compressed earth blocks, fly ash bricks, geopolymer concrete, low-cost housing, prefabricated construction, sustainable construction materials

1. INTRODUCTION

Housing is a fundamental human need and a key indicator of socio-economic development. In India, the demand for affordable housing has grown rapidly due to urbanisation, population growth, and migration from rural to urban areas. According to the Ministry of Housing and Urban Affairs (MoHUA), India faces an urban housing shortage of approximately 18.78 million units, with the majority of the deficit concentrated in the economically weaker sections (EWS) and low-income groups (LIG) [1]. The situation in rural areas is equally concerning, with millions of families still living in kutcha (temporary) houses lacking basic amenities.

Traditional construction methods, which predominantly rely on conventional materials such as cement, steel, and fired clay bricks, are increasingly becoming unaffordable for a large segment of the population. The cost of cement and steel has risen significantly over the past decade, increasing by more than 60% in the last five years alone [2]. Additionally, conventional construction practices contribute to environmental degradation through excessive energy consumption, carbon emissions, and depletion of natural resources such as river sand and topsoil for brick manufacturing.

Low-cost housing, also referred to as affordable housing, aims to address these challenges by optimising the use of locally available materials, adopting innovative construction techniques, and incorporating sustainable practices that reduce both construction cost and environmental impact [3]. The concept extends beyond merely reducing material cost; it encompasses holistic approaches that include efficient design, waste minimisation, energy-efficient construction, and the use of industrial and agricultural by-products as building materials.

The Government of India has launched several initiatives to promote affordable housing, most notably the Pradhan Mantri Awas Yojana (PMAY) launched in 2015 with the aim of achieving “Housing for All” by 2024. Under PMAY-Urban and PMAY-Gramin, millions of housing units have been constructed using alternative materials and technologies [4]. The Global Housing Technology Challenge (GHTC-India), initiated in 2019, has further accelerated the adoption of innovative construction technologies by identifying and demonstrating Light House Projects (LHPs) across different cities in India [5].

This paper presents a comprehensive review of sustainable materials and construction methods suitable for low-cost housing in India. The study examines both traditional and modern materials, evaluates their properties, cost-effectiveness, and suitability for different geographic and climatic conditions, and discusses the policy framework supporting affordable housing development.

2. REVIEW METHODOLOGY

This review paper follows a systematic approach to identify, evaluate, and synthesise existing literature on low-cost housing materials and construction methods. A comprehensive search of published literature was conducted using databases including ScienceDirect, Springer, ResearchGate, Google Scholar, and Scopus. Search terms included “low-cost housing India,” “affordable construction materials,” “sustainable building techniques,” “fly ash bricks,” “geopolymer concrete housing,” “bamboo construction,” “prefabricated housing India,” and “compressed earth blocks.”

Studies published between 2015 and 2025 were prioritised, although seminal earlier works were also included. The review encompasses journal articles, conference papers, government reports, and technical publications from organisations such as BMTPC, the Bureau of Indian Standards (BIS), and Indian academic institutions. The reviewed materials and methods were evaluated based on cost reduction potential, structural performance, durability, environmental sustainability, local availability, ease of construction, thermal comfort, and compliance with relevant Indian Standards (IS codes).

3. SUSTAINABLE BUILDING MATERIALS FOR LOW-COST HOUSING

Sustainable building materials play an important role in developing affordable and environmentally responsible housing. For low-cost housing, materials should be economical, locally available, durable, energy-efficient, and require minimal maintenance. The use of locally sourced materials can reduce transportation costs and associated carbon emissions while also supporting local employment and construction practices.

Materials such as stabilized mud blocks, compressed earth blocks, fly-ash bricks, hollow concrete blocks, bamboo, recycled aggregates, and agricultural waste-based materials can provide alternatives to conventional construction materials. Compressed earth blocks and stabilized soil blocks, for example, can reduce the dependence on energy-intensive fired bricks and may provide adequate thermal insulation when properly designed. Fly-ash bricks make use of an industrial by-product and generally require less energy during production than traditional clay bricks.

Natural and renewable materials such as bamboo, timber from responsibly managed sources, and agricultural-fibre boards can also be used for structural or non-structural applications where appropriate. Recycled materials, including recycled aggregates from construction and demolition waste, can reduce the consumption of natural resources and the amount of waste sent to landfills. However, their suitability depends on factors such as strength, durability, moisture resistance, fire safety, and local building regulations.

