

# FLEXURAL BEHAVIOR OF CONCRETE WITH BAMBOO AND STEEL REINFORCEMENT

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## ABSTRACT:

This paper Emphasizes on flexural behavior of concrete with or without reinforcement. Bamboo is the world's fastest growing woody plant and it grows three times faster than most other species. To reduce the cost of construction, bamboo prefers to use as reinforcement in structural elements and studied its flexural behavior with bamboo and steel reinforcement and evaluate the strength parameters with steel reinforced beam and PCC specimens. Flexural strength of the concrete with bamboo reinforcement with respect to PCC is increased to 15.8% for 7 days and 30.34% for 28 days. Similar trends were observed in flexural strength of the concrete with steel reinforcement with respect to PCC is increased to 28.6% for 7 days and 77.7% for days.

**Keywords:** Bamboo reinforcement, Culm, Flexural strength, Steel Reinforcement and Workability

## INTRODUCTION

Wide range usage of concrete is in infrastructural development because of its characteristics. The usage of available natural resources and the consequent energy requirement for this processing has a serious economic impact. For the past few years, several researchers found new materials for structural purpose in civil engineering construction. For this, many of them were chosen natural fiber utilization as reinforcement and it is being a convenient option over HYSD bars. In present state of study, both bamboo and steel are structural materials with different engineering properties. Due to the cost and availability of material, bamboo is used as alternative reinforcement in structural element. At present, bamboo is used in construction material because it is cheap and naturally available. In the present study, steel reinforcement is replaced by bamboo because of economical variation and plenty of quantity available in nature. The various constituents are presented in the bamboo culms, those are cellulose, hemi-cellulose and lignin, which occupy more than 90% of the total mass. Another reason for usage of bamboo in concrete making is consuming more than one ton of CO<sub>2</sub> from the atmosphere. Currently the load carrying capacity of bamboo and steel reinforcement are being studied and compared the results with unreinforced specimens. Bamboo is readily used as a structural material in concrete elements [1]. Bamboo has both merits and demerits, good mechanical and energy consumption are come under the good properties and preservation and fire risks are under the category of bad [2]. Bamboo shows ductile behavior as in steel, hence it can be used and replaced steel as reinforcement in structural elements [3]. The mechanical properties of Bamboo has been varied with respect to the diameter, length, age, type, position of culms and moisture content [4]. Flexural strength of beam with bamboo reinforcement was practically 50% of the steel reinforced beam specimen [5]. Modulus of elasticity of bamboo was much lower than the steel, therefore deflection was higher in bamboo reinforced specimens [6]. The flexural strength of concrete beam with bamboo reinforcement is nearly double with respect to PCC specimens [7]. Bamboo has low modulus of elasticity and it can't be preventing the cracking of the concrete [8].

The tensile stress vs strain curve of the bamboo is linear up to failure. Bamboo average tensile strength is approximately 275 MPa in the specimens without node and 100 MPa in the specimens along with node [9]. The bond stress of concrete with bamboo and steel was studied and concluded as bond stress with bamboo was 50% of the concrete with deformed steel [10]. The bamboo reinforced slab and steel slabs had high tensile stress than plain slab specimens, their deflection of the specimens were nearly 40 KN [11]. Bamboo has been used in various forms to determine its suitability as a construction material. For instance, the potential of bamboo as reinforcement in concrete was investigated [12]. It was observed that bamboo exhibits low modulus of elasticity than steel. So it doesn't avert cracks developed in concrete beneath final load [13]. The only difficulty with bamboo is subjected to fungal attack; hence before usage of this into the concrete composition, proper treatment to be needed like application of anti rusting elements.

## EXPERIMENTAL PROGRAMME

Experimentation was performed to conclude following

- ❖ Mechanical Properties of constituent materials of concrete
- ❖ Feasibility study of bamboo as a material in structural element
- ❖ Flexural strength of concrete beam with steel and bamboo reinforcement
- ❖ Load vs Deflection behavior of concrete specimens with steel and bamboo reinforcement.

