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Research Article

EXPERIMENTAL INVESTIGATION ON BAMBOO REINFORCEMENT IN CURVE BEAM

Chetan N. Bhatiwal and Uttam. R. Awari

Department of Civil Engineering AISSMS College of Engineering Pune, Maharashtra, India

A R T I C L E I N F O

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A B S T R A C T

Concrete is the man-made material in the world. Reinforced concrete is common building material in the world, reinforcement used in concrete is quite costly. There is a cheaper reinforcing material that can be used in concrete is bamboo. Bamboo is consider as reinforcing martial as a temporary structure and scaffolding. Bamboo as reinforcing martial to concrete is an investigation in structural engineering. The experimental investigation comparison of steel reinforcement and bamboo reinforcement. Verified the mechanical properties such as tensile strength, moisture content, specific gravity, density of specimen. Curve Beam specimens of 500 mm radius and 150 mm x 150 mm cross section were cast to check the flexural strength of concrete.

INTRODUCTION

As reinforced concrete is common building material, it is important to make the development of building construction, low cost material. For developing country steel is difficult to obtain because of expensive prices and for low cost housing and temporary structure.

Many researches around the world are began to explore the use of low-cost and low-energy substitute construction material as reinforcing material to reduce the cost of construction for low cost housing and temporary structure. Among the many possibilities for such substitution bamboo, which is one of the material fastest growing plants, and it is great economical potential. It grows naturally in many parts around the world and easily available. Bamboo takes less energy to harvest and transport. Therefore, bamboo has low manufacturing costs compared with steel. Bamboo has a good tensile strength and light weight. Bamboo has a good water absorption capacity it may reduce the mechanical properties and causes the structural failure. There is need to control the water abortion of bamboo. To reduce the water absorption proper seasoning method, require.

Bamboo is able to resist more tension than compression. The fire resistance is very good because of the high content of silicate acid. Durability of bamboo is heavily depending on the preservation treatment method to control the termite and water. This preservation method includes smoking, heating, drying, coating and another method is chemical treatment.

Corresponding author:* **Chetan N. Bhatiwal
Department of Civil Engineering AISSMS College of Engineering Pune, Maharashtra, India

J. G. Moroz *et al* (2014). studied masonry shear wall. In that one walls were reinforced with conventional steel reinforcement vertically and horizontally and the other walls were reinforced with different amount of bamboo reinforcement vertically and horizontally. In this bamboo is coated with varnish to waterproof the bamboo reinforcement and apply the sand to improve the bond with concrete. To prevent the cracking and shrinking, bamboo needs to be coated with water proofing material. Material that can be use asphalt emulsion, bitumen coating, anti-termite coating and varnish. [1]. S. Jeeva Chithambaram *et al*. (2017) studied the bamboo reinforced ferrocement slab panels was casted with flyash each specimen for 40 mm and 50 mm thick panels. Bamboo strips and wire mesh used as skeletal reinforcement for ferrocement slab panel. The locally available bamboo strips were used for skeletal reinforced coated with anti-termite and then protective coating to prevent it against the action of insect, fungus and water [2]. Atul Agarwal *et al*. (2014) studied the cylinder. Bond stress on different types of coating like Tapecrete p-151, Sikadur 32 gel, Araldite and anti Corr RC have been used for treatment of bamboo to study their effect on bond strength at the interface of the bamboo concrete composite. The average tensile strength was calculated 185.93 N/mm2. The average bond strength between the bamboo and concrete is highest for Sikadur 32 gel as compare to other coating, most of the specimen failed due to slippage of bamboo strips from the concrete cylinder. The column with treated bamboo reinforcement sustain the comparable load than untreated bamboo [3]. Abhijeet Dey *et al*. (2018) had a comparative study of bamboo reinforced beam with various frictional properties the frictional properties of bamboo have been achieved by rolling the bamboo reinforcement with sand, G. I.

