

# Experimental Investigation on Flexural Strength of Bamboo Reinforced Concrete Beam

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**ABSTRACT:** At present, concrete and steel are the most widely used construction materials in the world. The concrete has high compressive strength but low tensile strength. Therefore, steel is used to reinforce the concrete. Steel has a very high tensile strength as compared to concrete, but there are certain problems associated with it. Some of these problems are high production cost, large energy consumption during its production; it is a non-renewable resource and large amount of carbon emission during its production. The urge to overcome these problems without the tensile capacity of reinforced concrete being compromised, has prompted numerous scientists and engineers to seek out locally sourced materials as a replacement for conventional steel reinforcement. Specifically, bamboo is one of the most suitable materials that may be used as reinforcing bar in concrete. This project work assessed the suitability of bamboo as reinforcement in concrete.

Concrete mix for M-25 grade concrete has been found as per design requirement of the IS code 10262-2009. In this project, two size of beams were selected, which are 150 x 150 x 700 mm and 150 x 200 x 700 mm. Plain cement concrete (PCC) beam, bamboo reinforced concrete (BRC) beam, treated bamboo reinforced concrete (TBRC) beam and steel reinforced concrete (SRC) beam were casted for each size of beam and they were tested on flexural testing machine. The samples included 6 beams for each type of beam.

Area of reinforcement was kept same in steel reinforced concrete beam (SRC), bamboo reinforced concrete beam (BRC) and treated bamboo reinforced concrete beam (TBRC) for both the size of beams. The reinforced material Bamboo sticks, treated bamboo sticks and Fe 415 grade of steel were used for reinforcing in BRC, TBRC and SRC beams respectively. The bamboo sticks were seasoned for about 2 to 3 weeks and then they were used as reinforcement. The flexural test results showed that steel reinforced concrete beam had the highest flexural strength compared to others. However, bamboo reinforced concrete beams (treated and untreated) showed a significant improvement in their flexural strength as compared to plain cement concrete beam. Hence, it can be recommended to use bamboo reinforced concrete beam for light load bearing structures like beam and slab for small panel. Also, it may be used for temporary structure.

**KEYWORDS:** Bamboo, flexural strength, PCC beam, SRC beam, BRC beam, TBRC beam

## I. INTRODUCTION

In recent times, the high cost and shortage of reinforcing steel in many parts of the world has lead to increasing interest in the possible use of alternative locally available materials for the reinforcement of concrete. In this project work, use of bamboo which is fast growing and ecologically friendly material for structural applications especially in a developing country like India is being considered as quite appropriate.

Bamboo is an important non-wood forest resource which is found mainly in forest as well as non-forest areas of tropical regions of Asia, Latin America and Africa. Bamboo is a giant grass rather than a tree. It belongs to the subfamily of *Bambusoideae* and grass family *Poaceae*. Bamboo is a versatile material and is used in various fields like

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construction, defense, recreation, food and medicine industries. Due to its multiple utility and accessibility to common man, it is also known as green gold, poor man’s timber, etc (wikipedia).

Bamboo culms are a cylindrical shell divided by solid transversal diaphragms at nodes and have some intriguing properties such as high strength in the direction parallel to the fibers, which run longitudinally along the length of the culm, and low strength in a direction perpendicular to the fibers. The density of fibers in cross-section of a bamboo shell varies with thickness as well as height (Ghavami 2004). Bamboo being a living organism has certain moisture content, which has to be removed by seasoning the bamboo for 2 to 3 weeks. Thereafter the bamboo must be treated to prevent it from absorbing any water and also protect it against the attack of fungi or insects. Both physical and mechanical characteristics vary with respect to diameter, length, age, type, position along culm and moisture content of bamboo. Different bamboo species perform differently for the same set of test (US Naval Civil Engineering, 1966, 2000 and Iyer, 2002). Bamboo will perform differently depending on the specie and maturity.

