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ABSTRACT

Low-cost housing is a critical issue in India, as many people cannot afford to buy or rent a home. This research paper explores the use of low-cost construction techniques and local materials to provide affordable housing solutions for low-income communities. The paper begins by defining low-cost housing and discussing the challenges faced by middle and lower-income groups in attaining home ownership. It then identifies opportunities for cost reduction through technology integration and the reuse of waste materials as building materials. Preliminary findings indicate that by incorporating filler slabs as an alternative to conventional slabs, construction costs can be reduced by up to 25%. Moreover, ongoing studies are exploring the potential reuse of waste materials such as fly ash and rice husk as building materials, which could further minimize construction costs. Establishing cooperatives to supply these alternative raw materials locally instead of importing them from distant sources can potentially reduce costs by an additional 20 to 30%. The paper concludes by discussing the benefits of low-cost construction techniques and the utilization of local resources. The findings will assist policymakers, developers, and stakeholders in identifying practical strategies for providing affordable housing solutions to low-income communities. By embracing innovative and sustainable approaches, it is possible to address the pressing need for affordable housing in India while simultaneously promoting economic growth and environmental stewardship.

Keywords- Affordability, Construction cost reduction, India, Local materials, Low-cost housing, Predetermined building methodologies, Sustainability, Waste material reuse

INTRODUCTION

A crucial aspect of leading a healthy life is having a suitable place to reside throughout one's lifetime, commonly known as home. However, the current situation in India indicates a significant inadequacy in terms of the types and numbers of available homes, as reported by the Ministry of Housing and Urban Poverty Alleviation, Government of India. India's population has grown by 1.64% annually over the past decade, surpassing the world's population growth rate of 1.23%, there is an imminent need to address the increasing demand for housing in the coming years. Several studies have examined the impact of low-cost housing methods in India. For instance, Wardlaw et al. conducted a study in urban slums and found that the implementation of cost-effective construction techniques led to improved living conditions, enhanced social well-being, and reduced housing vulnerabilities [1]. Similarly, Warrior, A.G, et al., explored the impact of low-cost housing initiatives on poverty reduction and economic development, highlighting positive outcomes such as increased income generation and improved livelihood opportunities [2]. Low-cost housing methods offer numerous advantages. Mansour et al. discussed the benefits of incorporating eco-friendly and sustainable materials in low-cost housing construction, such as improved thermal insulation, reduced energy consumption, and enhanced environmental sustainability [3]. Additionally, Tam et al. emphasized the cost advantages of utilizing local materials and labor-intensive techniques, which can significantly lower construction expenses and make housing more affordable for low-income populations [4]. While low-cost housing methods show promise, they are not without challenges. Goebel et al., identified several obstacles, including limited access to finance, inadequate infrastructure, land tenure issues, and

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regulatory constraints. These challenges often hinder the scalability and sustainability of low-cost housing initiatives, requiring innovative approaches and policy interventions to overcome them [5]. The concept of sustainable development plays a crucial role in the evaluation of low-cost housing methods. Raj, PV et al, examined the relationship between low-cost housing and sustainable development, emphasizing the need for integrated approaches that consider social, economic, and environmental dimensions. They argued that sustainable low-cost housing should aim for energy efficiency, waste management, and community engagement to ensure long-term viability [6]. Numerous case studies provide insights into successful low-cost housing projects in India. For instance, Ferrar et al. analyzed the Mahindra World City in Chennai, which employed innovative construction techniques, community participation, and partnerships to create affordable housing solutions [7]. Similarly, Jasvi et al. studied the Dharavi Redevelopment Project in Mumbai, highlighting the significance of participatory planning, sustainable design, and livelihood integration for achieving effective low-cost housing outcomes [8]. Low-cost housing is a critical need in India, as the country faces a shortage of affordable housing units. The Pradhan Mantri Awaas Yojana (PMAY) aims to provide housing to all citizens by 2022, but this will require the use of alternative building materials that are sustainable and affordable. Conventional building materials like steel, cement, and wood are not sustainable, as they require a significant number of natural resources and emit harmful pollutants during manufacturing. There is a need to explore alternative materials that are locally available, easy to work with, and have a low environmental impact. Some promising alternative materials include straw, bamboo, fibers, and earth. These materials were used in traditional construction in India, and they offered several advantages. They are locally available, easy to work with, and can be used to construct strong and durable structures. In addition to traditional materials, several industrial waste materials are used in low-cost housing. These materials, such as fly ash and rice husk, have pozzolanic properties that make them excellent substitute materials for cement. The use of alternative building materials in low-cost housing is not without challenges. There is a lack of codal guidelines, technology transfer, and manufacturing facilities for these materials. However, there is a growing interest in the use of alternative materials, and there have been some pilot projects to assess cost reduction. As India's population continues to grow, the need for affordable housing will become even more pressing. The use of alternative building materials is a promising way to address this need, while also protecting the environment. When focusing on low-cost walling and roofing solutions, significant savings of up to 26.11% and 22.68% were achieved, respectively. Additionally, using alternative building materials can help to reduce construction costs. Locally available materials can help to mitigate transportation costs, which typically account for about 30% of the overall construction budget.

