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Bamboo: A Sustainable and Low-Cost Housing Material for India

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***Abstract*— There has been a constant increase in the population of India. A large percent of the population is not able to afford their own homes owing to the increasing living costs. It is the need of the hour to adopt for cost effective housing solutions. The depletion in availability of natural resources and the climatic conditions has forced engineers to look for a more greener construction material. Thus a greener as well as an economical construction material is sought. Bamboo, because of its innumerable qualities may emerge as the necessary solution. Bamboo is available in abundance in the tropical and subtropical regions of India, China, Malaysia, Philippines, etc. and using it to its full potential may solve the housing needs of India. A review regarding the suitability of bamboo constructions so as to introduce a new low cost construction structural material to satisfy the housing needs of the poor has been presented here.**

Keywords—Bamboo, Low Cost Housing, Sustainability, Green Construction

I. INTRODUCTION

According to a certain survey the current housing shortage in India is about 5.9 crores and there is a stipulated requirement of about 5 crore houses by 2022. Hence the total need is about 10.9 crores. Also there is a constant increase in the inflation rates as well as people living below poverty line. [1]

This calls for the need of a low cost building material which allows for a speedy construction. The cost of constructing with cement and steel is already very high and it further inflates periodically. Also, cement and steel release a tremendous amount of CO_2 during their production. About 11% of the total CO_2 emissions are due to the steel industry while the cement industry contributes about 9% to it. [2] Thus steel and cement are costly as well as environmentally dangerous. On the other hand bamboo utilizes CO_2 during its production and releases O_2. Hence, bamboo can emerge as a naturally sustainable and a low cost construction material.

II. AVAILABILITY

India has the second largest bamboo reserve in the world. According to the state of forest report (FSI 2011) the total area under bamboo is 13.96 million hectares which is higher than the estimated value of 8.96 million hectares. This goes on to show that the bamboo productivity in India has been increasing very significantly. In India, the maximum bamboo production is found to be in the east with more than 50% of the total production. [3]

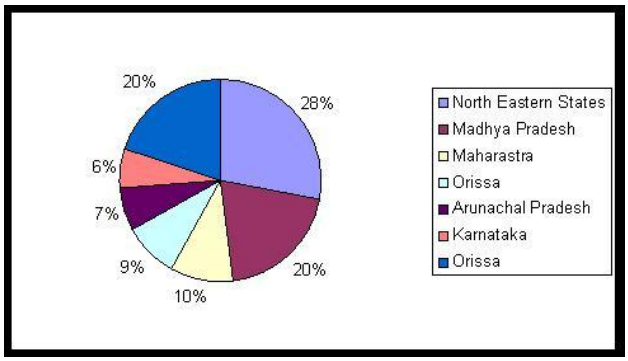

Fig.1 Percentage Distribution of Bamboo across India

Pie chart in Fig.1 shows the distribution of bamboo across India. North Eastern states are in the lead with about 28% of the total production.

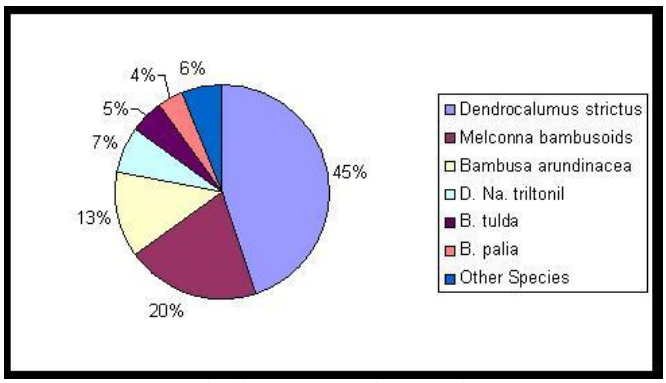

Fig.2 Percentage of different species of bamboo found in India

As shown in fig. 2, there are about 18 genera and 130 species of bamboo found across India. The National mission on Bamboo Applications has classified bamboo into several commercially viable species. Of these, the *Dendrocalamus Strictus* and *Melconna Bambusoides* are most commonly used as a building material.

