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Bamboo as Reinforcement in Concrete for Low Cost Housing

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Abstract - *Bamboo is a renewable and versatile resource, characterized by high strength and low weight, and is easily worked using simple tools. From the early times Bamboo is used as a construction material. The Bamboo is used in both technical as well as non-technical ways. Housing shortage in Urban India due to the rising unaffordability makes it logical to consider alternative technologies for their application. It is a fact that the construction industry is the main consumer of energy and materials in most of all countries. Development that meets the needs of the present without compromising the ability of future generations to meet their own needs' it has become a major issue when trying to meet the challenges in providing proper housing for the ever-increasing world population. The main obstacle for the application of Bamboo as a reinforcement having lack of sufficient information about its interaction with concrete, strength and durability.This project evaluation of the feasibility of the use of Bamboo as reinforcement in concrete members. In this study of the project Bamboo as reinforcement in that we are taken tensile test on bamboo, properties of bamboo, concrete mix design for M20 grade, Bamboo strips was used as a reinforcing material with any treatment and addition of bamboo fiber in concrete. In this respect doing project we are conclude that bamboo reinforcement is used for low cost building for low rise building.*

Key Words*: *Bamboo Strips, bamboo fiber, Concrete, Compressive test, Flexure Test, Tensile Test

1. INTRODUCTION

Bamboo is one of the oldest building materials used by mankind. The bamboo Culm, or stem, has been made into an extended diversity of products ranging from domestic household products to industrial applications. There is an intense on-going search for non-polluting materials and manufacturing processes, which require less energy. Attention of researchers and industries has turned to materials such as vegetable fibers including bamboo, soil, wastes from industry, mining and agriculture for engineering applications. In developing countries due to the educational system, which is mainly based on programs from industrialized nations, there are to date no formal education or research programs concerning the traditional and locally available materials and technologies. Lack of reliable technical information about the local materials makes the consumers use mainly industrialized materials for which the information is freely available. The main hurdle for the application of structural composites is the lack of sufficient information about the constituents of the composites and about their durability. The focus of this paper is to present a concise summary of the information about the range of material choices, which are locally available for producing concrete structural elements, reinforced with bamboo.

Table: I List of Abbreviation

Symbol	Description
UTM	Universal Testing Machine
E	Modulus of elasticity
$\in$	Strain
M	Bending moment
Y	Position of neutral axis of beam
Σ	flexural strength
I	Moment of inertia
R	Radius of curvature
B	Width of beam
D	Depth of beam
BMD	Bending moment diagram
EFD	Shear force diagram

1.1 Properties of Bamboo

A. Physical Structure of Bamboo

Bamboo is commonly compared to wood products due to its similar chemical structure. The physical structure is the aspect that differentiates bamboo from wood. Wood has anisotropic properties and contains grains oriented in the same direction throughout the whole structure. On the

exterior edge of each node, branches form creating different types of grass looking leaf structures. Bamboo contains parallel fibers that are reinforced along the axial direction of the Culm.

Shrinkage and Swelling

Bamboo, like wood, changes its dimension when it loses or gains moisture. Bamboo is a hygroscopic material, thus the moisture content changes with the changes in the relative humidity and temperature of the surrounding environment [6].

B. Mechanical properties of bamboo

The material properties of bamboo, as shown below in table II. These properties have been determined by E. Brink and J. Rush, in the U.S. Naval Civil Engineering laboratory in 1966.

Table: II Theoretical Properties of Bamboo

Mechanical property	Value
Ultimate compressive strength	50mpa
Allowable compressive stress	27.6mpa
Allowable tensile stress	27.6mpa
Allowable bond stress	344kpa
Modulus of elasticity	17.2gpa

2. Experimental work on Bamboo Reinforced Concrete

2. 1 Selection of bamboo

2.1.A. Sizing- Splints are generally more desirable than whole culms as reinforcement. Larger culms should be split into splints approximately 20mm wide. Whole culms less than 20mm in diameter can be used without splitting.

2.1. B. Seasoning- When possible, the bamboo should be cut and allowed to dry and season for three to four weeks before using. The culms must be supported at regular spacing's to reduce warping.

