MULTISCIA
JOURNALS PUBLISHERS

FRONTIERS IN CIVIL ENGINEERING AND CONSTRUCTION MATERIALS

ISSN: (3065- 4181)




editor.fcecm@gmail.com

https://multisciajournals.com/journals/index.php/fcecm

Frontiers in Civil Engineering and Construction Materials

Volume 1 Issue 1 2025

Utilizing Bamboo as an Affordable Material for Rural Construction

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Article Info

Received: 25-12-2024 *Revised:02-01-2025* *Accepted:11-01-2025* *Published:22-01-2025*

Abstract: Cement and steel, which raise the total cost of construction but provide a longer lifespan to structures, are having a significant impact on the building scene in rural India. Energy is required for the whole lifecycle of materials like cement and steel, from raw materials to finished products and beyond, for maintenance in many forms. The strain on conventional resources is growing as a result of a lack of attention to the accessibility of renewable building materials in rural regions and an unwillingness to use locally produced materials. Because of this, rural areas need to focus on sustainable, locally-sourced resources and affordable materials that can replace cement and steel without breaking the bank. One material that rural communities may employ in their construction is bamboo, which, with the right treatment and skilled labor, has enormous promise in the building industry. This report primarily aims to support the use of bamboo as a budget-friendly material. Buildings in rural areas might benefit from using bamboo in conjunction with current material technologies, according to this report.

Keywords: Bamboo, Rural construction, Cost effective.

1. STUDY BACKGROUND

The majority of the world's energy consumption now comes from building and other construction-related activities. Direct or indirect energy use in the construction industry accounts for 40% of overall energy consumption. Urban development's building projects have depleted Earth's traditional resources, and this tendency is quickly spreading to rural areas as well. Many ideas about housing and living circumstances in cities are not always applicable or suitable in rural areas, and this has been known from the start.

Deprivation is more concentrated in rural regions than to metropolitan ones. Homeownership is out of reach for many families due to lower-than-average wages and seasonal unemployment. The long-term viability of rural towns' social infrastructure is affected by this.It is leading to further division as young people leave their families for cities in quest of employment, which has a detrimental effect on businesses and economies in rural regions [1]. The home market in rural India is booming, but many can't afford the rising prices of building supplies like cement and steel. One alternative for the rural building sector that is both environmentally benign and cost-effective is bamboo constructions, which may replace steel structures. In contrast to conventional building materials, which are both expensive and harmful to the environment, this innovative method offers the rural community a long-term, low-maintenance solution

that is both high-quality and economical. The rapid growth and regenerative nature of bamboo give it a leg up when it comes to carbon credit. Meet the issues of the rural construction industry and the rising housing sector with the help of bamboo construction, which, with the right engineering, may contribute to alternative and sustainable development. There are far-reaching social, economic, and public-benefit implications of promoting inexpensive and environmentally friendly building practices.Bamboo has several potential use as a construction material. The use of bamboo reinforcement in lieu of steel reinforcement is rapidly growing in popularity due to the many advantages it offers in terms of both cost and environmental impact. In order to make tensile stresses of RCC members, engineered bamboo may replace steel, and it can also cut down on cement use.

2. RURAL CONSTRUCTION SECTOR

Traditional rural architecture relies on site-specific modifications and is often constructed by hand by local people, eliminating the need for outside machinery. Although affordability, beauty, tradition preservation, and climate-appropriate housing are all admirable goals in rural locations, long-term construction urability should also be a top priority. In contrast to a structure constructed with more traditional materials, such as cement and steel, a thatched roofed mud hut requires constant upkeep. The use of these traditional materials raises building costs generally [2]. In rural areas, the building structure types are gradually changing from Temporary ("Kutcha" - where both the walls and roof are made of materials that needs to be replaced frequently) to Permanent ("Pucca" - where the walls and roof are made of permanent material) and Semi Permanent ("Semi Pucca" - where either the walls or the roof is made of permanent material) types, according to the Census reports of India and other reports by different government departments [3].

As people's incomes rise, the tendency of converting temporary constructions to permanent or semi-permanent ones is expected to continue. Brick, sand, cement, steel reinforcement, and other traditional building materials are anticipated to be in high demand because to the anticipated large-scale construction of these structures in the near future. The insufficiency of homes and other buildings is mostly experienced by low-income groups in rural areas as a result of the ongoing increase in construction costs across the board.

Because of this, building development must make use of efficient technologies that make use of renewable resources that are readily accessible in the area. Despite the development of relevant knowledge, there has been a noticeable lack of application. Consequently, there is a significant need for rural regions to have access to construction delivery systems, technologies, and materials in order to conduct cost-effective construction activities.