## MATERIALS

### 3.1 Cement

Ordinary port land cement 53 grade confirming to IS12269 of **BIRLA** make was used in experimentation work. Specific gravity of cement was 3.13 and its consistency was 30%. Initial setting time and final were 65 min and 270 min.

### 3.2 Fine aggregate

Locally available "Penna River" sand was used in concrete composition, its specific gravity was 2.68 and confirming to Zone II of Table 4 of IS383-1970.

### 3.3 Coarse aggregate

Crushed granite aggregate available from local sources has been used. The size of coarse aggregate is 20mm and 12.5 mm.

**Table 1: Properties of Coarse Aggregate**

Description	Value
Specific gravity	
20 mm	2.60
12.5mm	2.56
Aggregate crushing value	18.20%
Water absorption	
20 mm	0.23%
12.5 mm	0.38%
Impact value	
20 mm	20.2%
12.5 mm	22.42%

### 3.4 Water

Local available source of water used for mixing and curing of concrete and it is safe for usage into the structural elements because of lower chlorides, fluorides and total solids are within the limitations.

**Table 2: Water Analysis**

Parameter	Experimental values in mg/l	Permissible limits of mixing of water to the concrete in mg/l
PH	7.5	6 -8
Taste	Agreeable	Normal
Acidity	10	50
Alkalinity	88	250
Chlorides	300	2000 for PCC 3000 for RCC
Total Hardness	230	300
Sulphates	90	150
Fluorides	0.60	1.5
Dissolved Oxygen	6	5-7
Total solids	120	500
Total dissolved solids	150	500
Total suspended solids.	100	300

### 3.5 Bamboo Reinforcement

It is considered a composite material because it consists of cellulose fibers imbedded in a lignin matrix. Cellulose fibers are aligned along the length of the bamboo providing maximum flexural strength and rigidity in that direction. Based on the previous study, following properties are listed below. Average size of the bamboo reinforcement was 12 to 14 mm into the beam elements. Fig 1 and 2 shows the fabricated beam elements with bamboo and steel. Fig1 and 2 shows the beam reinforcement with bamboo and steel

- ❖ Specific gravity - 0.575 to 0.655 gr/cc
- ❖ Average weight - 0.625kg/m
- ❖ Modulus of rupture - 610 to 1600kg/cm<sup>2</sup>
- ❖ Modulus of Elasticity - 1.5 to 2.0 x10<sup>5</sup>kg/cm<sup>2</sup>
- ❖ Ultimate compressive stress- 794 to 864kg/cm<sup>2</sup>
- ❖ Safe working stress in compression - 105kg/cm<sup>2</sup>
- ❖ Safe working stress in tension - 160 to 350 kg/cm<sup>2</sup>

**Fig 1: Bamboo reinforcement****Fig 2: Steel Reinforcement**

### 3.6 Steel reinforcement

12 mm and 8 mm diameter HYSD bars were used as reinforcement in concrete beams. 12 mm bars were used as main reinforcement and for stirrups 8 mm bars were used.

**Table 3: Properties of Steel**

Description	Value	
	Sample 20mm	Sample 12.5 mm
Elongation Length	70%	60%
Reduction Area	70.41%	67.0%
Yield Strength	629.46 N/mm <sup>2</sup>	617.26N/mm <sup>2</sup>
Ultimate Strength	733.26N/mm <sup>2</sup>	721.94N/mm <sup>2</sup>
Breaking Strength	544.13N/mm <sup>2</sup>	522.91N/mm <sup>2</sup>

### MIXING AND CASTING

M20 grade nominal mix proportion was chosen for casting of concrete beam specimens. To resolve the flexural strength of concrete, it is essential to cast beam specimen and evaluate at which load concrete beam specimen will fail. The size of the specimen was 700x150x150 mm used in experimental work. Modulus of flexure test has been performed under symmetrical third point loading pattern. Determination of flexural strength is an essential to estimate load at which concrete specimen will split into pieces.