III. SUITABILITY AS A BUILDING MATERIAL

Bamboo belongs to the grass family, Poaceae and it possesses the characteristics of wood. Hence once you cut bamboo it

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doesn't die but grows back on the same stem like grass. It grows about 30-100 cm a day with the world record being 91 cm in a day. It attains maximum size in 60-90 days after it starts sprouting and can be commercially used after 3 to 6 years. Moreover bamboo can also grow on less fertile soils. Hence it is very unlikely that bamboo will become scarce in a very short time. In a particular area a larger number of bamboo plantations are possible compared to other wooden plantations in the same area. Also bamboo houses stay warm in winters and cool in summers. Only mature bamboo between 3 to 5 years is used for construction purposes.

Bamboo has very convincing structural properties. It has a high strength to weight ratio which shall facilitate lighter constructions. It has a tensile strength comparable to steel. Also bamboo composites can be produced to enhance the required properties. Bamboo has very good earthquake resistant properties. Using bamboo as a structural material may reduce the cost of construction to about 40%. Thus, owing to the current scenario bamboo is the ideal choice for construction.

A. Bamboo as a Structural Material

According to the information given by the Stuttgarter Institute, the comparisons of properties of bamboo with those of steel are as follows:

TABLE I.

	Bamboo(N/mm^2)	Steel (N/mm^2)
Elastic Modulus	20000	210000
Tensile Strength	148-384	160
Compression Strength	62-93	140
Bending Strength	76-276	140
Shear Strength	20	96

Table I. Comparison of mechanical properties of bamboo and steel

This study shows that bamboo has comparable properties to steel. The tensile strength of bamboo and steel falls in the same range while the compressive strength of bamboo is slightly lesser than that of steel. In case of steel the tensile and compressive strengths are in the same range while in case of bamboo the compressive strength is much lower than tensile strength. The tensile and bending strength of certain bamboo is better compared to steel which shows that it should perform better in earthquakes. [5]

Bamboo can also be used in place of steel for concrete reinforcements. In that case the bamboo reinforcement area must be five times as compared to steel reinforcement area in order to achieve comparable shear strength. This is because the shear strength of steel is five times than that of bamboo.

Also wherever required, the properties can be strengthened by the use of composites. Thus bamboo is a suitable structural element for a building and with the proper use of technology, it can be used for extensive construction purposes. [4]

B. Bamboo as a Non Structural Material

Bamboo can be used extensively for non-structural applications like the construction of walls/partitions, flooring, roofing, scaffolding etc.

1. Walls

Bamboo is a lightweight material and hence during an earthquake there are very less chances that a bamboo wall will fall. Even if it falls it will cause comparably less harm to life and property. The exterior wall needs to be protected from atmospheric vagaries like rain, heat etc. and hence infill walls (grid of split bamboo covered in a wire mesh and cement mortar) must be used. Halved bamboo or its strips may be used to make bamboo mats which can be plastered with cement or lime on both sides can also be used. The interior walls can be made of a single layer of bamboo strips. [6] & [7]

2. Flooring

Split bamboo, flattened bamboo or bamboo mats can be used. In split bamboo flooring the bamboo culms are split with a certain specific width and then joined while in flattened bamboo flooring the split bamboos are flattened so as to have a uniform and plane surface. Very very thin strips of bamboo are joined with each other to form a mat and then laid as flooring. [6] & [7]

3. Roofing

Bamboo trusses can be adopted for roofing. Bamboo tile roofing can also be used wherein the bamboo culms are split in two and used with its convex side up alternately. A layer of bitumen can be applied between the two bamboo panels to form a more water-resistant panel. [6] & [7]

IV. DIFFICULTIES IN BAMBOO CONSTRUCTION

Bamboo has immense applications in the construction works and can suitably be used as a low cost sustainable material but it has to overcome certain drawbacks as insect infestation, natural shape, jointing etc.

A. Insect Infesation

Selection of the bamboo plays a vital role in decreasing the chances of an insect infestation. Mature bamboo between 3 to 5 years is selected for construction as it has very low sugar and starch content and hence has the least chance for an infestation. The bamboo must be treated first.

The most common treatment procedure is to soak bamboo in the solution of borax and boric acid for 7 days and then allowing them to dry under the sun for a week. Finally they are stacked in a cool place and are ready to use. Borax and boric acid are selected as they are natural repellent to insects. A week gives enough time to the bamboo to soak the solution and make it insect resistant. Basking in the sun gives it a golden yellow colour.

