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Use of Bamboo As Reinforcment Bars in Reinforced Concrete Structure

Alternate Solution for Low Cost Housing

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Abstract —*Reinforced concrete is most common material in the world but it become expensive when as reinforcement steel is used. So this present paper deals with the utilization of bamboo as reinforcement in place of steel. This study includes laboratory test of bamboo, cost analysis and limitations of bamboo. The intention of research is to utilize bamboo as a key structural material, for a safe and durable house, which can be affordable by poor people.*

Keywords-*Low cost housing, Bamboo as a Reinforcement, Bamboo Structure, Bamboo as a Structural Member, Replacement of Reinforcement bars*

I. INTRODUCTION

1.1. General

The concrete is widely used construction material in the world. It has very good compressive strength but it is weak in tension. To compensate this tensile strength of concrete we are using concrete and steel in most of all structural members. Reinforced Cement Concrete Sturucture become more expensive due to steel reinforcement bars use in the structural members. So it is necessary to findout some alternate for reinforcement bars. Bamboo can be the alternate material for the reinforcement bars in low cost housing. In this paper our focus is to provide a concise and detailed summary of bamboo as a reinforcing material in concrete for low cost residential building. This is done by analyzing the characteristics of bamboo whilst performing tests on bamboo. The result of this test will help us on determining the viability of bamboo as a cheap and renewable non-steel reinforcement within concrete.

1.2. Bamboo Diversity In India

India is the second richest country in bamboo genetic resources after China. These two countries together have more than half the total bamboo resources globally. There are 136 species of bamboos occurring in India. Fifty-eight species of bamboo belonging to 10 genera are distributed in the northeastern states alone.
The forest area, over which bamboos occur in India, on a conservative estimate, is 9.57 million hectares, which constitutes about 12.8% of the total area under forests. Out of the 22 genera in India, 19 are indigenous and three exotic. The annual production of bamboo in India is about 4.6 million tons; about 1.9 million tonesare used by the pulp industries. The annual yield of bamboo per hectare varies between 0.2 and 0.4 tones with an average of 0.33 tons per hectare, depending upon the intensity of stocking and biotic interferences. The economic impact of the agro forestry-based bamboo system may influence general economic development considerably. On average, 250 air-dried culms weigh one tone.

II. MATERIAL & METHODOLOGY

1.1. Overview of Bamboo

Bamboo is a variety of giant grass with woody stems. It consists of two parts, one is rhizome and other is stem. When plant is young the stems are called shoots , and when it matures they are called culms.it is fastest growing palnt in world reported to be 250cm in 24 hours, however the growth rate does dependent on species, climatic conditions and soil conditions. Bamboo plants are distributed into either runners or clumps. Runners grow in a haphazard fashion and clumps will add new shoots around a primary culm which grows clump size radially. One clump will produce approximately 15 kilometers of useable culm in its lifetime.

There are thousands of species of bamboo, and can be found in very diverse climates ranging from tropics to mountains Native growth and distribution is as far north as 50° N and as far south as 47° S which ranges through South East Asia and India, Central Africa and South America. Bamboo can be grown in almost any soil and can be full size within 12 months. The root systems of bamboo range from only 30-50cm in depth, therefore having minimal long term impact on its surrounding environment.

There are many uses of Bamboo, the most common uses include: culinary, medical, paper, instruments, and construction. Bamboo has been used in modern construction for years, however often only used for temporary uses such as scaffolding, as bamboo is a natural fiber and is relatively susceptible to deterioration. If bamboo is chemically, physically and/or thermally treated, it can suitably replace timber, steel, and other materials in a more permanent setting such as bridges and housing. Industrially treated bamboo has shown suitability for use within a composite and has already been successfully utilized for structural and non-structural applications in construction.

1.2. Mechanical Properties Of Bamboo

The material properties of bamboo, as shown below in table 1, gives a good theoretical base for assumptions and initial calculations as to determine the viability of bamboo for reinforcing concrete. These properties have been determined by E. Brink and J. Rush, in the U.S. Naval Civil Engineering laboratory in 1966.

Table-1

Mechanical property	Value
Ultimate Compressive Strength	55.0 Mpa
Allowable Compressive Stress	27.6 Mpa
Ultimate Tensile Strength	124.1 Mpa
Allowable Tensile Stress	27.6 Mpa
Allowable Bond Stress	344.0 Kpa
Modulus Of Elasticity	17.2 Gpa

1.3. Limitations Bamboo

The bulk of bamboo is gathered from the wild or rural environment, but in many areas bamboo resources have dwindled due to overexploitation and poor management. Possibly the major factor contributing to the view of bamboo as a temporary material is its lack of natural durability. It is susceptible to attack by insects and fungi. Its service life may be as low as one year when in ground contact. Even when issues of durability and strength are resolved, the question of acceptability remains.

