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Bamboo as a Green Alternative Building Material

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***Abstract*—In the world of constantly increasing population and depleting resources there is urge to adopt cost effective and ecofriendly structures. This paper discuss the potential of bamboo and project the possibilities of usage of bamboo in the construction field. Bamboo is an appropriate substitute for the present convention building material such as steel. The main characteristics of the bamboo which makes it suitable is its high tensile strength which is equivalent to mild steel at yield point and very good weight strength ratio making it high resilient against the forces created by the earthquakes and hurricanes etc. Bamboo can replace 70% of steel and wood used in the construction and reduce the cost by 40%. In fact, growth of every ton of bamboo consumes nearly a ton of carbon dioxide besides releasing 35 % more fresh oxygen into the atmosphere. Bamboo can be used from scaffolding to every stage of construction like in footings, beams, columns, slab, staircases, doors, windows, etc. Thus bamboo is environment friendly, energy efficient and cost effective material.**

***Index Terms*—bamboo, concrete, properties, reinforcement, steel, tensile strength**

I. Introduction

Bamboo has a long and well-established tradition as a building material throughout the world's tropical and sub-tropical regions. It is widely used for many forms of construction, in particular for housing in rural areas. It is estimated that there are 1200 species growing in about 14.5million hectares area. Most of them grow in Asia, Africa and Latin America. It grows approximately 7.5 to 40cm a day, with world record being 1.2m in 24 hours in japan. Commercially important species of bamboo usually mature in four to five years' time, after which multiple harvests are possible every second year, for up to 120 years in some species and indefinitely in others.

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 root of the plant.

Bamboo which is locally known as "Una" belongs to the family "Poaceae" and the subfamily "Bambusoidea" has approximate plot coverage of 5000 hectares. Out of all the species, only 5 species support the cottage industries, housing and construction projects in the country.

Fig. 1. 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. The 2-6% of starch content available in bamboo plays a major role in its durability. The long tapered fibers in bamboo culms are generally larger than that for wood and high concentrated in the outer 1/3of the wall and upper part of the culms giving it a superior slenderness.

III. Bamboo Structures in the World

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.

Fig. 2. Green School, Bali

Barajas International Airport, Madrid: The ceilings at Madrid International airport, designed by Richard Rogers, consists of 200,000m^2 of gently curved laminated bamboo laths, and is therefore the largest industrial bamboo project in the

world.

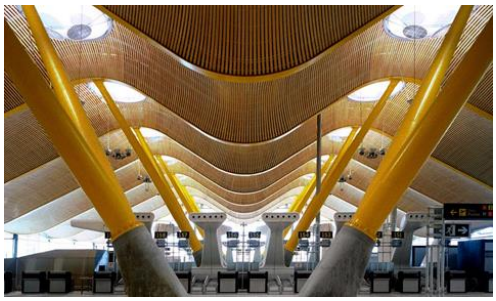

Fig. 3. Barajas International Airport, Madrid

A. 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. The use of bamboo for foundation is rather restricted. This is mainly due to the fact that like timber when in contact with damp ground, they deteriorate and decay very quickly unless treated with some very effective preservatives. However, in spite of their short life considerable use of bamboos is made as foundation or supporting posts in case of houses built on raised platforms.

Fig. 4. Bamboo footing

B. 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.

Fig. 5. Bamboo trusses

C. Bamboo Walls

The most extensive use of bamboo in construction is for the walls and partitions. The major elements, the posts and beams, generally constitute part or structural framework. They are to carry the self-weight of building and loads imposed by the occupants and the weather. An infill between framing members is required to complete the wall. The purpose of the infill is to protect against rain, wind and animals, to offer privacy and to provide in plane bracing to ensure the overall stability of the overall structure when subjected to horizontal forces.

Fig. 6. Bamboo walls

D. Bamboo Scaffolding

Because of the favorable relationship between load-bearing capacity and weight, bamboo can be used for the construction of safe scaffoldings even for very tall buildings. The cane extension is carried out by lashing the cane ends together with several ties. The ties are arranged in such a way that forces acting vertically downwards wedges the nodes in the lashing. The vertical and horizontal canes used for scaffolding are almost exclusively joined using soft lashing. This technique has the great advantage that the joints can be re-tensioned to the right degree without difficulty and also quickly released again.

Fig. 7. Bamboo scaffolding

E. Bamboo Tile Roofing

Fig. 8. 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 laid 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°.

F. 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.

Fig. 9. Bamboo reinforcement

IV. Properties of Bamboo

Tensile strength: Bamboo is good in tension more than the compression. There is highly tensile strength in outlying layer of bamboo. The fibers of bamboo take more tension force than the steel, but connection is not possible that can transfer tensile strength. Fibers of bamboo can be found with a tensile strength unto 400 N/mm^2.

Shrinkage: The shrike rate of bamboo is more than the wood when it losses water. The shrink rate is 15-17% of wall thickness.

Compressive Strength: There is a relation of higher compressive strength value on comparing bigger bamboo tube cross section and smaller tube cross section. Tubes of similar cross section have good material property.

Fire Resistance: In bamboo there is high content of silicate acid that shows its fire resisting ability.

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.

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 a 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.

TABLE I
Units for Magnetic Properties

Properties	Bamboo
Average weight	0.625kg/m
Modulus of rupture	610 to 1600kg/cm^2
Modulus of Elasticity	1.5 to 2.0 x105kg/cm^2
Ultimate compressive stress	794 to 864kg/cm^2
Safe working stress in compression	105kg/cm^2
Safe working stress in tension	160 to 350kg/cm^2
Safe working stress in shear	115 to 180kg/cm^2
Bond stress	5.6kg/cm^2

Flexural (bending) strength: A troops 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.

Stiffness of bamboo: A comparison of stiffness and strength of different construction materials is given in Fig 10.

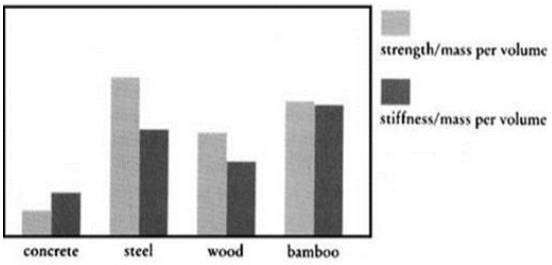

Fig. 10. Comparison of stiffness and strength

V. 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.

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.

Fig. 11. Splitting machine

Fig. 12. Bamboo bending

VI. Construction Principles

- Bamboo less than the size of 1.5 inches should not be used for reinforcement purpose.
- It should be tightly secured while placing the concrete with regular interval of 3 to 4 feet to prevent it from floating up in concrete.
- It has similar reinforcing design to steel reinforcement.
- In columns it resists same compressive load taken by concrete bamboo displaced.
- It has low modulus of elasticity; in flexural members some cracks are developed.
- When crack are not tolerable, steel reinforcement design or other designs are required.

VII. Types of Prevention

A. *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.

B. *Boric Acid Borax*

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

VIII. 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.

IX. Conclusion

At conclude we can say bamboo is a well-established building material. It is not easy to create beautiful spaces by using bamboo, because it is uneven material. We try to control the accuracy of the construction by applying unit-frame pre-fabrication. It is essential for us to educate workers and build the construction together. Good plantation control and management, straightening the culms through heat treatment, as well as good quality control can diminish irregularities of the material. However, bamboo gives a good thermal insulation by reflecting heat while brick absorbs heat, so the inside of house kept more comfortable.

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