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Bamboo - A Salutary Construction Material

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Abstract—*In the industry, business, society and environment, the present trend is to find an eco-alternative procedure which can, wholly or partially, replace the traditional procedures. Bamboo, as a building material, is a greedy approach towards construction in the present days. Bamboo can be used in the construction industry in limitless ways.*

But in today's trend of modernization with strength and endurance in the construction field, the uses of bamboo are limited and unknown. Hence, the present study is a humble effort towards the use of bamboo in construction field.

There are over 1000 species of bamboo. This amazing plant grows in tropical and temperate environments and is very hardy. When Bamboo is cut, it quickly grows back with most species maturing in 3-5 years. It is grown without pesticides or chemical fertilizers. It requires no irrigation and acts as a soil erosion inhibitor. Its production into fibres has lower environmental impact than other forms of fibre, especially synthetic one. According to UNESCO, 70 hectares of bamboo produces enough material to build 1000 houses. It is being used in road reinforcements in India and it is also used in bridges built in China, capable of supporting trucks that weigh as much as 16 tons. A 7.5 earthquake in Limón, Costa Rica, in April 1991 destroyed homes built with concrete and rebar, but all 20 of the more-flexible bamboo houses at the earthquake's epicenter remained standing. In Meghalaya, an ingenious system of tapping of stream and spring water by using bamboo pipes to irrigate plantations is widely prevalent. It is so perfected that about 18-20 liters of water entering the bamboo pipe system per minute gets transported over several hundred meters and finally gets reduced to 20-80 drops per minute at the site of the plant.

Keywords: *Bamboo, Construction, Irrigation, Reinforcement, Earthquake, Environment.*

1. INTRODUCTION

A study of the feasibility of using bamboo as a construction material was given recent consideration for use. Bamboo has a 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. The hollow structure of bamboo makes it unique to absorb some part of seismic waves. The traditional use of bamboo can be seen in drip irrigation in Eastern parts of India. 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. 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. Further studies will be required before complete confidence can be placed theoretical designs based on the material presented here.

2. SELECTION AND PREPARATION OF BAMBOO:

The following factors should be considered in the selection of bamboo culms (whole plants) for use as reinforcement in concrete structures:

1. Use only bamboo showing a pronounced brown color. This will insure that the plant is at least three years old.
2. Select the longest large diameter culms available.
3. Do not use whole culms of green, unseasoned bamboo.
4. Avoid bamboo cut in spring or early summer. These culms are generally weaker due to increased fiber moisture content.

A thorough treatment of Bamboo is required to protect it against insects and rot before it is put into use. Commonly a mixture of Borax and Boric acid are utilized for this purpose. Another procedure generally employed is to boil cut bamboo to remove the starches that draw insects. The development Bamboos are treated in such a way that they assume desired shapes and structures while they grow:

1. Squared cross-section can be obtained by compressing the growing stalk of bamboo within a square section.
2. Arch shapes of bamboo can also be created by compressing the bamboo's growth into the desired shape.

This would cost lesser than it would to get the same form with normal timber.

3. Curved and Flat shapes of bamboo are achieved through traditional techniques like applying heat and pressure.

Methods of Working on Bamboo

For a bamboo to be used as a building material, it must be worked on to create desired shape, bend and length to be used for structural or other purposes.

Following are the different works involved with use of bamboo:

1. Splitting
2. Shaping
3. Bending

Splitting of Bamboo

The bamboo canes are split into halves or quarter sections using a knife ideal for the job and setting them apart by a wedge. About four or eight segments can be acquired which are used as canes, strips or battens.

Shaping of Bamboo

Even though bamboos are naturally circular in form but if they are grown in a box of square shape they acquire a shape as desired.

Bending of Bamboo

Bamboos can be bent while they are freshly cut by heating them above the temperature of 150° C. Bamboo will retain this shape even after cooling and drying off.

3. DESIGN PRINCIPLES:

The results of these investigations form the basis of the conclusions and recommendations presented in this report. Further studies will be required before complete confidence can be placed theoretical designs based on the material presented here.

1. Domestic Housing and Small Buildings:

There is a long-standing tradition of bamboo construction, dating back to many hundreds of years. Different cultures have found in this material an economical system of building. Housing is one of the priority items and sensing the current shortage of the dwelling units, the present administrative leaders around the world find tough to hit upon a solution for. Bamboo building construction is characterized by a structural frame approach similar to that applied in traditional timber frame design and construction. Bamboo based materials are widely used too. In its natural condition as solid culms, halved culms or as longitudinally split strips, bamboo has been used in almost all parts of house construction except for the fireplace and the chimneys.

