



## **Adoption of Green Building Techniques (Replacement of Steel by Bamboo )**

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### **ABSTRACT**

The indiscriminate infrastructural growth is leading to rapid environmental degradation. Steel, cement, synthetic polymers and metal alloys used for construction activities are energy intensive as well as cause environmental pollution during their entire life cycle. In order to quantify the energy and CO<sub>2</sub> savings potential by applying best available technologies like vegetable fibres including bamboo, wastes from industry and mining etc., for engineering applications. In this paper an attempt has been made for finding bamboo as reinforcement in concrete by determining the various physical and mechanical properties of bamboo. The investigations conducted for the tested types of bamboo are evaluated using the same accept criteria as that of steel. This study investigates the Moso type bamboo tensile stress, compressive stress, Modulus of Elasticity, Water absorption capacity, Shear stress, and bonding stress. In general the strength of bamboo is as high as mild steel while, their density is as low as carbon fibre. In these investigation two types of Moso Bamboo specimens were considered. First type of specimen contains node at middle and second type of specimen contains nodes at 1/4th of length from each end. Tensile, Compressive, Shear and Bond tests for bamboo specimens were conducted on U.T.M and C.T.M the relevant graphs were drawn and are compared with graphs obtained for standard steel.

### **1. INTRODUCTION**

Globally, the iron and steel sector is the second largest industrial user of energy, consuming 616 Millions of tonnes of oil equivalent (Mtoe) in 2007, and the largest industrial source of Carbon dioxide (CO<sub>2</sub>) emissions with 2.3 giga tonnes of CO<sub>2</sub> (Gt CO<sub>2</sub>). India's iron and steel sector is the largest industrial user of energy in India, consuming 38 million tonnes of oil equivalent (Mtoe) in 2007. It is also the largest industrial source of carbon dioxide (CO<sub>2</sub>) emissions with 151 million tonnes of CO<sub>2</sub> (Mt CO<sub>2</sub>). There is urgency need for using naturally occurring products as a construction material to decrease the growth of energy consumption and CO<sub>2</sub> emissions replacement of bamboo in place of steel is widely recognized as one of the most important non-timber forest resources because of the high tensile strength and socio-economic benefits with bamboo based products. Bamboo has been used as a construction material in certain areas for centuries. As a result, many researchers have been trying to find on non-polluting and eco-friendly materials. Recently bamboo was considered to make use as a reinforcement material as it behave in-elastically even in light loads. This experimental research is focused on the use of bamboo as a reinforcing material instead of steel reinforcement in concrete. Bamboo is seismically resisting material and for sustainable environment development without harming our global environment since it absorbs a lot of nitrogen and carbon dioxide from the atmosphere during its growth.

## 2. MATERIALS

### 2.1. Bamboo

Bamboo is a tall grass, fast-growing and typically woody. The bamboo plant is a complex system, consisting of two sets of similarly structured vegetative axes: one above the ground and the other below the ground and the features are shown in Fig 1. The portion between two successive nodes is called an internode. Internodes are invariably, but not always, hollow. They are covered by sheaths at the initial stages of growth, which fall off as the plant matures. The inter-nodal length varies considerably across bamboo species, ranging from 5 to over 60 centimetres. In general, the inter-nodal length increases upwards along the culm from the lower portion to the middle, and then decreases as shown in Fig 1. Mainly cross section of bamboo has fibres from which the mechanical properties of bamboo vary. The properties may vary based on the nature of growth, climatic conditions and soil moisture condition

#### Selection and Preparation of Bamboo

The brown colour bamboos are selected, which indicates that the plant is at least three years old. Longest and large diameter culms are selected based on availability. In the preparation of bamboo the culms should be seasoned and split. The culms should be well seasoned before use so that sweetness of the bamboo will be lost and insect attacks will be minimised which is used for construction. The bambooculms are split or cut by means of hand knife or machine splitting equipment. The bamboos split into required dimensions based on use called as moso bamboo used in present study.

### 2.2 Water proof material

When bamboo is used as reinforcement in concrete it gets swelling; it should receive a waterproof coating to minimise swelling. “ALGICOAT RC-104” is used as a water proofing agent in present research.

