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Study of Bamboo as Reinforcement in Concrete

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Abstract: Bamboo is one of the oldest building materials used by mankind. Bamboo is used for various construction works. It has good strength and durability. Now a days concrete is a widely used as construction material for its various advantages such as low cost, availability, fire resistance etc. Reinforced cement concrete plays vital role in construction. The cost of construction is increasing due to increase in the cost of steel and cement. To control the cost of construction and promote the use of natural products the study is required be carried out. The aim of present research work is to explore the use of bamboo as reinforcement in reinforced cement concrete work. This paper shows the investigation of use of bamboo reinforcement in beam. To study the effect of replacement of steel reinforcement by bamboo, tests have been conducted on 28 beams of size 750 mm length and 150 mm x150 mm. Beams were tested to failure under two point load tests. The highest and lowest failure loads were recorded for the case of steel reinforcement and bamboo reinforcement with steel stirrups. Flexural strength of beam model has been studied by replacing bamboo completely, in compression zone and in tension zone.

Keywords: Bamboo, Reinforced cement, Steel Reinforcement.

I. INTRODUCTION

The development of science and technology is a continuing quest for improvement in infrastructure of world around us. The structures in nature are great lessons for human study. According to study, it is estimated that one billion people in the world live in bamboo houses. Since bamboo has been used in construction and currently they are used as props, foundation, framing, scaffolding, flooring, walls, roofs and trusses. Bamboos are tied together to make grid reinforcement and placed in soft clay to solve deformation problems in embankments. During the past years, several researchers have found new materials for structural purposes in civil engineering. The United States Navel Civil Engineering Laboratory (1966-2000) started the use of bamboo as concrete reinforcement for prefabricated structural elements. [1] reported that the highest strength of the bamboo culm on is in tension and compression strength is much lower. The culm tangential strength is low and cannot be considered. [2] conducted her study on building with bamboo. This book covered a wide variety of aspects of bamboo going back to the structure of the plant and its natural habitat. It gives calculation to show why it is economically competitive, mechanical properties, its many uses, its natural durability and the preservation of the bamboo. [3]mention that bamboo is the most effective material in construction by the superior character of bamboo such as being physically powerful, tough and a low-cost material. Normally, the Culm of bamboo with outer surface layer withstand strongly to any loading with stronger fracture resistance than the node. It suggests that the fibres in the node do not contribute any fracture resistance. The tensile strength of bamboo fibres almost corresponds to that of steel. Steinfeld has studied the current uses of bamboo around the world. In the United States, it is almost completely used for decoration. [4] suggested bamboo's advantages and disadvantages as a construction material. The advantage of bamboo is its ecological value, good mechanical properties, social and economic value and energy consumption. On the other side, the disadvantages of bamboo are preservation, fire risk and natural growth. [5]found that the tensile stress of seasoned bamboo is about 70N/mm2, about one-third of that of steel, with low ductility and a total strain of 5% compared with an average strain in steel of 12%. The use of bamboo strip as reinforcement in concrete column increased the load carrying capacity of the column compared to unreinforced concrete. It also improves the post cracking ability of the concrete but not as pronounced as in steel reinforced column. [6] studied the effect of nodes and its strength differs from those of intermodal regions. Further the nodes possess brittle behaviour and the inter-nodal region possesses ductile behaviour. The average tensile strength of moso behaviour from present study is 225N/mm2, which is half the strength of mild steel. [7] investigated the utilisation of bamboo as a construction/ structural element in various building components such as floor, roof, beam, wall-panel, column etc. An engineered bamboo can substitute steel in making tensile stresses of RCC members and also reduces the consumption of cement in building.[8] has studied researched a design using bamboo as one of the chief structural materials, for the safe and durable house, affordable by the urban poor. The design thus evolved shall clearly indicate the cost reduction of the superstructure where steel reinforced concrete is replaced by bamboo reinforced concrete in key structure elements. In the present study, an attempt has been made to study the behaviour of bamboo as reinforcement in concrete. For this, tests were performed on bamboo to study the properties. Along with these, compression and tension tests were performed for the study.

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II. CHARACTERIZATION OF MATERIALS

Cement: The cement used for the preparation of concrete is ordinary Portland cement of 53 grade confirming to [9]
Physical Properties: The physical properties of the cement used are given in Table 1.