2.1. C. Waterproof Coatings- When seasoned bamboo, either split or whole is used as reinforcement; it should receive a waterproof coating to reduce swelling when in contact with concrete. Without some type of coating, bamboo will swell before the concrete has developed sufficient strength to prevent cracking and the member may be damaged, especially various type of coating material are available in market.

2.1. D. concrete mix design- IS mix design method used for normal steel reinforced concrete is applied in the preparation of mix design for bamboo reinforced specimens. However, concrete slump are made as low as workability will allow minimizing excess water which causes swelling of the bamboo. From knowing all properties material we design For M20 grade as 1:1.44:3.45 with W/C ratio 0.50.

2.2 Tensile test on bamboo strip

- As the bamboo is used as to take tensile load in the flexural element the tensile test was conducted on the bamboo.
- The Bamboo strip was of the length 520 mm and the thickness of the Bamboo was average 10 mm. Specimens of such specifications were prepared. The ends of the specimen were roughed and wire wound at both the ends to have a better grip in Universal Testing Machine. The setup of tensile test on strip of the Bamboo is as shown in fig 1.

Fig. 1Tensile test on bamboo strips

Table: III Test result of tensile test

Area =185mm2		Length = 300mm	
Load P (N)	Elongation (mm)	Strain	Stress (N/mm2)
0	0.00	0.0000	0.0000
10000	0.10	0.0003	54.0540
12000	0.50	0.0017	64.8648

14000	0.50	0.0017	75.6756
16000	1.00	0.0033	86.4864
18000	1.50	0.0050	97.2972
20000	2.00	0.0067	108.1081
22000	2.50	0.0083	118.9189
24000	3.00	0.0100	129.7297
26000	5.00	0.017	140.5405
28000	7.00	0.023	151.3513
30000	8.00	0.0267	162.1621
32000	9.60	0.0320	172.9729

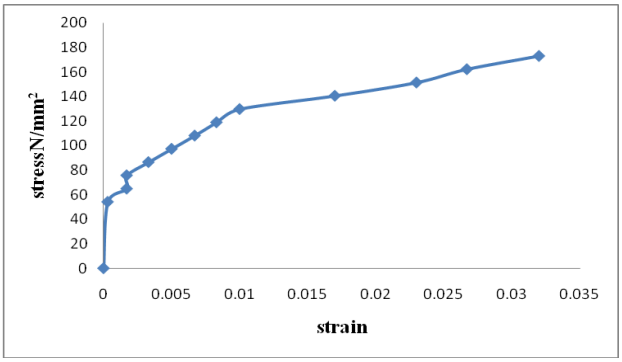

Fig.:2 Graph of Stress Vs Strain Curve of tensile test on Bamboo Strip.

2.2.1Calculation of Modulus of Elasticity of bamboo strip

The yield stress of the Bamboo strip is 64.8648 N/mm2.

The equation to calculate the Modulus of Elasticity is as mentioned below:

$$E = \frac{\sigma}{\varepsilon}$$

Where,

σ = stress

ε = strain

E = Modulus of Elasticity.

The data are

$\sigma = 64.8648 N/mm^2$.

$\varepsilon = 0.0017$

Thus, $E = \frac{64.8648}{0.0017}$

E= 38,155.7647 N/mm2.

The Modulus of Elasticity of the Bamboo strip is 38,155.7647N/mm2.

2.3 Size and proportion of bamboo fiber

The nominal size (15mmX8mmX1mm) of bamboo fibers have been selected to cast 150mm cube with 0.25% 0.50% 0.75% bamboo fibers of concrete total volume of concrete as shown fig 2.

Fig.:3 Bamboo fibers

2.4 Compression Test on Cement Concrete Cubes

The compression test was performed on the cement concrete cubes of M20 grade to check the compressive strength of the fiber with concrete & hence to justify the proportion of ingredients to have specific strength of concrete. The resulting concrete was poured in moulds of size 150mmx150mmx150mm. After casting concrete samples were kept in wet place and remolded at 24 hours age they were submerged in open water tank for curing up to 28 days as required for test. The preparation of cube as shown fig.4.