### 2.3 Steel bars

HYSD bars are used in this study, for determining bond stress. These values are compared with bamboo bond stress as per IS-456:2000 specifications.

### 2.4 Concrete

M-30 grade mix concrete used in the present study as per IS-456:2000 specifications. The concrete mix proportion (cement: fine aggregate: coarse aggregate) is 1:1.5:3 with a 0.54 water-cement ratio for cast cylinders for pull out test.

## 3. EXPERIMENTAL PROGRAM

Physical and mechanical properties of bamboo as reinforcement are determined. The properties are purely based on the requirements of reinforcement in concrete.

### 3.1. Physical Properties of Bamboo

Brown coloured bamboo specimens were selected and the length, weight, diameter, nodes were determined. The physical properties of bamboo culms are tabulated in table 2.

The physical properties like length, weight, no of nodes and diameter of each bamboo culms are different. No two bamboo properties are same because it is naturally grown; its properties vary based on growth, soil and climatic conditions.

S No	Length, m	Weight, kg	No of internodes	Base Dia	Middle Dia	Top Dia
1	5.50	9.45	20	77.7	80.1	67.3
2	5.50	7.77	13	72.1	75.2	65.7
3	4.63	6.81	15	75.6	76.0	69.8
4	5.78	11.40	22	89.5	85.4	72.9
5	5.55	10.12	21	76.2	75.3	70.1
6	4.92	6.41	18	72.4	79.7	70.2
7	5.10	8.65	18	87.3	79.6	75.4
8	5.37	9.43	16	77.5	80.2	69.4
9	4.91	8.25	15	71.1	76.7	62.2
10	5.25	9.28	21	89.5	97.5	92.8

Table 2 Physical characteristics of bamboo culms

### 3.2.Mechanical Properties of Bamboo

The mechanical properties are very important for using any material in construction and design. Mechanical properties of bamboo were determined by conducting the following tests:

- (1) Tensile test
- (2) Modulus of Elasticity
- (3) Compressive test
- (4) Pull-out test,
- (5) Shear test
- (6) Water absorption test

S NO	GENUS	NATURALLY OCCURING	INTRODUCED/ CULTIVATED	TOTAL NO OF SPECIES
1	Arundinaria	2	0	2
2	Bambusa	12	14	26
3	Dencrocalamus	1	8	15
4	Dinochloa	5	1	6
5	Gogantochloa	2	5	7
6	Melocanna	0	2	2
7	Ochlandra	9	0	9
8	Oxytenenhera	1	1	2
9	Pseudosasa	0	1	1
10	Siranundinaria	18	3	21

\*Bambusa and Dencrocalamus are discussed in this thesis

Table 1 presents the details of different types of Genus,number of species of bamboo and their occurrence. Table 1 Number of Species of Bamboos naturallyoccurring and cultivated in India

#### 3.2.4 Pull-out Test

##### BOND PROPERTIES OF BAMBOO BAR

The purpose of this chapter is to investigate the effect of the factors influencing the resulting of pull-out bond stress in the concrete.

The bamboo used in this investigation in Indian Timber Bamboo, Bamboosa. Two diameter of bamboo, 30mm and 22mm, were used. The yield strength of the bamboo was 197MPa as the test data carried out in our laboratory. Low strength concrete mix-designed were studied, in order to prepare a low strength concrete ( $f_c = 10\text{MPa}$  at 28days; water/cement ratio = 0.88), the aggregate being mixed and with a maximum size of 15mm.

##### Test Procedure

The measure of the bond strength or interfacial strength between the bamboo and a concrete can be found in this test. Also comparison between bamboo reinforced concreteand steel reinforced concrete is made as per requirement according to IS-456:2000 standards and requirements. Moso type bamboo of 1000mm length each and area based on cross section of bamboo are used. Concrete cylinders of size 150mmdia and 300 lengths are used for the test. Three types specimens of uncoated bamboo, water proofing material coated bamboo and HYSD steel bars of 8mm dia are used for this test. Concrete of M - 30 grade

with 1:1.5:3 (cement, fine aggregate and coarse aggregate). The bamboos specimens were placed at centre in concrete cylinders while casting. Three samples are prepared for each specimen by varying bond length until the specimen comes out of concrete by means of bond and not by tension while testing. Bond length ( $L_b$ ) is the length of bamboo which is in contact with concrete in cylinder as shown in Fig 2. The samples were tested after 28 days of curing are tested in universal testing machine of capacity 400KN. The ultimate load is recorded. The test results are tabulated in Table 5. The bond stress is determined from ultimate load using following formula.

$$\text{Bond Stress} = Z_{bd} = P/\pi d L_b \text{ Units are in N/mm}^2$$

Where P is the ultimate load at failure, dis the diameter of specimen and  $L_b$  is the length of bonding.

