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Bamboo as a Cost Effective Building Material for Rural Construction

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Abstract: **The construction scenario in rural areas of India is getting highly influenced by the materials like cement and steel, as it gives the long life to the structure but in turn it increases the overall cost of construction. These materials like cement and steel use energy extensively from its very beginning to its completion and even after for its maintenance in many forms. Without focusing on availability of renewable construction material in near vicinity of rural areas and also not utilizing the locally produced material, the pressure is increasing on conventional resources. This situation demands the attention of rural community on naturally available renewable local resources and cost effective materials, which will give the same result as that of cement and steel, but economically viable. Bamboo is one such material, which can be used by the rural community in their construction, which has extensive potential in building industry when supported with required treatment and trained workers. The main focus of this paper is to promote the use of bamboo as cost effective material. The present paper suggests the use of bamboo in combination with modern material technology as a building material in rural construction.**

Keywords: **Bamboo, Rural construction, Cost effective.**

1. STUDY BACKGROUND

In today's world, energy is extensively used for construction activities and is the major source of demand for energy. Alone construction sector has been accounted to consume 40% of total energy consumption directly or indirectly. The construction activities in urban development have exploited the conventional resources of the mother earth and now the trend is passing to the rural area too. From the beginning it was understood that many of the concepts applied to shelter and living conditions in urban communities are not always transferable or appropriate in a rural context.

Compared to urban areas, rural areas suffer more from the concentration of deprivation. With incomes generally lower than the urban areas and seasonal unemployment, many households find it difficult to gain ownership of homes. This has implications for social sustainability of rural communities and is causing increased polarization as younger people migrate to the urban areas in search of jobs leaving behind their old folk and children resulting in negative impact on rural enterprise and economic viability [1].

The housing sector in rural India is growing rapidly but with increased cost due to materials like cement and steel, it is getting out of reach of people. Bamboo structures are one, which can replace steel structures, thus providing an eco-friendly and cost-effective option for rural construction industry. This new construction approach shows the rural community an affordable, high quality and durable alternative compared to widely-used but higher cost and less environmentally-compatible construction materials. Bamboo has an advantage of being renewable and fast growing, contributes to higher carbon credit. With proper engineering, use of Bamboo in building can aid in the growth of alternative & sustainable development, meeting the challenges of rural construction industry and growing housing sector. Promoting sustainable and affordable construction delivers significant impacts, spanning both socio-economic and public welfare benefits.

Bamboo as a building material can be used in various forms. Bamboo reinforcement as replacement of steel reinforcement is gaining immense importance today, mainly on account of the improvement in the economical aspect combined with ecological benefits. An engineered Bamboo can substitute steel in making tensile stresses of RCC members and also reduces the consumption of cement in building.

2. RURAL CONSTRUCTION SECTOR

A traditional rural building is based on adaptations to the local environment, and is often built with the labor of the villagers themselves without the need for external mechanized inputs. In rural areas low cost, aesthetics, preserving traditions, and living in climatically suitable houses are all fine notions, but the durability of buildings is also an important consideration.

A mud building with a thatched roof needs continuous maintenance, whereas a building with conventional materials like cement and steel is far sturdier, and has a longer life span. These conventional materials increase the overall cost of construction [2].

As per the Census reports of India and other reports by different Government Departments, the building structure types are gradually transforming to Permanent (“Pucca” – in which the walls and roof of which are made of permanent material) and Semi Permanent (“Semi Pucca ” – in which either the walls or the roof is made of permanent material) types from Temporary (“Kutcha ” - in which both the walls and roof are made of materials that needs to be replaced frequently) in rural areas [3].

The trend of conversion from Temporary to Permanent or Semi- Permanent structures is likely to continue in view of economic growth of common people. It is expected that large number of buildings with durable and easily available conventional materials like brick, sand, cement, steel reinforcement etc. will be constructed in near future and demand of such building materials will shoot up.