A total of 18 specimens were cast in steel moulds of size 150x150x700mm. Among these, 6 specimens were cast without reinforcement as PCC specimens. Another 6 specimens were cast with steel reinforcement and rest of the specimens with bamboo reinforcement. Fig 3 and 4 are representing steel moulds and casting of specimens after manual vibration.

**Fig 3: Steel mould with reinforcement****Fig 4: Beam specimens after casting**

For evaluating the flexural strength, a concrete beam was subjected to flexure using symmetrical third point loading until failure occurs according to the ASTM C 78-02. The modulus of rupture is determined from the moment at failure. Flexural strength of the beam specimen is calculated according to IS516-1959.

$$\text{Flexural strength} = 3Pa/bd^2$$

$$\text{When 'a' < 13.3 cm and > 11 cm}$$

### TEST PROCEDURE

The load points were marked at one third of the span and the theoretical maximum tensile stresses reached at bottom fiber of the test beam, known as the Modulus of rupture. Under third-point loading, one-third the length of the extreme fiber in the beam was subjected to the maximum



stresses, so that the critical crack developed at any section in one-third of the beam length. The probability of a weak element (of any specified strength) being subjected to the critical stress is considerably greater under third-point loading than when a central load acts, the centre-point loading test will give a higher value of modulus of rupture and more variable values. In consequence of this, centre-point loading test is very rarely used in resolving the flexural strength. Test set up of third point loading specimen is represented in Fig 5.



**Fig 5 Third point loading arrangement**

## RESULTS AND DISCUSSIONS

### 1.1 Workability

Workability of concrete was studied by the slump values and compaction factor tests, these values are presented in Table No 4. The average value of slump was 15.5 cm for and CF was more than 0.86, hence these values show the workability condition.

**Table No 4: Test results for the slump values for beams**

Different samples	Slump Value in cm	Compaction Factor Value
Bamboo samples	16.5	0.88
Steel samples	14.5	0.85

### 1.2 Flexural strength of beam specimens

Sudden failure of PCC specimens was observed during the performance of test, but specimens with steel and bamboo reinforcement cannot fail suddenly due to the presence of reinforcement. Reinforcement is restraining the sudden failure because steel has high modulus of elasticity and bamboo has lower modulus of elasticity than steel. Flexural strength of the beams are tabulated in Table No 6

**Table No 5.1: Flexural Strength of PCC beams**

S.No	Weight of the beam (Kg)	Curing Period (Days)	Flexural Strength MPa	Average Flexural strength MPa
1	42.4	7	7.47	7.66
2	43.6		7.11	
3	40.0		8.4	
4	40.0	28	7.82	8.75
5	40.5		8.89	
6	41.0		9.55	

**Table No 5.2: Flexural Strength of Bamboo RCC beams**

S. No	Weight of the beam (Kg)	Curing Period (Days)	Flexural Strength N/mm <sup>2</sup>	Average Flexural strength MPa
1	39.0	7	7.21	8.54
2	38.0		9.13	
3	40.0		9.28	
4	42.0	28	10.48	10.91
5	39.0		10.13	
6	40.0		12.13	

