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Experimental investigation on flexural behaviour of bamboo reinforced concrete members

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Abstract
The indiscriminate infrastructural growth is leading to rapid environmental degradation. Steel, cement, synthetic polymers and metal alloys used for construction activities are energy intensive as well as cause environmental pollution during their entire life cycle. In order to quantify the energy and savings potential by applying best available technologies like bamboo for engineering applications. Bamboo is chosen, since it is neither a grass nor plant which is sustainable with a property of high strength and carbon sequestration. In this project an attempt is going to do for predicting the flexural behavior of bamboo reinforced concrete. Bamboo is used as reinforcement in concrete by determining the various physical and mechanical properties of bamboo. The investigations conducted for the tested types of bamboo are evaluated using the same accept criteria as that of steel. This study investigates the flexural strength and load deformation of behavior of BRC by experientially and In general the strength of bamboo is as high as mild steel while, their density is as low as carbon fiber its used as reinforcement in the concrete.

Keywords: bamboo, flexural strength, concrete

1. Introduction
In recent years, steel prices have soared. For developing countries, steel is difficult to obtain because of expensive prices, and for the construction industry, usage of steel is currently limited heavily. The production of steel has high consumption of fossil fuels, so, the steel discharge in the construction of structures has been presented, showing the possibility of drastic reduction by research institutes. Meanwhile, for developing countries, it is important to make the development of buildings construction; low cost, no requirement of sophisticated technologies and reliable construction methods. Environmental destruction such as pollution of air and water has been occurring in some regions by rapid development and production of materials like iron, steel, glass, cement and aluminum that use limited mineral resources. On the other hand, plants and fibers are annually reproducible clean resources.

Bamboo is a unique group of gigantic grasses the Culm of which originates in underground rhizomes. It grows naturally in many parts around the world country but some species are artificially planted. Bamboo forests are found across tropic and sub-tropic zones between latitudes of about 40° south, i.e. areas with mean annual temperatures of from 20° C to 30° C. Bamboo suitable for water pipes grows at altitudes from 20 to 3,000meters. The plant is fully mature at an age of three to four years. In recent years, many researches around the world are begun to explore the use of low-cost and low-energy substitute construction materials. Among the many possibilities for such substitutions, bamboo, which is one of the fastest growing plants, has got a great economic potential. Bamboo has been used in constructions of bridges and houses for thousands of years in Asia. Bamboo takes less energy to harvest and transport. Therefore, bamboo has low manufacturing costs compared with steel; bamboo is widely expected to be possible even in countries and regions that have no advanced manufacturing technology and construction techniques.

2. Materials
2.1 Cement
Cement is a fine powder, which when mixed with water and allowed to set and harden, is capable of uniting fragment are masses of solid matter together to produce a mechanically strong material. The most common cement is used is ordinary Portland cement.

Table 1: Physical characteristics of cement (OPC 53Grade)

No	Properties	Test Method	Test result	Limitations As per IS 12269-2004
01	Normal Consistency	Vicat Apparatus (IS:4031 Part-4)	33%	30-35%
2	Specific Gravity	Sp.gravity bottle (IS:4031 Part-4)	2.94	2.9-3.15
03	Initial setting time	Vicat Apparatus (IS:4031 Part-5)	45min	>30min
04	Final setting time	Vicat Apparatus (IS:4031 Part-5)	260	<600
05	Fineness test	Sieve test on 90µ sieve (IS:4031 Part-1)	6%	<10%

2.2 Fine aggregate

Locally available free of debris and nearly river bed sand is used as fine aggregate Natural river sand conforming to IS-383 Zone2, having specific gravity 2.59

Table 2: Physical characteristics of fine aggregates

No	Physical Properties	Result	Code of reference
01	Specific Gravity	2.5	IS 2386 -1963(Part 3)
02	Fineness Modulus	2.81	IS 383 -1970
03	Bulking	10%	IS 2386-1963(Part 3)

2.3 Coarse aggregate

Coarse aggregate is the aggregate having size greater than 4.75mm. The crushed aggregates used were 20mm nominal maximum size and are tested as per IS results are within the permissible limit.