Significance of Planning

This section outlines the incorporation of specific modifications and concepts during the structural planning process. These considerations aim to achieve affordable housing objectives by adopting various methodologies and technologies. Some of the alternatives that can be adopted in real-time construction –

- Employing the thinner wall concept, specifically utilizing 15 cm thick solid concrete block walls, to effectively reduce the plinth area.
- Introducing innovative alternatives to burnt bricks, such as locally available soil cement blocks, as a sustainable building material.
- Promoting the adoption of energy-efficient materials, such as concrete blocks instead of burnt bricks, to minimize energy consumption in construction.
- Encouraging the use of eco-friendly materials as substitutes for conventional building components, such as replacing wooden frames with R.C.C. (Reinforced Cement Concrete) door and window frames.
- Incorporating a comprehensive preplanning approach and streamlining the design process to optimize the size of building components and reduce wastage.
- Conducting thorough planning for each component of a house to avoid unnecessary material wastage caused by the demolition of unplanned elements.

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- Evaluating the usability of each component in the house and eliminating any unnecessary components to enhance efficiency and reduce costs.

Strategies for Achieving Cost Effectiveness

When focusing on low-cost walling and roofing solutions, significant savings of up to 26.11% and 22.68% were achieved, respectively. Additionally, using alternative building materials can help to reduce construction costs. Locally available materials can help to mitigate transportation costs, which typically account for about 30% of the overall construction budget.

Approaches

The following are environmentally-friendly material technologies that are suitable for low-cost housing:

- ***Lime-Sand Brick:*** Lime-sand bricks, made by combining lime, sand, and a small amount of cement, offer a sustainable alternative. They provide good thermal insulation and are environmentally friendly due to the reduced carbon emissions during production.
- ***Cement-Waste Slag Brick:*** Utilizing waste slag from industries as an ingredient in cement bricks reduces waste and promotes recycling. These bricks exhibit strength and durability while contributing to sustainable construction practices.
- ***Concrete Hollow Block:*** These are made from a mixture of cement, sand, and aggregate, and are an economical and eco-friendly choice. Their hollow design allows for effective thermal insulation and reduces overall material usage.
- ***Decorative Concrete Block:*** Incorporating aesthetics into low-cost housing, decorative concrete blocks offer visually appealing options. They can be manufactured using sustainable materials and techniques, contributing to both environmental and architectural considerations.
- ***Lightweight Concrete Block:*** Lightweight concrete blocks, created by using lightweight aggregate materials, possess excellent insulating properties. These blocks reduce the overall weight of the structure, resulting in cost savings and energy efficiency.
- ***Concrete Paving Block:*** Concrete paving blocks, made from cement, aggregate, and color pigments, provide durable and sustainable surfacing solutions for pathways and driveways. They offer easy installation, maintenance, and a visually pleasing appearance.
- ***Wall Plaster:*** Utilizing environmentally friendly wall plaster materials, such as lime or clay-based plasters, enhances indoor air quality and reduces the carbon footprint. These plasters offer a natural and breathable finish to the walls.
- ***Paint for Interior and Exterior Walls:*** Choosing low-volatile organic compound (VOC) paints for interior and exterior walls reduces the emission of harmful chemicals into the environment. These eco-friendly paints enhance indoor air quality and contribute to a healthier living environment.

By adopting these eco-friendly materials, low-cost housing in India can be developed sustainably and responsibly.

METHODOLOGY

The adoption of prefabrication and partial prefabrication techniques in construction has gained momentum due to their ability to expedite the building process, enhance component quality, and yield savings in material quantities and costs. This approach involves utilizing specific construction methods and materials for walls and roofs that can be repeatedly employed. Further details regarding these techniques and materials are described below.

Reviewing Various Techniques Employed in Modifying Design and Materials Usage

Eco-Friendly Wall Panels

There are many different materials used to construct walls, including rammed earth, bricks, soil cement blocks, hollow clay blocks, and concrete blocks. Bricks are a common building material, but the practice of breaking them to fit on-site can lead to waste. One way to address this issue is to produce low-density, larger-sized wall blocks made from industrial waste materials like blast furnace slag and fly ash. This can lead to economic benefits by

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reducing construction time and mortar use. While some prefabrication techniques have been developed for walls, medium and large panel techniques be not cost-effective for low-rise buildings when compared to traditional brickwork.

