

Bamboo Architecture-A Futuristic Sustainable Approach

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Abstract—In construction industry, Bamboo is used traditionally as a building material. Bamboo grows three times faster than other species which makes it fastest growing woody plant. In general it can be ready for construction within five to seven years. It is cost effective, aesthetically pleasing, renewal and environmental friendly building material. This versatile resource is characterized by high strength, low weight and does not required modern tool for processing. Also, high elasticity property of bamboo makes it prominent building material for earthquake-prone regions. Traditionally Bamboo was an integral part of building material in entire Southeast Asian region, nowadays due to its abundance and availability it gaining attraction all over the world. Due to rapid growth in construction industry, usage of modern building material has increased which lead to irreversible environmental damage. Hence, the need of the hour is to have a radical shift from modern building material to sustainable, eco-friendly and biodegradable building material. Bamboo, an eco-friendly and biodegradable, is naturally endowed with load bearing mass function, hollow inside and the fibers which run longitudinally, making it sustainable building material. This paper will focus on bamboo as a futuristic sustainable building material, a plant species recognized as a grass, its growing pattern, with respect to geographical condition, climate, soil and its availability. Furthermore, describes the government policies for usage of bamboo in different architecture, pros and cons as a sustainable building material.

Key words: Bamboo, sustainable, renewable, building material, issues, policy.

1. INTRODUCTION

Bamboo is a traditional building material widely used throughout the world. It belongs to grass family and in a developing country it is considered as the poor man's timber. It is widely recognized as highly renewable and versatile resource characterized by high strength and low weight. Bamboo is considered as the world's fastest growing woody grass. It is one of the most important non-timber forest resources due to the high socio-economic benefits from bamboo based products.

Since the Industrial Revolution, variety of new construction materials have been invented and developed, to meet the ever growing needs of people. Every year millions of new buildings are being constructed and new construction materials are being introduced. With the advent of new materials, the older materials were abandoned. Due to global warming issues across the globe, people are looking towards sustainable building material and technologies for solving the problem. the usage of, bamboo in modern construction have been driven by increasing needs for sustainable materials to meet rising demand due to rapid urbanization It helps in keeping the pace of development without further raising the carbon levels.

Bamboo has been used for centuries as a material for construction, furniture, crafts and food, among others. In recent years, the use of bamboo has been transformed, both in terms of design and products created. Paper industry, construction sector, wood substitutes and composites, furniture and handicrafts are the major consumers of bamboo in the country.

2. BAMBOO AS A PLANT

2.1 Features

Bamboo is a tribe of flowering perennial evergreen plants in the grass family *Poaceae*. It appears in Asian culture for centuries and nowadays it expands to western Continents. Bamboo is having 1450 species around the world, and appears in diverse climates from cold mountains to hot tropical regions except arctic Antarctica and Europe.

Bamboo grows very fast, approximately 7.5 to 40cm a day. Even though bamboo can reach up to 35 m high it is not considered as a tree or bush. It is called a grass because of its extensive underground network. Bamboos underground roots (rhizomes) can grow to another stem called *clum*. The stems are jointed, with regular nodes. They spread mainly through their roots or rhizomes, which can spread widely underground and send off new culms to break through the surface. It can

never happen to any kind of a tree. Having hollow and strong inner cylinder can grow to its maturity up to 3 years and then it is ready for harvesting. Bamboo plants are monocarpic, which means that it flowers and gives fruits once in their lifetime and then dies. Fig 1 explains the different parts of Bamboo.

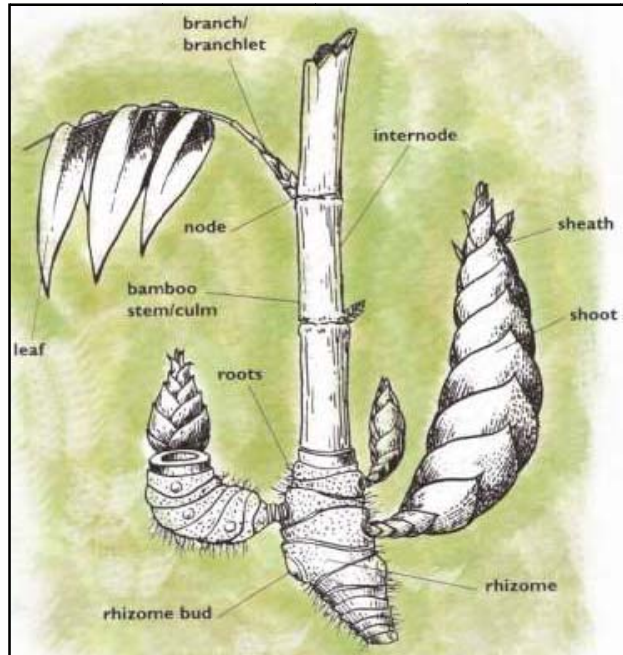


Fig 1- Parts of Bamboo

There are three main groups of bamboo (Characterized by the type of rhizome and the formation of upright canes)