Fig.: 4 Preparation of cube

2.5 Compression Test Results

Compression test was carried out on the cubes of grade M20. Total 12 cube of size 150x150x150 mm testing was carried out with percentage of bamboo fibers and the cubes were tested on 28 days as shown fig.6. The results obtained are shown in the Table IV.

Table: IV Cube tests results

	Load (KN)	Compressive Strength (N/mm²)	Average strength (N/mm²)
Without fiber	887.5	39.44	34.93
	740.5	32.91	
	730.1	32.45	
Fiber - 0.25%	669.6	29.76	27.39
	610.3	27.12	
	569.2	25.29	
Fiber- 0.50%	559.7	24.87	24.31
	557.3	24.77	
	529.4	23.53	
Fiber- 0.75%	551.6	24.52	23.92
	527.1	23.42	
	535.8	23.81	

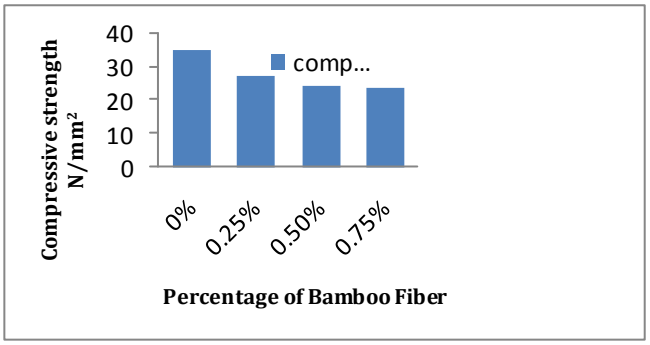

fig.:5 Graph of compressive strength of bamboo fibers cube.

Fig.: 6 Compressive Cube failures

3. Flexural Test of Bamboo Reinforced Concrete Beams

In order to check flexural strength of Bamboo Reinforced cement concrete, beam specimens are casted with dimension 150mmX150mmX700 mm. The Bamboo strips of the length 650 mm were used as reinforcement. To be acquainted with the behavior of Bamboo in concrete, different Bamboo reinforced concrete beam specimens were prepared. The different types of flexural beam specimen were:

- Plain Cement concrete beam without bamboo strips.
- Singly Reinforced Cement Concrete Beam having two Bamboo strips with treatment and various percentage of bamboo fiber of total volume of concrete at the bottom with 20mm clear covers. Beam specimens have no stirrups.
- Doubly Reinforced Cement Concrete Beam having two Bamboo strips at the top and two strips at the bottom of the beam with various percentage bamboo fiber of total volume of concrete with 20mm clear covers. Bamboo specimen used with treatment. Beam specimens have steel stirrups used at 200mm c/c.

The area of the Bamboo specimen used in the singly and doubly Reinforced Beam are shown in Table V.

Table: V Details of bamboo strips used as reinforced in beam.

Type of beam	Length of bamboo specimen(mm)	average Area (mm2)
Singly reinforced Beam	650	185
Doubly reinforced Beam	650	187

Test Setup

Flexural tests were conducted on Universal Testing Machine. The test was conducted with two points loading as per IS 516. Test setup to perform flexural test on Bamboo reinforced Concrete Beam is as shown fig.7.

Fig.:7 Flexural test of Bamboo Reinforced Concrete Beams.

3.1 Plain Cement Concrete Beam

In the plain beam test specimen, the first crack occurred vertically from the point of load application which was flexure crack and the crack was widened. Then, crushing of concrete at the point load application was observed. Plain concrete beam specimen failed suddenly and hence showed the brittle failure. The failure occurred in the Cement Concrete Beam as shown in fig.8.