Table 1 Physical Characteristics of cement

Characteristics	**Experimental values**
Consistency of cement	33.0%
Specific gravity	2.84
Initial setting time	145 min
Final setting time	330 min
Fineness of cement	1%

III. COMPRESSION TEST ON CONCRETE BLOCK

The concrete cubes of size 15cm x 15 cm was prepared of mix design M20 and the mix design was carried out as per [10]. Concrete cube specimen was tested at 7, 14 and 28 days using compression testing machine at a constant loading rate. Table 2 shows the compression tests results on concrete cubes.

Table 2 Compressive strength of concrete

Days	Compressive Strength (N/mm^2)
7	25.92
14	32
28	36.59

IV. BAMBOO REINFORCEMENT

Bamboo strips of 12 mm wide are prepared by the splitting bamboo. The steel bars of 12mm size are used as reinforcement in beam specimens. Flexural test is carried out using two-point load on various specimens with steel as reinforcement and replacing the steel in tension, compression and completely by bamboo.
The reinforcement of bamboo was introduced in the concrete beams in similar way as steel used in reinforced beams. The bamboo reinforcement was used in compression zone for some cases and also in tensile zone in some cases. For some cases, bamboo reinforcement was used both in compression and tensile zone as [11,12,13]

V. TENSILE STRENGTH OF BAMBOO

The tensile strength of bamboo strips of 12mm wide and 100 mm gauge length was found under UTM for node to node and centre to centre position. Table 3 shows the tensile strength of bamboo which was used as reinforcement.

Table 3 Tensile strength of Bamboo

Sample position	Specimen Size	Tensile Strength (N/mm^2)
Node to Node	300 mm	211.02
Node to Node	300 mm	201.08
Centre to Centre	300 mm	187.71
Centre to Centre	300 mm	187.58

VI. RESULTS AND DISCUSSIONS

The concrete beam reinforced with steel bars and bamboo bars were tested under flexure to study the suitability of bamboo as reinforcement in beam. The load-deflection behaviour, variation in modulus of elasticity, variation of failure load, variation in strength as [14], moment of beams and failure modes and cracking [15] were obtained from the performed tests.

VII. LOAD-DEFLECTION BEHAVIOUR

The load deflection behaviour of reinforced concrete beams depend on the amount and type of reinforcement, concrete strength and shear span effective depth of the beam. In the 28 beams tested to failure, the longitudinal tension reinforcement in bamboo varied from 4.17% to 7.83% of the gross concrete section. The deflections of the beam when tested, results followed a fairly accurate straight line variation until the appearance of the first crack in the concrete.
Figure 1(a), (b), (c), (d) and (e) show the load deflection behaviour for various reinforcement positions of bamboo in concrete beam at 14 days.

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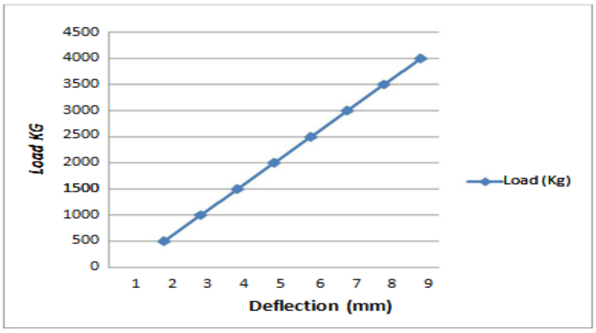
Figure 2(a), (b), (c), (d) and (e) show the load deflection behaviour for various reinforcement positions of bamboo in concrete beam at 28 days.



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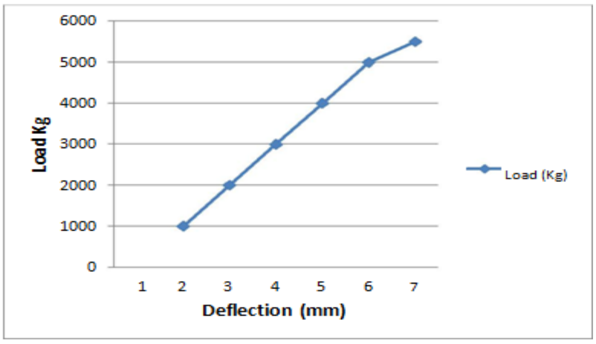