- **Monopodial bamboos**
They form long and thin extensions of the Rhizome whose buds produce single shoots at regular intervals.
- **Sympodial bamboos**
They have short, thick rootstocks the tips of which produce the canes.
- **Climbing bamboos**
They can grow very irregularly and may form impenetrable thickets

2.2 Growth rate of Bamboo

Generally Bamboo takes about three to four years to get mature. It produces new canes (culms) in the spring. These shoots emerge out of the ground and grow in height and diameter for around 60 days. During this 60 day period it will produce limbs and leaves. It takes a varying number of years (4-15) for different species to reach their maximum size. It's dependent on species selection, soil, sunlight, climate and watering conditions. Fig 2 explains the growth rate of bamboo per year.

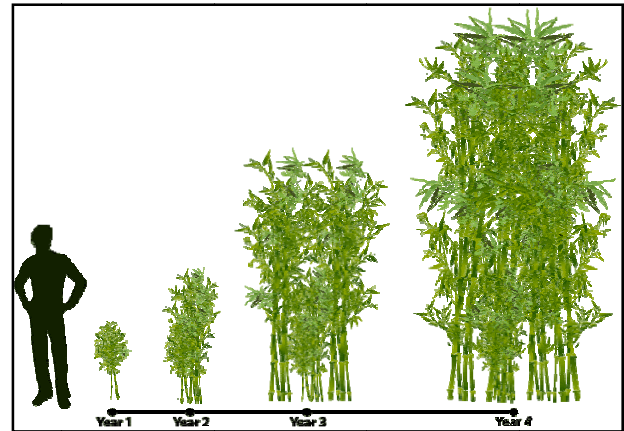


Fig 2- Growth Rate of bamboo

2.3 Geographical distribution climatic & soil conditions

Warm temperate, tropical climates offer optimum conditions for most bamboo species. They occur from East Asia through Northern Australia to West India and Himalayas. We can also find some species in sub-Saharan Africa and mid-Atlantic United States, Argentina and Chile. Unfortunately, there are no native species of bamboo found in Europe.

Generally bamboo plants prefer temperature between 20 to 30 degree Celsius, but there are some exceptions like "*Oxytenanthera abyssinica*" that can grow in central Africa within temperature 40-50 degree Celsius and "*Phyllostachys mitis*" in China, in the temperature under 0 degree Celsius. Fig no 3 explain the availability of bamboo throughout the world.

Bamboos grow mainly on sandy loam to loamy clay soils. They prefer well drained soils. They do not tolerate saline soils.



Fig 3- Bamboo distribution world wide

2.4 Availability in India

Bamboo is most abundant in India. India has the huge potential for bamboo with 14 million hectares of bamboo forest area. India is the second largest country in terms of bamboo resources.

Pie chart in Fig.4 shows the distribution of bamboo across India. North Eastern states are in the lead with about 28% of the total production.

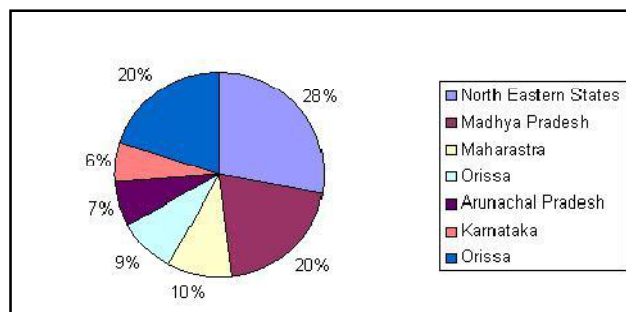


Fig 4- Distribution of bamboo across India

There are about 130 species of bamboo found across India. The National mission on Bamboo Applications has classified bamboo into several commercially viable species. Pie chart in fig no 5 explains the different species of bamboo in India and its availability. *Dendrocalamus Strictus* and *Melconna Bambusoides* are most commonly used as a building material.