1.4. Improve Durability & Water Absorption of Bamboo

Bamboo durability heavily depends on the preservation treatment methods. These preservation methods include smoking, heating, drying, coating with limestone (calcium hydroxide) and more recently, in addition with these methods, a chemical treatment is applied. The chemical composition used should have no effect on the bamboo fiber once injected, and should not be washed away by rain or humidity. No matter the treatments used, drying is a critical process in bamboo conservation. Bamboo with lower moisture content is much less prone to mould and insect attacks, ideally moisture content would be below 15%. The most common and effective preservation methods used globally is drying and then chemical treatment of the bamboo.

Bamboo has a great capacity to absorb water, so much so that a dimensional variation of up to 20% was found after a 7 day immersion in fresh water. A decrease in mechanical properties after this same water absorption was also apparent, due to the development of hydrogen bonding between the cellulose fiber and water molecules. On average tensile strengths recorded a 30% drop, flexural strengths had a 23% drop, and impact strength experienced a 32% drop. As can be seen from the findings of this previous study, it is imperative to implement some form of water repellent when using bamboo in a permanent, structural manner.

1.5. Selection Of Bamboo

When selecting bamboo culms, the following factors need to be considered as they have a significant effect on the bamboo's properties: Do not use bamboo harvested in spring or early summer, or green unseasoned bamboo, the fibers in these culms generally have increased moisture content, making them weaker. Select the largest diameter culms available, this is a sign of plant maturity and higher fiber density and strength. Use bamboo of a distinct brown colour, this warrants the plant is a minimum of three years old. As bamboo is a plant, it goes through a photosynthesis process and during the height of the day this process peaks. This means that the highest daily level of sap will be present with the sun, therefore making dawn, dusk, or night the ideal times to harvest.

1.6. Preparation Of Bamboo

- **Sizing**
  When using bamboo as reinforcement, splints are preferable over whole culms. This is due to the size of a whole culm and also considering culms are hollow, therefore possessing a higher buckling failure, which could be possible after load is applied to the concrete, or even due to the self-weight of the concrete.

- **Seasoning**
  After Bamboo is cut, it needs to be dried, seasoned and leached prior to use. This seasoning process will last two to four weeks, and culms must have regularly spaced support to minimalize warping. Leaching is the removal of sap after harvest, and is done via post-harvest photosynthesis or with force from mechanical treatments. These practices include pumping water through freshly cut culms, forcing sap out immersing culms in running steam and placing the base of the culms in water which will leach out the sap and also allow for full consumption of sugars by the bamboo. Bamboo should be dried slowly and evenly, in the shade. This will avoid the cracking of external skin membrane, and therefore reduce opportunities for fungal and pest infestations.

- **Bending**
  Bamboo can be permanently bent and shaped if heat and pressure is applied. This technique can be used to form the bamboo into ties, stirrups, and to put hooks or pegs into the bamboo for additional anchorage in the concrete.

- **Water-proof Coatings**
  Bamboo has a high water absorption capacity, and with this added water comes a decrease in mechanical strength due to excess hydrogen bonding between water molecules and the cellulose fiber of the bamboo. A water proof coating then becomes apparent and essential, if bamboo is to be used as a structural material. There are many water replant coatings which can be considered, such as coal tar, bituminous paint, sodium silicate, epoxy, the list goes on.

  A water resistant treatment will need to be applied to the bamboo before applying it as reinforcement to concrete. In all cases of treatment applications, only a thin coating shall be applied. A weaker bond with the concrete may be created with a thicker coat, due to lubrication of the bamboo. Treatment materials are bituminous paint, paraffin wax with helical copper wire, epoxy with fine sand. Finally, a control will be added to the trials. This will simply be untreated bamboo with its outer skin removed.

1.7. Bonding Issues

Bamboo has a high capacity for water absorption. When bamboo fibers are saturated their mechanical properties are dramatically reduced. Along with this mechanical reduction there is a dimensional variation due to water absorption which, if untreated, can cause micro cracks during the curing of the concrete. Factors which affect bonding, due to water absorption are; adhesive properties of cement environment; surface friction compression on bamboo due to concrete shrinkage; and shear resistance of the concrete, via roughness of reinforcement bar and surface form.

