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Predictive Analysis of Bamboo-Reinforced Concrete Beam

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ABSTRACT: Bamboo, which is a fast-growing and ecologically friendly material for structural applications, is being considered quite appropriate. The tensile strength of bamboo is high and can reach up to 125 to 150 mph. This makes bamboo a pretty alternative to steel in reinforcement loading applications. The bamboo-reinforced concrete composite elements can be used as an alternative to concrete, steel, and wood used in housing and other products required in day-to-day applications. In this study, it has been attempted to develop engineered bamboo structural elements for use in low-cost housing or G+1 structures. All the experiments were carried out on a universal testing machine with a capacity of 1000 KN.

KEYWORDS: Experimental Investigation, Bamboo Reinforced Concrete, Universal Testing Machine (UTM), Tensile Strength, Compression Strength, Flexural Strength.

I. INTRODUCTION

Steel costs have risen dramatically in recent years. Steel is difficult to get in underdeveloped countries due to high pricing, and its use in the building industry is now restricted. Steel manufacture uses a lot of fossil fuels, thus the steel discharge in the construction of structures has been given, demonstrating how research institutions can drastically reduce it. Bamboo, as one of the fastest-growing plants, has a lot of economic potential among the many options for such substitutes. Bamboo has been utilized in Asia for thousands of years to build bridges and buildings. Bamboo is easier to harvest and carry than other plants. As a result, bamboo has lower manufacturing costs than steel. As a result, even countries and locations with no advanced manufacturing technologies or construction skills are projected to be able to use bamboo.

II. LITERATURE REVIEW

There are no research papers, discussing about the possibility of bamboo as a reinforcing material. According to Saurabh Jayagond, and Mr Sudhanshu Pathak All of the experiments in this study were carried out in a testing facility with a 1000 KN universal testing machine (UTM) (100 tons). Although the tensile strength of Manga and Dagdi bamboo is half that of steel, it was also put through a flexural strength test. The minimum flexural strength requirement for the M20 grade of concrete, which is easily available in bamboo-reinforced concrete, is 3.13 N/mm².

According to Mritunjay Kumar Singh, found that steel and bamboo will be utilized together whenever possible and no more than 25% of the steel in a member can be replaced while the light load is being applied to the entire structure. Bamboo can be used to reinforce a structure that is fully reinforced with steel, and the diameter of the bars in the zones where it is employed can be increased to retain the strength factor. This report can be utilized for all parts of civil engineering and has a better structural application than typical reports.

Saurabh Jayagond studied the load-carrying capacity of bamboo reinforcement concrete beam was nearly 3 times of plain concrete beam with the same dimension of the beam. The deflection of a bamboo reinforcement concrete beam is

around 1.5 times that of a steel reinforcement concrete beam. The tensile strength of bamboo is roughly 1/3 of that of steel.

Masakazu Terai and Koichi Minami's study presents the feasibility of using bamboo and non-steel as the reinforcing material in concrete members. To investigate the fracture behaviour and the mechanical properties of bamboo-reinforced concrete members. It can be used as reinforcement at low levels. Before being utilized as a concrete reinforcement, bamboo must be treated.

III. PROJECT SCOPE, AIM AND OBJECTIVE

To determine the feasibility of bamboo by collecting information on the mechanical properties and behaviour of bamboo reinforced beams, to reduce the quantity of steel and make the structure economic.

1. To investigate the physical properties of the bamboo as a reinforcement.
2. To Examine the deflection of bamboo reinforced concrete under load.

IV. SELECTION OF BAMBOO

There are two types of bamboo involved in this project. Which are sources from the local market at Katraj, Pune. Those two species include Messy and Manga. These two types of species were selected and left to dry for 2 weeks.



Fig. 1. Manga bamboo



Fig.2. Messy bamboo

V. PROPERTIES OF BAMBOO

1. Physical properties of bamboo

Bamboo is commonly compared to a wood product due to its chemical structure. Bamboo is lightweight weight Flexible, and tough. The bamboo is used in various construction activities. Physical properties based on the given procedure are IS: 8242-1976 and IS 6874-2008.

5.1.1. Moisture content

Moisture content was determined using small samples with a dimension of 25 x 25mm, as shown in the figure. The sample was weighted. The test specimens were weighed (m1) to a precision of 0.01gm and then dried in an oven for 24 hours at 103 2°C. The sample was weighed again and the weight was recorded to quantify the quantity of moisture content left over after being dried in the hot air-drying oven.