wires and coir. Bamboo are to be used for construction which shows brownish-green colour. Bamboo is treated with Copper Chrome Boron (CCB) to prevent bamboo from insect attack. The tensile strength of varies from species to species. In this study the tensile strength is an average tensile strength is 250 N/mm2. The G. I. Rolled bamboo reinforced beam also attain the maximum value than the sand and coir. The tensile strength of bamboo actually depends on the area of cultivation, type of species and cross-section area of the bamboo [4]. Khosrow Ghavami, (2004) studied according to researcher the density of the fibers in the cross-section of a bamboo shell varies along the thickness of the bamboo. The durability of bamboo strongly depends on the preservative treatment methods. The swelling and shrinking of bamboo in concrete create a serious limitation in the use of bamboo as a substitute for steel in concrete. Bamboo treated with the Sikadur 32 gel with a thin coating shows good bond stress [5]. Alireza Javadian *et al*. (2016) studied bonding properties of a newly developed bamboo-composite reinforcement in concrete through the pull-out test. There a five type of coating used water based epoxy, Truegrip BT, Truegrip EP, Exaphen bio-based, Enamel coating. After applying a thin layer of coat apply fine sand and coarse sand particles on coating to prevent the slippage. All samples are tested with and without coating [6]. Nathan Schneider *et al*. (2014) studied preliminary result of tensile strength and pull out test result are discussed. Test result shows that bamboo is viable alternative to steel as tensile reinforcement for concrete structure. Beam shear reinforcement made with bamboo by heating a bamboo and bent it in U shape and joined two U shape to make stirrups. The bond stress of a bamboo is increase as application of fine sand on a coating material [7]. M. Usha Rani *et al*. (2017) the tensile strength of bamboo is quite high and can reach up to 125 MPa. The use of bamboo as a structural element may contribute to the reduction of material-based energy use of a structure. To investigate the feasibility of using bamboo as a reinforcing material in reinforced-concrete members, flexural Strength were carried out on reinforced-concrete beams in which all rebars, including the main rebar and the stirrups, were replaced with bamboo [12].

Pratish Kumar Singh *et al*. (2016) has the bamboo in the vertical position is more durable than in horizontal. The type of coating will be depending on the material available. Bamboo reinforced concrete design is similar to steel reinforcing design [13]. M. M. Rahman *et al*. (2011) investigated the three types of specimens in that plain concrete, singly reinforced and doubly reinforced bamboo beam was casted and tested their flexure test using Universal Testing Machine. It was concluding that, for singly bamboo reinforced beam in concrete could increase the load carrying capacity of beam having the same dimension. For the singly bamboo reinforced concrete beam, load carrying capacity increased two times and that for doubly bamboo reinforced concrete beam about two and half times than that the plain concrete beam having the same dimension [17].

Design of Bamboo Reinforcement

Reinforcement design of control specimen as per IS-456:2000 [19], clause number 26.5.1.1 requirement of reinforcement for structural member can be calculated by following formula.

$$A_{st} = \frac{0.85 \times bd}{f_y} \quad (2.1)$$

Cross-section of the beam 150 mm x 150 mm.

$$A_{st} = \frac{0.85 \times 150 \times 121}{500}$$

$$A_{st} = 30.855\ mm^2$$

$$A_{st\,min} = 0.12\%\, b\, D \quad (2.2)$$

$$A_{st\,min} = \frac{0.12 \times 121 \times 150}{100} = 21.78\ mm^2$$

Therefore, provide 8mm diameter bar

Bamboo reinforcement design is similar to the steel reinforcement design. The area of bamboo reinforcement is calculated according to force calculation the force calculation as follow.

Area of steel provided, $2 - 8mm\text{ø} = 100.5\ mm^2$

$$F_s = A \times f_y \quad (2.3)$$

$$F_s = 100.5\ x\ 500$$

$$F_s = 50.20\ kN$$

Now using equation 2.3 calculate the area required for the bamboo reinforcement

$$F_s = A \times f_y$$

$$A = \frac{F_s}{f_y}$$

The experimental yield stress of bamboo was obtained 150.9N/mm^2

$$A = \frac{50200}{150.9} = 332.67\ mm^2$$

Therefore, provide 20 mm width and 8.5 mm thickness of bamboo as reinforcement.