To examine the behavior of bamboo reinforced in concrete beam, flexural tests of bamboo reinforced concrete beams were conducted. The bamboo sticks used in this project was taken from Sindri, Dhanbad near bank of river Damodar. The type of bamboo specie used was Bambusa species that were cut into 650 mm length. Design consideration for selecting the number of sticks and stirrups are followed with similar procedure as adopted in case of RCC beam with steel. Here, size and shape and number of reinforced material kept constant for all other types of beam under testing.

## II. EXPERIMENTAL SETUP, INVESTIGATION AND MIX DESIGN

**Cement:** Portland Slag Cement conforming to IS: 455-1989 was used in the entire experimental study. The detail of physical properties of cement is presented below in tabular form.

**Table I Physical Properties of cement (Lafarge PSC)**

Properties	Results	Standard Limits (IS: 455)
Consistency	34%	-
Soundness	Expansion 3.5 mm	<10mm
Initial setting time (min)	90 minutes	>30 min
Final setting time	285 minutes	<600 min
Specific gravity	3.11	3.14
Fineness	4.0% Retain on 90 micron sieve	<10%
Compressive strength	N/mm <sup>2</sup>	N/mm <sup>2</sup>
1. 3days	20.00	>16
2. 7days	31.00	>22
3. 28 days	38.00	>33

According to table I, the test results are within permissible limits.

**Aggregate:** The test results conducted on fine and coarse aggregate for this Research work are given in table II and III respectively.

**Table II Tests of Fine Aggregate**

S. No.	Test	Fine Aggregate
1	Zone	III
2	Moisture content	0.20%
3	Specific gravity	2.55
4	Bulk density	1.62 gm/cc
5	Fineness Modulus	2.21
6	Water Absorption	1.37%

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**Table III Tests of Coarse Aggregate**

S. No.	Test	Coarse Aggregate
1	Bulk density	1.87 gm/cc
2	Moisture content	0 %
3	Water absorption	0.2 %
4	Specific gravity	3.0
5	Fineness modulus	7.92
6	Crushing value	23.43 %
7	Impact value	16.0 %
8	Elongation index	9.30%
9	Flakiness index	8.5 %

**Concrete mix design:** M 20 grade of concrete has been decided for present work as per IS 10262:2009. The mix proportions are given in Table IV

**Table IV Quantity of Materials for M 20 Concrete**

Water	Cement	fine aggregate	coarse aggregate
201.21 kg/m <sup>3</sup>	425.73 kg/m <sup>3</sup>	592.32 kg/m <sup>3</sup>	1306.82 kg/m <sup>3</sup>
0.47	1	1.39	3.07

**Types of beam and their design:** The purpose of this project work is to determine the feasibility of the use of Bamboo as reinforcement in concrete, it is necessary to compare its behaviour to steel i.e.; the traditional reinforcement. In this project work two size of beam (150 x 150 x 700 mm & 150 x 200 x 700 mm) were selected. Plain cement concrete (PCC) beam, bamboo reinforced concrete (BRC) beam, treated bamboo reinforced concrete (TBRC) beam and steel reinforced concrete (SRC) beam were casted for each size of beam. For both the sizes of beam, same area of reinforcement was provided.

**Steel reinforced concrete (SRC) beam:** Steel bars of Fe 415 grade were selected for reinforcing SRC beams of both the sizes. The design of the steel reinforced concrete (SRC) beam is shown below in tabular form.

**Table V Design of steel reinforced concrete (SRC) beam**

Type of beam	SRC1 beam	SRC2 beam
size of beam	150 x 150 x 700 mm	150 x 200 x 700 mm
Grade of concrete	M25	M25
Grade of steel	Fe-415	Fe-415
Design constants a) Limiting value of percentage reinforcement , Pt,lim b) Limiting value of depth of neutral axis, xu,lim	Pt,lim = 1.19 % xu,lim = 0.48d	Pt,lim = 1.19 % xu,lim = 0.48d

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Percentage reinforcement provided, Pt	1.20 %	0.86 %
Reinforcement provided	2 no. 12mm diameter bars	2 no. 12mm diameter bars
Type of section	Balanced (as $Pt = Pt_{lim}$ )	Under-reinforced (as $Pt < Pt_{lim}$ )
Cover	25 mm	25 mm

**Bamboo reinforced concrete (BRC) beam:** The bamboo sticks were obtained from Sindri, Dhanbad near the bank of Damodar River. The bamboo sticks were seasoned for about three weeks and then were used to reinforce the bamboo reinforced concrete (BRC) beams.