Non-Erodable Mud Plaster Technology

Mud walls are susceptible to erosion during rainfall, which can lead to costly annual repairs. One solution is to apply a bitumen cutback emulsion to the wall surface. This emulsion is a mixture of hot bitumen and kerosene oil, and it is blended with mud mortar and wheat/rice straw. The resulting mortar is applied to the wall in a thickness of 12 mm. After the plaster dries, one or two coats of mud cow dung slurry mixed with cutback are applied for added protection and durability. This approach can help to reduce maintenance costs and extend the lifespan of mud walls, Fig. 1.

Figure 1: *Mud-plastered house.*

Fly-Ash - Sand Lime – Bricks

Fly ash sand lime bricks are made by mixing lime and fly ash with water. The reaction between lime and fly ash creates a compound with cementitious properties. This compound, which is composed of calcium silicate hydrates, gives the bricks their high strength. These chemically bonded bricks are made using a hydraulic press and dried in an autoclave. They have several advantages over clay bricks, including adequate crushing strength, uniform shape, and smooth finish, which eliminate the need for plastering. Additionally, they are lighter in weight than ordinary clay bricks, Fig. 2.

Figure 2: *Fly ash lime blocks.*

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Solid Concrete and Stone Blocks

The solid concrete & stone block is apt for regions, where stones and aggregates required for block production are locally available at lower costs. This approach involves innovative methods that incorporate lean concrete and stones in the production of walls. A gang-mold has been developed to facilitate the semi-mechanized production of these blocks, enabling faster manufacturing processes, Fig. 3.

Figure 3: *Solid concrete block.*

Floors & Roofs

Use of Voided Filler Slab Technology

A filler slab utilizes a reusable material to provide an advantage over RCC (Reinforced Cement Concrete) slabs [9, 10]. Filler slabs are a simple and innovative approach to roof construction that is commonly used in southern India. These slabs use a filler material, such as Mangalore tiles or coconut shells, to replace the concrete in the tension zone of the slab. This reduces the amount of concrete required, which can save costs and reduce the dead load of the roof. Filler slabs can also improve the thermal performance of the roof and reduce carbon emissions. The type and size of the filler material must be determined before finalizing the slab design. This is because the filler material affects the slab depth and reinforcement spacing. The filler material should also be soaked in water before use to prevent it from absorbing water from the concrete, Fig. 4.

Figure 4: *Filler slab system.*

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Roof - Brick Panels

Brick Panel Roofing is a construction technique developed by the Central Building Research Institute (CBRI) in Roorkee. It is a cost-effective and efficient way to build roofs, and it can save up to 20-25% in concrete and 25-35% in total slab costs. The roof is made up of brick panels that are reinforced with mild steel bars. The panels are typically 1200 mm long, 530 mm, wide, and 75 mm thick. The gaps between the bricks are filled with cement mortar [11]. The advantages of Brick Panel Roofing include:

- *Cost Savings:* The technique can save up to 20-25% in concrete and 25-35% in total slab costs.
- *Reduced Construction Time:* The panels can be mass-produced in a factory, which can reduce construction time.
- *Efficiency:* The technique is a more efficient way to build roofs than traditional methods.

The disadvantages of Brick Panel Roofing include:

- The panels are relatively heavy, which can make them difficult to transport and install.
- The panels must be reinforced with mild steel bars, which can increase the cost of the roof.

Overall, Brick Panel Roofing is a cost-effective and efficient way to build roofs. It can save up to 20-25% in concrete and 25-35% in total slab costs. However, the panels are heavy and require reinforcement, which can increase the cost of the roof, Fig. 5.

Figure 5: *Brick panels.*

Flat-Slab System

Flat slab systems are a type of reinforced concrete floor system that is characterized by a slab that is supported directly by columns, without the use of beams. This type of system has several advantages, including:

- *Reduced Material Costs:* Flat slabs require less concrete and steel than conventional floor systems, which can lead to significant cost savings.
- *Shorter Construction Time:* Flat slabs can be constructed more quickly than conventional floor systems, which can also save money.
- *Greater Flexibility in Design:* Flat slabs offer more flexibility in terms of room layout and column spacing, which can be beneficial for architects and engineers.

As a result of these advantages, flat slab systems are often considered to be more cost-effective than conventional floor systems. However, there are also some disadvantages to flat slab systems, including:

- *Increased Deflections:* Flat slabs are more likely to deflect than conventional floor systems, which can be a problem in some applications.
- *More Complex Design and Detailing:* Flat slab systems require design that more

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complex and detailing than conventional floor systems, which can lead to higher engineering fees.

Overall, flat slab systems can be a cost-effective choice for floor systems in certain applications [12]. However, it is important to weigh the advantages and disadvantages of this type of system before making a decision.

In addition to the cost savings mentioned above, flat slab systems can also lead to other economic benefits, such as:

- *Reduced Energy Costs:* Flat slabs can help to reduce energy costs by improving the thermal performance of the building.
- *Increased Occupant Comfort:* Flat slabs can provide a more comfortable environment for occupants by reducing noise and vibration levels.
- *Improved Fire Safety:* Flat slabs can help to improve fire safety by providing a more robust structural system.

