# Sustainable Construction Using Bamboo as Compression Members

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Abstract: Concrete is the largely using construction material. But it possesses some limitations in its application. The pollution created by cement is one of the major problems. Also the steel will become a scarce material after 20 or 30 years, so that, we should go for some sustainable building materials. The material should be also renewable. The significance of bamboo as a construction material arises in this situation. It is proven that bamboo possesses good tensile strength as well as compressive strength [6]. This material is also renewable and eco-friendly. Studies are conducted to analyze the performance of bamboo in place of reinforcement. This paper discuss about the physical and mechanical properties of bamboo and the behaviour of bamboo as a structural column. The columns are made with bamboo either bolted or tied together. The connection material is bolts. Normal strength tests are conducted over columns. The load and deflection is analyzed. It is seen that the load carrying capacity and load- deflection properties are better for steel bolted column. And it is also comparable with concrete and steel. This type of columns can be used for residential building purposes. By using bamboo structural members, the cost can be reduced. Of course the economic benefit will go to the rural people, who cultivate bamboo. The method is sustainable, economic and possess nearly no pollution to the atmosphere. Since the material is renewable, it is highly reliable.

Keywords: Bamboo, physical properties, mechanical properties, sustainability, column

## 1. Introduction

Safe, reliable housing is recognized as a basic human need and a basic human right. The growing demand for adequate housing across the globe is straining the resource availability of conventional building materials (steel& concrete). The availability of steel will become very poor in the next 20 or 30 years, since it is not a renewable material and its making will take hundreds of years.

The increased use of concrete produces large environmental impacts as the production of cement generates large amount of  $CO_2$ . One tone of cement produces about 0.83tonnes of  $CO_2$ . That means 20 bags of cement itself produces a huge amount of  $CO_2$  emission.

It is found that 1 hectre of bamboo will absorb 21.41 tonnes of CO<sub>2</sub>. So it can be used as an eco-friendly construction material. It also possesses high compressive as well as tensile strength [6]. Bamboo has been used as a construction material from the ancient time period. The invention of concrete reduced the use of bamboo technology. But the drawback of concrete is recalling bamboo for take up the role. Bamboo is an eco-friendly, building renewable, low cost material. Bamboo construction satisfies the triple bottom line of sustainability. Economy, social aspects and environmental aspects are the triple bottom line of sustainability.

#### 1.1 Dendrocalamus strictus

Dendrocalamus strictus is the type of bamboo used for the testings. It is a bamboo species belongs to the Dendrocalamus genus. The culms are often solid. Common names are male bamboo, solid bamboo, and calcutta bamboo.

#### 2. Physical Properties of Bamboo

The physical properties of bamboo are found out using standard tests recommended in IS 6874:2008.The test results are given in the Table 1

Property	Value	
Moisture content	25.48%	
Density	765kg/m <sup>3</sup>	
Shrinkage along diameter	1.53%	
Shrinkage along thickness	2.16%	
Shrinkage along length	0.34%	

Table 1: Physical properties of bamboo

The greater values of shrinkage indicate the higher moisture content in the bamboo. When the moisture content increases, the shrinkage also increases.

#### 3. Mechanical Properties of Bamboo

#### 3.1 Static Bending Strength.

The test setups (fig.1) consist of four point loading. The test specimen is a full culm bamboo with length is equal to 30 times its diameter.



Figure 1: The test setup for bending test



Figure 2: The load deflection graph

The test is conducted according to IS 6874:2008. The bending strength is given by the equation,

$$\sigma_{ult} = \frac{1}{6l} (FL\frac{D}{2}) \tag{1}$$

Where

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

F= maximum load in N D= diameter in mm t= thickness in mm L= effective span in mm

Also the modulus of elasticity can be determined from bending test by using the equation

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

Where s= slope of a linear part in the load deflection diagram, in  $N\!/mm$ 

#### 3.2 Compressive Strength.

Specimens for compressive strength tests are taken from the undamaged ends of specimens used in static bending tests. The test specimens shall be from internodes. The length of the specimen shall be taken equal to the outer diameter.



Figure 3: Compression testing of bamboo

#### 3.3 Tensile Strength

The test specimens are with one node in the centre. The general direction of the fibres is parallel to the longitudinal axis of the test specimen. The unsupported length of the specimen is 60mm and the width is 15mm. The thickness of specimen is the wall thickness.



Figure 4: Tensile strength test



Figure 5: Specimen after test

#### 3.4 Shear Strength

The test specimens are from internodes. The length of the specimen is equal to the diameter of the specimen. The specimens are supported at the lower end over a steel block of two triangles opposite to one another. The test specimen is loaded at the upper end over the other two independent triangular blocks. This results in four shear areas.



Figure 6: Shear testing

#### 4. Test Results

The mechanical strength of bamboo is obtained from the above discussed tests. The values obtained are listed in Table.2

Property	Value for bamboo [N/mm <sup>2</sup> ]	Value for concrete (M20) [N/mm <sup>2</sup> ]	Value for steel [N/mm <sup>2</sup> ]
Bending strength	82.8	3.6	140
Compressive strength	74.9	28.22	140
Tensile strength	148.15	2.81	160
Shear strength	31.88	-	92
Modulus of elasticity	1.62x10 <sup>4</sup>	2.72 x10 <sup>4</sup>	21 x10 <sup>4</sup>

The properties of bamboo are good enough to compare with concrete and steel. Bending strength, compressive strength, tensile strength and shear strength of bamboo is better when compared with M20 grade concrete. The tensile strength value is pretty higher as it is about twice its compressive strength. Even though its values are lesser than steel, it can be used in residential buildings.

## 5. Treatment of Bamboo

The treatment is done for avoiding the fungal attack and infestation due to insects and rodents. Fungi and insects are attacked to the starch content in the culm and animals can nest in hollow internodes. To overcome this problem, bamboo is treated using boric acid ( $Na_2B_2O.10H_2O$ ) and borax ( $H_2BO_2$ ) in the ratio 1:1.5 at a concentration of 5% in water. That is 10kg boric acid and 15kg of borax is used in 500Ltr of water. The chemical will replace the sap content inside bamboo and will cause dehydrating effect to insects. For entering the solution completely inside the culm, small holes are drilled in the internodes. Then the bamboos are placed inside the solution for a period of 2 weeks.



Figure 7: Drilling holes to bamboo



Figure 8: Preparation of treatment tank

#### 6. Bamboo Columns

Bamboo columns are fabricated using steel bolts as the connectors. Short columns are made up with 1m long bamboo culms and the connections are provided at 500mm centre to centre. The testing is done using a loading frame and the end connection is assumed to be pin joint.



Figure 9: Testing of column

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## 7. Results and Discussions

The columns are tested for load-deflection. The load-deflection graph is plotted and ultimate load for each column is noted. The average ultimate load capacity for the columns is 230kN.

The cracks appeared at the load 200kN. The cracks are developed at the points of bolted connections.

The load carrying capacity of the column is safe enough to provide for a residential building up to 3storeys.







Figure 11: Crack formation



Figure 12: Bending pattern of column

## 8. Conclusion

- The mechanical properties of bamboos are good and comparable with concrete and steel.
- The tensile strength dominates for bamboo when compared with the compressive strength.
- Bamboo can be used as structural members such as columns.
- The load carrying capacity for steel bolted bamboo column is high enough for a residential building which requires lesser load carrying capacity.
- It is a solution for many environmental problems caused by concrete.

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