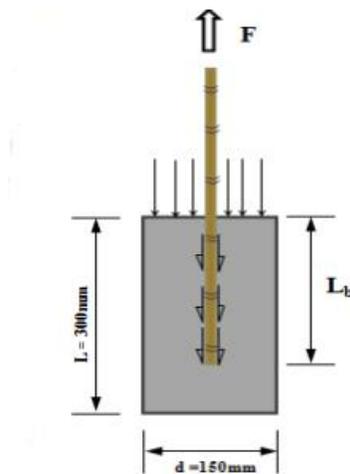


Fig. 2 Schematic diagram of specimen

For first few samples at the time of testing the bamboo were broken in tension without bond failure from concrete so, these values are not considered as bond stress. The samples were again cast by changing bond length  $L_b$  i.e., the length of bamboo embedded in concrete was decreased and was tested and the procedure was repeated until bamboo comes out smoothly from concrete while testing and these values obtained are due to bond failure. Pull-out failure occurred due to the shear strength between the bamboo and the concrete. From the table 5 it is observed that bond stress of coated and uncoated bamboo samples is nearly same if it pulls by an amount 0.1mm. It is observed that the bond stress of bamboo is 4.7 times less than that of steel.

### FURTHER INVESTIGATIONS

To improve the bond stress between the bamboo reinforcing bars and the surrounding concrete, pull-out tests were conducted on the specimens shown in Figure. Six prismatic specimens were cast with a single bamboo or steel embedded longitudinally in the specimen. In order to verify the effect of the difference in the bamboo surface condition, variables considered in this study were the material coated on the embedded bamboo surface (synthetic resin and synthetic rubber) and the surface condition (groove and its space). A summary of specimens is listed in Table 3.1.

Table 3.1. Detail of specimens

Specimen	No.1	No.2	No.3	No.4	No.5	No.6
agent	Synthetic resin	Synthetic resin	Synthetic resin	Synthetic rubber	Synthetic rubber	Synthetic resin
method	Brush coating	Spraying	Spraying	Spraying	Spraying	Brush coating
Surface	-	Slot processing @25mm	-	-	Slot processing @60mm	Slot processing @40mm
Treatment	Whole	Whole	Whole	Whole	Partial	Partial
Photo						

It is well known that bamboo embedded in concrete absorbs the water contained in the concrete. Therefore, bamboo repeats the relaxation and the expansion of volume, the bond between bamboo bars and the surrounding concrete is reduced. In addition, as the cause of bamboo loses its strength in concrete, it is also known that the alkaline component in the concrete decompose the fat content of bamboo. In this experiment, a synthetic resin and synthetic rubber is used for waterproofing on bamboo surface. Instead of expensive and special materials, as a readily available, a synthetic rubber has been used.

The strength of the joint between Bamboo bar and PC bar had to take into account the necessity of

preventing joint broken before the bond slip occur. So, bamboo bar and PC bar connected with the center hole jack, was joined by adhesive force, as shown in Figure 3.5. To begin, insert the screw inside the bamboo bar, filled with a chemical reaction of epoxy resin adhesive form (left Figure 3.5). Then, covered with a steel pipe welding a nut on the outside of the bamboo, was firmly adhered to the same adhesive filling the gap on the inside of the steel pipe to the surface of the bamboo. Based on preliminary tests several times, it was confirmed that the bond length of this joint is least 200mm or more.