Flexure Strength of Curved Beam in Elevation

The flexural strength of curved beam in elevation calculated from following equation.

$$\sigma = \frac{M\,(R - r)}{r\,A\,e} \quad (3.1)$$

Where,

r_i : The inner fiber distance from center
r_o: Outer fiber distance from center
A: Area of tension reinforcement
e: ($\bar{r}$ - R)

R: Distance of neutral surface from center
$\bar{r}$: Distance of centroidal axis from center

Experimental Work

Bamboo used for this investigation strip of size of 20 mm width and 8.5 mm thick as per design of reinforcement. The bamboo was coated with bituminous paint and oil paint to control the water absorption and termite attack, Beam specimens of size 500 mm radius and 150 mm x 150 mm cross section. The concrete used was of M20 grade and steel used was Fe500. The bamboo samples were cut to the proper size and shape as per design of bamboo reinforcement. The bamboo reinforced beam compare with steel reinforced beam which design for minimum reinforcement as per IS 456: 2000. These beams were tested for flexure using Universal Testing Machine (UTM).

MATERIALS

Cement used is Ordinary Portland cement (OPC) of the grade of 53 grade is used. Coarse aggregate with 20 mm size and fine aggregate were use used which are locally available conforming IS 383-1970. Locally available bamboo brownish green in colour was cut as per required specimen sizes. Concrete mix of M20 grade concrete of proportion 1:1.5:3 with water-cement ratio of 0.45 was designed as per IS 10262-2009 [21].

Table I M20 Design for per m^3 quantity of concrete

Sr. No.	Material	Quantity in kg
1	Cement	438
2	Fine Aggregate	610
3	Coarse Aggregate	1240
4	Water (litre)	197.16

RESULTS

The properties of bamboo like tensile strength, moisture content, specific gravity, density were tested using IS 8242-1976 [20] and IS 6874-2008 [19]. Beam specimens were tested for flexure.

Tensile Strength of Bamboo

Specimen used for tension test 10 mm thick and 20 mm width and 400 mm length, with top node, middle node and bottom node using universal testing machine (UTM) capacity of 200 kN as shown in Fig, 1. Tensile strength of bamboo is shown in Table II.

Fig 1 Tension test specimen

Table II Tensile strength

Sr. No.	Node position	Average stress (MPa)
1	Top	129.33
2	Middle	158
3	Bottom	160

Moisture Content

Bamboo absorbs water, which reduces the mechanical properties of the bamboo and causes the structural failure. In this study bamboo coated with bituminous paint and oil paint further compare with uncoated specimen. The moisture content in bamboo is calculated using IS 8242-1976. The size of specimen is 25 mm x 25 mm x 10 mm. Moisture content result as shown in Table III.

Table III Moisture Content

Sr. No.	Coating type	Average moisture content (%)
1	Uncoated Specimens	2.92
2	Bituminous Paint Specimens	2.576
3	Oil Paint specimens	1.87

Specific Gravity

Specific gravity of bamboo specimen was calculated using IS 8242-1976. There are three specimen of size 20 mm x 20 mm x 10 mm. Specific gravity test result as shown in Table IV.

Table IV Specific Gravity

Sr. No.	Specimens designation	Specific gravity	Average specific gravity
1	S1	0.606	
2	S2	0.596	0.602
3	S3	0.603	

Density

Density test of bamboo was calculated using IS 6874-2008. The size of specimen are 25 mm x 25 mm x 10 mm. the test results for density as shown in Table V.

Table V Density

Sr. No.	Specimens designation	Oven dry weight (gm)	Volume (cc)	Density (Kg/m^3)	Average density (Kg/m^3)
1	D1	2.389	1.856	128.71	
2	D2	2.425	1.780	136.256	129.312
3	D3	2.377	1.933	122.97	

Flexure Test

Flexure test was carried on 12 number of curved beam specimens using Universal Testing Machine (UTM). Fig. 2 shows flexural test setup. Where, RCB - Reinforced concrete beam specimen, BBO - Bamboo reinforcement coated with oil paint, BBB - Bamboo reinforcement coated with bituminous paint, BUC - Bamboo reinforcement with uncoated bamboo.

