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Structural Behaviour of Bamboo Reinforced Two Way Slab

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Abstract: This study presents the evaluation of the feasibility of the use of bamboo as a potential reinforcement in concrete structural members. An experimental work was conducted to determine the structural performance of two way slabs reinforced with bamboo. Four types of RC slabs which consist of 2 specimens for each type were tested by central concentric loading test. These include two slabs reinforced with mild steel and other six slabs reinforced with triangular, square and circular cross-section of bamboo. . All the bamboo samples used in this study were collected from three-four years old tree. Among them the stress-strain curve of all samples were studied to find out Modulus of Elasticity and Yield Strength using Offset Method. There was an indication that the fracture points of the tensile samples containing nodes occurred at the nodes.

Keywords: Bamboo reinforcement, Flexural strength, Mild steel, Two way slab.

I. Introduction

In today's society, most buildings are built using such materials as steel reinforced concrete and structural steel. Specifically, concrete is a high quality and economical material with its ability to support fire and earthquake defense in buildings constructed in developed and developing countries. One of the significant faults of concrete is its low tensile strength. Steel reinforcing bars are typically used for reinforcement. Steel is one of the best materials for complementing the low tensile strength of concrete because of its high tensile strength. Unfortunately, structural steel is not easy to find in many countries due to limited natural resources and lack of skilled labor. For the same reasons, use of steel reinforcement in concrete is not widespread. Some buildings in the world have been built of just plain concrete or bricks without steel reinforcement. These buildings typically cannot withstand the effects of natural disasters such as earthquakes, hurricanes, and storms. In a few countries, buildings which did not use enough steel have been crumbled by natural disasters such as earthquakes. Even though steel reinforcement is a very suitable material for complementing concrete's low tensile strength, there are many difficulties such as economics, technique, and efficiency that need to be addressed. To overcome these problems, many scientists and engineers have been trying to seek out new materials for increasing the tensile capacity of concrete. Specifically, bamboo is one of the most suitable materials to substitute for reinforcing bar in concrete.

Under certain conditions, bamboo splints may safely be used as substitutes for steel in slabs[1]. Markos Alito et. al [2] studied the bamboo reinforcement as construction material for the construction of low-cost houses in Ethiopia. In his experimental study he found out to give encouragement. It identifies the potential for an alternative method for low-cost construction for areas where steel reinforcement is costly. In this case, bamboo might replace steel in light constructions as the tensile element in reinforced concrete design. As tensile strength of bamboo is greater than that of resin, the author recommends bamboo fibre for reinforcement of plastic[3]. In spite of clear advantages, the use of bamboo has been largely restricted to temporary structures and lower grade buildings due to limited natural durability, difficulties in jointing, a lack of structural design data and exclusion from building codes[4].The American Bamboo Society [5] provided a very intricate collection of specialized terms followed by their definitions relating to Bamboo. It also has a glossary of questions and answers common to someone new to the topic. These questions ranged from identifying Bamboo, preserving Bamboo, finding help with your Bamboo, to other topics not as closing connected to the research of this project. The bonding between the Bamboo and concrete is considered the biggest problem due to absorption of water and smooth wall of the Bamboo Culm[6]. Youngsi Jung et al [7] investigated the feasibility of using bamboo as a reinforcement alternative to steel in concrete structural members. H.Y Fang et al. [8] Department of civil engineering, Lehigh University, Bethlehem submitted his paper which presents the basic factors for selecting bamboo, the mechanism of bamboo-water-concrete interaction, and the sulfur-sand treatment of the bamboo used for reinforcement in structural concrete.

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II. EXPERIMENTAL PROGRAM

The experiments were conducted on three different cross sections of bamboo reinforced concrete slab namely square, triangular and circular. Also, the experiments were designed in such a manner that the effect of different cross section of bamboo on concrete slab could be studied. The experimental program also involved the evaluation of tensile strength of three different cross- sections of bamboo samples.