Figure 1

2. Foundation:

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. The types of bamboo foundations identified are:

a) Bamboo in direct ground contact: Bamboo is placed either on the surface or buried. For strength and stability, large diameter and thick walled sections of bamboo with closely spaced nodes should be used. Where these are not available, smaller sections can be tied together. It can decay within six months to two years, and hence preservative treatment is recommended.

b) Bamboo on rock or preformed concrete footings: where bamboo is being used for bearings, it should be placed out of ground contact on footings of either rock or preformed concrete. The largest and stiffest sections of bamboo should be used.

c) Composite bamboo/concrete columns: a concrete extension is given to a bamboo post using a plastic tube of the same diameter. The result is a bamboo post with an integral durable foundation.

d) Bamboo piles: it is used to stabilize soft soils and reduce building settlement. The treated split bamboo piles were filled with coconut coir strands wrapped with jute. The sections were then tied with wire. After installation of the piles the area was covered with a sandy material.

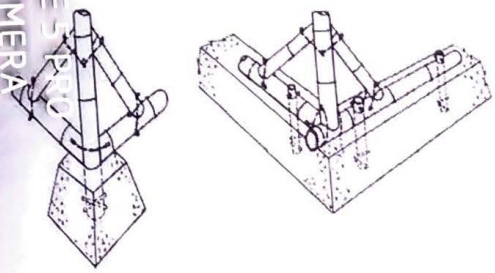

Figure 2

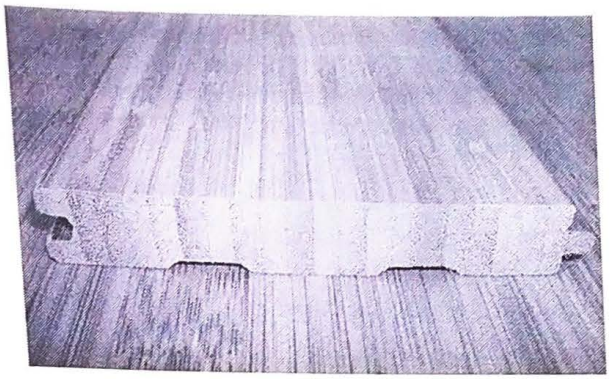

Figure 3

3. Flooring:

The floors may be at ground level, and therefore consists only of compacted earth, with or without a covering of bamboo matting. The preferred solution is to raise the floor above the ground creating a stilt type of construction. This improves comfort and hygiene and can provide a covered storage area below the floor. The surface of earth floor is sometimes made more stable by paving it with crude bamboo boards made by opening and flattening whole culms. The various types used are:

a) Small bamboo culms: they are directly tied and nailed together.

b) Split bamboo: culms are split along their length into strips, several centimeters wide.

c) Flattened bamboo: formed by splitting green bamboo culms removing the diaphragms, then rolling and flattening them. The resulting board is laid across the joists and fixed by nailing or tying. They are screened with cement mortar for reasons of hygiene and comfort as they are uneven and difficult to clean.

d) Bamboo mats: thin strips varying in size from 5-6mm or 10-15mm and thickness of 0.6-1.2mm. These slivers are then woven into mats of different sizes according to the available hot-press plates and user's demands. After drying the mats to 6-10% moisture content, sufficient glue is applied to ensure enough bonding between the overlapped areas. In construction using bamboo mats, phenolic resins are employed.

e) Bamboo plastic composites: it is an innovative technology in which bamboo fiber is the raw material and compounded with plastic as the core material of the flooring. This has higher water resistance and dimensional stability properties than those of normal floorings.

4. 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, 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.

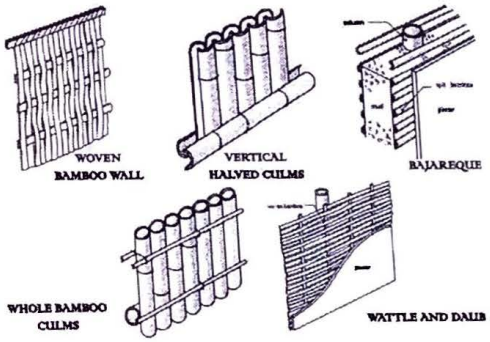

Figure 4

5. Roofing:

The roof offers protection against extremes of weather including rain, sun and wind, and to provide shelter, clear and usable space beneath the canopy. Above all it must be strong enough to resist the considerable forces generated by wind and roof coverings. In this respect, bamboo is ideal as a roofing material - it is strong, resilient and light weighted. The bamboo structure of a roof can comprise of purlins, rafters and trusses.

a) The simplest form consists of a bamboo 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.

b) Corrugated sheets made out of bamboo are also used commonly as roof covering. The bamboo mats are dipped in resin, dried and heat pressed under pressure in a specially made platen, to give strong, reliable sheets of bamboo, which is lightweight.

c) A layer of bitumen is sandwiched between two mats of bamboo forming a semi rigid panel. The mats can be fixed to rafters at 200-250mm center to center. A bituminous or rubberized weatherproof coating is then applied to the finished roof.

d) Plastered bamboo: A cement plaster, with or without the addition of organic fibers, is traditionally applied to bamboo roofs, to get stronger roof coverings. Various forms of trusses are also adopted using bamboo culms of diameter ranging from 40mm-100mm.

