INVESTIGATION ON PROPERTIES OF BAMBOO AS RAINFORCING MATERIAL IN CONCRETE

Tank Mihir P. #1, Prof. Suhasini M.Kulkarni#2
#Civil Engineering Department
Parul Institute of Engineering & Technology,
P.O.Limda, Ta. Waghodia, Dist. Vadodara
INDIA
1 er.mihirtank@gmail.com
2 suhasini_aarya@gmail.com

Abstract- ***This research is undertaken to investigate the possibility of using bamboo as a potential reinforcement in the concrete to compensate the low tensile property of the concrete. The strength of bamboo is greater than many timber products which are advantageous. Bamboo is easily accessible as it is available in almost every tropical and subtropical regions, this lowers the cost of construction. Bamboo may be the best alternative materials to substitute the reinforcing bar in concrete for less important structures by investigating the physical properties and mechanical of this type of natural reinforcement. Bamboo provides a more economical and environment-friendly alternative that is accessible to every section of the society.***

Key words: Bamboo, physical properties, mechanical properties.

I. Introduction

Bamboo is commonly introduced as a giant grass rather than a tree. It grows very rapidly as most growth occurs during first year and becomes matured by fifth year. The strength of bamboo increases with its age and reaches to the maximum strength at 3-4 years and then starts to decline in strength. Bamboo is a great renewable resource and can grow very rapidly with minimal help. When substituting bamboo for steel, it could save a lot of money and energy that goes into manufacturing, shipping, installation, and the disposal of steel for construction. Figure 1 compares the amount of energy that is used during the primary production for the same unit volume of both bamboo and steel. In addition, steel has about 85times more carbon impact of the environment than bamboo during its primary production. The bottom diagram in Figure.1 compares steel and bamboo's carbon foot print in kg of carbon dioxide per same unit volume of material. Another benefit that bamboo has is its ability to sequester up to 12 tons of CO_2 per hectare. Just by growing bamboo without removal from the land, It helps fight the reduction of CO2 in the atmosphere.

Bamboo contains parallel fibers that are reinforced along the axial direction of the Culm. At the node sections however, fibers are reinforced along the transverse direction towards the inner diameter of culm. These transverse fibers are aligned parallel with each other to a certain degree in a circular shape similar to observing rings at the base of a tree. Since these node sections contain material that connects the bamboo walls together, bamboo is not a completely hollow material. Since structure has a major impact on properties and performance, it is important to understand how the physical and chemical structures of bamboo can be influenced during its growth period. Multiple growth factors can affect, for example, Climate Factor, topography Factor, Soil Factor.

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 fiber. Tensile, Compressive, test for bamboo specimens were conducted on U.T.M and C.T.M the relevant graphs were drawn.

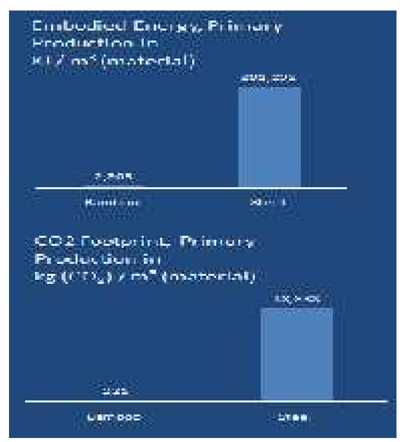

Fig.1 top graph shows Values of embodies energy for both amount of co_2 produced by both material.

II. BAMBOO

Bamboo culms are cylindrical shells as shown in Figure 2, and are divided by nodes as solid transversal diaphragms. The strength distribution is more uniform at the bottom of bamboo than at the top or at the middle of it since it is subjected to maximum bending stress due to wind at the top portion of the culms.

The following criteria should be considered in the selection of bamboo culms (whole plants) for use.

1. At least three years old plant should be used showing a pronounced brown colour.
2. The longest large diameter culms available should be Selected.
3. Whole culms of green, unseasoned bamboo should not be used.
4. Bamboo cut in spring or early summer should be avoided since they are generally weaker due to increased fiber moisture content.

In this research, three year old bamboo plants of pronounced brown colours were selected.

III. EXPERIMENTAL PROGRAM

Physical and mechanical properties of bamboo as reinforcement are determined.