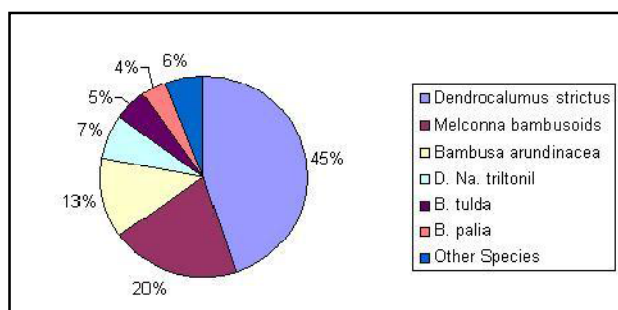


Fig 5- Different species available in India

3. BAMBOO IN ARCHITECTURE

There is a very old tradition of using bamboo in construction. The majority of bamboo used in architecture relates to the rural community in developing countries. The methods, activities and tools used in construction are very simple, straightforward and easily accessible. Bamboo in its natural condition (as solid culms, halved culms or as longitudinally split strips), has been used in almost all parts of house construction except for the fireplace and the chimneys.

3.1 Why bamboo is used as building material?

Bamboo is used as a construction material due to its diverse properties. Important properties are:

- It is fast growing, renewal, eco-friendly building material which is easily available.
- Tensile strength: Bamboo has higher tensile strength than steel because its fibers run axially.

- Fire Resistance: Capability of bamboo to resist fire is very high and it can withstand temperature up to 4000 C. This is due to the presence of high value of silicate acid and water.
- Elasticity: Bamboo is widely preferred in earthquake prone regions due to its elastic features.
- Weight of bamboo: Bamboos due to their low weight are easily displaced or installed making it very easier for transportation and construction.
- It can be easily bend, give desired shape and provide joints to suit the construction.
- They are cost effective and easy to use.

3.2 Uses of bamboo in architecture

Utilization of Bamboo for construction is achieved by a structural frame technique which is very similar to usual timber frame design and construction. It can be used in different ways for roof structure (purlins, rafters and reapers) roof covering, flooring, doors and windows, walls, ceiling, etc. Different uses are:

3.2.1 Foundations

There is very limited use of bamboo in foundation because when it is in contact with moisture laden surface they decay fast. However, this issue can be tackled to quite an extent though proper treatment using appropriate chemicals. The types of bamboo foundations identified are:

- Bamboo which is in direct contact with ground surface.
- Bamboo fixed to rock or preformed concrete footings
- Composite bamboo or concrete columns
- Bamboo piles

3.2.2 Walls Construction:

Bamboo is extensively used for construction of walls and partitions. Posts and beams, a part of structural frame work, are the main elements of the bamboo wall. It carry self-weight, internal and external load. An infill is used between framing elements to add strength and stability to the walls. Figure no 6 explains the different types of bamboo wall used in construction.

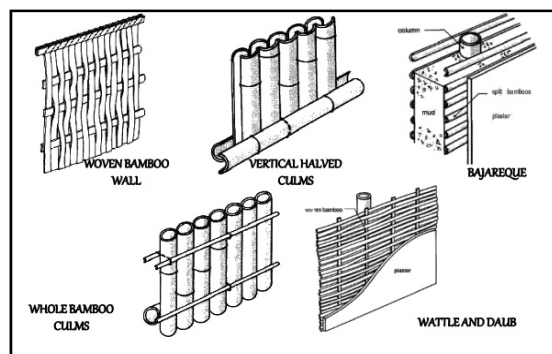


Fig 6- Types of bamboo walls

3.2.3 Roofing

Bamboo is one of the best roofing materials and provides ample sturdiness to the structure. It is considerably light weighted which makes them easy to install. The bamboo structure of a roof can comprise of purlins, rafters, battens and trusses. Because of its flexibility it is even possible to make

Various types of lightweight sheltering construction, depending on desired size, shape and load

The simplest form of bamboo roofing consists of a purlin and beams, supported on perimeter posts. Halved culms are then laid convex side down, edge-to-edge, spanning from the ridge to the eaves. A second layer, convex side up, is then laid to cover the joints.

Fig no 7 & 8 explains the traditional Truss King-post and Fink trusses with the span of 4 m.