Overall, flat slab systems can offer some economic benefits in addition to cost savings. These benefits can make flat slab systems a wise choice for many types of buildings Fig. 6.

Figure 6: *Flat slab system.*

Materials Used in Affordable Housing Solutions

Low-cost housing materials can be categorized into two main types: natural materials and fabricated materials.

- Natural materials are those that are derived from nature, such as bagasse, rice husk, banana leaves, and coconut husk. These materials are readily available and have great potential for use in construction. They are also often more environmentally friendly than synthetic materials.
- Fabricated materials are those that are made from processed materials, such as fly ash and Ferro cement. These materials are often more durable and resistant to the elements than natural materials. However, they can also be more expensive.

The choice of materials for low-cost housing will depend on many factors, including the availability of materials, the cost of materials, and the desired durability of the housing. Here are some additional details about the two types of materials:

- Natural materials are often more sustainable than synthetic materials. They are also often more affordable, as they are readily available and do not require as much processing. However, natural materials can be less durable than man-made materials.
- Fabricated materials are often more durable than natural materials. They are also often more resistant to the elements. However, manufactured materials can be more expensive, as they require more processing.

The choice of materials for low-cost housing will depend on some factors, including the availability of materials, the cost of materials, and the desired durability of the housing, refer to Fig. 7.

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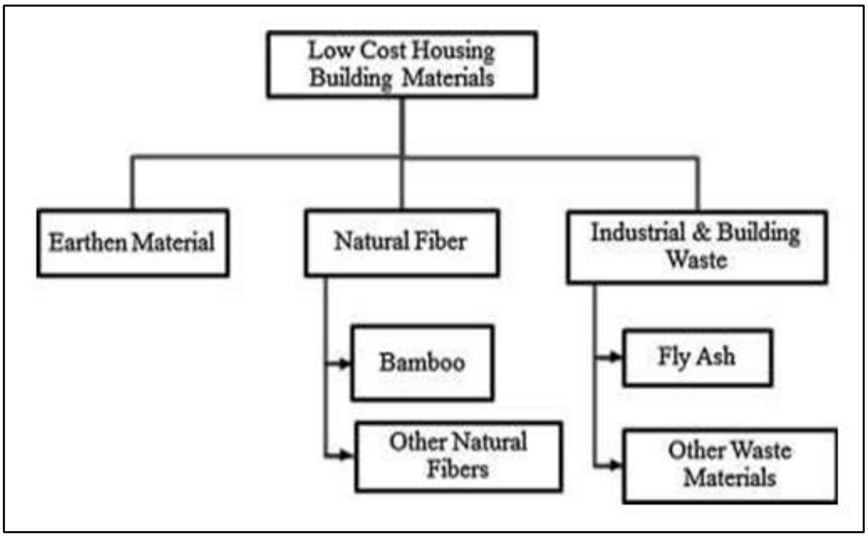

Figure 7: *Various low-cost building materials.*

Earth

Earth is one of the oldest available construction materials in India. Despite its limitations such as erosion, water penetration, termite attacks, and high maintenance requirements, these challenges can be overcome through the following techniques:

- *Compressed Earth Blocks (CEBs):* CEBs are developed by compressing adobe blocks or earth blocks with the addition of cement using a manual process.
- *Non-Erodable Mud Plaster:* This type of plaster consists of a specific mud paste mixed with bitumen, which enhances its resistance to water penetration.

Natural Building Materials

Natural fibers are a type of thread-like material that has many advantages over other composites. They are paintable, attractive, affordable, and resistant to rot. They also have a low density and are environmentally friendly. However, one of the main disadvantages of natural fibers is that they absorb water, which can lead to problems such as swelling and mold growth. This can be addressed by treating the fibers with chemicals, but this can also have environmental impacts.

Use of Bamboo Fiber

Bamboo is the second largest produced material in the world after China, and grows abundantly in India, covering approximately 9.57 million hectares. With a tensile stress of 650 N/mm², bamboo is comparable to steel, but it is more flexible with a lower modulus of elasticity (55 GPa). Bamboo is commonly used as a structural element material in India, China, and Japan, especially for roofing sheets, due to its rapid growth, easy availability, strength, durability, lightweight nature, and fire resistance [13]. However, connecting bamboo culms poses a major challenge, Fig. 8.

Figure 8: *Bamboo fiber.*

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Straw Fiber

Straw, obtained as a byproduct of the agriculture industry after removing chaff and grain, has been used historically to reinforce ancient products like boats and pottery. Straw fibers are the toughest compared to other types of straws. Proper disposal methods need to be adopted for straws, as burning it can cause breathing problems. Straw fibers find applications in the construction of life-extended thatch roofs, which are environmentally friendly, fire-resistant, and waterproof. Additionally, the Central Building Research Institute (CBRI) has developed techniques to improve thatch roofs by applying mud plaster, making them more resistant to fire [14] Fig. 9.