3.1PHYSICAL PROPERTIES

(A) Moisture contain:-

The specimens for determining moisture content shall generally be taken be about 25 mm in length and 25 mm in width and having full wall thickness. The test specimens shall be weighed (mi) to an accuracy of 0.01 g and then dried in a hot-air oven at a temperature of 103 k 2°C for 24 h. The test specimen shall then be weighed and drying continued there after. The weighing shall be carried out and recorded every2 h until the difference between successive weighting's does not exceed 0.01 g, when the drying shall be completed. The final mass shall be considered as the oven dry mass (Mo).

Moisture contain can be calculated by following formula,

Moisture content, percent = M_i - M_o / M_o X 100 %

Where,

m_i = initial mass of the test specimen in 'g',

m_0 = oven dry mass, in g.

(B) Basic Mass per Volume or Density:-

The green volume shall be measured by water displacement method. The specimens for determining moisture content shall generally be taken be about 25 mm in length and 25 mm in width and having full wall thickness. The reading in the balance would indicate the mass of the displaced water. After determining the green volume, the test specimen shall be dried in a hot-air oven to obtain the oven dry mass (Mo).

Mass per volume, in kg/m^3 = M_o / V_g X 100

Where

m_0 = oven dry mass, in g; and

V_g = Volume, in cm^3

(C) Shrinkage:-

Shrinkage shall be determined along diameter, wall thickness and length of the test specimen. Specimens shall be 100 mm in length and free from nodes. The test specimens shall be taken from freshly felled culms, preferably from the lowest section of the culm.

Suitable marking shall be done on the specimens to facilitate taking observations at the same place every time, on each specimen, dimensions off our diameters and four wall thicknesses (two at either end) and two lengths shall be measured. Mass and dimensions of diameter, wall thickness and length of the specimens shall be recorded periodically until the readings are constant (air-dry condition).

Fig. 2Specimen for the Test of Shrinkage

Fig.3 Vernier caliper

The specimens shall then be placed in a hot-air over at 103 & 2°C till it reaches a constant weight (oven-dry condition).Shrinkage percentage (along diameter or wall thickness or length) correct to one decimal place shall be calculated in percentage as follows:

Shrinkage along diameter = D_i - D_f / D_i X 100 %

Shrinkage along wall thickness = T_i - T_f / T_i X 100 %

Shrinkage along length = L_i - L_f / L_i X 100 %

Where,

D_i,T_i,L_i = initial dimensions of outer diameter, wall thickness and length, respectively, in mm; and

D_f,T_f,L_f = final dimensions of outer diameter, wall thickness and length, respectively, in mm.

3.2 MECHANICAL PROPERTIES

(A) Static Bending Strength:-

A suitable testing machine capable of measuring loads to the nearest 100 N and deflection to the nearest 1 mm shall be used. The test shall be a four-point bending test. The length of the specimen shall be suitable to have a clear span of 30 times its diameter at the middle point. The loading of the test specimen shall be carried out uniformly at constant speed. The loading head of testing machine shall move at the rate of 0.5 mm/s. Deflection at the middle of the span shall be noted by means of a dial gauge at load increments of every 500 N. The load shall be recorded at the points of sudden changes in deflection, at the time of failure and at maximum level, if different from the load at failure. Crack development and the form of failure shall be noted. A load-deflection diagram shall be plotted.

a) The moment of inertia I in mm^2 shall be calculated as follows:

$$I = \Pi/64 [D^4 - (D - 2t)^4]$$

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

b) The ultimate strength σ_{ult} in static bending, in N/mm^2, shall be determined as follows:

$$\sigma_{ult} = 1/6I [FLD/2]$$

Where,
I = moment of inertia, in mm^4
F = maximum load, in N;
L = effective span, in mm;

c) The modulus of elasticity (Young's modulus), E, in N/mm^2, shall be determined as follows:

$$E = 23sL^3/1296 I$$

Where,
L = Clear span, in mm;
I = moment of inertia, in mm4; and
s = slop of a linear part in the load deflection diagram, in N/mm^2.

(B)Compressive Strength Parallel to Grain:-

The test specimens shall be from inter node. The length of the specimen shall be taken equal to the outer diameter. Outer diameter and wall thickness shall be measured. The specimen shall be placed so that the centre of the movable head is vertically above the centre of the cross section of the specimen and a small load of not more than 1 KN shall be applied to set the specimen. The load shall be applied continuously and the movable head of the testing machine shal1travel at a constant rate of 0.01 mm/s. The maximum load at which the specimen fails shall be recorded.

Fig.4 Specimen before test.

Fig.5 Specimen after test.