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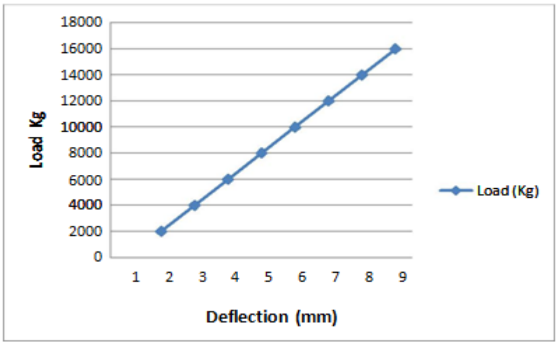

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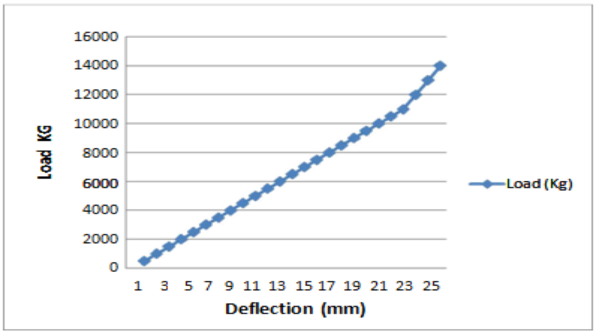

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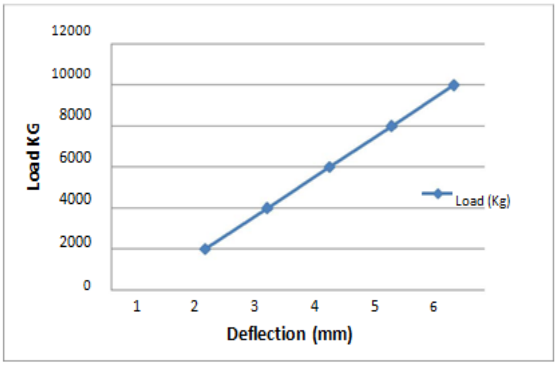
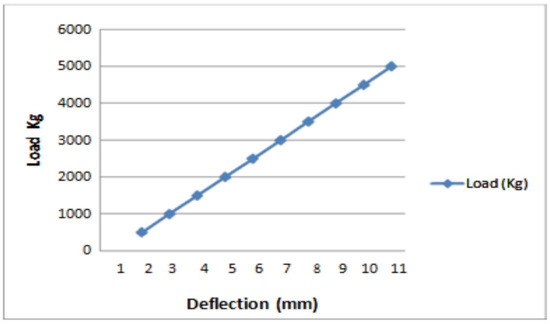


(e)

Fig 1 Load Deflection behaviour for (a) plain beam, (b) bamboo beam, (c) reinforced concrete beam ,(d) composite beam for tension and (e) composite beam for compression for 14 days



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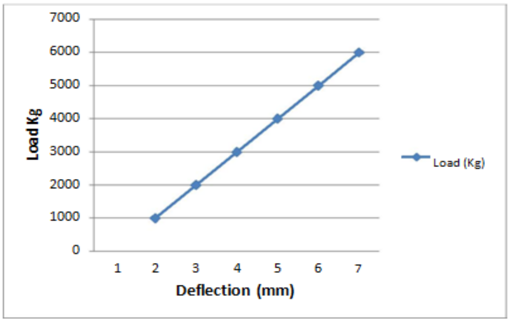

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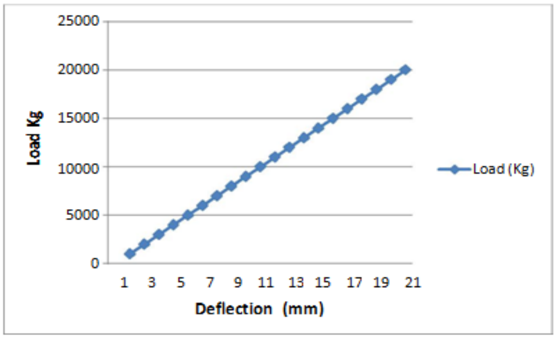

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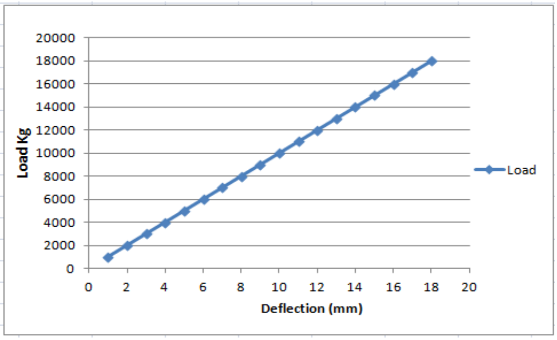