Table 3: Physical characteristics of Coarse aggregates

No	Physical Properties	Result	Code of reference
01	Specific gravity	2.68	IS 2386-1986(Part 3)
02	Water absorption	0.29%	IS 2386-1986(Part 3)
03	Impact Value	14.31%	IS 2386-1986(Part 3)
04	Los Angles abrasion	29%	IS 2386-1986(Part 3)
05	Flakiness index	14.06%	IS 2386-1986(Part 3)
06	Elongation Index	62.4%	IS 2386-1986(Part 3)

2.4 Water

Combining water with cementations materials forms a cement paste by the process of hydration. The cement paste glues the aggregate together, fills voids within it, and makes it flow more freely as per IS:456-2000.

2.5 Mineral Admixture

GGBS has been well known ground granulated blast-furnace slag can increase the abilities to prevent water penetration. It can improve the durability of concrete structures. The use of GGBS for concrete material contributes to the saving the natural resources and energy in cement manufacturing process and to reducing CO2 emissions and environment impact.

Table 4: Chemical constituents of GGBS

S. No.	Chemical constituents	In Percentage
1	Sio_2	39.18
2	Al_2o_3	10.18
3	Fe_2o_3	2.02
4	Cao	32.82
5	Mgo	8.52
6	Na_2o	1.14
7	K_2o	0.3

2.6 Bamboo

The bamboos are evergreen perennial flowering plants in the sub family Bambusoideae of the grass family Poaceae. In bamboo, as in other grasses, the intermodal regions of the stem are usually hallow and the vascular bundles in the cross section are scattered throughout the stem instead of in a cylindrical arrangement. The dicotyledonous woody xylem is also absent. The absence of secondary growth wood causes the stems of monocots, including the palms and large bamboos, to be columnar rather than tapering.

Fig 1: Species of bamboo

3. Experimental Investigations

3.1 Test on Bamboo

A tensile test, also known as tension test, is probably the most fundamental type of mechanical test you can perform on material. Tensile tests are simple, relatively inexpensive, and fully standardized. As the material is being pulled, you will find its strength along with how much it elongate. In order to conduct the tensile tests will, it was necessary to prepare the bamboo samples. First, the samples were cut to the proper size and shape. The length of the samples was largely determined by the distance between the nodes. Most of the samples tested were between 9 and 12 inch (229 and 305 mm) long. So we have taken 9 inches (230mm) sized specimen bamboo strips. The widths of the samples were reduced since some of the original samples were too strong to be broken. The thickness, along with the width, differed between the samples because Bamboo is a natural material whose physical properties vary. For this reason a careful dimensioning of the sample was done before testing the bamboo.

Fig 2: Bamboo Specimen

Table 5: Tensile Test Result of Bamboo Specimen

Specimen No	Diameter (mm)	Area (mm^2)	Load (KN)	Tensile Strength (MPa)	Average Tensile Strength (MPa)
01	8	50.27	5.75	114.38	116.70
02	8	50.27	6	119.36	
03	8	50.27	5.85	116.37	
04	12	113.09	8.56	75.70	73.95
05	12	113.09	8.15	72.07	
06	12	113.09	8.38	74.10	

3.2 Mix Proportion

Cement	Fine aggregate	Coarse aggregate
1	1.95	2.52

3.3 Test on Fresh concrete

The slump test is carried out as per the guidelines given by IS: 1199-1959. The test is carried out using a metal mould in the shape of frustum known as slump cone. It is open at both end has attached handles The tool typically has an internal diameter of 100 mm at the top and of 200 mm at the bottom with a height of 300 mm.