As a result of a 50% increase over inflation in the cost of essential building materials and labor, the cost of construction is rising at a regular inflation rate. Hence, even the most basic kind of housing has become unaffordable for the average individual living in rural regions. It is critical to use technological solutions that provide affordable outcomes for those living in rural regions. Despite many efforts by different scientific and R&D organizations to develop cost-effective technologies in the lab, these endeavors have not been successful in finding practical applications in the field. In addition, neither consumers nor experts have shown much "awareness" of these sustainable alternatives [4]. Current methods of building in rural regions, which rely on traditional methods, result in the waste of expensive and precious resources. In terms of the exhaustion of traditional resources, these activities have a more significant effect on the

environment. Another issue that has hindered the deployment of cost-effective choices in rural regions' construction industry is the absence of assistance via the building regulatory system. The rural residents are faced with a conglomeration of construction structures that are either prohibitively costly or

above what is reasonably priced. There is a distinct lack of training and skill-enhancement in rural areas, not only for conventional but also cost-effective technologies. since a result, community structures and housing initiatives for all demographics have been negatively impacted, since inadequate funding is always an issue. One way to tackle this problem is by providing construction artisans with the training they need to become more proficient in the use of sustainable, innovative, and alternative building materials and technologies.

Another way is to enlist their help in producing various building components at the ground level. Helping the locals with construction-related questions, concerns, and advice can raise their "awareness" of the options available to them and their "appreciation" of how well they meet their needs in terms of aesthetics, functionality, and cost-effectiveness. A more favorable view of "low cost housing" (i.e., buildings of poor quality and lack of durability) will emerge as a result of these "cost-effective options" being used.

3. COST-EFFECTIVE CONSTRUCTION TECHNOLOGIES

The following factors influence the level of acceptance of building construction technologies in India: safety, manufacturing and construction costs, comfort, maintenance expenditures, aesthetics, and, to a lesser degree, social standing. Large amounts of energy are required to construct buildings using traditional materials such as cement and steel. There are five stages to construction energy use. Embodied energy refers to the initial stage, which is the production of construction materials and components. In the second and third stages, gray energy (the energy required to move materials from manufacturing facilities to the construction site) and induced energy (the energy required to actually construct the structure) are considered. In the fourth stage, known as the operational phase, energy is used up while the building is in use by its occupants. Lastly, when this is encouraged, energy is used up during building destruction and recycling [5].

The embodied energy level of building materials may be reduced by the use of cost-effective construction solutions that reduce the usage of energy-consuming materials. As far as sustainable technologies in rural India are concerned, the most financially and ecologically sound options would be those that pertain to building.

Technologies that are both creative and cost-effective in the construction industry, which not only lower the overall cost of construction by lowering the amount of building materials used, but also by using alternative materials, may greatly contribute to lowering CO2 emissions, which in turn aids in environmental conservation. One material that rural communities may employ in their construction is bamboo, which, with the right treatment and skilled labor, has enormous promise in the building industry.

4. BAMBOO AS A BUILDING MATERIAL

The majority of bamboo construction relates to the rural community needs in developing countries. It is mainly used in housing but other common types of construction include school buildings, community buildings and bridges. Further applications of bamboo relevant to construction include its use as scaffolding, water piping and as shuttering and reinforcement for concrete.

Bamboo has historically been used as a building material due to its inherent properties, being regenerating, biodegradable, with high tensile strength, and lightweight. However, despite its innumerable qualities one does not get to see bamboo as popular building material. Bamboo reinforced Concrete for the key structural elements like slab, walls, columns and beams, of a modest dwelling unit can be successfully utilized for structural and non-structural applications in construction [6].

As an economic building material, bamboo's rate of productivity and cycle of annual harvest outstrips any other naturally growing resource, if today we plant three or four structural bamboo plants, then in four or five years later we will have mature clumps, and in eight years we will have enough mature material to build a comfortable, low cost structure [7].

Main characteristic features, which make bamboo as a potential building material, are its high tensile strength and very good weight to strength ratio. It can withstand up to 3656 Kg/cm2 of pressure. The strength-weight ratio of bamboo also supports its use as a highly resilient material against forces created by high velocity winds and earthquakes. Above all bamboo is renewable raw material resource from agro-forestry and if properly treated and industrially processed, components made by bamboo can have a reasonable life of 30 to 40 years. Though natural durability of bamboo varies according to species and the types of treatments. Varied uses and applications in building construction have established bamboo as an environment-friendly, energy-efficient and cost-effective construction material [8].

4.1 Botanical classification of Bamboo

Bamboo is a perennial, giant, woody grass belonging to the group angiosperms and the order monocotyledon (McClure, 1966, Liese, 1985*)* [9].