Slippage of a reinforcement bar in concrete is prevented by adhesion or a bond between the materials. Whilst moulding and curing concrete the bamboo reinforcement will absorb water from the concrete mix, leading to swelling. Towards the completion of the curing period, the bamboo will lose its moisture and shrink back to its original dimensions, therefore leaving voids around itself and resulting in cracking of the concrete. This issue creates severe limitations to the usage of bamboo as a replacement to steel, for concrete reinforcement. Therefore an effective water-repellent treatment must be executed in order to improve the bond of bamboo and concrete.

1.8. Adhesion Strength

On top of water absorption being an issue, bamboo’s outer layer has a smooth waxy coat, which will prevent adhesion. Steel rebar increases adhesion with ‘ribs’ which are added during the manufacturing process. A similar approach can be taken with bamboo, by first sanding away the smooth outer coat, and then creating a surface modification. This topography change can be achieved either by cutting small portions out of the edges of the bamboo, or by helically wrapping the bamboo in thin wiring.

III. LABORATORY TEST

3.1. Water Saturation Test

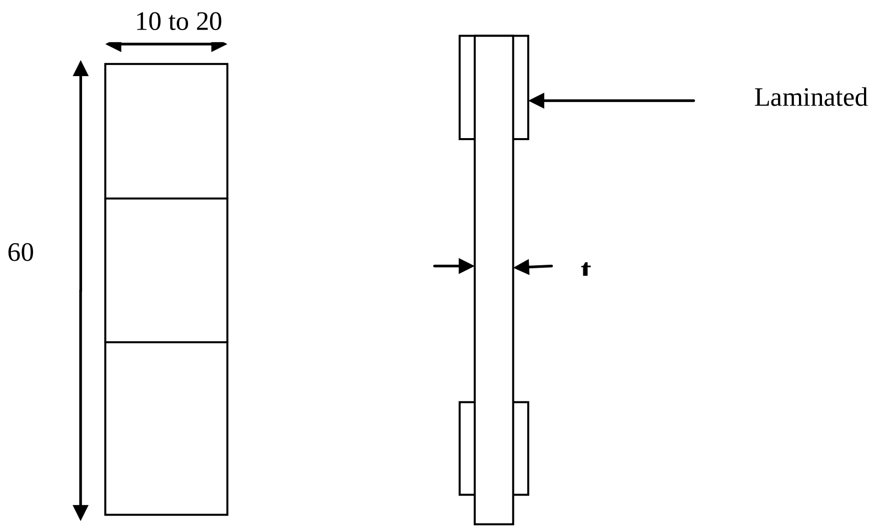
A water saturation test was performed on the treated bamboo to evaluate their impervious properties. Bamboo splints with coatings were initially weighed then submerged in water for 72 hours. They were then removed from the water chamber and patted dry with paper towels and then re-weighed to assess any water permeability. Permeability was assessed by the increase in water mass compared to the initial mass of the samples.

Table 2- Permeability of Applied Coating	
Sample	**Permeability(%)**
Bituminous paint	0.0
Paraffin wax with helical copper wire	0.0
Epoxy with fine sand	0.0
Control	18.71

3.2. Tensile Test (As Per IS 6874:2008)

3.2.1. Test Specimen

Specimens for tensile strength test shall be taken from the undamaged ends of specimens used in static bending tests. The test specimens shall be with one node in the center. The general direction of the fibers shall be parallel to the longitudinal axis of the test specimen. The length of the specimen shall be 60 mm and the width shall be 10 to 20 mm, so that the test specimen is more or less flat. The thickness of the specimen shall be that of the wall thickness or less, depending on the diameter of the culm. All the dimensions shall be measured to an accuracy of 0.1 mm, It shall be permitted to use test pieces with laminated ends for better grip, as shown in Fig.



Preparation of Specimen

3.2.2. Calculations

The maximum tensile strength σ_{ult} N/mm², shall be determined as follows:

$$\sigma_{ult} = \frac{F_{ult}}{A}$$

Where

F_{ult} = maximum load, in N; and

A= area of cross-section of test specimen, in mm².

σ_{ult}, shall be rounded to the nearest full number.