Separate design criteria for BRC & TBRC beams are not available. Therefore, area of reinforcement provided in BRC & TBRC beams were kept same as that provided in SRC beam for both the sizes.

**Table VI Design of bamboo reinforced concrete (BRC) beam**

Type of beam	BRC1 beam	BRC2 beam
size of beam	150 x 150 x 700 mm	150 x 200 x 700 mm
Grade of concrete	M25	M25
Type of reinforcement bars	Bamboo sticks	Bamboo sticks
Percentage reinforcement provided	1.20 %	0.86 %
Reinforcement provided	2 bamboo sticks of about 12 mm diameter	2 bamboo sticks of about 12 mm diameter
Cover	25 mm	25 mm

**Treated bamboo reinforced concrete (TBRC) beam:** In this type of beam, bamboo sticks were selected and seasoned for three weeks. After that body surface of the bamboo sticks were roughened using knife and then a thin coat of coal tar paint were applied all over the surface. Immediately after that sand was sprinkled over the layer of paint. The sand got adhered to the layer of paint, which may later improve the bonding effect between bamboo sticks and concrete in the TBRC beams. Thereafter, the bamboo sticks were left for 48 hours for the drying of paint and then these treated bamboo sticks were used in the casting of TBRC beams of both the sizes.

**Table VII Design of treated bamboo reinforced concrete (TBRC) beam**

Type of beam	TBRC1 beam	TBRC2 beam
size of beam	150 x 150 x 700 mm	150 x 200 x 700 mm
Grade of concrete	M25	M25
Type of reinforcement bars	Treated bamboo sticks	Treated bamboo sticks
Percentage reinforcement provided	1.20 %	0.86 %

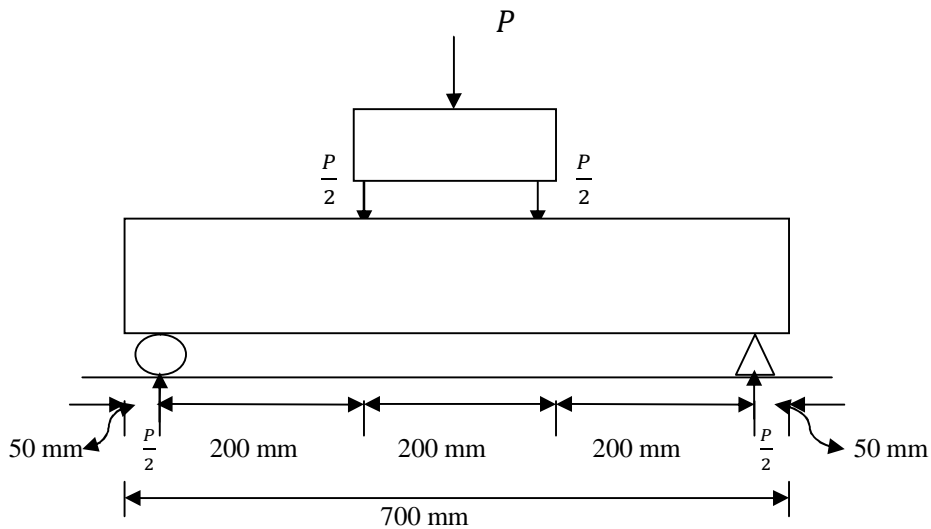
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Reinforcement provided	2 treated bamboo sticks of about 12 mm diameter	2 treated bamboo sticks of about 12 mm diameter
Cover	25 mm	25 mm

**Experimental setup of flexural strength test:** This test were performed in accordance with IS: 516-1959 on beams of size 150 x 150 x 700 mm and 150 x 200 x 700 mm after 7 & 28 days curing under flexural testing machine.



