Review On Bamboo as Building Material

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Abstract- ***In this world of constantly increasing population and depleting resources there is urge to adopt cost effective and eco-friendly structures. This paper discusses the potential of bamboo and project the possibilities of usage of bamboo in the construction field. Bamboo is an ancient solution for the present-day problem. Bamboo is an appropriate substitute for the present convention building material such as steel and wood. The main characteristic of the bamboo which makes it a suitable building material is its high tensile strength which is equivalent to mild steel at the yield point and very good weight strength ratio making it high resilient against the forces created by the earth quakes and hurricanes. Bamboo can replace 70% of steel and wood used in the construction and reduce the cost by 40%. Bamboo can be used from scaffolding to every stage of construction like in footings, beams, columns, slabs, stair cases, etc. Bamboo is the renewable resource with amazing growth rate, rejuvenates the soil and grows in varied climatic conditions. Bamboo absorbs carbon dioxide and releases 35% more oxygen into the atmosphere than other hardwood trees. There are few building codes also available for the usage of bamboo in the construction such as ISO 22156:2004 Bamboo structural design, ISO 22157:2004 Bamboo physical and mechanical properties, IS 9096:1979 Code of practice for preservation of bamboo for structural purposes, IS 15912:2018 Structural design using Bamboo. Thus, bamboo is environmentally friendly, energy efficient and cost-effective material.***

Indexed Terms- ***Bamboo, Building, Steel, Structure.***

I. INTRODUCTION

The use of bamboo as building materials has occurred in a long period. Most of traditional houses in Asia use bamboo as building materials, both as structural and non-structural materials. The use of bamboo in traditional houses is due to the fact that bamboo grows abundantly in tropical rain forest. But after industrial era has begun the use of bamboo as building material become obsolete. Bamboo is considered as cheap and non-permanent materials. It is also considered as low-class material, even called as "the poor man timber" by many modern builders (Lobokivov, 2009). People tend to choose brick, concrete and steel as structural and construction materials for modern building.

But nowadays, after global warming and sustainability issues are emerged, bamboo as building materials is widely discussed and reviewed. Some architect and builder nowadays tend to choose bamboo for building material. High-quality woods for construction are rarely found nowadays because of deforestation. Wood also takes long time to regrow and ready to use as construction materials. Meanwhile bamboo can be harvested in a short time, which is between 3-5 years. When planting, bamboo also releases oxygen into the air, the ability that cannot be performed by industrial materials like steel, plastic and concrete. For the reasons, bamboo has been widely known as sustainable building materials.

Bamboo naturally grows in the forest but also can be cultivated in plantation [1].

Bamboo is primarily a type of giant grass with woody stems. The stems are called "shoots" when the plant is young and "culms" when the plant is mature. Each bamboo plant consists of two parts – the "Culm"/stem that grows above the ground and the underground "rhizome" that bears the roots of the plant. "A single bamboo clump can produce upto 15 kilometres of usable pole (up to 30 cm in diameter) in its lifetime." [2].

Fig. 1 – Various Types of bamboo

II. ADVANTAGES OF BAMBOO

"Reference [3]"The various advantages of bamboo are mentioned below:

1. Light, strong and versatile
2. Environment-friendly
3. Affordable
4. Self-renewing resource
5. Fast growing grass – 30cm to 1m in a day
6. Extremely strong natural fibre at par with standard hardwoods. Strongest part is its node.[4]
7. It has a great capacity for stock absorption, thus makes it useful in earthquake-prone areas [5].
8. Highly productive.

III. DISADVANTAGES OF BAMBOO

"Reference [6]"The major disadvantages of bamboo are as follows:

1. Lack of design guidance and codes.
2. Requires preservation.
3. Durability–bamboo is subjected to attack by fungi, insects; for this reason, untreated bamboo structures are viewed as temporary with an expected life of not more than 5 years.

