Test on Bamboo Reinforced Concrete Beams

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Abstract— This paper presents experimental study of a pair of Bamboo reinforced concrete (BRC) beams. The grades of concrete and yield stress of Bamboo used were M 20 and 98.5 MPa respectively. The beams were tested under four point loading. Flexural Behaviour, Failure mode, Load-deflection, Ultimate Load were studied and reported. The experimental results are verified for salient points. Locally available materials were used and real time cross section and spans were adopted. Hence, the results obtained is more realistic and thus, it can support the further researches and also motivate wider application of bamboo as reinforcement.

Keywords: Bamboo, Reinforcement, failure mode, Load – deflection, Ultimate Load

I. INTRODUCTION

Bamboo is a natural material product, its quality will vary as per the ground soil, age, cross sectional uniformity, sap content, type of seasoning, protective coating, distance between node (diaphragm) etc., Similarly, concrete though, in general prepared as per the code guidelines, based on the various properties of the basic ingredients, with or without use of one or more admixtures, the properties of concrete can differ from one place to other. In this paper bamboo splint is used as reinforcement in beam for tension face, compression face and also as shear reinforcement, and flexural behavior is studied. The important advantages of Bamboo reinforcement in beams are; locally available, weight per volume is lesser handling is easier, will not get corroded, fabrication is simple, skilled labour not necessary, cost is lesser.

II. LITERATURE

H.Y Fang et al. 1978 Lehigh University, Bethlehem presented paper with basic factors for selecting bamboo, interaction of bamboo-water-concrete, and treatment of sulfur-sand treatment to bamboo to be used as reinforcement. Lakkad et al. 1981 studied mechanical properties of bamboo, mild steel, polyester resin and glass reinforced plastic, and concluded as mechanical properties of bamboo were found to be better than those for other reinforcing materials. Markos Alito 2005 used bamboo as reinforcement material in low cost houses in Ethiopia, bamboo as economical alternative for reinforcing steel. He concluded that bamboo might replace steel in light constructions of tensile elements. Youngsi Jung 2006 at University of Texas, verified the use of bamboo as reinforcement in concrete as a substitute for steel. He aimed to verify the tensile strength of bamboo and its pullout characteristics in concrete. Adom-Asamoah Mark, Afrifa Owusu Russell, 2011, tested 16 beams, with each set of beams had without shear reinforcement, bamboo stirrups, steel stirrups and rattan cane stirrups and concluded with bamboo reinforced beams developed considerably higher load capacities than similar section of unreinforced concrete beams. The ductility of tension bamboo reinforcement is low and failure was splitting of concrete from the tension reinforcement and brittle failure. The shear capacity was enhanced by increased amount tension reinforcement and addition of web reinforcement. Low strength concrete cause concrete crushing before the full shear capacity is reached. The predominant failure mode of bamboo reinforced concrete beams was shear. Beams reinforced with steel stirrups had highest load capacity. IK Khan 2014, tested four groups of each three beams, totally, twelve beams each of size 150x150x700 mm, so, supported length of 600 mm with 50 mm overhang. Out of which 1st group was with 10mm conventional reinforcement, remaining 3 groups, each group were provided with bamboo stick of cross section triangular, circular and square. The load carrying capacity of the beam with bamboo square cross-section was higher than other cross sections of bamboo reinforced beam. He found that load at first crack and ultimate load in beam with square cross section bamboo was 53% lesser than that of mild steel reinforced beam. Deflection of beam with square cross section bamboo was higher than cross section of bamboo reinforced beams. He also, found that first crack and ultimate load, deflection in beam with square bamboo cross section was 30% lesser than that of mild steel concrete beam. He finally concluded that Bamboo may be used as substitute of steel reinforcement in beams for regions of the world where availability of steel is limited. Sani Haruna and M. Lakshmipathy 2015, experimented with four sets of beams, a) Normal concrete beam b) Coconut shell aggregate (CSA) beam, c) Bamboo reinforced CSA beam and d) CSA Beam with wire wound bamboo reinforced beam. They found bamboo strip had elastic behaviour and ultimate tension strength of 112.05 MPa. The young modulus of coconut shell concrete was 12075.2 MPa and it was 54%, 57%, 43.88% and 60.36% of conventional concrete as per BIS 456, ACI-318, EU and BS 8110 codes respectively. The load carrying capacity of the NWC beams were slightly higher than CSCS, BCSC, and BCSCB beams. The stiffness behavior of beam b) was a). Deflections were higher in beam c) and d) compared to a) and b). However, in beam d) the deflection was slightly lesser due to wire wound on bamboo reinforcement. The ductility of c) and d) beams were higher that of a) and b), due to larger deformations by the bamboo reinforcements. Rahul Padagannavar, K Arjun 2016, used Boucherie technique for treating bamboo to water absorption; as untreated bamboo absorbs more water. He carried out tension test on 6 bamboo splints; in which 3 were with nodes at ends and the remaining were nodes at middle, resulted in brittle behaviour 190 MPa with brittle behavior and 212 MPa with ductile behavior respectively. He also observed compressive strength of 140 MPa. He tested four pairs of beams with a) tension, compression and shear reinforcement with steel, b) tension with steel, hanger