Calculation,

$$\text{Moisture Content (\%)} = \frac{M1 - M0}{M0} \times 100$$

Where,

M1 = Initial mass of test specimen in gm

Mo = Oven dry mass in gm



Fig.3 Specimen for Moisture Content

VI. RESULTS

Type of Bamboo	Sample No.	M1 (gm)	Mo (gm)	Moisture Content in %	Average (%)
Messy					
Top	1	4.13	3.66	12.84	11.36 %
	2	4.28	3.8	12.63	
	3	4.32	3.85	12.21	
Middle	4	4.34	3.87	12.14	
	5	4.23	3.85	09.87	
	6	4.49	4.09	09.78	
Bottom	7	3.94	3.58	10.06	
	8	3.99	3.56	12.08	
	9	4.53	4.04	12.13	
Manga					
Top	1	3.46	3.07	12.70	11.88%
	2	3.09	2.78	11.15	
	3	3.26	2.96	10.14	
Middle	4	2.84	2.57	10.51	
	5	3.02	2.73	10.62	
	6	3.72	3.32	12.05	
Bottom	7	3.18	2.80	13.57	
	8	2.96	2.61	13.41	
	9	3.45	3.06	12.75	

Table No. 1 Moisture Content

As per IS 6874:2008 code the desired optimum moisture content of bamboo material is 10-12%.

5.1.2. Density Test

This test is conducted as per IS 6874-2008. Pieces of bamboo size 25 mm x 25 mm with 10 mm thickness. Specimens are made by the water displacement method, then dried in an oven for 4 hours at 103 °C.

The calculation, $Density\ in\ kg/mm^3 = \frac{Oven\ dried\ mass\ in\ gm}{Volume\ in\ cm^3} \times 10^6$



Figure 4 Specimen for Density Test

Table No. 2 Density

Type of Bamboo	Sample no.	M1 (gm)	Mo (gm)	Volume in cm ³	Density g/cm ³	Average g/cm ³
Messy						
Top	1	4.13	3.66	6.25	0.585	0.621
	2	4.28	3.8	6.25	0.608	
	3	4.32	3.85	6.25	0.616	
Middle	4	4.34	3.87	6.25	0.619	
	5	4.23	3.85	6.25	0.616	
	6	4.49	4.09	6.25	0.654	
Bottom	7	3.94	3.58	6.25	0.726	
	8	3.99	3.56	6.25	0.572	
	9	4.53	4.04	6.25	0.569	
Manga						
Top	1	3.46	3.07	3.125	0.982	0.920
	2	3.09	2.78	3.125	0.889	
	3	3.26	2.96	3.125	0.947	
Middle	4	2.84	2.57	3.125	0.822	
	5	3.02	2.73	3.125	0.873	
	6	3.72	3.32	3.125	1.062	
Bottom	7	2.18	2.80	3.125	0.896	
	8	2.96	2.61	3.125	0.835	
	9	3.45	3.06	3.125	0.979	

Mechanical Properties

Bamboo is tested for mechanical properties discussed below.

5.2.1. Compressive strength

Compression tests are conducted as per IS:6874-2008. Specimens were sliced from the bottom, middle, and top regions. All specimens with free nodes were chosen for compression tests. Universal Testing Machine (UTM) compression tests were performed on the specimen under constant load as shown in the figure.

Calculation,

$$\text{Compressive Strength} = \frac{\text{Ultimate failure load in N}}{\text{Area of application of load in mm}^2}$$



Fig. 5. Compression test specimen



Fig.6. Vertical crack failure of the specimen after compression test.

Type of Bamboo	Inner dia in mm	Outer dia in mm	Area in mm	Ultimate failure Load in KN	Compressive Strength In KN	Average
Messy						
Top	21	31	408.40	40	97.94	90.94
Middle	13	32	671.51	50	80.41	
Bottom	18	34	653.86	60	93.136	
Manga						
Top	23	31	339.29	47	138.52	102.22
Middle	25	37	584.33	50	85.56	
Bottom	24	45	1138.04	94	82.59	

1.5.2.1 Tensile test:

The tensile test is calculated by applying the tensile load on bamboo splints in the UTM. Species are selected 650mmx35mmx10mm.



Fig. 7. Tensile test specimen

Calculation,

$$\text{Tensile Strength} = \frac{\text{Ultimate failure load in N}}{\text{Area of cross section liad in mm}^2}$$

Test results

Table No. 4 Tensile Test

bamboo	Wide in mm	Thickness in mm	Area in mm	Ultimate Failure load in N	Tensile Strength MPA
Messy					
M 1	35	10	350	37700	107.71
M 2	35	10	350	38600	110.28
Manga					
M 1	35	10	339.29	40700	116.28
M 2	35	10	584.33	41500	118.57

5.3. Design of Beam

Dimension of Beam = 700mmx150mmx150mm

$F_y = 125\text{Mpa}$... (Assumed)

$F_{ck} = 20$

Load calculation

Dead load = Self wt of beam

$= 0.15 \times 0.15 \times 11 \dots$ (11 is density of bamboo)