Table 6: Slump Test Values on Fresh Concrete

Water/Cement ratio	Slump in mm
0.55	80

3.4 Flexural Strength Test

Flexure tests are performed to find out the flexural modulus or flexural strength of a material. The flexural strength represents the highest stress experienced within the material at its moment of rupture. The modulus of rupture is determined from the moment at failure as

$$Fr = pl/bd^2$$

Where
p = max.load (kg)
l = supported length (cm)
b = width of specimen (cm)
d = failure point depth (cm)

Flexural strength test of Plain concrete beam, Steel reinforcement concrete beam and Bamboo reinforcement beam members of 200x200x800mm was done. A concrete beam member was placed and tested at 7, 14 and 28 days using UTM.

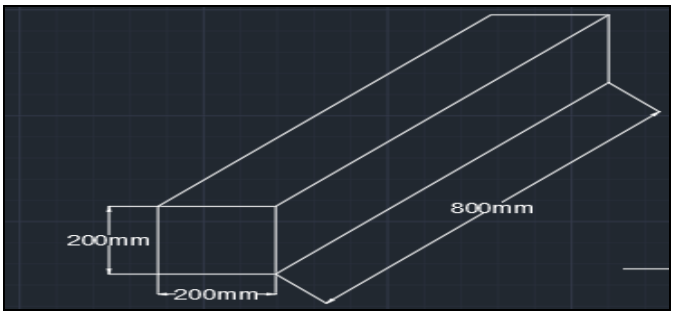

Fig 3: Dimensions of Sample Beam

Fig 4: Bar bending of Steel for Reinforcement

Fig 5: Formwork of Beam mould

Fig 6: Bar bending of Bamboo for Reinforcement

Fig 7: Casting of Steel Reinforced Concrete Beam (200×200×800) mm

Fig 8: Casting of Bamboo Reinforced Concreteeam (200×200×800) mm

Fig 9: Curing Of Specimens

Fig 10: Placing of Beam in UTM Machine

The beam was carefully placed under the testing machine and supports were placed at the measured location of 125 mm inside from each end. Dial gauges are also provided at midspan to calculate the deflection. After placing the beam, one point loading at the midspan of the beam was applied gradually by controlled pumping unit. The deflection of the beam at midspan was measured at regular interval of loading.

Table 7: Flexural Strength Value of Plain Concrete Beam

No of Days	Trail 1 Load in KN	Trail 2 Load in KN	Trail 3 Load in KN	Average Load in KN	Flexural Strength in N/mm²
7	18	19.35	20.15	19.16	1.92
14	28.12	29.20	29.89	29.07	2.91
28	50.54	49.38	51.76	50.56	5.06

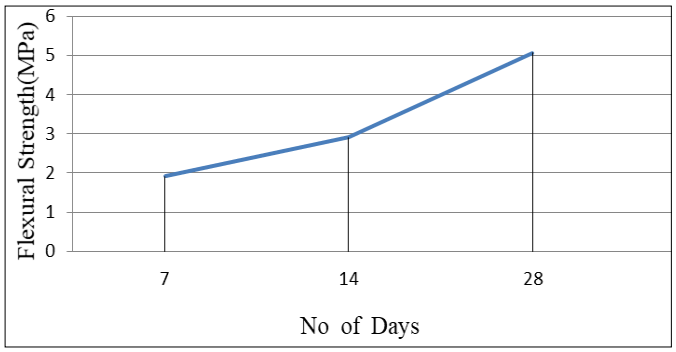

Fig 11: Variation of Flexural strength with respect to No of days (Plain Concrete Beam)

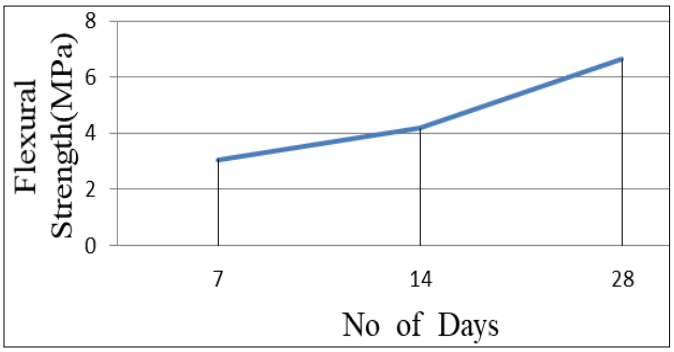

Fig 12: Variation of Flexural strength with respect to No of days (Steel Reinforced Concrete Beam)

