EXPERIMENTAL STUDY OF BEHAVIOR OF BAMBOO REINFORCED CONCRETE BEAMS

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Abstract*: The importance of bamboo as a sustainable material is gradually increasing in the construction sector. It is rapidly becoming a concerned area of research, either as a construction material or alternative replacement to steel. This study involves use of bamboo as an alternative to steel reinforcement in concrete beams and its comparative analysis with reinforced cement concrete beams. The present study involves casting of 15 beams i.e., 3 RCC, 3 BSRCC & 9 BRCC. The reinforcement used in BRCC beams had an average dimension of 20 mm x 8 mm and were divided into plain, coated-plain & coated-grooved types. The beams were subjected to four-point loading using universal testing machine. The results of casting suggested that BRCC beams sustain better load and deflection than RCC beams.*

Keywords*: Bamboo, Bamboo Reinforced, Four Point Loading, Bamboo Steel Reinforcement, Flexural Tension Failure*

1. Introduction:

Construction industry is one of the booming industries of today. It has a great impact on the economy of any nation. But around half of all non-renewable resource's mankind consumes are used in construction. Depletion of these resources further lead to pollution. Thereby, making it one of the least sustainable industries. In industrialized countries, the environmental impact is enormous. It accounts for the use of 40% of natural resources extracted the consumption of 70% of the electricity and 12% of potable water the production of 45-65% of the waste disposed to landfills. Further these values are expected to increases with population.

In every construction project, the main objective is cost optimization and the prime materials influencing cost of reinforced concrete are cement and steel. Apart from cost factor, they have environmental impact related issues associated with them. Cement and Steel production are very high energy consumption processes. In the process of manufacturing of 1 ton of cement, there is a formation of the equivalent quantity of CO_2 emissions. The world is slowly starting to realize the importance and sustainability and is in search for a suitable and sustainable alternative to these materials.

Past Research has shown that many alternatives have been used and their feasibility is shown to be good. For example: Partial replacement of cement by fly ash, rice husk ash, limestone, marble powder, ceramic waste, different types of dusts etc. Similarly, replacement of steel by synthetic fibres, bamboo reinforcement. Steel production processes has three times more energy consumption than cement production.

Bamboo has long and well-established tradition as a building material throughout the world's tropical and sub-tropical regions. Many bamboo species are found all over the world but only certain species are suitable to be used as building material. Bamboo is a renewable and versatile resource, characterized by high strength and low weight, and is easily worked using simple tools. Housing is one of the priority items and sensing the current shortage of the dwelling units, bamboo appears to be most promising material. It is widely used for many forms construction, in particular for housing in rural areas. Use of bamboo as a structural reinforcement in low-cost housing scheme can greatly benefit the developing countries. Bamboo building construction is characterized by a structural frame approach similar to that applied in traditional timber frame design and construction.

2. Test Specimens

For experimental investigation 15 concrete beams are tested, 9 of which are to be reinforced with bamboo splints and the 3 are to be reinforced with steel and remaining are reinforced with both bamboo splints & steel.

a. Reinforcement: Reinforcements used for RCC beams are nominal 8 mm diameter mild steel bars comprising of 4 bars arranged at a spacing of 100 mm c/c. The reinforcements used for BRC beams are in the form of bamboo splints with splint width ranging from 19 mm-22 mm and splint thickness ranging from 6 mm-8 mm.

Fig 1 Prepared Grooved Bamboo Reinforcements

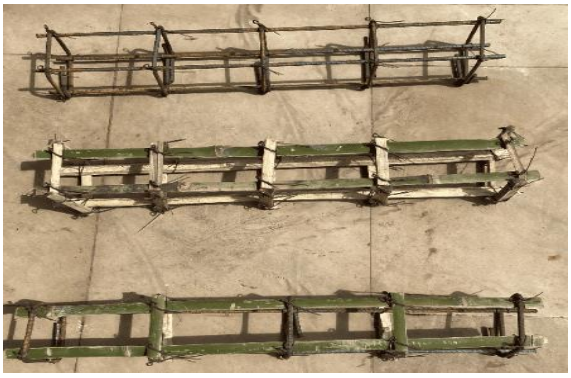

Fig 2 Prepared Bamboo & Steel Reinforcement

Fig 3 Prepared Coated Bamboo Reinforcement

b. Moulds: 6 Plywood Moulds of size 700 mm x 150 mm x 150 mm are fabricated for casting of 15 beams. These moulds are provided with holes on either side to conveniently lift the beams, when required to be cured. The moulds are then to be coated with grease or oil before casting in order to easily remove the concrete from mould.

Fig 4 Casting of Beam Panels

3. Experimental Investigation

The dimension of beams to be casted is fixed at 700 mm x 150 mm x 150 mm. The particular dimension is selected because of the available testing facilities restrict the size of the beam to a maximum of 700 mm. The nominal clear cover provided in the beams is of 25 mm. The concrete consist of ordinary Portland cement grade 53, natural pit sand and aggregates of 20 mm size. The beams are casted for M20 Mix design (1:2.46:4.07) grade of concrete and tested at the age of 28 days.