IV. GENERAL USES

1. Soil stabilization, wind break, urban waste water treatment and reduction of nitrates contamination
2. Creating a fire line in traditional forests-due to the high content of silica.
3. Removing atmospheric carbon - bamboo can capture 17 metric tons of carbon per hectare per year, i.e., effectively than any other species.
4. Building and construction.
5. Small scale and cottage industries, for handicrafts and other products.
6. New generation products as wood substitutes
7. Industrial products
8. Transportation industry- truck bodies, railway carriages etc.
9. Boards and furniture
10. Long-time source of biomass for industry
11. Fuel source - capable of generating 1000-6000 cal/g- for households and small industries is an age-old, continuing practice. [7]

V. MAIN PROPERTIES OF BAMBOO

"reference [8]"Because As discussed before that Bamboo is a viable alternative for steel, concrete and masonry, it is so because of its properties which are clearly mention below:

A. TENSILE STRENGTH

Bamboo is able to resist more tension than compression. The fibres of bamboo run axially are of highly elastic vascular bundle that has a high tensile strength. The tensile strength of these fibres is higher than that of steel, but it's not possible to construct connections that can transfer this tensile strength. Slimmer tubes are superior in this aspect too. Inside the silicate outer skin, axial parallel elastically fibres with a tensile strength up to 400 N/mm^2 can be found. As a comparison, extremely strong wood fibres can resist a tension up to 50 N/mm^2.

B. 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 fibres.

C. ELASTIC MODULUS

The accumulation of highly strong fibres 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.

D. ANISOTROPIC PROPERTIES

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

E. 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.

F. 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.

Table 1 - Properties of bamboo, steel and spruce wood

KN/cm^2	Spruce wood	Bamboo	Steel
Elastic Modulus	1100	2000	2100
Compressive Strength	4.3	6.2-9.3	14
Tensile Strength	8.9	14.8	16
Bending Strength	6.8	7.26-27.6	14
Shear Strength	0.7	2.0	9.2

VI. B A M B O O AS ABUILDINGMATERIAL

Bamboo as a building material has high compressive strength and low weight has been one of the most used building materials as support for concrete, especially in those locations where it is found in abundance.

Bamboo as a building material is used for the construction of scaffolding, bridges and structures, houses.

Due to a distinctive rhizome-dependent system, bamboos are one of the fastest-growing plants in the world and their growth is three-times faster than most other species of plants. They are renewable and extremely versatile resource with multi-purpose usage. Among many uses of bamboo, Housing is one of the major areas applications especially in the wake of residential shortages around the globe.

Bamboo as a building material is conventionally associated with the region of Southeast Asia and South America where climate is best suitable for its cultivation. In many of the nations, bamboo is used to hold up suspension bridges or simply make places of dwelling.

Utilization of Bamboo for construction is achieved by a structural frame technique which is related to same approach applied in usual timber frame design and construction.

In the case bamboo, floor, walls and roof are interconnected and often rely on the other for overall stability. Bamboo has played a vital role in the growth of enterprises and the rural transformation [9].