/ compression with bamboo and shear with steel, c) tension and compression with bamboo and shear only with bamboo and d) all reinforcement with bamboo only. He showed that beam a) and beam b) were behaving similarly till ultimate load, except that beam a) ended up with extra ductility. Also he mentioned that bamboo can be used in structural members of low cost single storey building. The author also opined that the replacement of steel by bamboo makes the structure most economical and feasible for lower-income families to build their houses. Dr. M. Usha Rani and J. Martina Jenifer (2017) conducted flexural experiment with 9 bamboo reinforced beams. The authors found that the tensile stress of the bamboo as 125 MPa. They concluded that the bamboo reinforced beams have 50 % of the flexural strength of the steel reinforced beams; steel reinforced beam as load increased, the deflection curve steadily raised up, whereas in the bamboo reinforced one, the deflection is steeply increased.

III. SCOPE

Referring to the literature, it evident many authors have used bamboo sticks or split bamboo called as splint as main reinforcement; but, researches in which the main reinforcement and stirrups for both split bamboo used was sparse. Moreover, using the available bamboo in local market, the flexural behavior and the failure mode, ultimate loads are studied.

IV. REINFORCEMENT FABRICATION

The fabrication of the bamboo splints as reinforcement for beam is sown in figure.1. In which both bottom reinforcement, top reinforcement are kept at four corners, each one splint.

Fig. 1: Fabrication of reinforcement

The shear stirrups are spaced at 150 mm c/c. The junctions of the reinforcing bamboo splints are tied with binding wire. For stirrups, instead of continuous strap time splints; 2 horizontals and 2 verticals are connected to form one full stirrup.

V. CASTING

The figure.2 shows the typical cross section and longitudinal sections of the bamboo reinforced beam. The steel moulds are cleaned and oiled. The table 1 shows the materials used per m^3 M 20 grade concrete.

Cement (kg)	Sand (kg)	20mm Course aggregate (kg)	Water (Litres)	W/C
420	653	937	176	0.42

Table 1: Materials used / m^3 of concrete.

Fresh concrete was mixed using electrically operated mixer machine. Fresh mixer of concrete was filled in the moulds and hand compacted in three layers. The beams were de-moulded after 24 hours and they were cured in controlled humid condition for 28 days. Small difference in front side surface was finished with lime wash two coat. Pencil markings were made in horizontal and vertical fashion approximately for 25 mm square for easy observation of cracks, then the testing was proceeded. The figure 3 shows the laying of concrete and finishing of beam.

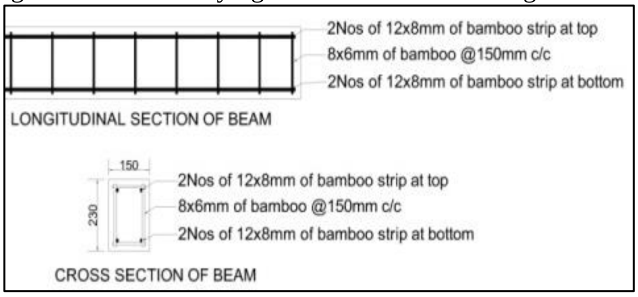

Fig. 2: Bamboo Reinforced Beam Sections

Fig. 3: Beam casting and finishing

VI. DESIGN PARAMETERS

Table.2 shows the results obtained from the tests of concrete auxiliary specimens, and the bamboo splints with nodes at ends.

f_{ck} (MPa)	f_y (MPa)	E-Bamboo (MPa)	f_{cr} (MPa)	fct (MPa)
26.72	98.5	$1.82x10^4$	3.65	3.01

Table 2: Design parameters

VII. TEST SETUP AND PROCEDURE

The entire tests were carried out using 300 kN loading frame with load cell attached to a hydraulic pump at Sri Ramakrishna Mission Vidyalaya Polytechnic College Coimbatore. Tamilnadu, India. The test arrangement and instrumentation are shown in figure 4. At mid span a linear variable displacement transducer (LVDT) is setup to measure the deflection digitally. The span of the beam was 1050 mm and the edge distance of 115 mm was left on each ends beyond knife edge and circular bar, which are ensuring the simply supported condition. The load is applied on $1/3^{rd}$ points spaced at middle third points at 350 mm c/c.

Fig. 4: Test arrangements

VIII. Load Deflection Curve:

Both the beam specimens followed the same path of load – deflection curve. That is up to 21 kN load the both curves go at par with each other. As there is no change in the cross section, grades of concrete and bamboo, the results predicted in the same way up to 80 to 86 % of their Ultimate load.

