A Case Study on Bamboo as Green Building Material

Ayesha Syeda, Barvaliya Shrujal Jayesh Kumar

Abstract— In this world of constantly increasing population and depleting resources there is urge to adopt cost effective and ecofriendly structures. These papers discuss 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 it's 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, doors, windows 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. Thus bamboo is environmental friendly, energy efficient and cost effective material.

Keywords— Bamboo, ISO 22156:2004, ISO 22157: 2004, IS 9096: 1979

I. INTRODUCTION

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 up to 15 kilometers of usable pole (up to 30 cm in diameter) in its lifetime."

Fig1: Various species of Bamboo

II. POTENTIAL OF BAMBOO

It is Fastest growing plant. Bamboo has highest carbon dioxide absorption. It has Continuous absorption of carbon dioxide and release of oxygen .Quick harvest is possible which can be also continuous harvest .Sustains green cover of world.

III. GROW BAMBOO AT YOUR OWN PLACE

Just a 2ft length, 2 ft width and 2 ft depth pit is required. Mixture of 1/3rd of soil sand and manure each .The bamboo is to be properly watered it properly until it is nourished. If you don't have proper place it can also be planted in a 100 liters plastic drum. To protect it once in every 6 months remove weak shoots affected by insects.

IV. BAMBOO STRUCTURES IN THE WORLD

Bird-Like Amphitheater, Hanoi, Vietnam: This amphitheater in Vitenam used for the plays, auditorium is constructed only with bamboo and ropes.

Fig2: Bird-Like Amphitheater

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Green School, Bali: The Green School in Bali is the school with no walls. It's one of the green schools in the world where education is taught in the laps of environment.

Fig3: Green School, Bali

4.1 BAMBOO FOOTINGS

For use as foundation, the bamboo poles are directly driven into the ground. They have to, however, be pre-treated for protection from rot and fungi.

4.2 BAMBOO TRUSSES

For the spanning larger distances in public utility buildings like schools, storage areas, commercial buildings, bamboo is utilized as a truss member. Bamboo has a high strength /weight ratio and hence is a good alternative for roof framing.

Fig4: Bamboo Truss

4.3 BAMBOO WALLS

Bamboo walls are constructed by nailing a thin bamboo mat to either sides of a braced timber frame.

Fig4: Bamboo Walls

4.4 BAMBOO SCAFFOLDING

Since ancient times, bamboo poles have been tied together and used as scaffolding. The properties of bamboo such as resilience, shape and strength make it an ideal material for the purpose. The working platforms for masons can also be built of bamboo.

Fig5: Bamboo Scaffolding

4.5 BAMBOO TILE ROOFING

- This is the simplest form of bamboo roofing. The culms are split into halves, the diaphragms scooped out and these run full length from eave to ridge.
- The first layer of bamboo splits are layed concave side up and the second layer interlock over the first with convex side up. Though a very simple method, it can be completely watertight. The minimum pitch of the roof should be 30°.

Fig6: Bamboo Tile Roofing

4.6 BAMBOO REINFORCEMENT

Besides the use of bamboo as a building material, there have been proposals to use bamboo as reinforcement in RC columns, beams and slabs. One of the examples is a silo made of bamboo-reinforced concrete. This is the avenue for further research in the process of combining the ancient of bamboo building with modern materials like concrete**.**

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Fig7: Bamboo Reinforcement

V. PROPERTIES OF BAMBOO

Tensile strength: The fibers of the 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.

Shrinking: Bamboo shrinks more than wood when it loses water. The canes can tear apart at the nodes. Bamboo shrinks in the cross section ca. 10-16 %, in the wall thickness ca. 15-17 %.

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

***Strength Compressive*:** The portion of lignin affects the compressive strength. Whereas the high portion of cellulose influences the buckling and the tension strength, because it represents the building substance of the bamboo fiber.