A. Bamboo Preparation

Three to Four year old dry bamboo (*Dendrocalamus strictus*) culms were obtained from Aligarh local market which was supplied from District Bareilly (Utter Pradesh) India. At the time of purchase, bamboo culms were already treated with smoke. Bamboo pieces were cut in the form of squire (10x10 mm^2), triangular (h=10mm, b=10mm) and circular (d=10mm) cross-section which were 970mm overall length.

when bamboo, either split or whole, is used as reinforcement, it should receive a waterproof coating to reduce swelling when in contact with concrete. Without some type of coating, bamboo will swell before the developed sufficient strenght to prevent cracking and the member may be damaged, especially if more than 4 percent bamboo is used. The type of coating will depend on the material available. Bamboo sticks which was used in experiment, brush coat of thin coating of varnish was appied because thick coating will lubricate the surface and weaken the bond with the concrete. Nomenclature of different specimen according to the cross-section is tabulated in Table 1.

TABLE 1 BAMBOO AND STEEL SPECIMEN FOR TENSILE TEST

Specimen code	**Shape**	**Sample position**	**Cross-section *(mm)***	**Cross sectional area [mm^2]**
T_1BC_1	Circular	With node	10	78.5
T_2BC_2	Circular	Without node	10	78.5
T_3BS_1	Square	With node	10×10	100
T_4BS_2	Square	Without node	10×10	100
T_5BT_1	Triangular	With node	10×10	50
T_6BT_2	Triangular	Without node	10×10	50
T_7SC_1	Steel (Circular)		10	78.5

The stress-strain curves are shown in the Fig .1 for circular, square and triangular cross-section bamboo specimens. Form Figure it is observed that, the ultimate stress for specimens without node is higher than that of the specimen containing node.

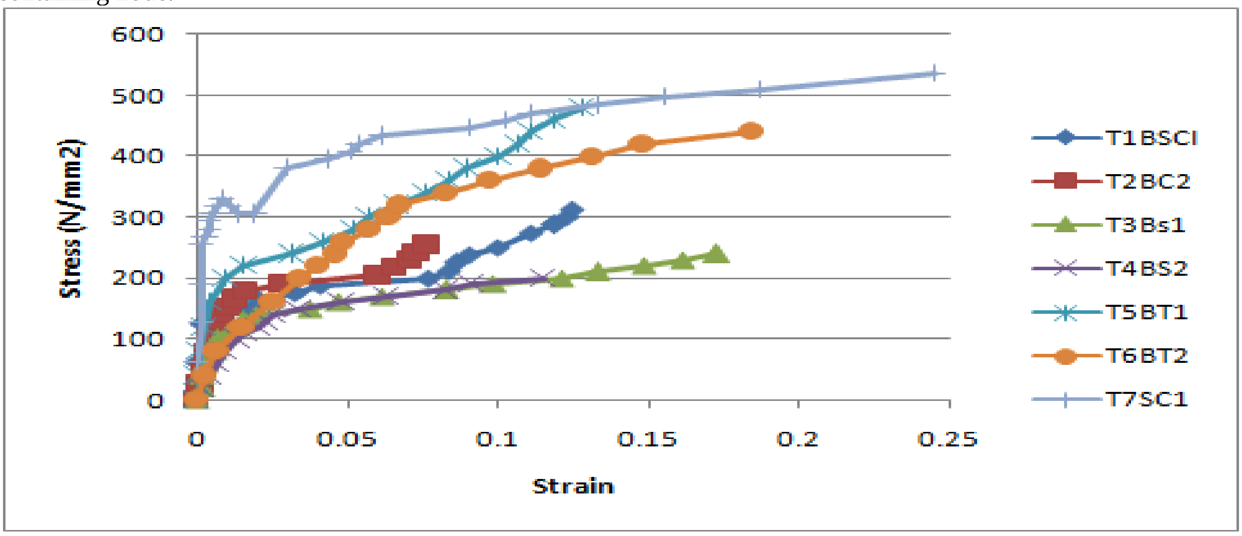

Fig. 1 Stress strain curve for all specimens

B. Concrete Mix Design

Indian standard method for M20 concrete

- Type of cement = Cement OPC 43 grade conforming to IS-8112

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- Exposure condition =Mild exposure
- Compactor factor = 0.9
- Maximum nominal size of aggregate = 10 *mm*
- Type of aggregate = crushed angular aggregate
- Degree of supervision = Good

