Utilization of Bamboo as Reinforcement Steel in Concrete for Sustainable Development

Agunlungbo N[1], Devi Singh[2], Safwaan S[3], Jairaj D[4], Sachin S[5]

[1,2,3,4] B. Tech. Student, Department of Civil Engineering, Aravali Institute of Technical Studies, Udaipur, India
[5]Associate Professor, Department of Civil Engineering, Aravali Institute of Technical Studies, Udaipur, India

***

Abstract - India has one third of the world's poverty. 87.2% of the population of Indians lives below the poverty line. Since the population is soaring high, the demand for basic needs also increases. We, civil engineers also deal with providing shelter for humans. Our main priority is to provide best facilities at cheapest cost. Concrete has many advantages over like low cost, availability, high strength, fire resistance etc. But it cannot be used alone because of its low tensile strength; which is why it is reinforced with materials that are strong in tension like steel. Since some of the poor citizens cannot afford steel to be used in reinforcement due to its high cost, we hop in for a material which can be replaced for steel. Bamboo is a giant grass and is considered to be the fastest growing grass on planet. It grows chiefly in the tropics, where it is widely cultivated. Bamboo proves to provide excellent reinforcement and is eco-friendly. Moreover it is very economic as it is low in cost and is found abundantly. In this paper, a review of the research carried out on bamboo reinforced concrete is provided with emphasis on experimental work.

Keywords – Bamboo, Reinforcement, Concrete

1. INTRODUCTION

In the past few years, steel prices have soared high. For underdeveloped and developing countries, steel is difficult to obtain because of its expensiveness, and for the construction industry, usage of steel is limited heavily. The production of steel consumes high amount of fossil fuels, so, the steel discharge in the construction of structures has been presented, showing the possibility of drastic reduction by research scientists. Meanwhile, for developing nations, it is very crucial to make the constructions of buildings and structures; low cost, discouraging use of sophisticated technological equipments and reliable construction methods.

Environmental and man-made destructions such as pollution of air and water has been occurring in some regions by rapid development and production of materials like iron, steel, glass, cement, aluminium,etc are materials that use limited mineral resources. On the other hand, plants and fibers are annually reproducible green resources. Bamboo is a special group of gigantic grass the Culm of which origin in the underground rhizomes. It grows naturally in most parts around the planet but some species are artificially planted for beneficial purposes. Bamboo forests are found across tropical and sub-tropical zones between latitudes of about 20° c to 30°c south. Bamboo is suitable for water pipes grow at altitudes from 20 to 3,000 meters [1]. The plant gets fully matured at an age of three to four years.

Studies have shown that steel requires 50 times more power and energy than bamboo to produce a material equivalent of 1 m^3 per unit stress. The tensile strength of bamboo is much higher and can also reach up to 370MPa [4]. In past few years, many research scientist and engineers around the world have begun to explore the use of low-cost and low-energy substitute construction materials. Among the many possibilities for the substitutions, bamboo, which is one of the fastest growing plants in the planet, has got an economically great potential. In Asia, Bamboo has been used in constructions of bridges and houses for thousands of years. Bamboo takes quite less energy to harvest and transport. Therefore, bamboo has pretty low manufacturing costs as compared with steel. Bamboo is now widely expected to be a possibility even in countries and nations that doesn't have advanced manufacturing technology and construction techniques.

2. BAMBOO AS CONSTRUCTION MATERIAL

Through a research it has been known that some species of bamboo have ultimate tensile strength the same as of mild steel at yield point. Experimentally it has been found that the ultimate tensile strength of some species of bamboo is comparable to that of mild steel and it varies from 140 N/mm^2- 280 N/mm^2 [2]. Bamboo is an efficient material because of its high strength-to-weight ratio, fine workability and availability. Bamboo must be chemically treated due to their low natural durability. It can be used as Bamboo trusses, Bamboo Roofs frame, Bamboo walling/ceiling, Bamboo Doors and Windows, Bamboo Flooring, Reed Boards, Scaffolding, etc.