The maximum compressive strength σ_{ult} N/mm^2, shall be determined as follows:

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

Where,
F_{ult} = maximum load, in N;
A = area of cross-section of test specimen,
$= \Pi/4 [D^2 - (D - 2t)^2]$ in mm^2;
D = outer diameter, in mm; and
t = wall thickness, in mm.

(C) Tensile Strength Parallel to Grain:-

The test specimens shall be with one node in the centre. The length of the specimen shall be 60 mm and the width shall be10 to 20 mm, so that the test specimen is more or less flat. All the dimensions shall be measured to an accuracy of 0.1 mm. The use of laminated ends can be performed on test pieces for better grip.

(i) Sample Preparation :-

First a bamboo was divided into two pieces length wise with the carpenter's tools like hammer, chisel etc. Each of the two halves was further divided into three pieces. It was then rounded to shape of a rod as shown in the Fig.1,Fig. 2, Fig. 3 and Fig. 4.

Fig.6 Bamboo splitting into Two pieces

Fig.7 Half bamboo Splitting into three pieces.

Fig.8preparation of Bamboo Sample using fem.

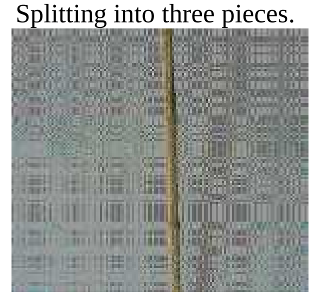

Fig.9final Bamboo sample.

Fig.10Bamboo sample Under Tension

Fig.11Typical tensile failure at knot between grip.

The maximum tensile strength σ_{ult} N/mm^2, shall be determined as follows:

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

Where,

F_{ult} = maximum load, in N;

A = area of cross-section of test specimen, in mm^2.

IV. TEST RESULTS AND DISCUSSIONS

4.1 Physical properties

(A) Moisture contain:-

The moisture contain capacity of bamboo increases by presence of powder like substance at nodes. In this test a main point observed was though the moisture contain capacity of bamboo is evaluated by weight and there is no large amount of swelling in bamboo. The percentages of water absorption values for different samples are shown.

Sample (1) m_i = 3.52g m_0 = 3.22g

Moisture Content = 3.52 – 3.22 / 3.22 x 100

= 9.31 %

Sample (2) m_i = 3.34g m_0 = 3.06g

Moisture Content = 3.34 – 3.22 / 3.22 x 100

= 9.15 %

Average Moisture Content = 9.20 %

(B) Basic mass per volume or density:-

The green volume is measured by water displacement method. A simple way is to place a beaker containing water on a top-pan balance and tare the weight to zero. The test specimen attached to a sharp needle shall then be completely immersed in water while ensuring that the specimen does not touch the beaker. The reading in the balance would indicate the mass of the displaced water. Considering the specific gravity of water as 1.0, this reading shall be considered as the volume of the test specimen, in cm3 (Vg).

Experiment result,

Sample (1) m_0 = 3.306 g V_g = 3.125 cc

Mass per volume, in kg/m^3 = (3.306/3.125) x 1000

= 1058 kg/m^3

Sample (2) m_0 = 3.22 g V_g = 3.105 cc

Mass per volume, in kg/m^3 = (3.22/3.105) x 1000

= 1037.04 kg/m^3

Average density = 1047.51 kg/m^3

(C)Shrinkage:-

Mass and dimensions of diameter, wall thickness and length of the specimens shall be recorded periodically until the readings are constant (air-dry condition). The specimens shall then be placed in a hot-air over at 103 &2°C till it reaches a constant weight (oven-dry condition). The mass and dimensions of the specimens shall be taken at the oven dry condition.

Experiment Result

D_i = 41.56 mm, D_f = 41.40 mm

T_i = 5.34 mm, T_i = 5.26 mm

L_i = 10.33 mm, L_f = 10.47 mm

Shrinkage along Diameter (%)= D_i - D_f / D_i X 100 %

= 41.56 - 41.40 / 41.56 x 100

= 0.384 %

Shrinkage along wall thickness = T_i - T_f / T_i X 100 %

= 5.34 – 5.26 / 5.34 X 100

= 1.50 %

Shrinkage along length = L_i - L_f / L_i X 100 %

= 10.33 – 10.47 X 100

= -1.35 % (elongation in length)

4.2 Mechanical Properties of Bamboo

(A) Static Bending Strength:-

Considering Load Vs. Deflection graphs and simply supported bamboo deflection formula, modulus of elasticity (E), The Ultimate Strength (σ_{ult}) and Moment of Inertia (I) of bamboo were determined and the results are tabulated.