**Fig. 1 A typical arrangement for the calculation of flexural strength**

Flexural strength ( $N/mm^2$ ),  $f = \frac{PL}{bd^2}$  and Bending moment,  $M = \frac{PL}{6}$

Where,  
 P = maximum load  
 L = Span of beam (600mm)  
 b = Width of the beam,  
 d = Depth of beam

### III. RESULTS AND DISCUSSION

**Flexural strength:** Flexural strength tests were performed on plain cement concrete beams (PCC), bamboo reinforced concrete beams (BRC), treated bamboo reinforced beams (TBRC) and steel reinforced concrete beams (SRC) for both the sizes (150 x 150 x 700 mm and 150 x 200 x 700 mm). During the experimental test, load carrying capacity of the beam and the type of failure were observed. The maximum failure loads were recorded. At the same time, with the help of dial gauge which was fitted on experimental set up, deflection of beams under load were recorded. After that load-deflection curve has been plotted and maximum bending moment obtained.

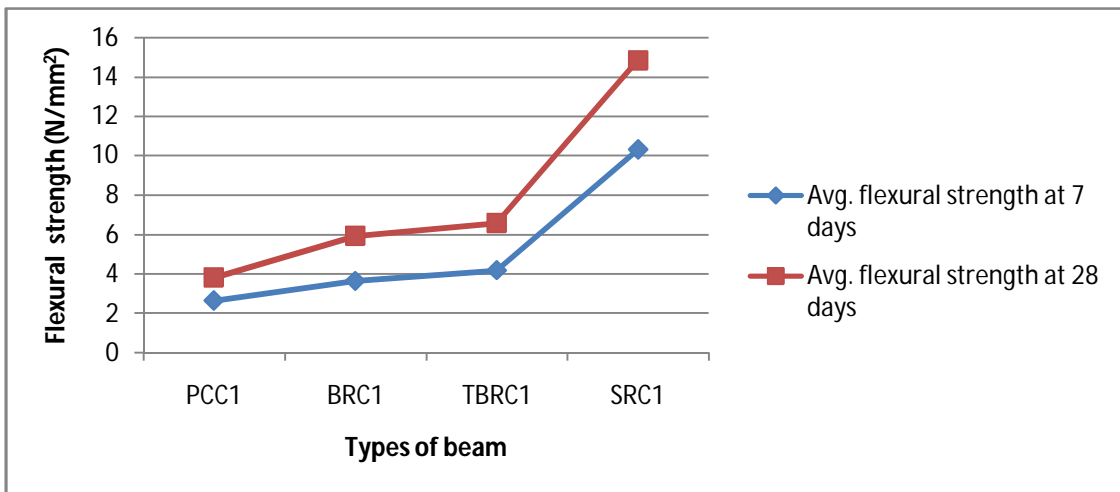
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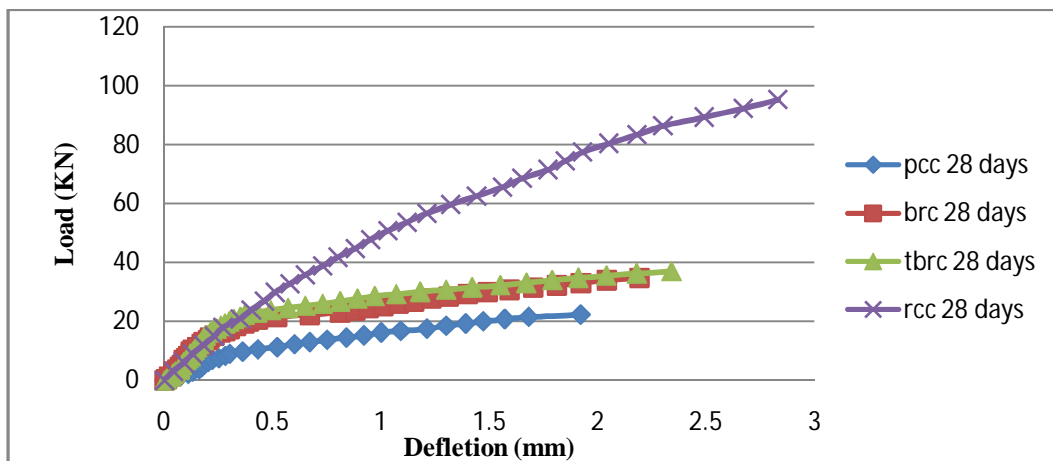
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**Table VIII Flexure test results of PCC1, BRC1, TBRC1 and SRC1 beams at 7 & 28 days**