2.1 Strength Properties of Bamboo

It has been found that bamboo acts very well in buckling but due to low stresses as compared to steel and due to its irregularity it may not be very good. Further, it has been known that in seismic zones the failure of bamboo is very less since the maximum absorption of the energy is at the joints. Cellulose is the main component present in bamboo which is also the main source of mechanical properties of bamboo.

Various tests were conducted and have been researched on physical, chemical and mechanical properties of moso type bamboo. The result of the conducted test shows that the tensile strength of moso type bamboo is approximately half the strength of mild steel. The compressive and tensile strength of bamboo is also approximately same and this behavior is similar to that of steel. The surface of bamboo is smooth which is why the bond stress of bamboo with concrete is very low compared to HYSD steel bars. The absorption of water by bamboo is very high and so waterproofing agent is recommended [6].

Some of the specific properties of Bamboo are given below:

¤ Specific gravity - 0.575 to 0.655

¤ Average weight - 0.625 kg/m

¤ Modulus of rupture - 610 to 1600 kg/cm^2

¤ Modulus of Elasticity - 1.5 to 2.0 x105 kg/cm^2

¤ Ultimate compressive stress- 794 to 864 kg/cm^2

¤ Safe working stress in compression – 105 kg/cm^2 [3]

2.2 Selection and Preparation of Bamboo Selection

The following factors are to be considered in selection of bamboo culms (whole plants) for reinforcement in concrete buildings and other structures [5] :

¤ Only use bamboo showing a light brown color to ensure that the plant is at least three years old.

¤ Select the longest large diameter culms available.

¤ Do not use whole culms of green, unseasoned bamboo.

¤ Avoid bamboo cut in spring or early summer. These culms are generally weak due to increase in fiber moisture content.

Preparation

¤ **Sizing-** Splits are generally better than whole culms as reinforcement. Larger culms are to be split into splints approximately 3/4 inch wide. Whole culms less than 3/4 inches in diameter can also be used without splitting [3]. Splitting the bamboo is done by separating the base with a sharp knife and then pulling a dulled blade through the stem. The dull blade will force the stem to split open; this is better than cutting the bamboo since splitting results in continuous fibers and a nearly straight section

¤ **Seasoning-** Whenever possible, the bamboo should be cut down, allow drying and seasoning for three to four weeks before being used. The culms should be supported at regular spacing's to reduce warping in the structure.

¤ **Waterproof Coatings-** When seasoned, bamboo either split or whole is used as reinforcement; the reinforcement should receive a waterproof coating to reduce swelling when in contact with concrete. Without some external coating, bamboo will swell before the concrete has developed sufficient strength to prevent cracking in the reinforcement and the member may be damaged, especially if more than 4 percent bamboo is used.

¤ **Copper Chrome Boron treatment-**

Fig -1 : CCB Treatment of Bamboo

It is known that bamboo is more prone to host insects than other trees and grasses because of its high nutrients content and abundances; hence in order to fight this problem it necessary to treat bamboo so as to protect it from the environment.
Copper Chrome Boron (CCB) treatment of bamboo has been adopted to prevent bamboo from insect attack. CCB is a broad spectrum chemical bamboo preservative and a good alternative to CCA which is particularly hazardous to human health.
The content of various chemicals is in the ratio- *Boric acid: Copper Sulphate : Sodium Dichromate-1.5:3:4* and its recommended concentration is 8-10% for outdoor use (structures exposed to weather and in ground contact).

Fig. shows the CCB treatment of bamboo splints respectively [8].

2.3 Construction

In general, techniques and methods used in a conventional reinforced concrete construction need not change when bamboo is to be substituted for reinforcement.

Concrete Mix Proportions - The same usual mix designs of concrete can be used normally with steel reinforced concrete. The concrete slump should be as low as workability will allow it to be. Excess water in the mix causes the swelling of the bamboo. High early-strength of cement is always preferred to minimize the cracks caused by swelling of bamboo. Seasoned bamboo cannot be waterproofed.