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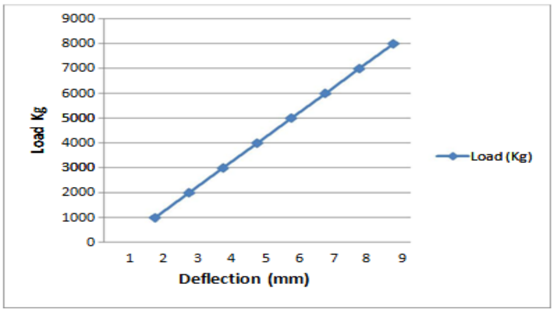

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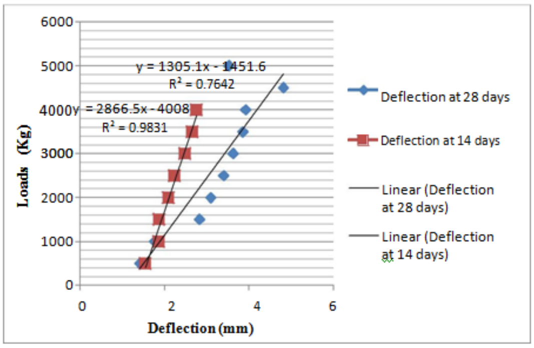
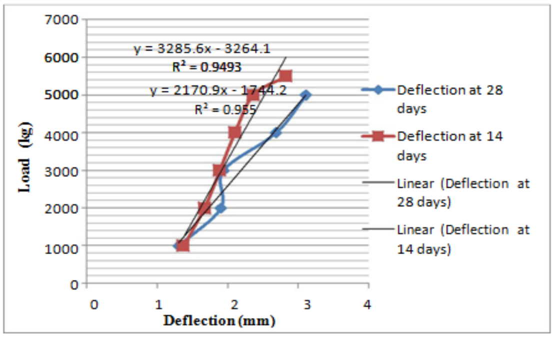
Fig 2 Load Deflection behaviour for (a) plain beam, (b) bamboo beam, (c) reinforced concrete beam, (d) composite beam for tension and (e) composite beam for compression for 28 days



(a)



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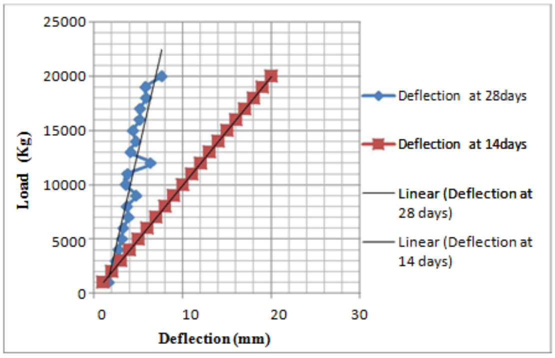

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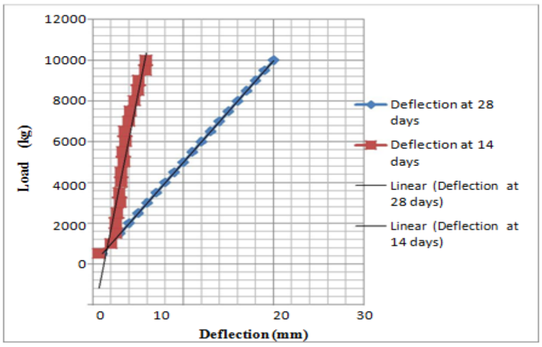

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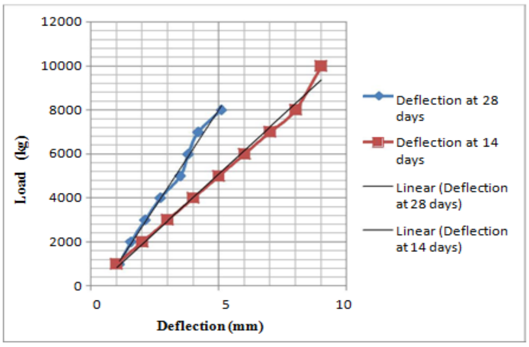

(e)

Fig 3 Load Deflection behaviour for (a) plain beam, (b) bamboo beam, (c) reinforced concrete beam, (d) composite beam for tension and (e) composite beam for compression for 14 and 28 days.