Beam designation for beam of size 150 x 150 x 700 mm	Avg. Flexural strength at 7 days (N/mm <sup>2</sup> )	Percentage variation in flexural strength with respect to PCC1 beam	Avg. Flexural strength at 28 days (N/mm <sup>2</sup> )	Percentage variation in flexural strength with respect to PCC1 beam
PCC1 beam	2.64	0%	3.82	0%
BRC1 beam	3.64	37.88%	5.93	55.23%
TBRC1 beam	4.18	58.33%	6.57	68.73%
SRC1 beam	10.32	290.91%	14.84	288.48%



**Fig. 2 Flexural strength graph of beams of size 150 x 150 x 700 mm at 7 & 28 days**



**Fig. 3 Load-deflection graph of beams of size 150 x 150 x 700 mm at 28 days**

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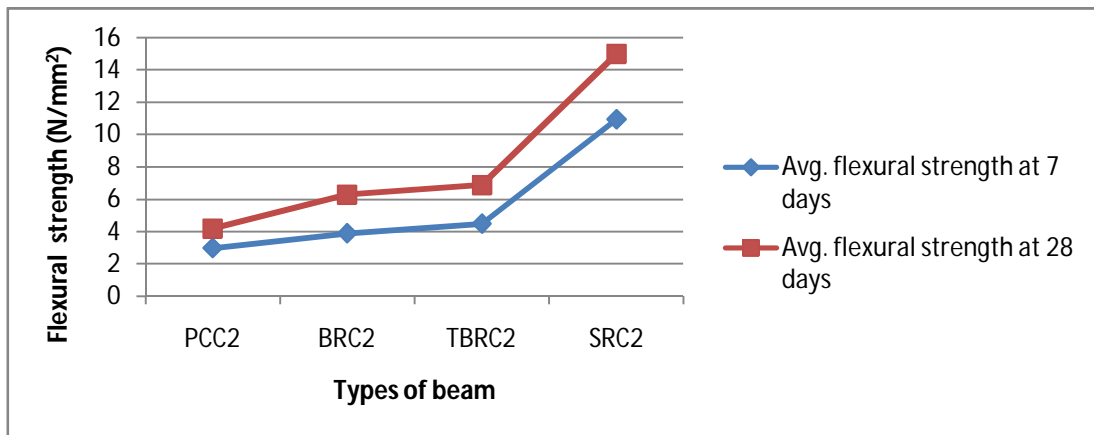
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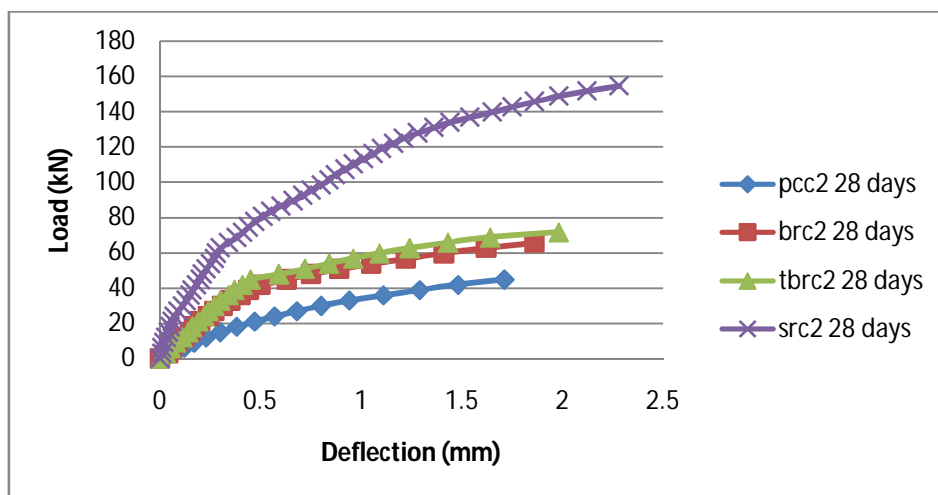
From table VIII & fig. 2, the flexural strength of PCC1 beam at 28 days has been found 3.82 N/mm<sup>2</sup> and flexural strength of BRC1, TBRC1 and SRC1 beams at 28 days are found 5.93 N/mm<sup>2</sup>, 6.57 N/mm<sup>2</sup> and 14.84 N/mm<sup>2</sup> respectively. From fig. 3, the maximum deflection of the samples of PCC1, BRC1, TBRC1 and SRC1 beams at 28 days were found to be 2.01 mm, 2.19 mm, 2.42 mm and 2.92 mm respectively.