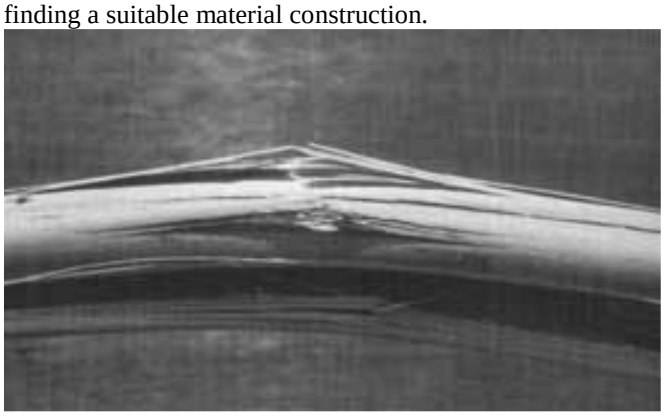
***Elastical modulus*:** In connection with the elastic modulus you can see an advantage in the use of slim tubes in relation to their cross section, too. The accumulation of highly strong fibers in the outer parts of the tube wall also work positive in connection with the elastically modulus like it does for the tension shear and bending strength. There exist an perfect relation of the cross section of the tube, if you fall below or above it the elastically modulus decreases (the higher the elastically modulus of the bamboo, the higher is the quality). Like the elastically modulus of solid wood the one of bamboo also decreases 5 to10% with growing stress. The enormous elasticity makes bamboo to be a very useful building material in areas with high risk of earthquakes. In Asia they still construct scaffolds with bamboo tubes

***Flexural (bending) strength*:** A trops analyzed common bamboos: diameter of tubes= 70-100 mm, wall thickness= 6-12 mm with a span of 3,60m. The elastically deflections were minimum =1/25under maximum 1/16, and as an average 1/20,1 of the spans. Where a deflection in the construction was unavoidable and annoying, one could bend the recently harvested tubes so that you get a super elevation, which later will be compensated under the working load.

Shearing strength: Especially for the construction of the bamboo tube joining it is important to consider the shearing resistance. The influence of the distance of the shearing surface decreases with growing length of shearing surface. At a wall thickness of 10 mm the shearing strength is about 11% lower than at a tube with a wall thickness of 6 mm; this could be explained by the distribution of the high-strength fibers per cross section surface..

VI. THE FRACTURE BEHAVIOR

The behavior of breaking of common building wood differs clearly from the breaking conditions of bamboo. Here you don't have a spontaneous break through the whole material after the tearing of single bamboo fibers like wood does. The appearing clefts are led off immediately in direction of the fiber and so they impair the critical region less. The energy transfer is delayed by diffusion. Especially the pressure-, shearing-, and inter laminar strength are raised by the knots. Those symptoms are titled as increasing factor of the fracture toughness. In the research of modern compound material it is less important to prevent the formation of cracks than to counteract the distribution of the clefts by finding a suitable material construction.



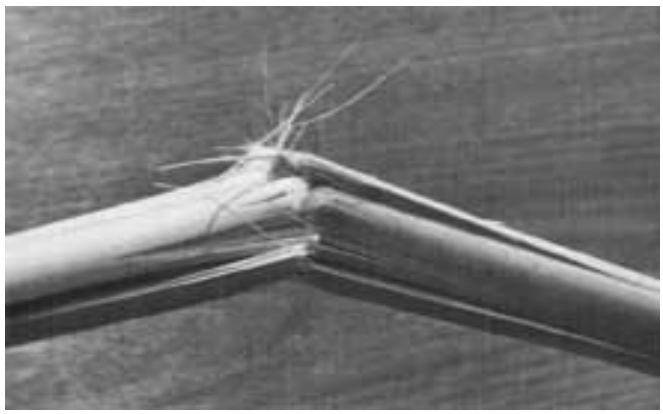


Fig8: The fracture behavior

The work that is needed for the punch of a bamboo tube is nearly the same whether the punch hits the knot or the intern odium. But the breaking conditions itself are totally different. If the punch hits the knot the tube will burst in axial stripes; that means a break as a result of the effort of the strength vertical to the fibers.. It is not comparable to the value of the spruce (0,5 mkp/cm²) because the bamboo is of course not solid but a tube.