Some of the others procedures of bamboo treatments involve using preservatives like zinc chloride, copper sulphate, CCA etc. [9]

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B. Shape

Bamboo grows naturally and hence it is not possible that it would be exactly straight. Also it would not have the same cross sectional area throughout its length. Hence such limitations need to be considered while building a bamboo house. Although bamboo can be forced to grow in a particular shape if a mould of that shape is used during it growth, but would require planning years ahead of actual construction. If a bamboo element has to be bent to a particular shape it has to be inserted with a steel bar and some vapour holes must be created. Now on applying heat we can bend the bamboo and when cooled it would gain the bent shape.

C. Jointing

The traditional practice involves tying a rope around the joint but such joints lack stiffness and has very low efficiency. With the advancement in bamboo construction techniques lap joints and butt joints can also be seen in bamboo structures. Even plywood or timber gusset plates fixed to the bamboo with bolts may be used. [8]

V. ADVANTAGES

- Light in weight
- Economical and available in abundance
- Structural properties comparable to steel and concrete
- Rapid growth and higher yield per area of field
- Construction at a faster pace
- Economical
- It can address our climatic concerns by reducing the CO_2 content of the air and increasing the O_2 content.

VI. DISADVANTAGES

- It has a natural shape
- Must be treated for fire and insects
- Weak joints
- Requires detailed study and research for its use in construction.

VII. APPLICATIONS

The following are some of the applications of bamboo and it has an ability to offer much more when used in congruence with latest science and technology.

A. Use in Bridge Construction

Fig. 3. Hanging Bamboo bridge over Siang River, Arunachal Pradesh, India

B. Bamboo Amenities

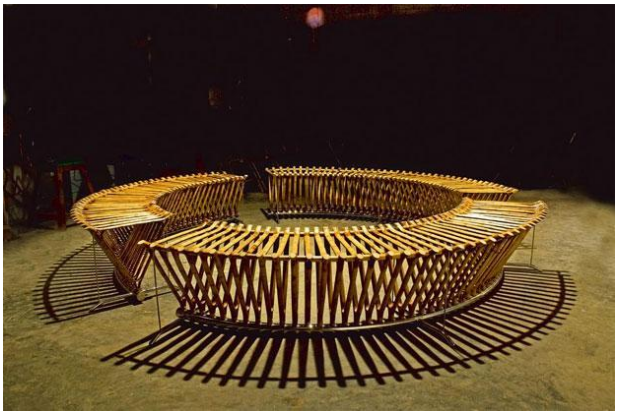

Fig. 4. Bamboo Benches

Fig. 5 Bamboo Busstop

C. Use of Bamboo In Various Housing Components

Bamboo has very good mechanical properties so it can be used in buildings as a structural component like columns and beams. It can also be used for roofing and flooring.

Fig. 6. Layered Bamboo Columns

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Fig. 7. Beam Column Joint

Fig. 8. Bamboo Roof

Fig. 9. Bamboo Truss

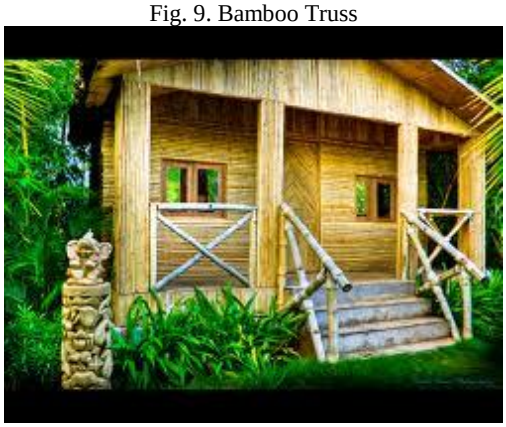

Fig. 10. Bamboo house

VIII. ECONOMY

A typical bamboo house can be built for a lifespan of about 25 – 30 years. Also, it can cost upto Rs. 300 – 700 per square feet as against the approximated Rs. 1500 for concrete buildings. [25]

IX. CONCLUSION

Sustainable products are those which along with its use for a required purpose also tend to cause little or no harm to the environment and they help in normalizing the climatic irregularities that have been caused over the period of years. Bamboo is one such product. It grows on less fertile soils, is a very light material, has higher strength to weight ratio, releases oxygen, grows rapidly, has great structural properties, is available in abundance and is very economical. It can be used to provide shelter to the larger mass of the nation who cannot afford their own house at a very economical rate and can speed up the mass housing projects. Thus, along with research advances and scientific precisions, bamboo can emerge as a material which will solve the housing needs of the country without harming the environment.

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