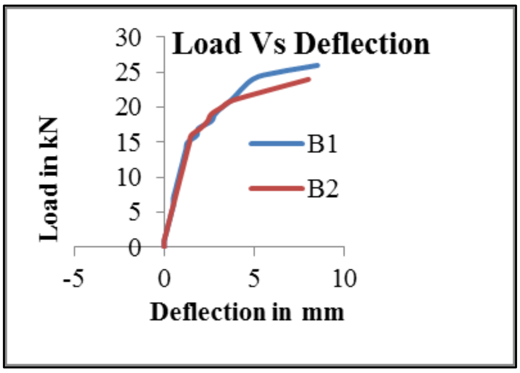

Fig. 5: Load Vs Deflection

The stiffness of the both beams were worked out to be 10 kN/mm. The average span / max deflection ratio is 125.

IX. Failure Modes

In both beams the first crack was noted in 30% of the ultimate load. In B1 it appeared below left point load. In B2 it appeared below right point load. Around 50% of the Ultimate load, the cracks raised up rigorously. Around 60 to 70 % of Ultimate load, 2^{nd} crack in B1 appeared below other point load. In B2, the 2^{nd} crack appeared at mid span. The location of 2^{nd} crack in each beam is indicated by an arrow mark. Beyond this stage, for every increment of load the first crack widened and the 2^{nd} crack progressed upwards towards top. Around 90% of the ultimate load both cracks raised up to a depth of around 40 to 50 mm from extreme compression fibre and showed clear visible sag of the deflection.

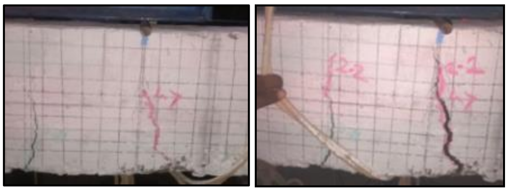

Fig. 6(a): Failure mode

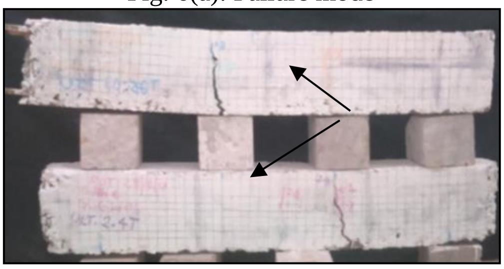

Fig. 6(b): Specimens after testing

At ultimate load, the beams failed with a sudden breaking sound of the bamboo. The observations were stopped when, further load increment was not possible. In all, the failure is due to yielding of bamboo at mid span and flexural shear failure in the region of load points.

X. Ultimate Moment

Table 3 refers the observed loads, moments and theoretical moments. The experimental moments were calculated by multiplying the Span/3 distance with observed P/2 load. The theoretical moments are calculated using IS 456-2000 [10] guidelines, for design of flexural members, considering all assumptions to hold as they are, except in place of steel, it is replaced by bamboo. The results of previous author [11] is also verified and found in agreement.

ID	Load (kN)		M_{exp} (kNm)	M_t (kNm)	M_{exp}/M_t
	1^{st} crack	Ultimate			
B1	8	26	4.55	4.33	1.05
B2	7	24	4.20	4.33	0.97

Table 3: Observed Loads and Moments

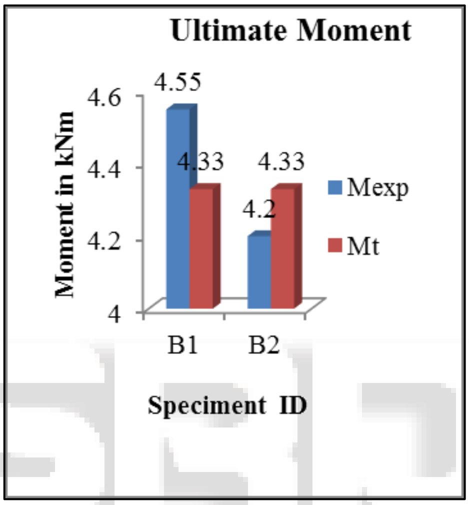

Fig. 7: Ultimate Load

XI. Results and Discussions

The flexural behaviour of both the beams were almost similar up to 87% of ultimate load. The over all pattern of Load Vs Deflection curve may be termed as Bi-linear in nature. Final failure of beam was sudden, hence, design safety factors in bamboo reinforced beam is very important. Both beams were of same material and cross section and resulting in nearer values of ultimate moment, the results can be more relied upon for extending similar one for application in cost effective structures were steel is in scarce. The percentage difference between M_{exp} and M_t are less than 6.

XII. Conclusion

The following conclusions can be drawn:
Using locally available materials, the test is done, and bamboo is found as suitable for reinforcement as main and stirrups in low and medium loaded beams of residential buildings. Flexure character, failure mode and ultimate loads and moments are observed. These results will serve as a tool for further researches.

XIII. Suggestions

Tests on BRC Beams with confined compression zone can be done. For varying material strength of bamboo, a design table can be prepared. Behaviour of BRC beams on continuous supports can be studied. Test & results may verified with sophisticated finite element techniques.

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