Bamboo (Bambuseae) is a tribe of flowering perennial evergreen plants in the grass family Poaceae, subfamily Bambusoideae, tribe Bambuseae. Giant bamboos are the largest members of the grass family. In bamboos, the internodal regions of the stem are hollow and the vascular bundles in the cross section are scattered throughout the stem instead of in a cylindrical arrangement. The dicotyledonous woody xylem is also absent. The absence of secondary growth wood causes the stems of monocots, even of palms and large bamboos, to be columnar rather than tapering. Bamboos are some of the fastest-growing plants in the world, due to a unique rhizome-dependent system. More than 10 genera are divided into about 1,450 species [10].

Characterized by the type of rhizome and the formation of upright canes there are three main groups of bamboo. The first group is called monopodial bamboos. They form long and thin extensions of the rhizome whose buds produce single shoots are regular intervals. The sympodial bamboos constitute the second group. They have short, thick rootstocks the tips of which produce the canes. The third group is called climbing bamboos. They can grow very irregularly and may form impenetrable thickets.

4.2 Growth of the Bamboo

The growth pattern of the bamboos is a singular combination of grass, leaf-bearing tree and palm. Like the grasses they have tubular blades, lancet-shaped cover leaves and panicular flowers and from a subterranean rootstock branch extensively to form dense to loose bushes. The following characteristics distinguish

bamboos from grasses: the longevity of their canes, their branching and the lignification. Like leaf bearing trees they increase their crown every year by throwing out new branches and also shed their leaves each year. Emerging with its definitive circumference from the soil without increasing in diameter later.

4.3 Properties of Bamboo:

4.3.1 Mechanical Properties:

It has also been found that bamboo acts very well in buckling due to low stresses than compared to steel .It has been established that in seismic zones the failure of bamboo is very less as the maximum absorption of the energy is at the joints. Cellulose is the main component present in bamboo, which is the main source of mechanical properties of bamboo.

4.3.2 Tensile Strength:

Experimentally it has been found that the ultimate tensile strength of some species of bamboo is comparable to that of mild steel and it varies from 140N/mm^2- 280N/mm^2. Bamboo is able to resist more tension than compression. The fibers of bamboo run axial. In the outer zone are highly elastic vascular bundles that have a high tensile strength. The tensile strength of these fibers is higher than that of steel, but it's not possible to construct connections that can transfer this tensile strength.

4.3.3 Compressive Strength:

Compared to the bigger tubes, slimmer ones have got, in relation to their cross-section, a higher compressive strength value. The slimmer tubes possess better material properties due to the fact that bigger tubes have got a minor part of the outer skin, which is very resistant in tension. The portion of lignin inside the culms affects compressive strength, whereas the high portion of cellulose influences the buckling and the tensile strength as it represents the building substance of the bamboo fibers.

4.3.4 Elastic Modulus:

The accumulation of highly strong fibers in the outer parts of the tube wall also work positive in connection with the elastic modulus like it does for the tension, shear and bending strength. The higher the elastic modulus, the higher is the quality of the bamboo. Enormous elasticity makes it a very useful building material in areas with very high risks of earthquakes.

4.3.5 Anisotropic Properties:

Bamboo is an anisotropic material. Properties in the longitudinal direction are completely different from those in the transversal direction. There are cellulose fibers in the longitudinal direction, which is strong and stiff and in the transverse direction there is lignin, which is soft and brittle.

4.3.6 Shrinkage:

Bamboo shrinks more than wood when it loses water. The canes can tear apart at the nodes. Bamboo shrinks in a cross section of 10-16 % and a wall thickness of 15-17 %. Therefore it is necessary to take necessary measures to prevent water loss when used as a building material.

4.3.7 Fire Resistance:

The fire resistance is very good because of the high content of silicate acid. Filled up with water, it can stand a temperature of 400° C while the water cooks inside [11].

4.4 Application of Bamboo

- **Bamboo Trusses:**

The bamboo has strength comparable to that of teak and sal. An experiment with the construction and testing of a 4m span truss made of round bamboo and different jointing techniques for web-chord connections gave results that were matching with the strength of timber.

- **Bamboo Roofs Skeleton:**

It consists of bamboo truss or rafters over which solid bamboo purlins are laid and lashed to the rafter by means of G.I. wire.

- **Bamboo walling/ceiling:**

As the bamboo material is light in weight it is more advantageous in earthquake prone areas as its chances of falling are very less and even if it falls it can be re-erected easily with less human and property loss with least efforts and minimum cost.