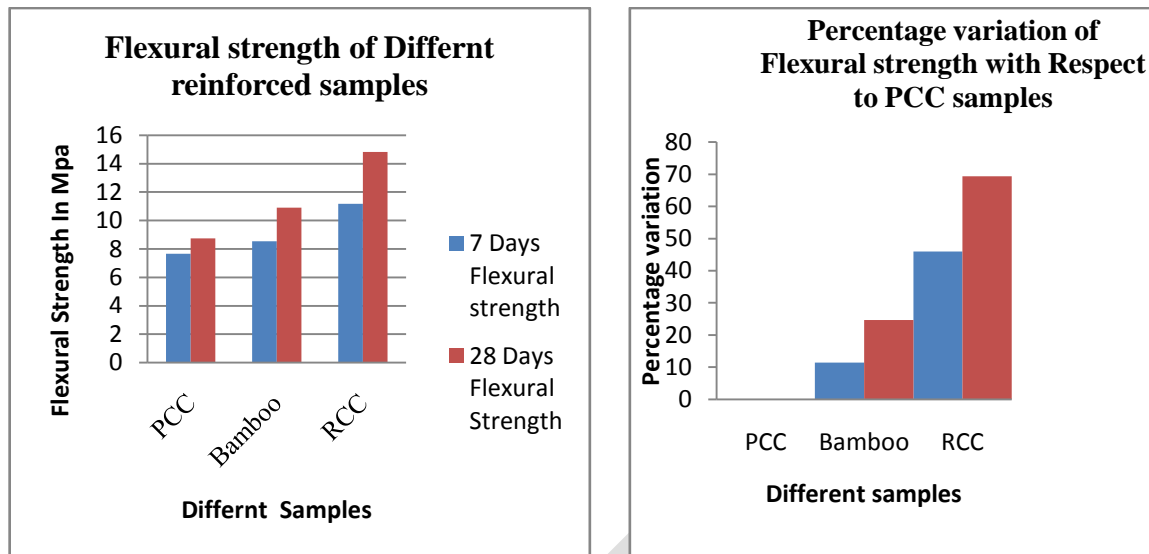
As per the above test results, average 7 days strength of PCC, BRCC and SRCC are 7.66, 8.54 Mpa and 11.18 Mpa. 7 days Strength of the concrete is being increases to 11.49% and 45.95%. Average 28 days flexural strength of PCC, BRCC and SRCC are 8.75, 10.91 and 14.82 MPa. 28 days Strength of the concrete is being increases to 24.69% and 69.37%. The increase of flexural strength is due to the ductility and malleability of steel and bamboo reinforcement. The elastic modulus of bamboo is smaller than the steel that why 28 days strength deviated from 10.91 to 14.82 MPa. Flexural strength is also influenced by the absorption capacity of bamboo reinforcement. It is concluded that flexural strength of the bamboo reinforcement is 73% of the steel reinforcement. Comparison 7 days and 28 days strength are shown in fig 6 and 7.

**Table No 5.3: Flexural Strength of Steel RCC beams**

S. No	Weight of the beam (Kg)	Curing Period (Days)	Flexural Strength N/mm <sup>2</sup>	Average Flexural strength MPa
1	40.0	7	11.6	11.18
2	42.0		10.22	
3	43.0		11.73	
4	43.5	28	14.08	14.82
5	44.0		15.36	
6	42.0		15.02	

**Table 5.4: Average Flexural strength of different specimens**

S.No	Type of Sample	7 Days Average Flexural strength in Mpa	28 Days Average Flexural strength in Mpa	Percentage variation of 7 days flexural strength	Percentage variation of 28 days flexural strength
1	PCC	7.66	8.75	--	--
2	Bamboo Reinforced samples	8.54	10.91	11.49	24.69
3	Steel Reinforced Samples	11.18	14.82	45.95	69.37

**Fig6 Flexural strength of Different specimens Fig 7 Percentage variation of flexural strength**

## CONCLUSIONS

Based on the experimental Results following results are drawn

- ❖ Based on the physical and mechanical properties, bamboo is a useful structural material
- ❖ Water absorption of bamboo is higher, hence epoxy coating is applied on surface .
- ❖ Flexural strength of the bamboo specimens are 11.49% and 24.69% more than the Plain cement concrete specimens
- ❖ During the testing, sudden failure observed in PCC specimens but for bamboo is restrain for sudden failure because of elasticity modulus of bamboo.
- ❖ Finally concluded as bamboo shall use as a reinforcement in beams, columns and stirrups in structural elements.

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#### AUTHORS INFORMATION



Prof V. Giridhar completed his post graduation in structural Engineering from JNTUH-Hyd and acquired doctoral degree from JNTUA-Ananthapuramu. He has wide experience in research on effective utilization of waste materials in concrete composition, high performance and high strength concretes. He published 15 research articles in international journals and 3 international conferences. He published a book in international publisher. Presently working as professor of Civil Engineering department at KSRM College of Engineering-Kadapa,