TABLE 2 MATERIAL PROPORTIONS PER METER CUBE OF AGGREGATE

Material	Quantity
Water	200 kg/m^3
W/C	0.55
Cement	364 kg/m^3
Fine aggregate	530 kg/m^3
Coarse aggregate	1200 kg/m^3

- Mix proportion is 1:1.46:3.29

C. Slab Design

Since the purpose of this research is to determine the feasibility of the use of Bamboo as reinforcement in concrete, it is necessary to compare its behaviour to steel, the traditional reinforcement. Therefore slab designs were in accordance with Limit state method, by using IS 456 (2000) code. The overall plan dimensions of the test slab 1000mmx1000mm were chosen. The slab thickness was normally 50mm. The slab was reinforced in accordance with the requirements for two-way systems using IS 456 (2000) code. The numbers of reinforcement are same in the longitudinal and transverse direction for two way slab of equal span. The reinforcement details have been tabulated below in the Table 3 for each shape of the bamboo and steel reinforcement.

TABLE 3 REINFORCEMENT DETAILS

Sample name	Cross –section of Reinforcement(mm)	Total Area (mm^2)	Number of Reinforcement
Mild Steel (circular)	10	1570	20
Circular Bamboo	10	1570	20
Square Bamboo	10	2000	20
Triangular Bamboo	10×10	2000	40

III.RESULTS AND DISCUSSION

A. Bamboo Reinforced Slab

Two square concrete slab (two way) specimen reinforced with triangular, square and circular cross section bamboo strips measuring 1000 mm by 1000 mm and thickness 50 mm were tested in the laboratory under central concentrated load. The average cross-section of all bamboo strips used in the bamboo mesh concrete reinforcement was 10 mm by 10 mm and total number of bamboo strips used in each slab reinforced with triangular, square and circular was 40, 20 and 20 respectively. All the readings regarding experiments were recorded and the results have been discussed below.

- Triangular Cross-Section Bamboo Reinforced Slab

Figure 2 (a) shows the crack patterns observed after failure in the specimen which failed dominantly in flexure. The First crack occurred just below the loading point and propagated towards the edges. When loads were increased, more vertical cracks developed at the bottom surface before it reached the ultimate capacity. The first crack in triangular cross section bamboo reinforced concrete slabs occurred at lower load than mild steel reinforced concrete slabs.

- Square cross section bamboo reinforced Slab

Initially, the slabs specimen was uncracked, and the application of load produced only small deformations which were within the elastic range of material behavior. Cracking initiated near the bases of the loading point. The slabs reacted as cracked reinforced concrete sections which were considerably more flexible than before cracking. During the gradually increment of the loads, cracking spread over most of the surface of the test area of the specimens. The cracks eventually

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were approximately evenly spaced in an orthogonal pattern, with each crack following the path of a reinforcing bar, as shown in Fig. 2 (b). The crack patterns occurred earlier than mild steel reinforced concrete slabs.

- Circular cross section bamboo reinforced Slab

First flexural cracking occurred at or near the load point. Increasing the deflection resulted in the opening of one or more major flexural cracks and appeared running from the load position to the near end of the slab. These cracks widened as the load increased and vertical movement occurred along the cracks. The first crack in circular cross section bamboo reinforced slab were recorded at load in between the first crack loads of triangular and square cross section bamboo reinforced concrete slabs. The crack pattern is shown below in the Fig. 2 (c).