**Table IX Flexure test results of PCC2, BRC2, TBRC2 and SRC2 beams at 7 & 28 days**

Beam designation for beam of size 150 x 200 x 700 mm	Avg. Flexural strength at 7 days (N/mm <sup>2</sup> )	Percentage variation in flexural strength with respect to PCC2 beam	Avg. Flexural strength at 28 days (N/mm <sup>2</sup> )	Percentage variation in flexural strength with respect to PCC2 beam
PCC2 beam	2.98	0%	4.18	0%
BRC2 beam	3.88	30.20%	6.27	50%
TBRC2 beam	4.48	50.34%	6.86	64.12%
SRC2 beam	10.92	266.44%	14.97	258.13%



**Fig. 4 Flexural strength graph of beams of size 150 x 200 x 700 mm at 7 & 28 days**



**Fig. 5 Load-deflection graph of beams of size 150 x 200 x 700 mm at 28 days**



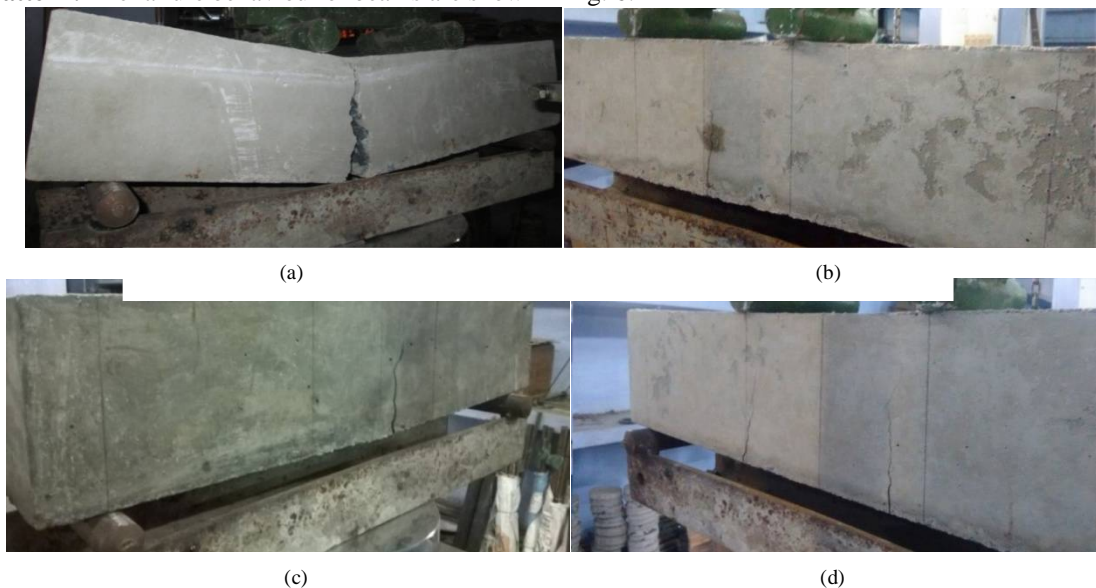
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From table IX & fig. 4, the flexural strength of PCC2 beam at 28 days has been found  $4.18 \text{ N/mm}^2$  and flexural strength of BRC2, TBRC2 and SRC2 beams at 28 days are found  $6.27 \text{ N/mm}^2$ ,  $6.86 \text{ N/mm}^2$  and  $14.97 \text{ N/mm}^2$  respectively. From fig. 5, the maximum deflection of the samples of PCC1, BRC1, TBRC1 and SRC1 beams at 28 days were found to be 1.71 mm, 1.86 mm, 1.98 mm and 2.28 mm respectively.