VIII. VARIATION IN MODULUS OF ELASTICITY

Based on the experimental study the modulus of elasticity of RCC beam is more than the bamboo beam and also modulus of elasticity of beam with bottom steel is more than the modulus of elasticity of beam with bottom bamboo. Table 4 shows the variation on modulus of elasticity for beam at 14 and 28 days. The modulus of elasticity is calculated

$$E = \frac{23WL^3}{648I\delta}$$

Table 4 Variation in modulus of elasticity at 14 days and 28 days

Type of beam	Modulus of elasticity after 14days (N/mm^2)	Modulus of elasticity after 28 days (N/mm^2)
RCC beam	948.61	1041.15
Beam with bottom steel	763.99	1218.32
Beam with bottom bamboo	702.87	958.93
Bamboo beam	565.48	571.00
Plain beam	322.838	468.786

IX. VARIATION OF FAILURE LOAD

Flexural test on the various specimens shows the variation in load carrying capacity of beam. The beam with steel reinforcement has highest capacity and plain beam has lowest as shown in Table 5. It shows that steel in compression side is replaced the strength reduces to 83.82 % and 57.34 % when steel in tension side is replaced by bamboo. If the all the longitudinal steel is replaced by bamboo the strength reduces to 26.47 %. As steel is very costly and if we achieve strength of 83.82 % by replacing 50% steel, then it can be economical option for low cost structures.

Table 5 Failure load at 14 days and 28 days

Beam Type	Failure Load (kN)	
	14 Days	28 Days
Beam with Complete steel in tension and compression	100.71	111.18
Beam with bamboo in compression zone	76.84	93.19
Beam with bamboo in tension zone	60.82	63.76
Beam with Complete bamboo in tension and compression.	29.43	49.05

X. VARIATION OF STRENGTH AND MOMENT

The variations in strength and moment for all type of beam were obtained. On comparing, the moment of bamboo beam is 46% of reinforced concrete beam and also strength is 46% of reinforced concrete beam. Also the moment and strength of composite compression beam is found to be 90% of reinforced concrete beam. Table 6 shows the strength and moment for various beams.

Table 6 Variation of strength and moment

Description of beam	Moment (kN-mm)	Strength (kN/mm^2)
Bamboo beam	6128.125	108
Reinforced concrete beam	13390.625	238
Composite compression beam	12262.99	217

XI. FAILURE MODES AND CRACKING

All the beams failed by a combination of some of the following failure modes: longitudinal bamboo in tension, concrete crushing, flexural shear, diagonal tension and shear bond with the exception of bamboo beam which failed by only bamboo in flexural tension. Reinforced concrete beam and composite tension beam failed by diagonal tension characterized by splitting of the concrete over the horizontal tension steel and bamboo bars.

Table 7 failure mode

Beam type	Failure mode	Number and type of crack	Max. crack width(mm)
Plain Beam	Concrete crushing and tension failure	2 diagonal shear + 7 pure flexure	3
Bamboo beam	Diagonal tension	4diagonal + 4pure shear	3
RCC beam	Diagonal tension and flexural shear	3 diagonal +6 flexure shear	2
Composite tension beam	Pure flexure and concrete crushing	1 flexural shear + 3 pure shear	4
Composite compression beam	Pure flexure and concrete crushing	1 flexural shear +3 pure shear	4

XII. CONCLUSION

To check the suitability of bamboo as reinforcement, experimental investigation has been carryout using flexural test with two-point load test. Following conclusions are made from various test results.

1. Bamboo shows reasonable tensile strength, which suggests that it can be used as reinforcement in RCC structure for low cost housing projects.
2. As bamboo is weak in shear it cannot be used as shear reinforcement in RCC structures
3. If complete steel reinforcement is replaced with bamboo then it gives only 26 % strength.
4. It gives reasonable strength of 83% when bamboo is placed in compression side only with steel at tension side.
5. Bamboo is weak at node section, major failure in bamboo occurs at node.
6. The tensile strength of middle portion of bamboo is always larger than that of top and bottom.
7. Bamboo does not show ductile behaviour as steel. Hence it can be used in compression members in steel as well as RCC structure.
8. It can be proved economical option for columns of compound walls.

9. Modulus of elasticity of bamboo is quite lower than that of the steel.
10. RCC beam has performed more elastically than the bamboo beam while flexural tests.
11. Vertical cracks are developed, on failure of beams, within middle third region of the beam. This type of failure is a proof existence of pure moment without any shear.
12. The mode of failure for bamboo and RCC beam was shear, indicated by diagonal cracks because of the short-span specimen adopted.

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