(a) (b) (c)

Fig. 2 First crack of bamboo reinforced slab (a) Triangular bamboo cross section (b) square bamboo cross section (c) circular bamboo cross section

B. Mild Steel Reinforced Slab

The slab was reinforced in accordance with the requirements for two-way systems using IS 456 (2000) code. The numbers of reinforcement are same in the longitudinal and transverse direction for two way slab of equal span. Mild steel rod of 10 mm diameter was used as reinforcement for S_7SC1C slab specimen.

For a two way slab simply supported on all four sides and subjected to a central concentrated load, the central area undergoes maximum punching shear as well as maximum bending moment. Failures are generally due to a combination of the two failure modes with the least ultimate load governing the failure of the slab. Usually bending failure cracks are the first to develop underneath the slabs as applied loading is gradually increased and the concrete tensile strength is exceeded. This is because concrete is weak in tension. The crack pattern observed underneath the slab is illustrated in Fig. 3. From the figure, it could be inferred that the first crack was initiated underneath the point load and propagated diagonally towards the corner. As the load increased, additional cracks started to form throughout the specimen, widening and propagating upward until failure occurred. Therefore collapse occurred from punching failure. The final failure mode however depends on the amount steel reinforcement, concrete strength and effective depth of the slab. Load deflection curve for all slab specimens have been shown in Fig. 4.

Fig. 3 First crack of mild steel reinforced slab

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C. Flexural Strength

The plot (load versus displacement) for each slab specimen is shown in Figure 4.. As expected the steel reinforced concrete slab achieved the highest flexural strength compared to the bamboo reinforced slabs. The bamboo reinforced slabs yielded between 26.3%, 29.5% and 36.6% lower flexural strength than the mild steel reinforced slab. Among the bamboo reinforced concrete slabs, SBS gained the highest flexural strength. SBS achieved 16.2% and 12.3% higher flexural strength compared to SBC and SBT respectively. From the test results, square shaped bamboo reinforcement performed better as compared to all other shaped bamboo reinforcement. The observed behaviour (load-deflection curves, failure mode) of slabs for all the cross-section of bamboo reinforcement was similar.

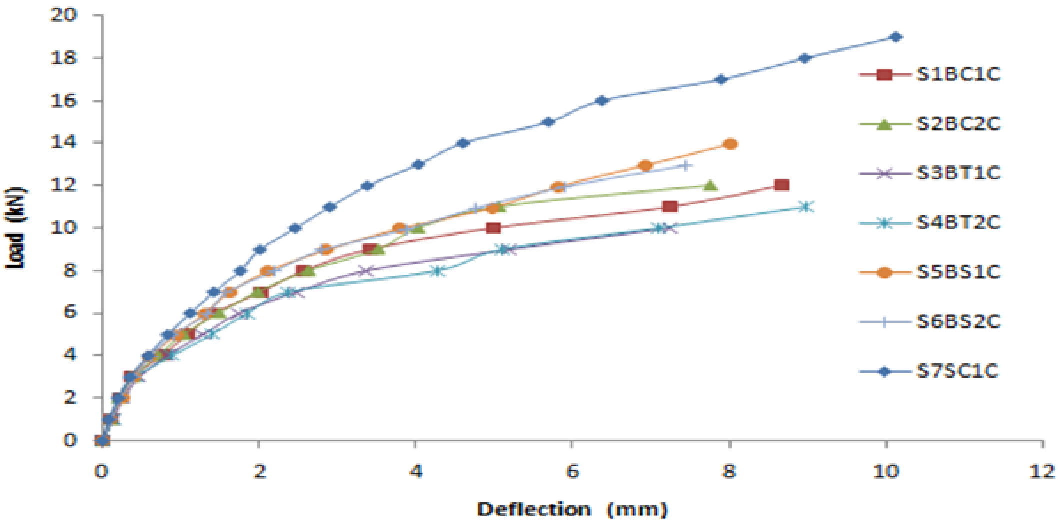

Fig. 4 Load- deflection curve for all slab specimens

When the central concentric load was gradually increased, the first crack loads for all the bamboo reinforced slabs were obtained 31 – 47% lower than that of mild steel reinforced concrete slab. The main reason for the low flexure strength of the bamboo reinforced slab was low tensile strength of the bamboo strips and the bonding between the concrete and bamboo reinforcement. The percentage reduction in first crack load for SBS is 31% which is lowest and for SBT recorded 47% which is highest in all test bamboo reinforced concrete slabs. It can also be observed that the percentage reduction of deflection at first crack load is 21%, 26% and 23% for SBC, SBT and SBS respectively as shown in Fig. 5.