A. SOME CUTES AND JOINTS IN BAMBOO

Figure 2 – Types of cut on bamboo

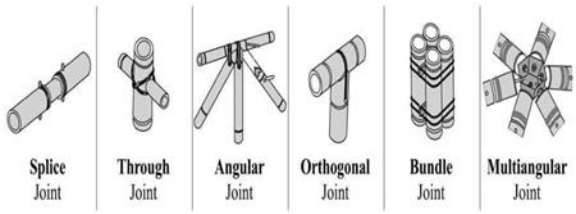

Figure 3 – Types of joint in bamboo

B. Bamboo Wall

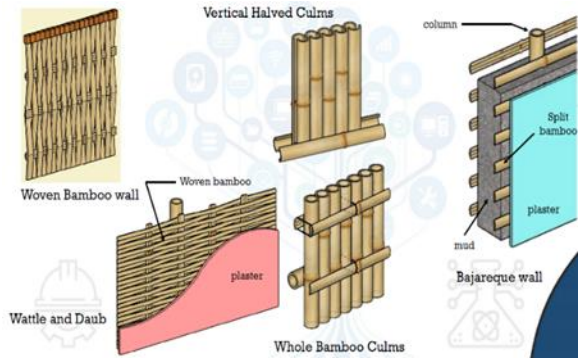

Figure 4 – Different types of bamboo wall

C. BAMBOO TRUSS

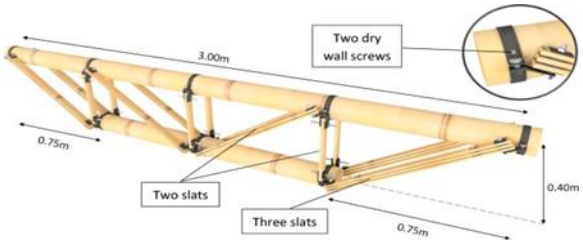

Figure 5 – Combined culm-slat Bamboo Truss

Figure 6- Bamboo Roof Truss

D. BAMBOO SCAFFOLDING

Figure 7 – Bamboo scaffoldings

Figure 8 – Bamboo scaffoldings

Figure 9 – Bamboo scaffoldings

VII. WHY BAMBOO AS REINFORCEMENT FOR RCC STRUCTURE FOR SMALL CONSTRUCTION IN HARSH CORROSIVE ENVIRONMENT?

In Brazil systematic studies were carried out on bamboo since 1979, of which the greater part was dedicated to the development of a methodology for its application in space structures and as reinforcement in concrete. The energy necessary to produce 1 m^3 per unit of stress projected in practice for materials commonly used in civil construction has been compared with that of bamboo. It was found that for steel it is necessary to spend 50 times more energy than for bamboo (Janssen, 1981). In the production of one tone steel two tons of CO2 is produced. In contrast bamboo plant absorbs CO2 besides producing oxygen. The tensile strength of bamboo is relatively high and can reach 370 MPa (Dunkelberg, 1985, Liese, 1992, Lopes, 1974), this turns the use of bamboo attractive as substitute of steel, especially when considering the relation between tensile resistance and specific weight of bamboo which is six times greater than that for steel (Ashby, 1992, Wgst, et al.,1993) [10].

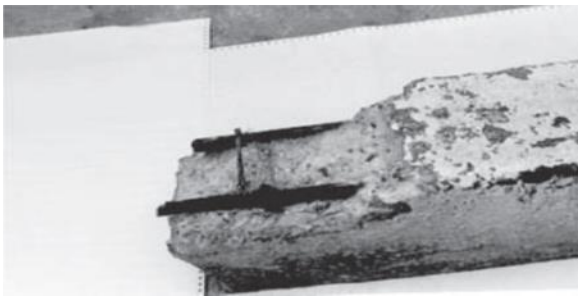

Figure 10 - Bamboo reinforcement after 15 years in open air

Figure 11 - Steel reinforcement after 10 years in closed area

In 1979 (Ghavami and Hombeeck, 1981). The steel reinforced concrete columns are part of the tunnel structure of Rio's Metro. The bamboo reinforced beam after testing has been exposed to open air in the PUC-Rio university campus. It can be observed that the bamboo segments treated against insects as well as for bonding with IGOL-T show a verysatisfactory behavior (refer fig. 10) and appearance after 15 years. However, the steel reinforcing bars after ten years had a serious corrosion problem (refer fig. 11) and are being substituted. The bamboo segments of the beam were taken out of the concrete and tested for their mechanical strength. They had a slight deterioration in their tensile strength as compared with the original untreated bamboo[11].