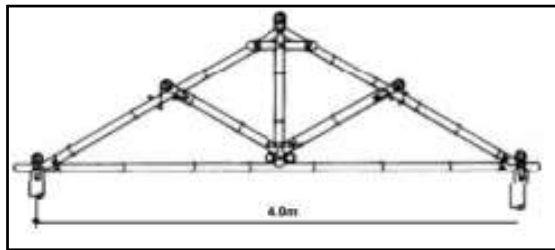


Fig no -7 traditional bamboo King post truss

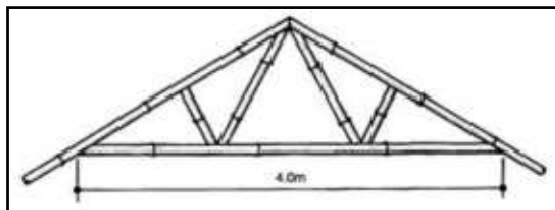


Fig no -8 bamboo fink truss

Janssen truss (fig no 9) can be achieved in an 8m span using improved jointing with the clum diameters range from 40-100mm

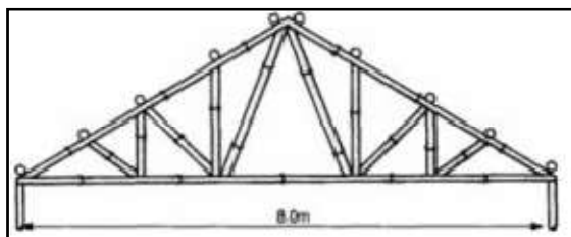


Fig no -9 bamboo Janssen truss

3.2.4 Roof covering

The bamboo roof covering is integrated part of the roof structure. It will provide non-structural function. Common roof covering examples are:

- Bamboo tiles
- Bamboo shingles
- Bamboo mats
- Corrugated bamboo roofing sheets

Bamboo tiles are same as ceramic mission tiles. For traditional rood covering, clums are cut vertically into half and overlapped.(fig no 10) Bamboo shingles are cut from green clums and shaped in traditional tile measurements (30-40mm width and 400- 600mm length). Bamboo mats and sheets include layers of bitumen and compressed between two mats forming covering panel. Then the mats can be fixed to the rafters in different layers. These products are strong, lightweight and provide good insulation.

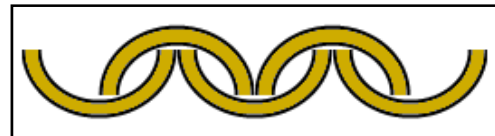


Fig no-10 overlapping of bamboo for rood covering

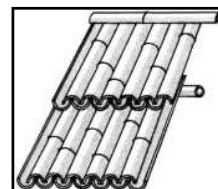


Fig no 11
Roof covering in

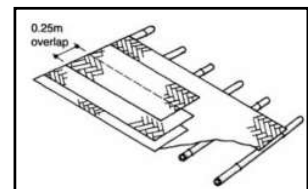


Fig no 12
Bituminized bamboo mat
Traditional houses

3.2.4 Bamboo Flooring:

Bamboo has been used as an alternative for flooring because of its physical similarities to true hardwoods and its properties like strength, durability, eco-friendliness. Basic floor structure is supported by joists that lay on the beams putted along the perimeter of the desired floor. Joist diameters are about 300-500mm, but depending on the floor area secondary joists of diameter 70 mm can also be added.(fig no-13)

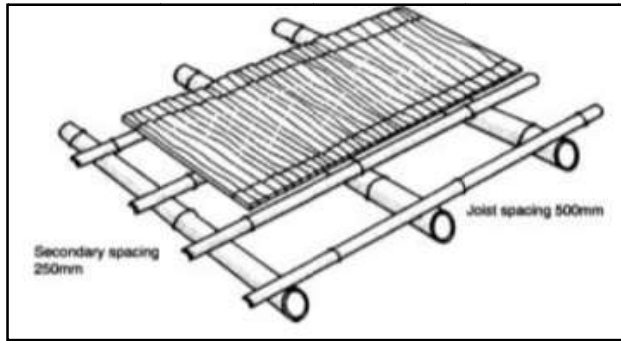


Fig no -13 primary and secondary Joist arrangement

4. BAMBOO AS A SUSTAINABLE MATERIAL

Bamboo is a, cost-effective and beautiful construction material for homes. It can be used throughout the entire structure (exterior and interior). It can be last for many years with proper treatment.

4.1 What is sustainability?

Healthy ecosystems and environments are necessary to the survival of humans and other organisms. Sustainability is the ability to meet the needs of the present without compromising the ability of future generations to meet their own needs. It helps in improving the quality of human life while living within the carrying capacity of the Earth's supporting ecosystems. And helps in minimizes negative impact in future life.

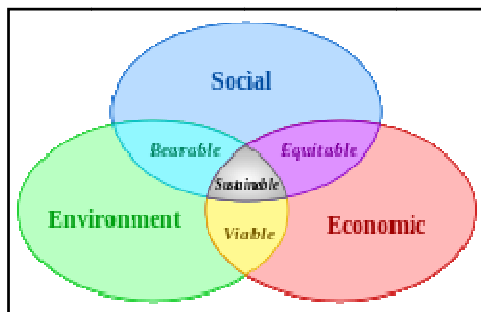


Fig no -14 three constituent parts of sustainability

Fig 14 explains that, environment, society and economy are the three main parts of Sustainability. The Brundtland Commission of United Nations on March 20, 1987 created sustainable development concept saying that “*sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs*”.