Table 1 test result for static bending test.

	Sample 1	Sample 2
Moment of Inertia (I)	66204.789 mm^4	68094.032 mm^4
The Ultimate Strength (σ_{ult})	177.42 mm2	93.91 mm2
Modulus of Elasticity (E)	3.2 × 104 N/mm2	2.85 × 104 N/mm2

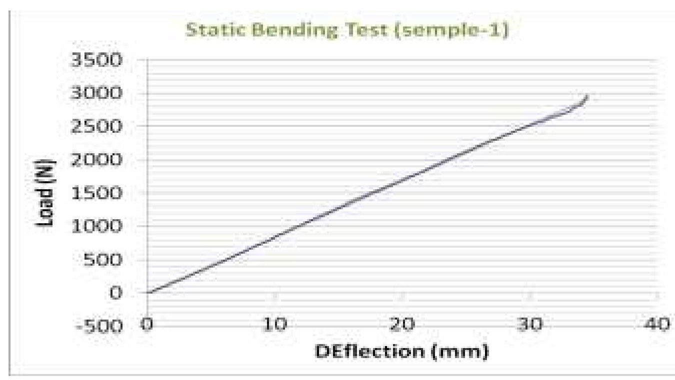

Fig.12 Load vs Deflection Curve for (Sample 1)

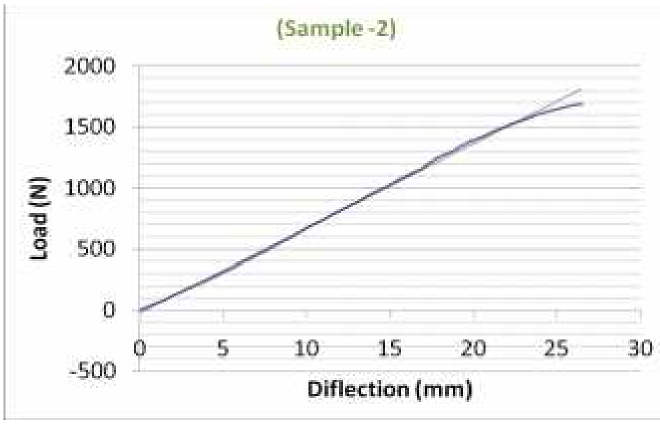

Fig.13 Load vs Deflection Curve for (Sample 2).

(B) Compressive Strength Parallel to Grain
The failure of bamboo is observed as compression failure as shown in Fig . The stress values obtained for central node specimen is greater. This is due to widely spacing of fibre and stiff behavior at node points. Table 2 test result of compressive strength

Table 2 test result of compressive strength

	Sample 1	Sample 2
Maximum load (F_{ult})	62,784 N	62,783 N
Area (A)	586.41 mm^2	561.35 mm^2
Maxi. Comp. Strength (σ_{ult})	107.5 N/mm^2	111.5 N/mm^2

(C) Tensile Strength Parallel to Grain
The failure of bamboo members are observed mainly as node failure due to brittle nature at nodes, because of widely spacing of fibers at the node points. In addition some powder like material is also observed at the node points. The type of failure is the node failure for first specimen samples containing node point at middle. For the second type of specimen samples containing node points at 1/4 length from each end, the failure is of node failure at end node points or split failure at middle of the specimen. For the third type of specimen samples containing random nodes the failure is node failure or splitting failure and combination of both is also observed.

Table 3 test result for tensile strength.

Sample	(1)	(2)	(3)	(4)
Area (mm^2)	88.56	81.4	67.5	55.8
F_{ult} (N)	9800	9750	7250	5700
σ_{ult} (N/mm^2)	110.66	119.77	107.40	102.15

V. Conclusion:-

Based on the limited number of testing conducted, it was concluded that Bamboo can potentially be used as substitute steel reinforcement. However, for regions of the world that availability of steel is limited and plain concrete members are commonly being used, the use of reinforced bamboo concrete is highly recommended. Thought the tensile strength of bamboo is about 1/3rd that of steel, this is sufficient for structures and provides a more economical and environment-friendly alternative that is accessible to every section of the society limiting the use of steel can reduce carbon dioxide emissions. In the green building concept use of bamboo reinforced concrete may be recommendable. However, there is still ample scope for research on the subject.

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