Table 8: Flexuaral Strength Value of Steel Reinforced Concrete Beam

No of Days	Trail 1 Load in KN	Trail 2 Load in KN	Trail 3 Load in KN	Average Load in KN	Flexural Strength in N/mm
7	30.26	30.49	31.20	30.65	3.06
14	42.26	42.75	40.06	41.69	4.17
28	62.64	65.30	65.87	64.60	6.64

Table 12: Flexural Strength Value of Bamboo Reinforced Concrete Beam

No of Days	Trail 1 Load in KN	Trail 2 Load in KN	Trail 3 Load in KN	Average Load in KN	Flexural Strength in N/mm
7	65.70	66.10	66.56	66.12	6.61
14	79.19	79.45	81.03	79.89	7.79
28	112.60	112.98	113.85	113.14	11.31

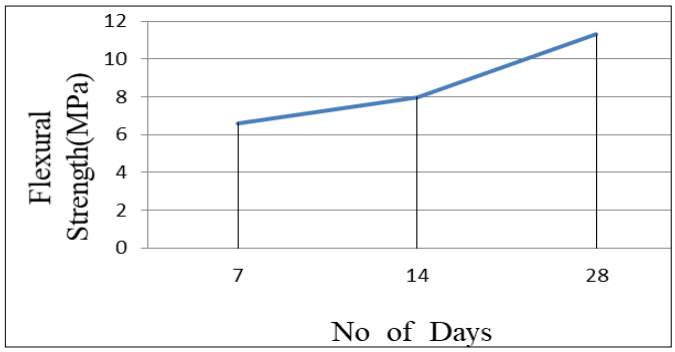

Fig 13: Variation of Flexural strength with respect to No of days (Bamboo Reinforced Concrete Beam)

Comparison b/w plain, steel and bamboo reinforced concrete beam

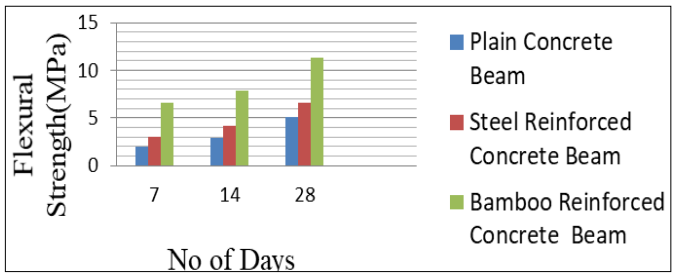

Fig 14: Variation of Flexural strength with respect to No of days

4. Conclusions

- From the flexural test of bamboo reinforced beam, it has been seen that using bamboo as reinforcement in concrete can increases the load carrying capacity of beam having the same dimensions.
- Bamboo reinforced concrete beam, the load carrying capacity increased about 2.25 times that of plain concrete beam having same dimensions.
- Bamboo reinforced concrete beam, the load carrying capacity increased about 1.75 times that of Steel reinforced concrete beam having same dimensions.
- Tensile tests indicated that presence of nodes in Bamboo samples did not affect the behavior.
- The waterproofing agent chosen provided poor bonding. Bond-enhancing applications should be required to strengthen the bonding b/w the concrete and the bamboo.
- This stirrups design provided small resistance to shear forces.
- Based on the limited number of testing conducted, it was concluded that bamboo can potentially be used as substitute steel reinforcement. however for regions of the world that availability of steel is limited and plain concrete members are commonly being used, the use of reinforced bamboo concrete is highly recommended.
- Bamboo reinforced concrete has low weight than the steel reinforced concrete.

Acknowledgments

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