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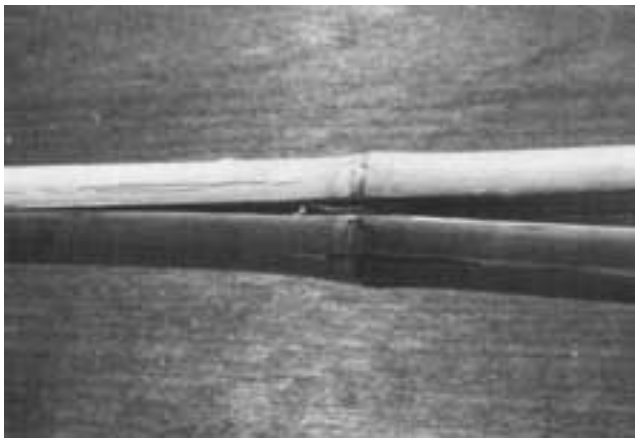

Fig9: The punch fracture behavior of bamboo

PROPERTIES	BAMBOO
Specific gravity	*0.575 to 0.655*
Average weight	*0.625kg/m*
Modulus of rupture	*610 to 1600kg/cm2*
Modulus of Elasticity	*1.5 to 2.0 x105kg/cm2*
Ultimate compressive stress	*794 to 864kg/cm2*
Safe working stress in compression	*105kg/cm2*
Safe working stress in tension	*160 to 350kg/cm2*
Safe working stress in shear	*115 to 180kg/cm2*
Bond stress	*5.6kg/cm2*

Table 1: Properties of bamboo

VII. WORKING OF BAMBOO

Bamboo can be worked with the simplest tools which must be especially sharp because of the highly silicified outer zone. Tool wear is considerably high.

Splitting: very easy as long as you work along the cane axis. The cane is split in halves and quarters and the driven apart by a wedge. It can also be split with a knife frame into four or eight segments cutting with a machete-type or knife used for cutting.

Fig10: Bamboo Splitting

Shaping: Bamboo which grows in a box gets a square shape. So it can be better used for connections.

Bending*:* Freshly cut, bamboo can be bent and will keep this shape after drying. When heated above 150° C, bamboo keeps its shape after it goes cold.

Fig11: Bamboo Bending

VIII. PRESERVATION AND TREATMENT

As bamboo has less natural durability it requires chemical treatment for longer life. Bamboos have low natural durability (1 to 3 years) against attacks by fungi and insects. They are very difficult to be treated by normal preservative methods in dry condition since their outer and to some extent inner membranes are impermeable to liquids. The treatment of bamboo is, therefore, best carried out in green conditions.

8.1 TYPES OF PREVENTION

Coal Tar Creosote:

- This is a fraction of coal tar distillate with a boiling point range above 200°C and is widely used admixed with fuel oil in the ratio of 50:50.
- The fuel oil ensures stability to creosote against evaporation and bleeding from the treated bamboos.
- Creosote has high performance; it is non-corrosive and provides good protection from termites.

Boric Acid Borax*:*

- This has been used successfully against lyctus borers. A mixture of 2:5 percent of each is found more suitable.

8.2 METHODS OF TREATMENT

- ***Surface Application*****:** this is done by brushing, spraying or dipping of timber in preservative solution for the required period.
- ***Soaking process*****:** the debarked timber is submerged in the preservative solution for sufficient period till the desired absorption is obtained.

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IX. ADVANTAGES OF BAMBOO

- Bamboo is low weight material to be used for construction.
- It can be transported and worked easily.
- The use of cranes is mostly unnecessary.
- It is a very flexible plant.
- Grows back very rapidly once harvested.
- Raw material for paper making.
- Bamboo has a higher tensile strength.
- Usage of bamboos will reduce deforestation
- Composite material

X. DISADVANTAGES OF BAMBOO

- If not treated well it will get attacked by the fungi.
- Bamboo does not lend itself to being painted because of its waxy coating.
- Bamboo is not designed to bear weight width-wise.

XI. 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 were 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.

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