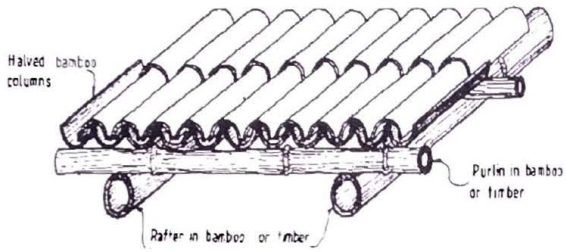

Figure 5

6. Scaffolding:

Because of the favorable relationship between load-bearing capacity and weight, bamboo can be used for the construction of save scaffoldings even for very tall buildings. Only lashed joints are used. 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

Figure 6

7. Bamboo as an earthquake proof material:

Bamboo as an earthquake proof material due to the lightweight and favorable elastic properties of bamboo, buildings made from it are very good at resisting earthquakes. Bamboo possesses excellent strength properties, especially tensile strength. Bamboo contains fibers which are up to 1 cm long as compared to wood (approx. 2 mm long). It has a tensile power up to 40 KN/cm2, whereas timber fibers as well as mild steel contain approximately 5 KN/cm2 or 36 KN/cm2 respectively. Bamboo is mostly suitable for seismic-resistant constructions as due to its capability for absorbing energy and superior bending strength. Its primary component is silicic acid that makes it long-lasting and inflexible. The tissues in bamboo are formed with 40% fiber, 51% parenchyma and 9% conductive tissue to make it more stable.

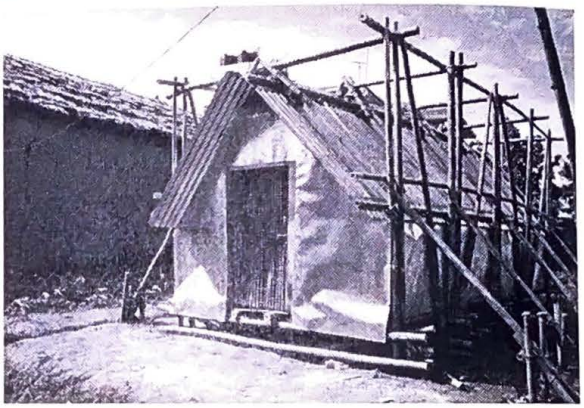

Figure 7

8. Bamboo as an irrigation material:

Bamboo pipes are use to divert perennial springs on the hilltops to lower reaches by gravity. In future we can use bamboo for laying channels for water line. We can use it at agriculture land, and house. It is low cost material and it is availability is very high. It is eco friendly. The only liability is the relatively short life of bamboo when it is in direct contact with earth and water. But bamboo has many advantages. A grove of bamboo, with little care, can come into commercial production in five years. Although the life of the construction material is not as long as metal or aluminum piping, the relative inexpensiveness of bamboo and the amount of production from a properly managed grove gives the farmer a reliable supply of replacement materials.

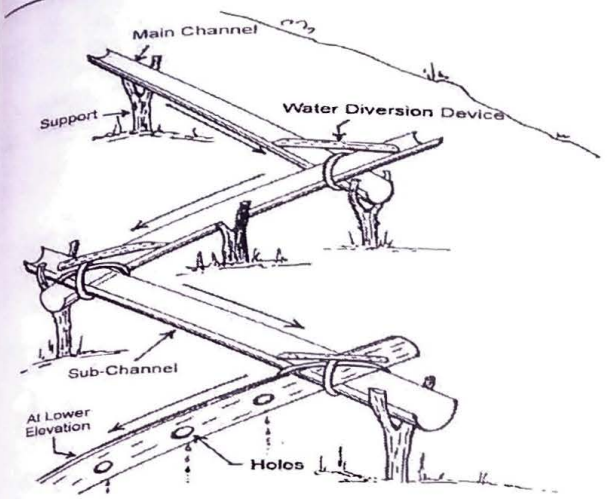

Figure 8

9. Bamboo as a road construction:

Bamboo we can use it as a road construction material. Using bamboo we can build pavement, bridge. In hill station we can build a bamboo bridge which is more stable and not more expensive. In road we may use it which is easy to use because the cost of it is very low, and it eco friendly.