3.2.3. Result

Table 3- Tensile Test Result	
Culm Diameter (mm)	Tensile Stress (Mpa)
57.5	130.1

3.3. Compression Test

3.3.1. Test Specimen

The samples used for the compressive testing are sections of the bamboo culm cut down to a length of 50mm. The lengths of the samples varied slightly as the cuts were not completely straight and true due to the cylindrical nature of the bamboo and cutting method used. A hacksaw was used to cut the lengths of bamboo meaning the end had a slight gradient to them. The ends also needed to be completely flat due to the testing procedure using flat plates to compress the bamboo on each end. This was dealt with by turning down each of the samples in a manual lathe to ensure the ends were perfectly flat and consistent throughout. This also meant the length of the samples varied slightly but were all within 1mm-2mm of each other. The average length of the samples whether it had nodes or no nodes is 46mm. The nodded samples were cut to ensure the node was in the centre of the sample to ensure consistent testing throughout. This was maintained by turning down the samples the same amount at either end when ensuring the ends where flat during sample preparation.

3.3.2. Calculation

The maximum compressive strength σ_{ult} ,in N/mm², shall be determined as follows:

$$\sigma_{ult}=\frac{F_{ult}}{A}$$

Where,

F_{ult} = maximum load, in N; and

A= area of cross-section of test specimen,

$=\frac{\pi}{4}[D^2-(D-2t)^2]$, in mm².

D=outer diameter, in mm; and
t=wall thickness, in mm.

σ_{ult}, shall be rounded to the nearest 0.5N/mm².

3.3.3. Result

Table 4- Compressive Test Results	
Sample	Compressive Stress (Mpa)
Nodes	70.1
Without Nodes	76.56

3.4. Three Point Bending Test

Flexural strength is the yield strength of a material where the top surface is under compressive stress and the bottom surface under tensile. For many materials it can be a similar value to that of a typical tensile test. However, since bamboo is not homogenous and is a natural material, the values are likely to be different between the Three Point Bending and Tensile tests undertaken in this study.

3.4.1. Test Parameters

Testing was done on full bamboo of width 60mm. The test is performed using a UTM machine. The sample setup as a simply supported beam where it has two underside supports spaced (L) distance apart. A load is applied to begin, after which a point load is applied in the centre of the beam at a rate of 2.5 mm/min. For this test, the distance travelled from the start position (mm), as well as the load (N) is recorded and is analysed in results section.

3.4.2. Calculations

a) The moment of inertia I , shall be calculated as follows:

$$I= \frac{\pi}{64}[D^4-(D-2t)^4]$$

where

D = outer diameter, in mm; and
t = wall thickness, in mm.

b) The ultimate strength σ_{ult} in static bending, in N/mm², shall be determined as follows:

$$\sigma_{ult}=\left[\frac{I}{6I}\left(FL\frac{D}{2}\right)\right]$$

where

I = moment of inertia, in mm^4;
F = maximum load, in N;
L = **effective** span, in mm; and
D = outer diameter, in mm.

σ_{ult}, shall be reported to an accuracy of 1 N/mm².

c) The modulus of elasticity (Young's modulus), *E*, in N/mm², shall be determined as follows:

$$E=\frac{23\ sL^3}{1296\ I}$$

where

L = clear span, in mm;
I = moment of inertia, in mm^4; and
s = slope of a linear part in the load deflection diagram, in N/mm.
E shall be reported by rounding to the nearest 100 N/mm².

3.4.3. Results

Table 4- Flexural Strength Result

Sample	Flexural Strength (Mpa)
Nodes	70.1
Without Nodes	76.56

IV. CONCLUSION & FUTURESCOPE

4.1 Conclusion

- After doing all these tests we can conclude that bamboo can be used as a construction material in replacement of reinforcement bars.
- However, water absorption is an unfavorable inherent material limitation, which can lead to poor bonding between the concrete and bamboo, and cracking of the concrete during the curing process. This needs to be rectified before bamboo can be used as a reinforcement material for concrete.
- Bamboo has very good tensile strength, but according to the availability of shape and size of bamboo we can use it up to two storey building. It is necessary to coated bamboo rods before use it in the construction.

4.2 Future Scope

- Before use bamboo as reinforcement bars in structural members it necessary to do some research on large scale.
- We can design and cast large size structural member like column, beam or slab and perform test like compressive or tensile test as per IS code it to check its viability.
- We can use coated bamboo and non coated bamboo pieces in structural member to check out the importance of coating on bamboo, change in its bonding strength and water absorption test.
- The life cycle of these components should be considered. Further long term testing needs to be performed to determine the design life of bamboo reinforced concrete structure.
- The specific elastic modulus is one of the important property bamboo to the strength and stiffness of it, so one can do the experimental work to check out these properties.

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