Bamboo Sticks as a Substitute of Steel Reinforcement in Slab

I.K. Khan
Department of Civil Engineering, Aligarh Muslim University Aligarh, Uttar Pradesh, INDIA

ABSTRACT

The cost of construction materials including steel is increasing continuously over the years and houses are becoming unaffordable for common man. Therefore in order to provide shelter to economically deprived persons of the society it is necessary to go either for alternate construction materials with conventional construction technique or to adopt conventional materials with alternate construction technique to reduce the cost of structure. In the present research work the first option i.e. alternate construction materials with conventional construction technique had been employed with the objective to utilize bamboo sticks of different shape of cross section as a substitute of steel bars in slab.

Key Words: Bamboo, Reinforcement, Slab, Concrete, Dial Gauge, Hydraulic Jack Deflection and Crack Pattern.

I. INTRODUCTION

In present study tensile strength and elongation corresponding to the yielding of bamboo sticks with and without nodes were determined experimentally with the help of Universal Testing Machine (UTM), in order to check the feasibility to use bamboo sticks as reinforcement in place of steel bars for low cost housing option.

Since the present study was experimental in nature therefore eight slabs each of size 1000x1000x50 mm were cast, out of which six slabs were reinforced with bamboo sticks and remaining two slabs were reinforced with steel bars. Out of six bamboo reinforced slabs, every two slabs were provided with bamboo stick of triangular, circular and square cross section. In each case spacing as well as number of steel bars/bamboo sticks was suitably provided based on the design as per IS-456:2000 as shown in Table 1.

Table 1 Reinforcement Details in Slabs

<table>
<thead>
<tr>
<th>Sample Name</th>
<th>Cross-Section of Reinforcement (mm)</th>
<th>Total Area (mm²)</th>
<th>Number of Reinforcement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circular Mild Steel</td>
<td>10</td>
<td>1570</td>
<td>20</td>
</tr>
<tr>
<td>Circular Bamboo</td>
<td>10</td>
<td>1570</td>
<td>20</td>
</tr>
<tr>
<td>Square Bamboo</td>
<td>10</td>
<td>2000</td>
<td>20</td>
</tr>
<tr>
<td>Triangular Bamboo</td>
<td>10x10</td>
<td>2000</td>
<td>40</td>
</tr>
</tbody>
</table>

All the slabs were tested under single concentrated load applied at the centre of slab with all sides of slab as simply supported. The load was applied and gradually increased till failure with the help of hydraulic jack. During test load and corresponding deflection were recorded at the centre and diagonally near the four corners of each slab with the help of dial gauges as shown in Fig. 1 and 2.

II. LITERATURE REVIEW

An exhaustive survey of the available literature was conducted to assess the present status of the work carried out on bamboo reinforced concrete elements. Some of the researches carried out by the past researchers are given below:

Kamkam [1] submitted a thesis to the Board of Postgraduate Studies, Kwame Nkrumah University of Science and Technology, Kumasi, which deals with an investigation into the effectiveness of bamboo as a substitute for steel in concrete reinforcement, with particular reference to slabs. After an extensive review of the available literature on pertinent work done by other investigators, the report gives an outline of the work in which the writer has been involved. It contains details about eleven bamboo-reinforced concrete two-way slabs which were manufactured and subjected to various conditions of loading. The variables were the grade of concrete, span/depth ratio, bamboo percentage and the treatment given to the bamboo reinforcement. In the eleven slabs tested, with bamboo percentages varying from 2.86 to 4.0, punching failure, whenever it occurred, always followed the full development of the flexural collapse mechanism and the punching load was always greater than the yield-line-theory load. There was therefore no sudden shear failure without warning. This indicates that, under certain conditions, bamboo splints may safely be used as substitutes for steel in slabs of this nature.

H.Y Fang et al. [2] 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.

Youngsi Jung [3] at University of Texas at Arlington studied the investigation of bamboo as reinforcement in...
concrete. His study investigated the feasibility of using bamboo as a reinforcement alternative to steel in concrete structural members. The specifications studied were the bamboo’s tensile strength and its pullout characteristics in concrete. Two types of bamboo, Solid and Moso, were used for tensile testing. The tensile test specimens were prepared with different lengths, 6 in (152 mm) and 12 in (304 mm), and different physical characteristics (with and without nodes). Tensile test specimens were tested to failure and their load deformation characteristics are reported. The failures of the test specimens were identified as: (1) node failure; (2) splitting failure; and (3) failure of the end-taps. The test results show a high degree of variability iii between the samples. Test samples without nodes exhibited both a higher strength and stiffness compared to those with nodes.

Markos Alito [4] studied the bamboo reinforcement as construction material for the construction of low-cost houses in Ethiopia. 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.

Janseen [5] 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 calculations to show why it’s economically competitive, mechanical properties, its many uses, its natural durability, and the preservation of the Bamboo. In much more detail, it discusses the joints and building with pure Bamboo. In relation to this project, her book does touch on Bamboo used as reinforcement in concrete. Listed in her book are several things that are more of a hassle than steel reinforcement. Of those, the bonding between the Bamboo and concrete is considered the biggest problem due to absorption of water and smooth wall of the Bamboo Culm.