Table VI Flexure Strength

Sr. No	Specimen designation	Average flexural strength (MPa)		Deflection (mm)	Analytical flexural strength (MPa)	
		+ve	-ve		+ve	-ve
1	RCB	61.3	49.2	6.37	56.4	44.4
2	BUC	62.6	49.4	7.10		
3	BBB	57.1	55.4	6.81	36.4	28.6
4	BBO	77.5	61.1	6.00		

Fig 2 Flexure Test Setup

DISCUSSION

The water absorption capacity of bamboo reduced by 36% and 12% when coated with oil paint and bituminous paint respectively. As per test results, bamboo coated with oil paint provided the better resistance to water, bituminous paint contains turpentine as a solvent, due to which is less effective as compare to oil paint. Nodes of bamboo provide brittle resistance to tensile force, it was observed that failure occurred at nodes due to splitting of fibers. The density of fibers is maximum at the bottom of bamboo so tensile strength of bamboo is maximum at bottom. The load carrying capacity of bamboo reinforced beam increases due to increase in area of bamboo reinforcement, due to brittle behaviour of beam reinforced with bamboo, the deflection of bamboo reinforced beam is less than steel reinforced beam. It was observed that the crack developed on internal radius of curved beam mostly below the loading point and then propagated to the outer radius.

Validation

The fiber stresses of bamboo reinforced and steel reinforced beam curved in elevation are calculated using flexure formula and validate using ansys software. Normal stresses are find from Ansys 17.1 and using normal stress, horizontal thrust was calculated, further the moment was calculated with the help horizontal thrust. Using the flexural formula stress are calculate as shown in below.

$$H_T = \frac{\text{Normal Stress}}{\text{Corss - section Area}}$$

Bending moment at any cross section of the arch is given by,

$$M = M_o - H.T$$

$$M = R_A R.(1 - \cos\theta) - H\,R\sin\theta$$

The flexural stress at inner fibers calculated using following expression.

$$\sigma = \frac{M(R - r_i)}{r_i A e}$$

Similarly, stress at outer fibers,

$$\sigma = \frac{M(R - r_o)}{r_o A e}$$

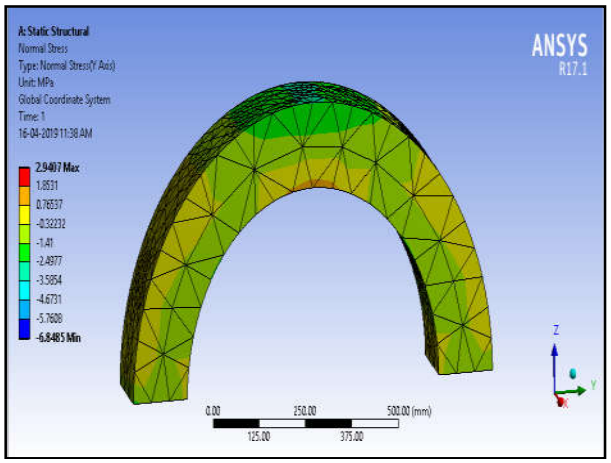

Fig 3 Normal Stress find using Ansys

Table VII Comparison of results

Sr. No	Specimen designation	Expereimental Stresses (MPa)		Ansys stresses (MPa)	
		+ve	-ve	+ve	-ve
1	RCB	61.3	49.2	61.06	48.13
2	BUC	62.6	49.4	62.10	48.97
3	BBB	57.1	55.4	55.94	44.09
4	BBO	77.5	61.1	77.29	60.92

CONCLUSION

From the test Results it can be Concluded that

1. Maximum flexural strength of 77.5 MPa is obtain for bamboo-reinforced beam coated with oil paint, was increase by 21% as compared to control specimen, 26% as compare to bituminous paint and 19% compare to uncoated bamboo specimen.
2. The maximum experimental tensile strength of bamboo specimen with node at bottom is 160 MPa, 129.33 MPa at top and 150 MPa at middle node. The bamboo specimen failed at node due to splitting of fibers.
3. Bamboo has a good water absorption capacity. The water absorption reduced to 36% and 12% for coating with oil paint and bituminous paint as compare to uncoated specimens. The reduction in water absorption capacity of bamboo coated with oil paint more than the bituminous paint.

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