Figure 9

4. RESEARCH AND DEVELOPMENT

Bamboo is not included as a mainstream material for Building construction in the curriculum of architecture, civil and interior design disciplines.

Hence most of the designers remain unaware of this wonderful sustainable material. Awareness needs to be built through workshops, seminars and lectures etc by experts in the Universities and Institutes. Most of the bamboo buildings in India today have been done by govt agencies as part of some testing and research with minimum attention to aesthetics and finish. Construction of aesthetically designed prototypes in prominent locations, for active promotions and display, to attract those willing to experiment with construction of bamboo buildings, has to be taken up on to make bamboo a desirable material. Research and innovations in alternative materials and building technologies hardly see the light of day.

Comparison of the mechanical properties of natural bamboo with other materials

Material	Density (g cm^{-3})	Tensile strength (MPa)	Specific tensile strength (N mg^{-1})	Tensile modulus (GPa)	Specific tensile modulus (kN mg^{-1})	Compression Strength (MPa)	Specific Compression Strength (N mg^{-1})
Wood	0.46	104	226	10	22	7	80
Concrete	2.5	4	2	48	19	69	28
Glass	2.5	50	20	69	28	50	20
Aluminium	2.7	247	88	69	25	-	-
Cast iron	7.8	138	18	207	26	120	15
Steel (0.06% C)	7.9	459	58	203	26	800	101
Polyester	1.8	276	153	18	10	270	150
Epoxy	1.8	1100	611	45	25	400	222
Bamboo	0.66	206	312	20	31	79	120

Figure 10

There could be many reasons for these experiments, though successfully conducted in Laboratories, to never reach the field of applications. Formulation of a set of standards for using bamboo, with treatment and testing methods etc included into the National building Code will make it convenient for architects and civil engineers to include bamboo in material specifications of their projects easier without risking the clients financing options.

5. ADVANTAGES OF BAMBOO AS CONSTRUCTION MATERIAL:

The various advantages of bamboo, in the construction methodology are as mentioned below:

1. Tensile strength: Bamboo has higher tensile strength than steel because its fibers run axially.
2. 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.
3. Elasticity: Bamboo is widely preferred in earthquake prone regions due to its elastic features.
4. Weight of bamboo: Bamboos due to their low weight are easily displaced or installed making it very easier for transportation and construction.
5. Unlike other building materials like cement and asbestos, bamboo poses no danger to health.
6. They are cost effective and easy to use.
7. They are especially in great demand in earthquake prone areas.

6. DISADVANTAGES OF BAMBOO AS CONSTRUCTION MATERIAL

With a handful of great boons of bamboo, lie some limitations side by side. As per observation and predictions, the following are the disadvantages of bamboo in construction field:

They require preservation
Shrinkage: Bamboo shrinks much greater than any other type of timber especially when it loses water.

3. Durability: Bamboo should be sufficiently treated against insect or fungus attack before being utilized for building purposes.
4. Jointing: Despite prevalence of various techniques of jointing, structural reliability of bamboo is questionable.

7. CONCLUSION:

Bamboo has a good engineering properties and it is a feasible substitute for other materials for housing and construction sector. Bamboo has high tensile strength to weight ratio. It can be easily worked upon by simple tools. It is one of the rapidly growing natural reserves also it is easily and locally available. Bamboo had been using for construction even from early times. From the Experiment, the elasticity of Bamboo strips is evaluated 5098 N/mm2, which is comparative same as steel. And also load carrying capacity of bamboo strips with concrete is similar to the steel reinforcement. The tensile strength is also dependent on the weight ration of bamboo and cement used for the making the Bamboo Fiber concrete. So it is seen that when the content of bamboo is an increase in the bamboo fiber concrete, so their strength will be increased up to some limited content of Bamboo fiber. We use bamboo in beams and girdlers because bamboo reinforcement in columns serves to resist a compression load equal to that taken by the concrete it displaces. It also will resist shear and tensile stresses. Bamboo cannot prevent cracking of concrete under ultimate load but from flexural test of bamboo reinforced beam, it has been seen that using bamboo reinforcement in concrete can increase the load carrying capacity of beam having same dimensions. We can use bamboo in building like flooring, scaffolding, walls, roofing, etc. It also helps to protect from the earthquake. An ingenious system of tapping of stream and spring water by using bamboo pipes to irrigate plantations is widely prevalent. It is so perfected that about 18-20 liters of water entering the bamboo pipe system per minute gets transported over several hundred meters.

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