In rural area housing and other building inadequacy is largely felt at the level of low income groups due to continuous rise in cost of construction at all levels.

This necessitates the use of cost effective technologies in building construction using locally available and renewable materials. Though the information in this regard has been developed, there has been a large gap in application. Therefore access to building materials, technologies and construction delivery systems for cost effective construction activity is an important need in rural areas.

The cost of construction is increasing by 50 per cent over the normal inflation due to hike in the cost of basic building materials and labor. Consequently, even basic housing is now beyond the reach of a common person in rural areas. There is an imperative need to utilize technology options leading to cost effective results, which people in rural areas can afford. Although many attempts for evolving cost- effective technologies have been made at the laboratory level by various scientific and R & D agencies, but these initiatives were not finding applications at the field level. Further, the 'awareness' level of these alternative and sustainable options has been minimal among users as well as professionals [4]. The existing construction practices in rural areas, using conventional options, lead to misuse of scarce and costly materials. Such practices have a larger environmental impact in terms of depletion of conventional resources. The lack of support through building regulatory system is another factor that has inhibited the use of cost effective options in construction sector of rural areas. As a cumulative effect, the building structures offered to the rural people are either expensive and beyond the affordable limit. There is a distinct lack of training and skill-enhancement in rural areas, not only for conventional but also cost-effective technologies. This has adversely affected housing and building programs for all target groups and community buildings since financial resources available are always limited.

This issue can be addressed by, training and skill-enhancement of construction artisans in terms of alternative, innovative and sustainable building materials and technologies and also by assisting in the production of various building components at the base level by utilizing the services of trained artisans in the construction program. Providing construction guidance, information and counseling to local people will help in creating 'awareness' about the available alternative options and also an 'appreciation' of these options not only in terms of cost effectiveness but also in terms of structural, functional and aesthetic sufficiency. The use of these "cost-effective options" will change the negative perception of "low cost housing" (eg. low quality, non- durable structures).

3. COST-EFFECTIVE CONSTRUCTION TECHNOLOGIES

Safety, capital cost (production and construction), comfort, expenditure on maintenance, availability of materials and artisans, aesthetics and to some extent the societal status are guiding criterion of acceptability of building construction technologies in India.

Buildings with conventional materials like cement and steel consume very large quantity of energy. Energy consumption in buildings occurs in five phases. The first phase corresponds to the manufacturing of building materials and components, which is termed as embodied energy. The second and third phases correspond to the energy used to transport materials from production plants to the building site and the energy used in the actual construction of the building, which is respectively referred to as grey energy and induced energy. Fourthly, energy is consumed at the operational phase, which corresponds to the running of the building when it is occupied. Finally, energy is consumed in the demolition process of buildings as well as in the recycling of their parts, when this is promoted [5].

Cost-effective construction technologies can bring down the embodied energy level associated with production of building materials by lowering use of energy-consuming materials. The cost-effective construction technologies would emerge as the most acceptable case of sustainable technologies in Rural India both in terms of cost and environment.

Cost-effective construction technologies, which apart from reducing cost of construction by reduction of quantity of building materials through improved and innovative techniques or use of alternate low-energy consuming materials, can play a great role in reduction of CO2 emission and thus help in the protection of the environment.

Bamboo is one such material, which can be used by the rural community in their construction, which has extensive potential in building industry when supported with required treatment and trained workers.

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]The use 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	Weight 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

The initiatives described in this paper can be useful tools for overall cost-effective development of rural areas. Imaginative design and the use of other locally available materials within the cultural context can make the bamboo building desirable rather than just acceptable. The current study reflects that, with the advent of new technology bamboo has become an alternative material to conventional materials thereby substituting the rapidly depleting resources. Bamboo is not merely a material for construction but also sustains the local economy in the process, balances the environment and generates local employment. Thus bamboo will continue to play an important part in the rural construction sector, as an economical building material.

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