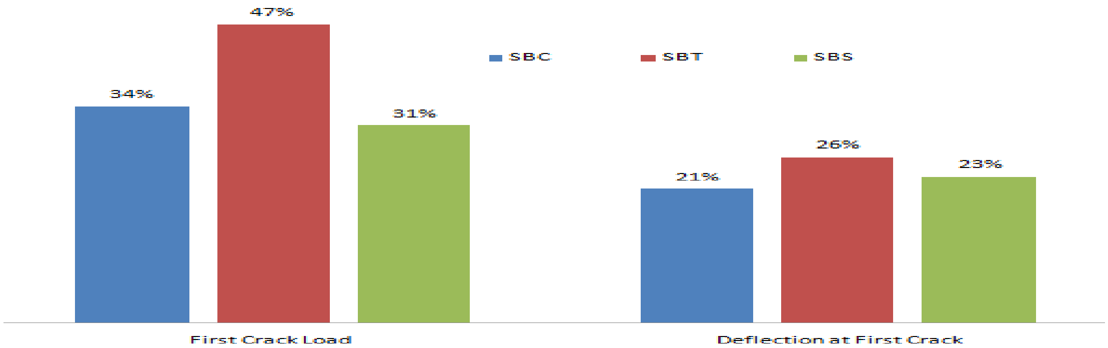

Fig. 5 Percentage Reduction in Flexural load and corresponding deflection w.r.t MS slab

The percentage change of ultimate load of all bamboo reinforced concrete slabs with respect to mild steel reinforced concrete slabs are demonstrated in the Fig. 6. Among the bamboo reinforced concrete slabs, the flexure strength of SBS recorded the lowest change which is 29% and SBT recorded the highest change which is 45%. The SBC achieved 37% lower flexural strength compared to mild steel reinforced concrete slabs. As per the bar diagram shown above, square cross section bamboo reinforced concrete slab (SBS) shows better performance regarding flexural strength for central concentric loading as compared to the other cross section bamboo reinforced slabs.

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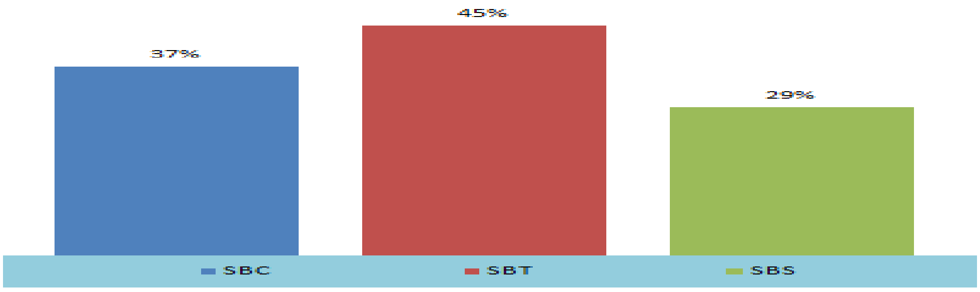

Fig. 6 Percentage reduction in ultimate load of all bamboo slab w.r.t MS slab

IV. CONCLUSION

On the basis of experimental results, the following conclusions have been drawn.

1. Bamboo reinforced concrete slab gave a reduction of 37% flexural capacity compared to the mild steel reinforced concrete slab.
2. Among the bamboo RC slab, SBS achieved the highest capacity.
3. Pure bending cracks were found at the bottom of the slabs under central concentrated load.
4. RC slab with opening gave a reduction of 36% in capacity compared to RC slab without opening.

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