$= 0.2475 \text{ kN/m}$

Live load = 2 kN/m ... (Assumed) $W = 2 + 0.2475 = 2.2475 \text{ kN/m}$

$W_u = 1.5 \times 2.2475 = 3.37\text{ kN/m}$

Moment = $M_u(l^2) = 3.37 \times (0.7^2)$

8 8

$= 0.206 \text{ kN.m}$

Reinforcement calculation

$A_b = 0.5 f_{ck} (1 - \sqrt{1 - 4.6 \times M_u}) / F_y f_{ck} \times b d^2$

$= 0.5 \times 20 (1 - \sqrt{1 - 4.6 \times 0.206 \times 10^6})$

$125 \times 20 \times 150 \times 150^2$

$= 15.29\text{ mm}^2$

$A_{b\text{max}} = 0.85 \times b d$

125

$= 127.5 \text{ mm}^2$

Area of bamboo Strip = $\Pi/4 (D^2 - d^2) \times 1/4$

$= \Pi/4 (32^2 - 21^2) \times 1/4$

$= 167.87\text{ mm}^2$

no. of bars = $127.5 / 167.87$

$= 0.75 \text{ nos.}$

Assume no. of bars 4 nos for the safer side.

$A_{st\text{ provided}} = 4 \times 167.87 = 671.48 = 671.48\text{ mm}^2$

Check for deflection

$F_s = 0.58 f_y (A_{st\text{ req}} / A_{st\text{ pro}})$

$= 0.58 \times 125 (127.5 / 671.48)$

$= 13.76 \text{ N/mm}^2$

Percentage of reinforcement $P_t = A_{st} / b d$

$= 671.48 / 150 \times 150 = 0.89\%$

Take 1 % of reinforcement.

Modification factor for p_t and f_s is $= 2 (L / D)_{\text{max}} = 20 \times \text{MF}$

= 20x2

= 40mm

$(L / D)_{pro} = 700 / 150 = 4.66mm$

Hence, $4.6 < 40$ beam is safe in deflection.

Shear reinforcement

From table 6.6.1

% τ_c

0.75 0.57

0.895 x

1.0 0.64

$\tau_c = 0.61 \text{ N/mm}^2$ $\tau_c < \tau_c$

Hence design of shear reinforcement requires $V_{uc} = \tau_c \times b \times d$

= $0.421 \times 150 \times 150$

= 7893.75 N $S_v = 0.75 d$

= 0.75×125

= 130mm, b= 150mm Whichever is less = 130mm

Hence provide 10mm dia stirrups @130mm c/c.

5.3.1 Process:

All the bamboo was cut down to the length of 650mm leaving 25mm cover from both sides. Which will replace steel in place of reinforcement.

Use the binding wire to bind the bamboo and the stirrups.

With the help of measuring tape maintain the exact center-to-center distance (130mm) between the two stirrups.

Casting the beam uses M20 grade concrete, and curing for 28 days. after the testing is conducted in UTM.



Fig. 8. Casted beam



Fig. 9. Reinforcement of Beam

5.4 Testing Result of Casted Beam.

Table No. 5 Tensile Test

Type of bamboo	Length mm	Width mm	Depth mm	Reinforcement %	Load in KN	Deflection in mm	Flexure strength (Mpa)
Messy	700	150	150	1	19.09	4.57	2.828
	700	150	150	1	27.4	4.38	4.05
	700	150	150	1	23.19	4.48	3.43
	700	150	150	1	17.98	6.49	2.66
Manga	700	150	150	1	11.07	2.35	1.64
	700	150	150	1	11.84	3.26	1.75
	700	150	150	1	14.95	2.35	2.21
	700	150	150	1	10.34	1.3	1.63

$$\text{Flexure Strength} = \frac{P.L}{BD^2}$$

where,

P= Load at failure in N L= Span in mm

B = Width in mm D= Height in mm

F.S = $0.7\sqrt{f_{ck}}$

= $0.7\sqrt{20}$

= 3.13 N/mm²

The minimum strength required is 3.13 N/mm² which is easily achieved in all messy specimens tested above



Fig. 10. 1-Point loading in beam



Fig. 11. Failure of beam

VII. CONCLUSION

All the experiments were carried out in a testing laboratory on a universal testing machine (UTM) capacity of 1000 KN (100 tonnes). The Moisture Content of manga bamboo is 11.36% and messy bamboo is 11.88%. The density of manga bamboo is 0.92 and the mess is 0.621. As per IS 6874:2008 density of bamboo is 0.5 – 1.0.

The tensile strength of manga is 118.37 and messy is 109.9 bamboo. Steel Flexure strength 3.13 N/mm², The Flexural strength of manga and messy if compared with the strength of steel bar is less than half. For the flexural strength 8 beams were cast 4 specimens each for messy and manga compositing each other with beam size 150mmx150mmx700mm, the result clearly showed that the average of manga is less than that of messy bamboo. The minimum strength required is 3.13 N/mm² which is easily achieved in all messy specimens tested above.

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