Fig.: 8The development of the crack and propagation

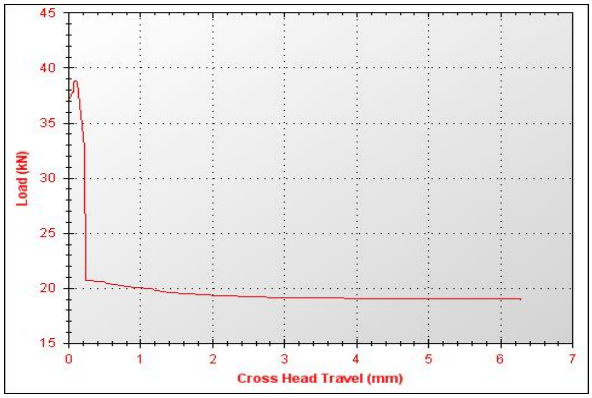

Fig.:9 Load Vs Deflection Graph for plain Beam

3.2 Singly Bamboo Reinforced Concrete Beam

In singly bamboo reinforced concrete beam initially the crack developed vertically in middle third portion, on further loading crack widened as shown in figure. Then the crack got widened. The crack was rising very smoothly and slowly. From the failure of the beam it was observed that the there was well bonding between the concrete and the Bamboo as it was treated Bamboo and addition of bamboo fiber flexural strength increases as shown in below table. Fig.10 shows the crack development and the failure of the beam.

Fig.: 10 failure of the beam in flexure

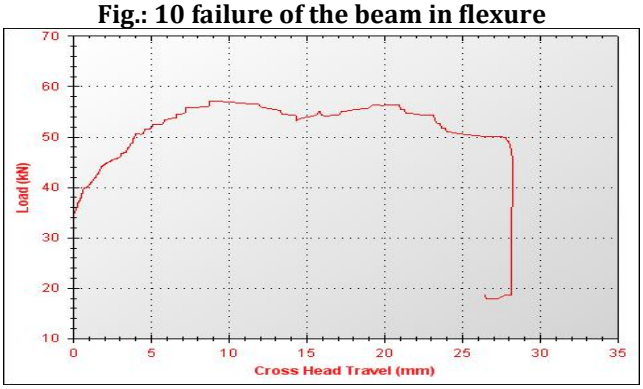

Fig.:11 Load Vs Deflection graph for singly reinforced Beam without fiber

3.3 Doubly bamboo reinforced beam

In Doubly Reinforced Beam the crack developed in flexure. Two cracks were generated in the beam. The cracks developed at a very slow rate. The cracks formed irregular shaped. During the failure the Bamboo in the bottom was failed by a node failure. The upper Bamboo also failed at node. The failure type is node split failure. And addition of bamboo fibers flexural strength increases. The beam failed Lack of gripping between the Bamboo and the concrete was observed. The failure pattern and the development of the crack are shown in the Fig.12.

Fig.:12 The failure pattern of doubly beam

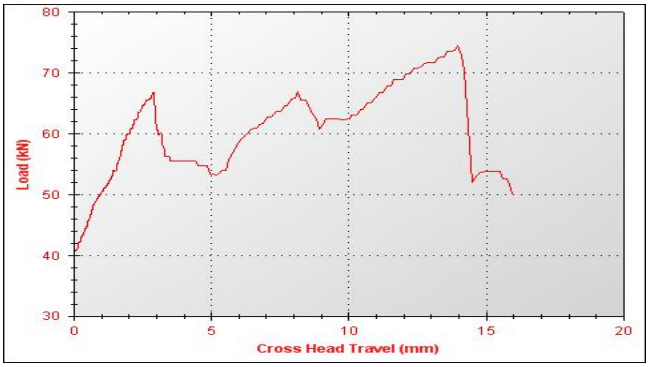

Fig.:13 Load Vs Deflection graph for doubly reinforced Beam without fiber

4. Experimental analysis and results of bamboo reinforced concrete

4.1 Singly bamboo reinforced concrete beam

Singly bamboo Reinforced Cement Concrete Beam having two Bamboo strips with treatment and various percentage of bamboo fiber of total volume of concrete at the bottom with 20mm clear covers. Beam specimens have no stirrups. The flexural strength is determined by using pure bending theory. It calculated as per shown in appendix no.1.The calculated flexural strength is shown in table VI.

Table: VI Result of flexural strength of singly beam

	Load (kN)	Flexural strength (N/mm2)
Without fiber	25.50	4.53
0.25% fiber	23.07	4.10
0.50% fiber	19.95	3.55

4.2 Doubly bamboo reinforced concrete beam

Doubly bamboo reinforced concrete beam having two Bamboo strips at the top and two strips at the bottom of the beam without & with various percentage bamboo fiber of total volume of concrete with 20mm clear cover. Bamboo specimen used with treatment. Beam specimens have steel stirrups used at 200mm c/c. the flexural strength is determine by using pure bending theory. It calculated as per shown in appendix no 1.the calculated flexural strength is shown in table VII.