Lakkad et al. [6] studied the detailed mechanical properties of bamboo. Mechanical properties of bamboo, mild steel, polyester resin and glass reinforced plastic are compared. The mechanical properties of bamboo are found to compare favorably with those for other reinforcing materials. As tensile strength of bamboo is greater than that of resin, the author recommends bamboo fibre for reinforcement of plastic. Typically, species like Dendrocalamus Giganteus (DG) have tensile strength of about 120 MPa, compressive strength of 55 MPa and Young’s modulus of 14 GPa. These figures do not compare badly with mild steel which has an ultimate strength of 410 MPa, yield strength of 250 MPa and Young’s modulus of 200 GPa. Concrete has much lower strength than those of bamboo reported here. In addition, the low density of bamboo, which is typically 700 kg/m³, results in much higher strength to weight ratio as compared to steel (density = 7800 kg/m³) and concrete (density = 2400 kg/m³). The only shortcoming with raw bamboo is susceptibility to termite attack which can be set aside by suitable chemical treatment.

Bhalla [7] work on the use of bamboo as an engineered structural material, and sets aside the conventional belief that only concrete and steel structures can be engineered. In order to exploit fully the potential of bamboo as a construction material, various structural components using bamboo concrete composites demonstrated them in building houses using bamboo as a structural element, two bamboo arches vertically separated are connected using Ferro-Cement Band ties to generate a Bow Beam Arch as a load bearing member. Associated products such as bamboo based panels and bamboo reinforced concrete also find applications in the construction process. In spite of these clear advantages, the use of bamboo has been largely restricted to temporary structures and lower grade buildings due to limited natural durability, difficulties in joining, a lack of structural design data and exclusion from building codes.

III. EXPERIMENTAL PROGRAMME

Properties of Materials Used
Ordinary Portland cement of 43 grade was used throughout the study. Normal consistency of cement was 28%, initial setting time 26 min., final setting time 550 min. and compressive strength at 28 days was 40 MPa. Locally available Badarpur sand was used as fine aggregate having specific gravity and fineness modulus as 2.60 and 2.65 respectively. Crushed stone of nominal size 10 mm was used as coarse aggregate having specific gravity and fineness modulus as 2.68 and 3.58 respectively. M20 grade concrete was used for casting of slabs.

Bamboo sticks were tested under UTM and yield strength as well as modulus of elasticity was found to be 132 and 52000 MPa respectively. All the slabs were designed in accordance with IS :456 -2000.

Testing of Slabs
All slabs were tested as simply supported subjected to a single concentrated load at the centre. Slabs were mounted on four concrete pillars with the help of four steel rods each of size 25 mm diameter. One steel rod was provided along each side of the slab to give simple support condition. Hydraulic jack was used to apply single concentrated load on slabs. Five dial-gauges were used for each slab to record vertical deflection; one dial-gauge was located at center of the slab and four other dial-gauges were located at four different positions near four corners of slab diagonally as shown in Fig. 1. Slabs were tested under single concentrated load applied at the centre of slab with the help of hydraulic jack as shown in Fig. 2.

124
IV. RESULTS AND DISCUSSIONS

4.1 Bamboo Reinforced Slab

Crack Pattern

Fig. 3 shows the crack patterns observed after failure in bamboo reinforced slab which failed dominantly in flexure. The First crack occurred just below the loading point and propagated towards the edges. When loads were increased, more cracks developed at the bottom surface before it reached the ultimate load capacity.

4.2 Steel Reinforced Slab

Crack Pattern

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. Usually bending failure cracks were the first to develop at the bottom surface of slab. This is because concrete is weak in tension. The crack pattern observed at the bottom of slab is shown in Fig. 6. First crack was initiated under the point load and propagated diagonally towards the corner. As the load increased, additional cracks started to form throughout the slab that widened and propagated upward till the failure occurred due to punching.

Load-Deflection curve

Typical load deflection curves of two-way slab reinforced with bamboo sticks subjected to central concentrated load are shown in Fig. 4 and 5.
Load-Deflection Curve

Load-deflection curve of the two-way slab reinforced with mild steel bars and subjected to central concentrated load are shown in Fig 7.

Fig. 7 Load Deflection Curve for Steel Reinforced Slab

V. CONCLUSIONS

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

1. From test result it was found that tensile strength of bamboo is approximately one half that of mild steel and modulus of elasticity is approximately one third that of mild steel.

2. The load carrying capacity of the bamboo reinforced slab using square cross-section was higher than other bamboo reinforced slabs reinforced with bamboo stick of triangular and circular cross section. From test result it was found that load at first crack and ultimate load in bamboo reinforced slab with square cross section was 30% less than that of mild steel concrete slab.

3. Deflection of bamboo reinforced slabs with square cross section was 25% less than that of mild steel concrete slab.

4. Based on the limited number of test conducted, it was concluded that Bamboo may be used as substitute of steel reinforcement. However, for regions of the world where availability of steel is limited and plain concrete members are commonly being used.

REFERENCES