Figure 9: *Rice straw fiber.*

Bagasse Fiber

Bagasse fiber is a natural fiber that is obtained from the remains of sugarcane or sorghum stalks. It is a renewable resource that is abundant in India, where there are approximately 500 sugar mills. Bagasse fiber contains approximately 50% cellulose and 25% lignin and hemicellulose. When properly modified, bagasse fiber can exhibit excellent mechanical properties. Bagasse fiber has several advantages, including low energy input requirements, eco-friendliness, and reduced product density [15]. However, it also has some disadvantages, such as low impact strength, stocking issues, and fiber degradation. Bagasse fiber finds applications in a variety of products; including bagasse cement boards and panels, bagasse PVC boards, and biomass power generation. It is a versatile material that has the potential to be used in many other applications, Fig. 10.

Figure 10: *Sugarcane bagasse fiber.*

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Jute and Coir Fiber

Jute, cultivated in India since around 800 BC, is predominantly used for packaging materials, while coir is obtained from coconut husks and has two-thirds of India's total production [16]. Jute cultivation covers approximately 98.41% of the total area under jute cultivation, spanning 33 districts in India. Jute and coir fibers have a length of 350 mm and a diameter of 12 to 25 microns [17]. They are durable and find applications in the production of coir-CNSL boards, jute-coir composites, coconut & wood chips roofing sheets, and geotextiles, Fig. 11.


Figure 11: *Jute & coir fiber.*

Sisal Fiber

Sisal fiber is a natural, low-cost, and recyclable material that can be used as reinforcement in polymer composites. Sisal plants have a lifespan of 7-10 years, during which they produce 200-250 leaves, each with 1000 fibers. Sisal fiber is used in a variety of applications, including paper production, cordage, tiles, geotextiles, roofing sheets, and cement flooring sheets [18]. However, sisal fiber is not suitable for use in severe weather conditions, such as prolonged exposure to water, snow, or heavy rain, Fig. 12.

Figure 12: *Sisal fiber.*

Banana Fiber

Banana fiber is a strong, lightweight, and biodegradable material that can be used in a variety of applications, including building boards, fire-resistant boards, medical applications, ropes, mats, and home furnishings. Other natural sources that can be used in building materials include rice husks, banana leaves and stalks, coconut husks, groundnut shells, jute fiber, rice and wheat straw, sawmill waste, sisal fibers, and cotton stalks [19]. Rice husk is used as a fuel source in rice mills and also finds application in the manufacturing of building materials and products. Banana leaves and stalks are used in the production of building

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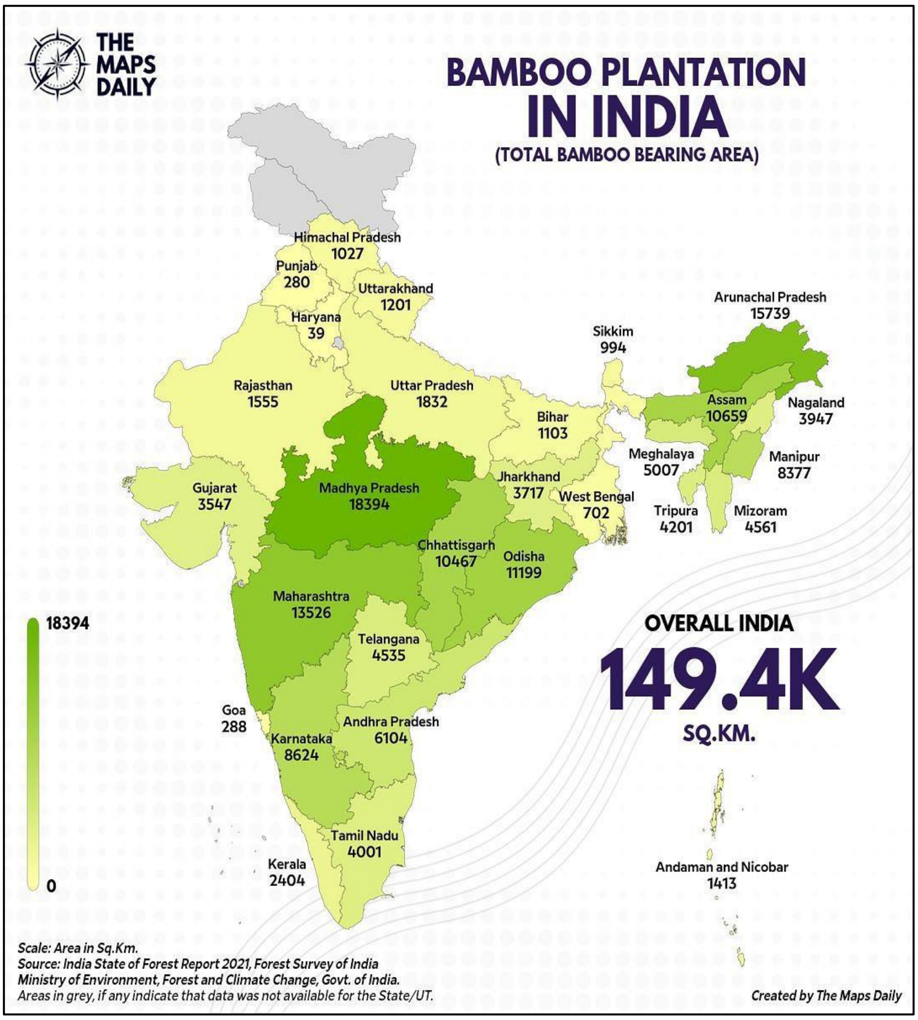
boards, fire-resistant fiberboards, and other related materials. Coconut husk is used in the manufacture of various building components, such as building boards, roofing sheets, insulation boards, building panels, lightweight aggregates, and coir fiber-reinforced composite boards. Groundnut shells are used in the manufacturing of building wall panels, building wall blocks, chipboards, and top roofing sheets. Jute fiber is used in the manufacturing of chipboards, and top roofing sheets, and door shutters. Rice and wheat straws are used in the production of roofing units, wall panels, and boards. Sawmill waste is used in the manufacture of cement-bonded wood chips, blocks, and boards. Sisal fibers are used for plastering walls and manufacturing roofing sheets, and can also be used in composite boards alongside rice husk and cement. Cotton stalks are used in the manufacturing of fiberboards, wall panels, door shutters, top roofing sheets, AAC composites, and paper. These natural sources are a sustainable and environmentally friendly alternative to traditional building materials. They are also abundant and affordable, making them a viable option for low-cost housing.