3.3 Environmental benefits:

- 35% higher oxygen emission into atmosphere than tree
- 40% more CO₂ absorption than trees
- No fertilizer or pesticides required for growth.

- Establishing an extensive root system into soils, which help in storing double the amount of water into watersheds, hence preventing soil erosion.
- Other parts of bamboo plants like leaves, stems, and stalks can be used for biomass to generate energy.

3.4 Economical & social benefits:

Bamboo can be alternative for building materials such as timber. Instead of cutting down trees that need 30 years to grow, we can harvest bamboo. For the comparison, giant bamboo species “*Bambusa balcooa*” come to maturity in 5 to 7 years, while commonly used wood teak takes 30 years to get full mature. Bamboo plywood is more efficient than regular plywood. It requires less raw material and energy in its productions, compared to regular plywood. Future bamboo might be a substitute for steel also.

Growing bamboo industry will provide good employment and help in preventing poverty and allowing poor people finding a job. Local people can cultivate process and trade the product all over the world, without using heavy machinery.

5. PARADIGM OF BAMBOO AS FUTURISTIC BUILDING MATERIAL

Bamboo is very versatile natural material, which is durable biodegradable and Environment friendly. In spite of many advantages, there are certain limitations which need to be focused, and make it sustainable for future.

5.1 Material limitations:

- Bamboo require preservation
- Splitting behavior: most common failure is splitting in longitudinal direction due to tension, compression and flexure load
- Shrinkage: Bamboo shrinks much greater than any other type of timber especially when it loses water.
- Durability: Bamboo should be sufficiently treated against insect or fungus attack before being utilized for building purposes.
- Jointing: Owing to the round shape, jointing is very difficult. Despite prevalence of various techniques of jointing, structural reliability of bamboo is questionable.
- Conical form of bamboo: can't be used in multi-story building.

5.2 Academic research and development issues

- Bamboo should be included in curriculum of architecture, civil and interior design.
- Lack of Skill development and training programs.
- Non-availability of data and Research results.
- Standardization of bamboo as a construction material.
- General usage and economical testing methods should be developed.

5.3 Legal, Financial and policy issues

- Redefining a 'Pucca house'
- It should be included in Standard Schedule of Rates and National Building Code published by the government.
- Changing Definition of Bamboo as Tree
- Special policies & funding for Bambo buildings
- changes in Housing standards

5.4 Social issues

- Substituting common material can reduce the cost up to 40%.
- Social acceptability

5.5 Execution issues

- Material availability and skill development
- Pre fabrication.
- Treatment of bamboo
- Raising the standards of implementation
- Elaborate, expensive and inaccurate testing methods
- Customized design, specification and constructional detail.

5.6 Government policies

Indian government is working at various levels for future development of bamboo in the country. National bamboo mission is established with the aim to promote the use of bamboo at district, state and National level.

National bamboo mission have some key elements-

- Research for sustainable Development and new bamboo agro-forestry Technique.
- Raising high yielding bamboo plantation on commercial basis in forest and non-forest area.
- Pest and disease management for bamboo plantation.
- Capacity Building and human resource development of famers, field functionaries and others.
- new marketing Strategy for bamboo, establishment of bamboo Markets, bamboo bazaar and retail outlets

- Meticulous monitoring, evaluation, reporting, database generation, compilation and analysis
- Organizing training program to various institute for increasing awareness of the material

6. CONCLUSION

Bamboo is tradition building material used in rural areas. With urbanization usage of modern building material is rapidly increasing. To handle the emerging trends and challenges posted by modern construction material, the goal is to provide cost effective, eco-friendly and sustainable material.to meet the challenges of modern era Bamboo is gaining attraction all over the world. Bamboo is extremely Strong, durable, lightweight & bio degradable material, considered to be a sustainable and renewable alternate construction material. Along with all these it is a prefabricated product, regrows quickly and absorb high level of carbon emission as compare to timber.in Furthermore it can be used in post construction decoration, also can be considered for pile foundation after suitable treatment. To enhance the usage of bamboo as a futuristic sustainable material architects, government bodies, and research organizations are working in tandem. Bamboo the sustainable material is most prominent as "NEO-MODERN MATERIAL IN CONSTRUCTION"

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