To get the Load Carrying Capacity of Bamboo Reinforced Cement Concrete & Reinforced Cement Concrete Beams, four point bending test is used. 1000 kN capacity universal testing machine is used for that purpose. Sections were simply supported at 600 mm center to center distance with overall length of section 700 mm. The whole load is distributed through two anvils, two point loads are at distance of 200 mm center to center so that the whole beam is divided into three parts each of 200 mm. This arrangement produces pure bending of beam. One dial gauge is used to measure central deflection of beam.

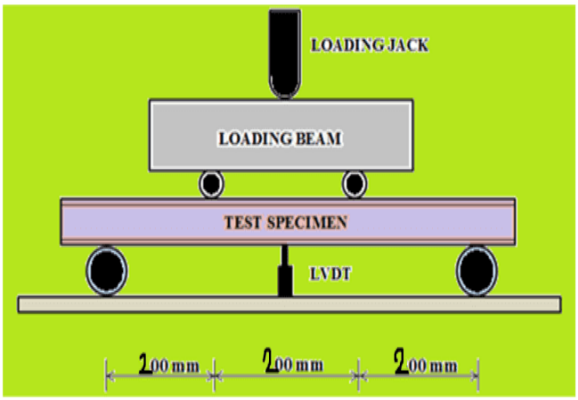

Fig 5 schematic diagram of test set up for 4-Point bending test.

Fig. 6 Beam Testing Setup

Fig. 7 Beam Subjected to Loading

Table 3.1 First Crack Loads and Failure Loads

Sr. No.	Beam Specimen	First Crack Load (kN)	Experimental Failure Load (kN)	Deflection (mm)
1	Bamboo Steel Reinforced Cement Concrete	59.4	82.5	4.34
2	Reinforced Cement Concrete	106.1	127.9	2.47
3	Plain Bamboo Reinforced Cement Concrete	49.1	78.4	3.76
4	Bamboo Coating Reinforced Cement Concrete	60.6	89.1	4.48
5	Grooved Bamboo Coating Reinforced Cement Concrete	110.7	143.6	2.94

4. Crack Failure Pattern

The crack pattern observed to be same in all beams with beams subjected to flexural tension failure and cracks originating on the tension side. The cracks propagated towards the compression side, finally reaching the boundary of the beam. Beams across all the categories exhibited similar behavior with cracking of concrete initiating at the tension side of the beam and radiating towards the compression side of the beam. After the cracks had extended deep into the compression zone, the collapse of the beams was observed

Fig. 8 Flexural Tension Failure in Reinforced Cement Concrete Beam

Fig. 9 Flexural Tension Failure in Bamboo Reinforced Cement Concrete Beam

Fig. 10 Flexural Tension Failure in Grooved Bamboo Coating Reinforced Cement Concrete Beam

Fig. 10 Flexural Tension Failure in Bamboo Coating Reinforced Cement Concrete Beam

Fig. 11 Flexural Tension Failure in Bamboo Steel Reinforced Cement Concrete

5. Results and Discussion

Table 3.1 shows that the crack load, experimental failure loads and deflection of all categories of beam. The result suggest that the average load sustained by Plain BRCC beam is lowest followed by BRCC coated beam. It was observed that load carrying capacity of BRCC coating beams improved by 9% compared to BRCC plain non coated beams.

Further enhancement in the load carrying capacity is observed for BRCC grooved coated beams, which showed an increase of 45% and 10% compared to BRCC plain non coated beams and RCC beams respectively. The first crack load was seen to be in the range of 20% to 45% of the experimental failure load in each of the category. Also, it was observed that all beams exhibited large ductility before final failure in flexure.

From overall result of beam testing, the feasibility of bamboo with surface treatment inside the concrete is clear. The performance of BSRCC and BRCC beams was lower than that of RCC beams, indicating inefficiency of BRCC beams. But when same bamboo was subjected to grooving with surface treatment and use as a reinforcement in beams, there performance was observed to have significantly increased and reached at par with that of RCC beams. This clearly indicates the effect of surface treatment on bamboo reinforcement. It also shows that the grooved treated bamboo reinforcement has the potential to replace conventional steel used in RCC beams.

6. Conclusion

A total of 5 categories of beams are tested under Universal Testing Machine. The average loads sustained by BRCC beams is lowest followed by BSRCC beams. It has been observed that the load carrying capacity of BRCC plain coated beams improved by 9% compared to BRCC plain non coated beams. Further enhancement in the load carrying capacity is observed for BRCC grooved concrete beams, which showed an increase of 45% and 10% compared to BRCC plain non coated beams and RCC beams respectively. The first crack load to be in the

range of 20% to 45% of the experimental failure load in each of the category. This study also indicates that the with proper coating, a 22 mm x 8 mm bamboo bars can exhibit behavior similar to that of 8 mm mild steel bars. Based on the experimental results obtained, it can be concluded that bamboo strips when grooved and coated with suitable sealant material can exhibit behavior similar to that of steel bars to a certain extent. The result seems to be promising considering bamboo as structurally suitable and durable alternative to conventional reinforcement in concrete beams.

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