For low-income communities, the sustainability of a material should not be assessed only on its initial purchase price. Life-cycle cost, availability, transportation, construction skills, maintenance requirements, durability, and end-of-life recyclability should also be considered. A material with a slightly higher initial cost may be more economical over time if it reduces energy consumption and maintenance expenses.

Therefore, the selection of sustainable materials for low-cost housing should follow a locally appropriate and life-cycle-based approach. Combining affordable materials with passive design strategies—such as proper orientation, natural ventilation, shading, and thermal insulation—can further reduce operational energy requirements while improving indoor comfort. This approach can contribute to housing that is not only affordable to construct but also economical, resilient, and environmentally sustainable over its entire life cycle.

4. Traditional Materials

Stone: Stone masonry has been used in Indian construction for centuries, particularly where natural stone is available in abundance such as Rajasthan, Gujarat, Karnataka, and parts of Maharashtra. Stone offers excellent compressive strength (60-200 MPa depending on type), durability, and thermal mass. Local varieties such as sandstone, limestone, granite, and basalt can be used for foundations, walls, and flooring. The principal advantage is availability at or near the construction site, eliminating transportation cost [6]. However, stone masonry requires skilled labour for dressing and fitting, which can raise cost where masonry expertise is limited.

Bricks: Fired clay bricks remain the most widely used building material in Indian construction. Standard bricks (190 x 90 x 90 mm per IS 1077) have compressive strength ranging from 3.5 to 35 MPa depending on class [7]. While conventional bricks are affordable, their production involves topsoil depletion and significant carbon emissions from kiln firing. Alternative brick technologies described later address these environmental concerns while maintaining cost-effectiveness.

Timber: Timber is a traditional building material used for structural framing, doors, windows, roofing, and flooring. Species such as sal, teak, deodar, and shisham are commonly used. Timber offers an excellent strength-to-weight ratio, thermal insulation, and aesthetic appeal. However, concerns about deforestation, rising cost, and susceptibility to termite damage have necessitated the exploration of engineered wood products and alternative structural materials [8].

Bamboo: Bamboo is one of the most promising sustainable building materials for low-cost housing in India. India has an estimated bamboo growing area of 15.69 million hectares with an annual production of approximately 3.23 million tons [9]. Bamboo possesses remarkable mechanical properties, with tensile strength comparable to steel (150-200 MPa) and compressive strength of 40-80 MPa. It is lightweight and renewable, with a growth cycle of 3-5 years compared to 20-30 years for timber, and it sequesters significant carbon during growth.

Bamboo has been traditionally used in construction in the northeastern states of India, Assam-type houses, and in various rural housing programmes. Modern engineering applications include bamboo-reinforced concrete, bamboo-composite panels, treated bamboo structural framing, and bamboo-based roofing systems [10]. Recent studies demonstrate that bamboo-reinforced geopolymer concrete panels exhibit adequate structural performance while being significantly more sustainable than conventional reinforcement [11].

Mud and Earth: Mud construction, including adobe, rammed earth, and cob, represents one of the oldest and most cost-effective building traditions. Stabilised earth blocks, treated with small quantities of cement (5-8%) or lime, offer improved strength and water resistance while retaining the low-cost and thermal comfort advantages of earth construction. The compressive strength of cement-stabilised earth blocks typically ranges from 3-10 MPa, sufficient for load-bearing wall construction in low-rise buildings [12].

5. Modern Alternative Materials

Fly Ash Bricks: Fly ash, a by-product of coal combustion in thermal power plants, has emerged as a transformative material for low-cost housing. India generates more than 300 million tons of fly ash annually, making it one of the largest producers of this industrial waste globally [13]. Fly ash bricks are manufactured by mixing fly ash with lime, gypsum, and water, followed by compaction and curing. They offer compressive strength of 7-15 MPa comparable to Class I clay bricks, uniform dimensions, lower water absorption (12-16% versus 20-25%), higher thermal insulation, weight reduction of 20-30%, avoidance of topsoil depletion, and cost savings of 15-25%. The Indian government has mandated fly ash use in construction within specified distances of thermal power plants, creating a robust supply chain [14].

Autoclaved Aerated Concrete (AAC) Blocks: AAC blocks, manufactured using fly ash, cement, lime, aluminium powder, and water, are lightweight cellular concrete blocks cured under high-pressure steam. Key characteristics include density of 450-750 kg/m3, compressive strength of 3-5 N/mm2, thermal conductivity of 0.16-0.21 W/mK, fire resistance up to 4 hours, and sound insulation with an STC rating of 40-45. The larger block sizes reduce joints, accelerate construction, and cut mortar consumption by up to 50%. Although unit cost is slightly higher than conventional bricks, overall wall construction cost is comparable or lower [15].