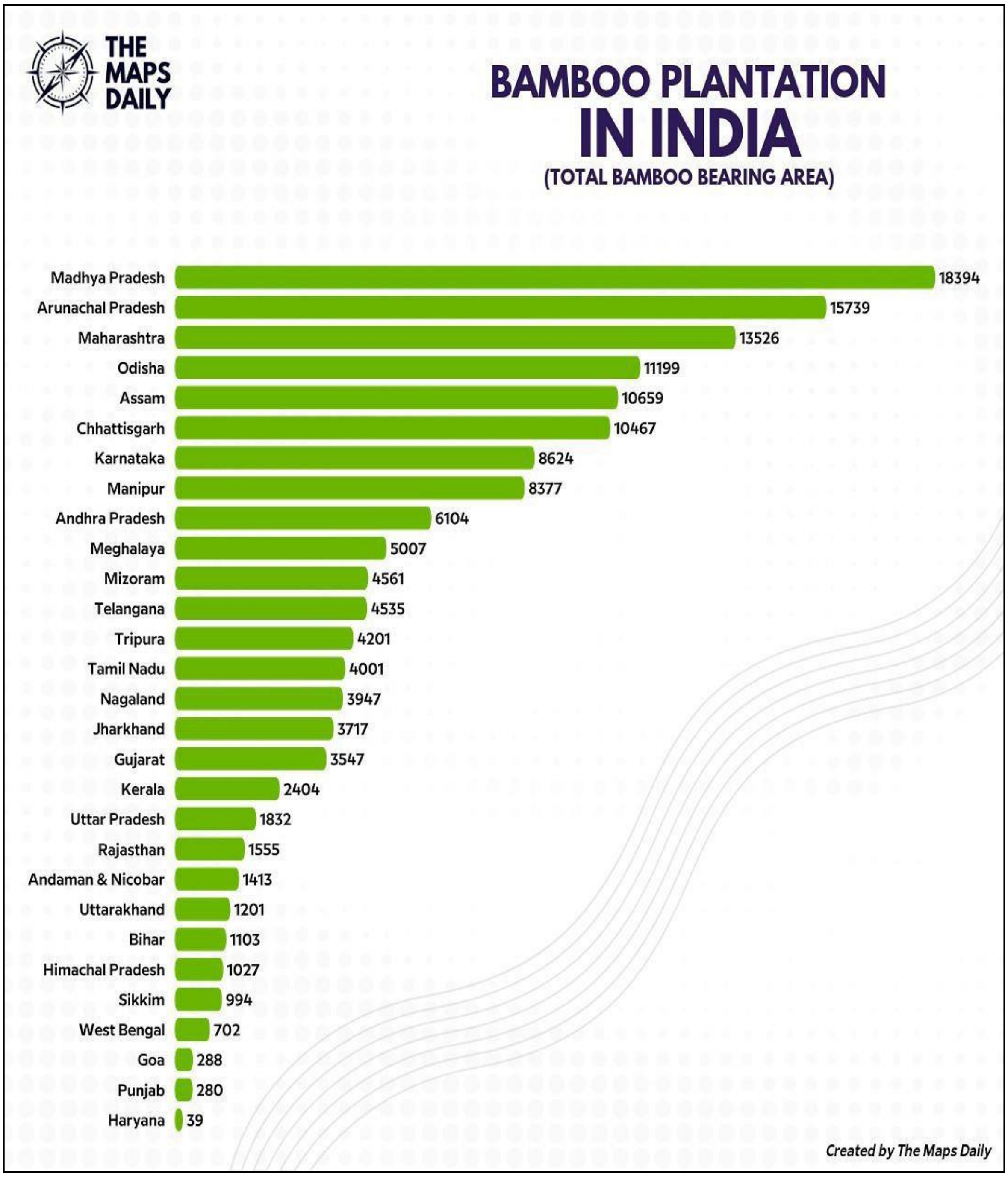
Bamboo as Reinforcing Material

Bamboo material exhibits a remarkable weight-to-stress ratio, making it an ideal material to withstand high winds and earthquakes. Its production requires significantly less energy compared to the materials like steel, plastics, and aluminum. For increased longevity, bamboo structures in India undergo treatment as per the specifications outlined in IS 9096. India, the second largest bamboo producer globally, cultivates over 136 species [20]. Fig. 13 and 14 illustrate the major bamboo growing regions in India.



(Source: The Maps Daily)

Figure 13: *Map showing bamboo growing states in India.*



(Source: The Maps Daily)

Figure 14: *Bamboo plantations in India in different states.*

Rice Husk Grains

India produces about 600 million tons of rice annually, and 20% of that is waste in the form of rice husk. Rice husk is typically discarded or burned, but the burning process produces rice husk ash. About 220 kg of husk can be obtained from 1000 kg of rice, generating approximately 55 kg of ash. India accounts for 20% of global rice production, with West Bengal having the highest production area and Punjab having the highest productivity. Rice husk is composed of 75% organic matter and 25% husk-to-ash conversion by weight. The ash contains about 85-90% silica. Rice husk and its ash have a variety of applications, including power plants, roofing units, rice husk binders, fibrous building panels, bricks, acid-proof cement, activated carbon production, thermal insulating bricks, and production of acids, building materials, and low-

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cost sand concrete blocks [21], Fig. 15.

Figure 15: *Rice husk grains.*

Manmade Materials

The industrial revolution resulted in the creation of various by-products that, if left unused, would have posed disposal challenges. Thorough research into their properties revealed their excellent pozzolanic properties, prompting their utilization as alternative materials.

Fly Ash

Fly ash is the by-product of burning coal and is recovered from flue gases. Its major constituents include Fe, Al, and Si. Fly ash has increased from 68 million tons per annum to 131 million tons per annum in 15 years. However, its usage has only seen a modest increase of 6.6-73.1 tons per annum, which amounts to around 14% [22-23]. Fly ash finds applications in fly ash bricks, bituminous mix, and artificial aggregate production, Fig. 16.