Table: VII Result of flexural strength of doubly beam

	Load (kN)	Flexural strength (N/mm2)
Without fiber	34.59	6.13
0.25% fiber	41.68	7.41
0.50% fiber	46.98	8.35

5. Comparative study of the singly & doubly beam

From the pure bending theory, the calculating the flexural strength both singly & doubly beam the comparative graph will plotted percentage bamboo vs flexural strength as shown in fig.13.

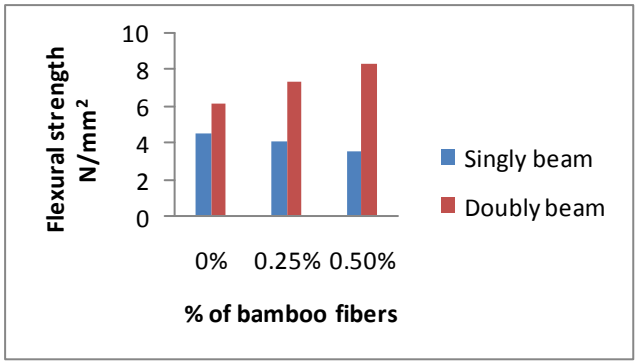

Fig.:13 Graph of % of bamboo vs flexural strength

6. Conclusion

From the present experimental work the following conclusion are drawn:

- The modulus of elasticity E of bamboo is found to be much lower than the steel reinforcement.
- Density of bamboo depends on the thickness bamboo.
- From compressive test on concrete cubes it's conclude that with addition bamboo fibers in concrete doesn't show much improvement up to 28 days.
- The flexural strength of doubly reinforced beam increases as high as nearly doubled than singly

reinforced beam, so bamboo doubly reinforced beam can be used in low cost buildings.

- From load vs. elongation curve on UTM it's conclude that singly and Doubly Reinforced Beam has shown elastic behavior while performing flexural test on UTM (Universal testing machine).
- By calculating flexural strength it concludes that Doubly Reinforced Beam has performed more elastically than Singly Reinforced Beam.

Appendix

Calculation of flexural strength of bamboo reinforced beam

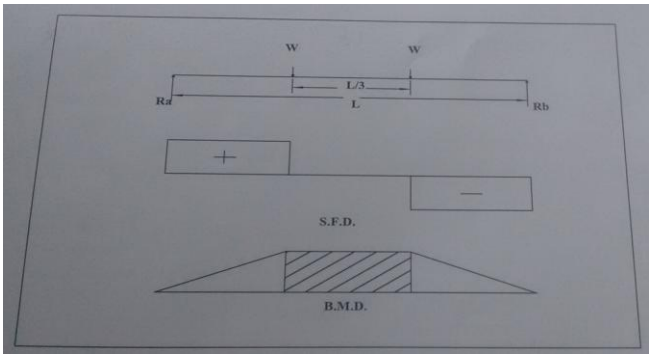

Fig.: 14 Loading for pure bending in flexural

The Flexural formula for pure bending is given by the following equation:

$$\frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R}$$

Where,

M = bending moment.

Y = position of neutral axis of Beam

σ = flexural strength

I = Moment of inertia.

E = Young's modulus

R= Radius of curvature

Now,

$$I = \frac{bd^3}{12}$$

Where,

b = Width of the beam

d = Depth of the Beam

$$I = \frac{150X\,150^3}{12}$$

I = 42187500 mm4

$$Y = \frac{d}{2}$$

Y = 75mm

Load=34.49kN

M= 3.449kN.m

Now,

$$\frac{M}{I} = \frac{\sigma}{Y}$$

$$\frac{3449000}{I42187500} = \frac{\sigma}{75}$$

σ =6.13 N/mm2.

Flexural strength= 6.13 N/mm2

From this theory we calculated all the flexural strength as the describe in table VI &VII.

Acknowledgment

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