- **Bamboo Doors and Windows:**

Bamboo frames can replace timber frames appropriate to function. Bamboo mat shutters fixed to bamboo frame or a panel of bamboo board fixed to the frame, which is hinged to the wall, can be used as door.

- **Bamboo Flooring:**

Bamboo can be used as flooring material due to its better wear and tear resistance and its resilience properties.

- **Scaffolding:**

Bamboo poles lashed together have been used as scaffolding in high-rise structures due to their strength and resilience [12].

4.5 Advantages of Bamboo

- Bamboo is an extremely **strong** natural fiber, on par with standard hardwoods, when cultivated, harvested, prepared and stored properly. The strongest part of a bamboo stalk is its node, where branching occurs.
- Bamboo is an exceptionally **versatile** material. It is used in a myriad of ways for building, such as for scaffolding, roofing, flooring, concrete reinforcement, walls and piping. It may be used structurally and as a decorative element.
- Bamboo is extremely **flexible.** During its growth, it may be trained to grow in unconventional shapes. After harvest, it may be bent and utilized in archways and other curved areas. It has a great capacity for shock absorption, which makes it particularly useful in earthquake-prone areas.

- Bamboo is extremely **lightweight** as compared with hardwoods. Consequently, building with bamboo can be accomplished faster than building with other materials.
- Bamboo is considered to be a **sustainable** and **renewable** alternative to hardwoods, foremost because it regenerates at exceptionally fast rates
- Bamboo is **cost-effective**, especially in areas where it is cultivated and is readily available.
- Construction using bamboo ordinarily does not require machinery and can be accomplished with **simple tools.**
- Bamboo is as **long - lasting** as its wooden correlates, when properly harvested and maintained.

4.6 Disadvantages of Bamboo:

- Bamboo does not contain cross fibers and is, consequently, not designed to bear weight width-wise, with the exception of the points at the nodes. Bamboo is prone to splitting.
- Bamboo does not lend itself to being painted because of its natural waxy coating.
- Bamboo is prone to insect invasion, especially when not treated properly after harvest.
- Untreated bamboo is prone to breaking down if it comes in contact with excess moisture.
- Bamboo that has been harvested prematurely cannot bear as much weight as its more mature counterparts.
- Natural variations in species may be difficult for installers to accurately gauge the quality of bamboo material.
- Designing and constructing with bamboo requires a special skill set that the average contractor may not possess [13].

4.7 Chemical treatment for bamboo:

The natural durability of bamboo is lower than for wood. The lifetime of an untreated bamboo can vary between 1 and 15 years depending on conditions, depending on variety. Bamboo needs to be chemically treated. Preservation treatment methods of bamboo are of 2 types: the traditional or non- chemical methods and chemical methods. The choice of treatment method will depend on the state of bamboo, whether it is green or dry, whether whole cane or split, its future application, quantity to be treated and the time available [14].

Traditional and non-chemical methods:

- Smoking:
- Baking over open fire
- White washing
- Soaking in water

Chemical treatment methods:

- Tanalised method - chromated copper arsenate (CCA)

- Treatment with Boric acid / Borax

4.8 Embodied energy of Bamboo compared with conventional building Materials:

Bamboo is used as a cost effective building material due to its various aspects. But the most important factor, which makes it cost effective, is the embodied energy of this material. [4]Theuse cost effective technology has led to solutions with 15 to 40 percent savings over the conventional costs.

Table 1. Energy Requirement of Construction Materials

Materials	Energy for production MJ/Kg	Weigh t per volume Kg/ m^3	Energy for production Kg/m^3	Stress when in use	Energy per unit stress
Concrete	0.8	2400	1920	8	240
Steel	30	7800	234000	160	1500
Wood	1	600	600	7.5	80
Bamboo	0.5	600	300	10	30

Source: Prof.J.A.Janssen, Eindhoven University The Netherlands [8].

5. CONCLUSION

In order to improve rural regions in a cost-effective manner, the approaches outlined in this article may be helpful. Creative planning and the integration of other locally sourced materials into the cultural setting may elevate the bamboo structure from just acceptable to highly desired. According to the latest research, bamboo has replaced traditional materials due to technological advancements, which are causing a fast depletion of natural resources. Bamboo is more than just a building material; it helps keep the environment in check, creates jobs in the area, and supports the local economy. Because of its low cost and long history of use, bamboo will remain a popular choice among rural builders.

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One site that discusses bamboo's potential as a construction material is http://civil-resources.blogspot.in/2010/06/use-of-bamboo-as-construction-material.html. The article "Bamboo Construction and Inspection" by Nick Gromicko may be found online at http://www.nachi.org/bamboo-construction- inspection.htm. http://www.chalet-bamboo.com/treatment.html explains why treating bamboo is crucial [14].