Compressed Earth Blocks (CEB): CEBs are manufactured by compressing a mixture of soil (typically with 6-10% cement stabilisation), water, and sometimes aggregates using a manual or hydraulic press, then curing for 7-28 days. CEBs offer compressive strength of 2-10 MPa, very low embodied energy, use of locally available soil reducing transport cost, thermal mass advantages, and cost savings of 30-50%. CEB construction has been successfully demonstrated in projects across India, including those supported by Habitat for Humanity and BMTPC [16].

Geopolymer Concrete: Geopolymer concrete, first developed by Davidovits in 1988, replaces Portland cement with aluminosilicate-rich materials such as fly ash, ground granulated blast-furnace slag (GGBS), or metakaolin activated by alkaline solutions (typically sodium hydroxide and sodium silicate) [17]. Key advantages include a 40-80% reduction in CO2 emissions, compressive strength of 20-60 MPa, excellent chemical and fire resistance, and utilisation of industrial waste with potential cost savings of 15-30%. Recent research has demonstrated the viability of fly ash-based geopolymer concrete for rural construction in India [18]. The Bureau of Indian Standards has issued IS 16714:2018 for geopolymer concrete mix design.

Recycled Construction and Demolition Waste: India generates approximately 150 million tons of construction and demolition (C&D) waste annually, of which only a small fraction is currently recycled [19]. Recycled concrete aggregate (RCA), produced by crushing demolition waste, can replace natural coarse aggregate partially or fully in concrete. Studies show that concrete with 20-30% RCA replacement achieves compressive strength comparable to conventional concrete while reducing material cost and environmental impact.

Agricultural Waste Materials: India's agricultural sector generates substantial waste that can be valorised as building materials. Rice husk ash (RHA), containing 85-98% silica, serves as a pozzolanic material that can partially replace cement by 10-20% [20]. Sugarcane bagasse ash (SCBA) has similar pozzolanic properties, with studies showing compressive strength improvements of 15-25% [21]. Coconut coir and natural fibres reinforce concrete and earth construction, improving tensile properties and reducing cracking.

6. Prefabricated and Modular Materials

Precast Concrete Panels: Precast concrete elements manufactured in factory-controlled conditions offer consistent quality, reduced construction time, and lower on-site labour requirements. Precast wall panels, floor slabs, and roof elements are assembled on-site using bolted or welded connections. The Global Housing Technology Challenge has demonstrated precast technology in building approximately 1,000 housing units in Light House Projects across six cities in India [5].

Glass Fibre Reinforced Gypsum (GFRG) Panels: GFRG panels provide panel thickness of 12-35 mm, flexural strength of 15-25 MPa, fire resistance up to 3 hours, construction speed 3-4 times faster than conventional masonry, and weight reduction of 60-70% compared to brick walls. They have been used in India's LHP projects.

Modular and Container Homes: An emerging concept is the conversion of decommissioned shipping containers into habitable living spaces, leveraging the structural integrity of steel containers while minimising additional structural material. Although still nascent in India, container homes have shown potential for rapid deployment in disaster relief and temporary housing.

7. CONSTRUCTION METHODS FOR LOW-COST HOUSING

Filler Slab Technology: Filler slab is a cost-effective roofing technique that replaces non-structural concrete in the tension zone of a slab with lightweight filler materials such as clay pots, bamboo mats, expanded polystyrene (EPS) blocks, or coconut shells [22]. This reduces concrete consumption by 20-30% and the dead load, resulting in cost savings of 15-25% on slab construction, reduced steel reinforcement, and improved roof thermal insulation. Filler slab technology has been widely promoted by BMTPC and used in thousands of housing units across India.

Precast and Prefabricated Construction: Modern methods of construction (MMC) using prefabricated components offer construction time reduced by 50-70%, factory quality control, on-site labour reduced by 30-50%, and material wastage reduced to 10-15%. The six Light House Projects under GHTC-India have demonstrated alternative technologies including tunnel form technology, precast framed structure, foldable technology, plastic/composite materials, and 3D printed construction [5].

3D Printing in Construction: 3D printing (additive manufacturing) is a revolutionary approach in which robotic extrusion of concrete forms structural elements layer by layer. Advantages include construction cost reduction of up to 30-50%, construction speed permitting a basic house shell in 24-48 hours, minimal material wastage, and design flexibility. India's first 3D printed house was demonstrated at IIT Madras Research Park [23].