Figure 16: *Fly ash.*

Use of Aerocon-Panels

Aerocon panels are sandwich-type panels made from two fiber cement-reinforced sheets. They are composed of Portland cement, binders, and a mix of micaceous and siliceous aggregates [24]. These panels are eco-friendly, lightweight, fire-resistant, and sound-reducing,

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Fig. 17.

Figure 17: *Aerocon panels.*

Ferro Cement Material

Ferrocement is a cement-based composite material made by reinforcing cement mortar with one or more layers of wire mesh. High strength, durability, and corrosion resistance characterize it. However, it also exhibits high creep and shrinkage, which can lead to cracking over time. Ferrocement is used in a variety of applications, including the construction of water tanks, cycle sheds, boats, and other structures. It is also a popular material for post-disaster reconstruction, as it is easy to use and can be quickly deployed. Here are some of the advantages of using ferro cement:

- *High Strength:* Ferro cement is very strong and durable. It can withstand high loads and it is not easily damaged by impact.
- *Corrosion Resistance:* Ferro cement is resistant to corrosion, making it a good choice for use in wet or humid environments.
- *Easy to Use:* Ferro cement is relatively easy to use, even for unskilled workers. This makes it a good choice for post-disaster reconstruction, when skilled labor may be scarce.
- *Quick to Deploy:* Ferro cement can be quickly deployed, making it a good choice for emergency applications.

However, there are also some disadvantages to using ferro cement:

- *High Creep:* Ferro cement exhibits high creep, which means that it can slowly deform over time. This can lead to cracking in the material.
- *High Shrinkage:* Ferro cement also exhibits high shrinkage, which means that it can shrink as it dries. This can also lead to cracking in the material.

Overall, Ferro cement is a versatile and durable material with a wide range of applications. However, it is important to be aware of its limitations, such as its high creep and shrinkage, before using it.

Cement Concrete Hollow Blocks

The concrete hollow block serves as an economic and superior alternative to high-burnt clay bricks. It offers fire resistance and durability and facilitates faster construction due to the reduced quantity of required mortar. The strength of these blocks can be enhanced based on their intended use.