VIII. STRUCTURAL SAFETY

When considering a material for structural use, the first question that arises is about its safety. Fig. 12 shows a comparison between bamboo, timber, steel and concrete in term of their behavior under stress. The stresses, with the symbol "S" (pronounced "sigma"), are plotted on the horizontal axis. To make stresses between these different materials comparable, the value of the stress in the material when the building is in normal use is taken as the unit. This is indicated by the term "S use" (also called the "allowable stress") and is about 140 N/mm2 for steel and 10 N/mm2 for timber. In each of the three diagrams in Fig. 12, a formation like a hill can be seen. This is the area of stresses at failure during tests, the middle part of the "hill" indicating the mean stress at failure (denoted by "smean"). Each hill also shows an "S" value, which is the standard deviation indicating whether the results of a test are widespread or not. Technicians consider the stress under which 5% or 2.5% of the specimens fail as the limit, and the allowable stress shall be at a safe distance below this limit. These limits are indicated as $S_{5\%}$ or $S_{2.5\%}$. On the vertical axis, we see the value "p", which is the chance that a stress will occur. If a hill is wide and flat, the "p" is low; if a hill is narrow and steep, the "p" is high. The lowest diagram is for steel, a material that is produced using a very controlled process and hence, bad specimens are very rare. It shows a narrow and steep hill, indicating that failure under stress occurs in a narrow range indicated by a small value for "S". This means that the allowable stress ("S use") can be at a short distance from the stress at failure. The diagram in the middle for wood and bamboo, which are natural materials, shows a wide variety of stresses around the mean stress at failure. In these materials, specimen quality varies widely from very bad to very good. Because of this uncertainty, one finds a large distance between the stress at failure and the allowable stress. The top diagram is for concrete, which is between the other two as far as safety is concerned. In normal circumstances, the use of steel is economical because of the short distance between allowable stress and stress at failure, signifying the optimum use of the material. The use of timber and bamboo, on the other hand, is less optimal since the allowable stress is very low when compared with stress at failure [12].

In the case of a disaster like a hurricane or an earthquake, however, the stresses will get multiplied. They may become double the allowable stress. In such cases, stresses in steel will come into the area of failure, but not in timber and bamboo. This means that steel structures will suffer much damage, while most structures of timber or bamboo will remain in good condition. A bamboo house is a good place to stay during a hurricane or an earthquake (provided the house has been built with proper care) [13].

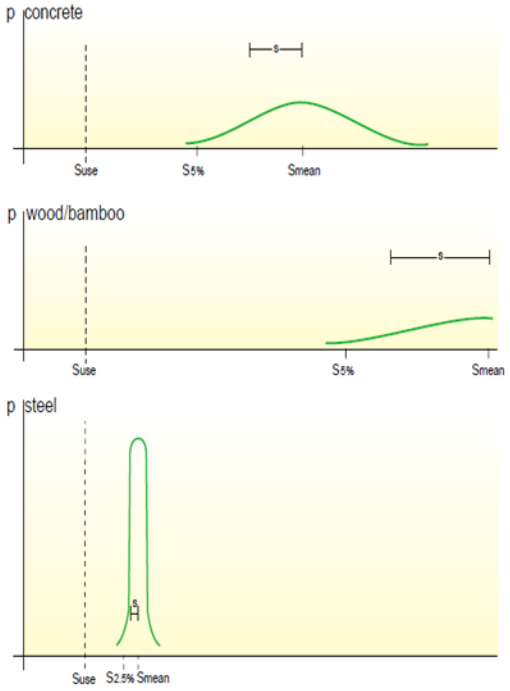

Figure 12 - A comparison of safety of bamboo and other materials

CONCLUSION

Bamboo is lighter in weight than bird but is stronger than steel. It takes carbon dioxide in and releases 30% more oxygen than tree. It grows a meter in one year and is mature in almost 3 years. Houses constructed using this bamboo are cool in summer and stays warm in winter and more over it can withstand earthquakes and can stand forever. The environmental and financial comparison demonstrates that bamboo can compete with building material. Bamboo is a natural product and will therefore always have some extent of irregularity. It is therefore suggested that the bamboo culm should be used in functions where the measurement requirements are not entirely precise or fixed, as in temporary buildings (e.g., pavilions and tents) or small civil projects. Furthermore, bamboo can play a role as a non-supporting or finishing material. And with more R&D on bamboo as a structural member will make it a replacement of steel in structural member in small civil engineering projects.

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