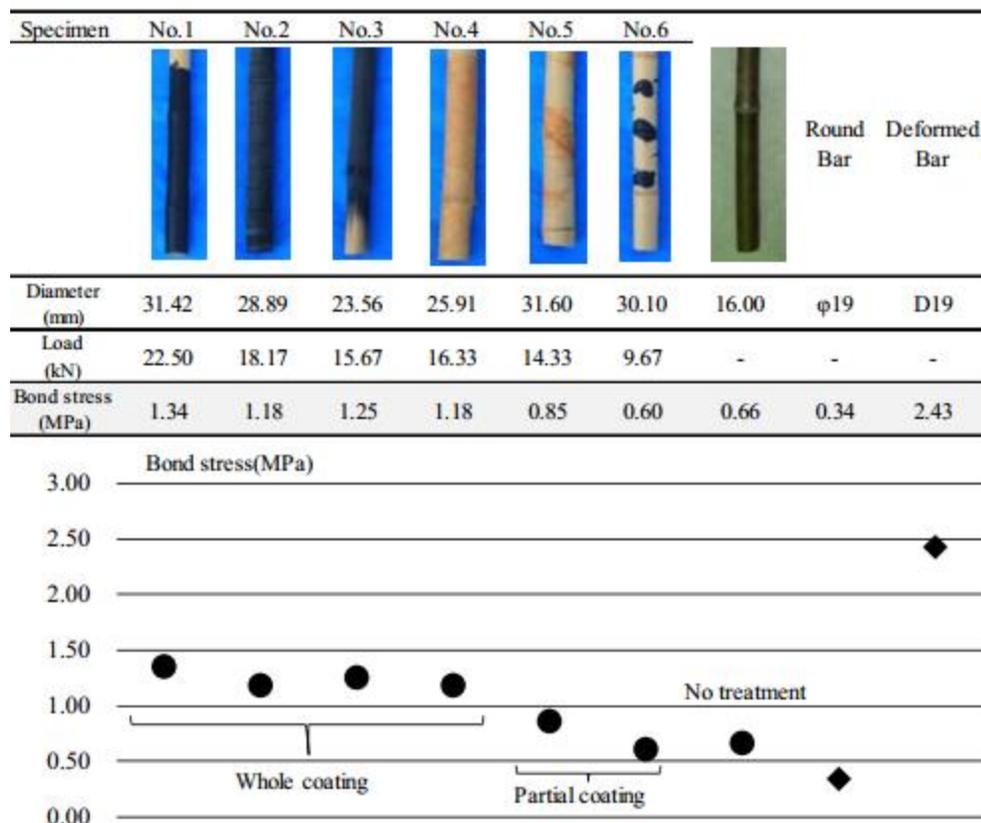


Figure 7 Bond Stress of Bamboo

Figure 7 shows a comparison of the bond stress of the nine experiments, just before the start of large slip deformation. Bond stress was calculated based on the measured value of the diameter of the test bars by the following equation:

$$\text{Bond Stress} = Z_{bd} = \frac{P}{\pi d L_b} \text{Units are in } N/mm^2$$

The surface of specimens No.1-4 is coated by the materials for treatment, entirely. The surface of specimens No.5 and 6 is smeared the materials on top of the groove on the bamboo surface, partly. It is considered that the bond stress of specimens No.5, 6 and non-coated bamboo is reduced, since the relaxation and expansion were repeated by the absorption of water on the surface of bamboo. Then, the bamboo began to slip in low bond stress 0.6-0.85MPa. On the other hand, the bond stress of specimens No.1-4 covering by full treatment show the high value 1.2-1.35MPa, but still is about half compared with the deformed steel bars. From the above, it is confirmed that such a simple surface treatment can be improved the bond stress between bamboo and the surrounding concrete. The difference by the materials on surface was not observed.

## CONCLUSION

For most people, it may seem odd to think about homes as a tool for changing behaviours or even for changing the world. Nevertheless, the preceding sections have argued that homes can and need to become just such a tool. In order to move toward sustainability, we as a society need to redefine what a home is. Part of that redefinition involves re-creating the job of the builder.

This synopsis has argued that creating such change is not a simple task. Green building practices are unlike other building innovations. The need for an integrated design and construction process and the diversity of possible solutions requires stakeholders to participate in new ways. While existing models of construction innovation may provide starting places for understanding the use of green building practices, this dissertation has outlined an approach to fostering green building practices that extends understanding in useful ways.

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