**Failure pattern:** The failure behaviour of beams are shown in fig. 6.



**Fig. 6 Failure of beams in flexural strength test (a) Failure of Plain cement concrete beam (b) Flexural failure of bamboo reinforced concrete beam (c) Flexural failure of treated bamboo reinforced concrete beam (d) Failure of steel reinforced concrete beam**

From fig. 6, the failure pattern for PCC beams at 28 days shows that, they behave like a brittle material. The load-deflection curve at 7 and 28 days were found curvi-linear for both BRC & TBRC beams. Failure of both BRC & TBRC beams showed flexural failure.

As per experimental results for both the size of bamboo beams, flexural strength of TBRC was greater than the flexural strength of BRC. This may be due to the bamboo being made water resistant by applying paint over its surface and the surface of bamboo roughened due to sand coating. Due to this the bonding capacity has been increased.

#### IV. CONCLUSION

Following conclusions can be drawn on the basis of the project work done in laboratory:-

- 1) The load carrying capacity of the BRC and TBRC beams on the basis of experimental result are found much better with respect to plain cement concrete beam for both the sizes (150 x 150 x 700 mm & 150 x 200 x 700 mm) of beam.
- 2) The flexural strength of SRC beam is found higher with respect to all other types of beam. The flexural strength of PCC beam is found least. This is true for both the sizes of the beams.
- 3) For the beams of size 150 x 150 x 700 mm, the flexural strength of BRC and TBRC beams are about 37.88 % and 58.33 % greater than that of PCC beam at 7 days. While at 28 days, the flexural strength of BRC and TBRC beams found about 53.23 % and 68.73 % greater than that of PCC beam.
- 4) The test results on the beams of size 150 x 150 x 200 x 700 mm indicated that the flexural strength of BRC & TBRC beams are greater than that of PCC beam by 30.20 % & 50.33 % respectively at 7 days. Whereas at 28 days, the flexural strength of BRC & TBRC beams found about 50 % & 64.11 % respectively more than the flexural strength of PCC beam.



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- 5) For the beams of size 150 x 150 x 700 mm, the flexural strength of TBRC beam are found 14.8 % and 10.79 % greater than the flexural strength of BRC beam at 7 and 28 days respectively. Similarly, for the beams of size 150 x 200 x 700 mm, the flexural strength of TBRC beam are found 15.46 % and 9.41 % greater than the flexural strength of BRC beam at 7 and 28 days respectively.
- 6) At the same load, the deflection of PCC beam is higher with respect to BRC & TBRC beams. While at the same load, the deflection of SRC beam is found least.
- 7) The flexural strength of beams of size 150 x 200 x 700 mm was found better than the flexural strength of beams of size 150 x 150 x 700 mm. While the deflections of beams of size 150 x 200 x 700 mm are found lower when compared with that of beams of size 150 x 150 x 700 mm.

This study gives bamboo as a potential material to be used as reinforcement for low load bearing structures.

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