Re-Cycled Steel as Reinforcing Material

Recycled scrap iron from used construction can be utilized as recycled steel reinforcement. It finds applications in steel-reinforced structures like buildings & bridges. Specific criteria, such as mass/meter run and rolling tolerance as per IS 1786, must be met for the use of recycled steel as reinforcing bars [25]. Purchasing standard lengths helps reduce wastage, but if varying lengths are required, wastage should be limited to no more than 5-7%. Recycled steel exhibits advantages such as high strength, bond strength, resistance to termites,

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and weathering.

Precast R.C.C Folds

Precast R.C.C. door frames feature welded-reinforcement and offer durability, affordability, fire resistance, corrosion resistance, and termite resistance. They alleviate issues of cracking, bending, and shrinkage and are easy to install on-site. Moreover, they possess higher strength-to-weight ratios compared to conventional R.C.C., resulting in 20% - 25% of cost and material savings, Fig. 18.

Figure 18: *Precast RCC wall.*

ANALYSIS & DISCUSSION

After analyzing various materials that are eco-friendly, cost-effective, and readily available:

- Voids creating filler slabs prove to be a more economical alternative to traditional slabs, resulting in savings of 16%, 44%, and 17% in terms of cement, steel, and overall costs in two-way slabs, and 33%, 46%, and 25% in one-way slabs, respectively.
- Brick panels offer significant savings of 22% per cubic meter (m^3) and Rs 450 in cement & 22% per m^3 and Rs 29 in sand, 22% per m^3 and Rs 142 in aggregate, and 44% per m^3 and Rs 586 in steel.
- Stabilized bricks are a cost-effective choice, being 29.6% cheaper than fired clay brick walls. While fired clay bricks require Rs 1025 per square meter, soil-stabilized bricks utilize Rs 826 per m2. Additionally, it contributes to reduced air pollution, more energy consumption, and carbon emission.
- Although Al formwork construction entails higher costs, it offers high-quality and swift construction, making it suitable for projects requiring rapid completion. In the case of flat slabs, the overall quantities of rebar and concrete used are 9.455 m^3 and 1309 m^3, respectively, the conventional buildings employ 10845 m^3 of steel and 16024 m3 of concrete. Cost savings of around 19% can be achieved in G+4 buildings when using flat slabs.
- Hollow concrete blocks are employed in areas where, the load does not influence the walls, resulting in a cost reduction of 17.78%, everything has been tabulated refer to Table 1 and 2.

Table 1: *Cost-saving comparison.*

Slab Type	Item	Cement (in kg)	Steel (in kg/m^3)	Cost (Rs per m^2)
Conventional Two-Way Slab	Slab of 125 mm thickness	42.3	68	465
	Filler slab 150 mm thick	38	6	395

	Savings (%)	11.31	91	11.7
Conventional One-Way Slab	Slab of 125 mm thickness	49	6.55	451
	Voided Filler slab of 150 mm thickness	33	3.55	337
	Savings (%)	33.2	45.6	24

Table 2: *Percentage usage of stabilization material.*

Type of Stabilization	Minimum %	Average %	Maximum %
Cement-stabilization	3.53%	6%	-
Lime-stabilization	2.54%	7.5%	10%
Mechanical-stabilization	1.68%	5.25%	12%

CONCLUSION

Mass production of houses targets can potentially be reached by replacing the conventional planning and execution methods in building operations, which currently focus primarily on individual needs. Instead, a common type denominator approach, which is based on the surveys, population needs, and utilization of materials and resources, should be embraced. Widespread adoption of alternative technologies requires a guaranteed market, which can only be established if the product proves to be effective and cost-efficient. However, constructing affordable housing for low-income growth families remains a significant challenge. It demands substantial effort in developing new technology that utilizes alternative construction materials. This article aimed to explore the very economical housing technology and discussed the potential of the materials that served as alternatives in building construction. Despite the development of various low-cost housing techniques, there remains a shortage of housing, particularly for individuals from low-income backgrounds. Additionally, there is a lack of comprehensive guidelines about the structural aspect of these alternative materials. Builders often lack awareness of the usage and advantages of these materials. To achieve cost-effective construction, the use of voided filler slabs as a substitute for conventional slabs and the increased utilization of fly ash, rice-husk ash-based materials as an alternative to cement are viable options. Bamboo can also be an effective supplement to steel in construction. Partial prefabrication can be employed as an approach to facilitate operations under controlled conditions. The crux of the matter lies in adopting a systematic approach to building methodologies rather than focusing solely on specific construction types or designs. The methodology used for low-cost housing should be intermediate, encompassing low sophistication and requiring lower capital investment. Cooperatives dedicated to low-cost housing need to be established to eliminate transportation costs and reduce the need for material imports, ultimately reducing the overall construction budget by 20 to 30%.

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