Incremental Housing: Incremental housing provides basic, structurally sound units that residents expand as their financial situation allows. Successfully implemented in projects such as the Bawana Housing Project in Delhi, the initial unit provides essential living space (typically 25-40 m2) with foundations designed for additional floors, extended utility provisions, and expandable wall layouts [4].

8. COST COMPARISON AND ANALYSIS

The review indicates that material substitution alone can reduce construction cost by 15-25%, while the integration of innovative methods such as prefabrication, filler slabs, and 3D printing can further reduce cost by 15-30%. The combined effect of material substitution and construction method optimisation achieves overall cost reductions of 20-40% compared to conventional RCC construction.

9. GOVERNMENT POLICIES AND INITIATIVES

Pradhan Mantri Awas Yojana (PMAY): Launched in 2015, PMAY aims to provide "Housing for All" through PMAY-Urban (PMAY-U) and PMAY-Gramin (PMAY-G). The scheme provides interest subsidies, credit-linked subsidies, and direct assistance for construction of pucca houses for EWS and LIG families, and has been instrumental in promoting alternative materials and technologies through its technology sub-mission [4].

Global Housing Technology Challenge (GHTC-India): Launched in 2019 under PMAY-U, GHTC-India identifies and mainstreams innovative, sustainable, and disaster-resilient construction technologies. The six Light House Projects demonstrate these methods at scale, serving as live laboratories for technology validation and worker skilling [5].

Building Materials and Technology Promotion Council (BMTPC): BMTPC, under the Ministry of Housing and Urban Affairs, is the apex body for promoting appropriate building materials and technologies. Its functions include developing performance standards, technology transfer and demonstration, training of engineers and workers, preparation of the Vulnerability Atlas of India, and promotion of disaster-resistant and sustainable construction.

Bureau of Indian Standards (BIS) Codes: Relevant Indian Standards for low-cost housing materials include IS 1077 (clay bricks), IS 12894 (fly ash lime bricks), IS 2185 (concrete masonry units), IS 1725 (stabilised soil blocks), IS 16714 (geopolymer concrete), IS 456 (plain and reinforced concrete), and IS 13311 (non-destructive testing of concrete).

National Building Code of India (NBC): The NBC 2016 provides comprehensive guidelines including provisions for alternative materials and technologies through performance-based specifications that allow innovative solutions to be incorporated in building design and construction.

10. RESULTS AND DISCUSSION

The review findings demonstrate that modern alternative materials such as fly ash bricks, AAC blocks, and CEBs provide adequate structural performance for low-rise housing. Fly ash bricks achieve compressive strengths comparable to Class I clay bricks, while AAC blocks provide superior thermal insulation contributing to long-term energy savings. Geopolymer concrete has achieved strengths comparable to conventional OPC concrete while reducing carbon emissions by 40-80%.

Despite the promising potential, several challenges persist: lack of awareness and acceptance among builders and homeowners; skilled labour shortage for innovative methods; the need for robust quality control and manufacturing standards; nascent supply chains for alternative materials; inconsistent implementation of regulatory codes at the local level; and reluctance of financial institutions to lend for non-conventional construction. Recommendations include integration of alternative material specifications in building bylaws, expansion of training programmes, strengthening of quality control through third-party certification, increased research funding, and public awareness campaigns.

11. CONCLUSION

This review demonstrates that significant cost reductions of 20-40% are achievable in low-cost housing through strategic material selection and innovative construction techniques. Traditional materials such as stone, brick, bamboo, and earth continue to offer viable low-cost solutions when combined with appropriate engineering and modern treatment technologies. Modern alternatives including fly ash bricks, AAC blocks, CEBs, geopolymer concrete, and agricultural waste materials provide enhanced performance while addressing environmental sustainability.

The convergence of government policy support (PMAY, GHTC-India), institutional capacity building (BMTPC, BIS), and technological innovation creates a favourable ecosystem for the widespread adoption of low-cost housing. Realising the full potential requires addressing challenges related to awareness, skilled labour, quality control, and regulatory implementation. Future research should optimise material combinations for specific regions, develop standardised construction protocols, and conduct life-cycle cost analyses.

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13. AUTHOR CONTRIBUTIONS

Shambhuraje Sarjerao Thorat: Conceptualisation, literature review, drafting of the original manuscript, and analysis and interpretation of reviewed data.

Vaibhav Rajkumar Mali: Literature search and screening, review and editing of the manuscript, data compilation, and table preparation.

Both authors have read and approved the final version of the manuscript.

14. CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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