3. PLACEMENT OF BAMBOO

Bamboo reinforcement should not be placed within 1.5 inches from the face of the concrete surface. When using the whole culms, the top and bottom stems of bamboo should be alternated in every line and the nodes (collars) should be staggered. This will ensure a fair uniform cross-section of the bamboo throughout the span of the member, and the effect of wedging obtained at the nodes will subsequently increase the bond between the concrete and bamboo. The wide and clear spacing between the bamboo rods shouldn't be less than the maximum size aggregate. Reinforcement should be spaced uniformly, evenly and lashed together on short sticks placed at 90° to the main reinforcement. If requirement is more than one layer, the layers should be tied together. Ties should be made with wire in important members of the reinforcement. For secondary members, ties are to be made with vegetation strips. Bamboo must be carefully tied down before the placing of concrete. It should be fixed and placed at regular intervals of 3 feet to 4 feet to prevent it from floating up in the concrete mix during the placement and vibration. In continuous flexural members, one-half to two-thirds of the bottom longitudinal reinforcement should preferably be bent up-wise near the supports. This is especially recommended for members continuous over several supports. The additional diagonal tension reinforcement in the form of stirrups must always be used near the supports. The vertical stirrups can also be made from wire or packing case straps; they can also be improvised from split sections of bamboo bent into U-shape, and tied securely to bottom longitudinal reinforcement and bent-up reinforcement. The spacing of the stirrups shouldn't exceed more than 6 inches.

4. ANCHORAGE AND SPLICING OF REINFORCEMENT

Dowels in the footings for column and wall reinforcement should be embedded in the concrete at such a depth that the bonding between the bamboo and concrete will resist the allowable tensile force in the dowel. The embedded depth is approximately 10 times the diameter of whole culms or 25 times the thickness of 3/4 inch wide splints. In many cases the footings might not be this deep; therefore, the dowels will have to bend into L-shape. These dowels should be either hooked around the footing reinforcement or be tied securely to the reinforcement to ensure complete anchorage. The dowels should extend above the footings and cut so that no more than 30 percent of the splices will occur at the same height. All such splices should be overlapped at least 25 inches and be tightly tied. Splicing reinforcement of bamboo in any member must overlap at least 25 inches. Splices should never occur in highly stressed areas and in no case should more than 30 percent of the reinforcement be spliced in any one of

5. LOAD-DEFLECTION BEHAVIOR

A simply supported beam is subjected to a four-point bend test, the middle third portion of
the beam is subjected to a maximum uniform bending and zero shear force, assuming the self
weight of the beam is fully negligible. Therefore, the largest flexural strains occur within this
region, consequently, cracking initiates at the soffit of this region, where the cracks then rapidly spreads towards the top of the beam with increase in applied load to collapse. The load deflection curves (Fig 2) for reinforced concrete beams with longitudinal bamboo reinforcement shows a behavior similar to beams with longitudinal steel reinforcement.
The load-concrete strength and the shear span-effective depth of the beam. In all the sixteen beams tested to failure test, the longitudinal tension reinforcement in bamboo varied from 4.17% to 7.83% of the gross concrete section.
The deflections of beams when tested on bamboo reinforced concrete followed an accurate straight line variation until the appearance of the first crack in the concrete. And immediately following the first crack, there was a significant flattening of the deflection curve (probably due to local bond slippage) followed by a period of fairly accurate straight line variation, but at a pretty much lesser slope, until the ultimate failure of the member occurred. This flattening of the deflection curve was more significant in the members where the amount of longitudinal bamboo reinforcement was small.
In all the beams tested, there was very less or no strain hardening observed. Beams which are prior to failure exhibit a very short range of deflections which indicates a very low ductile behavior of the bamboo. Beams with a smaller amount of tension bamboo reinforcement

deflected more at smaller loads than their corresponding beams with high tension reinforcement. This is typical in the case of two pairs of beams; BBR7/BB7 and BBR8/BB8 (Fig 2) which had the exact amount of shear stirrups (in terms of size and spacing) but different tension bamboo reinforcements and compressive strength of concretes.

It is now known that the beams with higher tension bamboo reinforcements and concrete compressive strengths (BBR7 and BBR8) did not consequently produce the highest failure loads and displacements. Lower tension reinforcement resulted in higher failure load for a beam with similar characteristics and (Fig 2). In terms of experimental failure loads or displacements, it was also observed that the beams BB5-BB8 which had tension reinforcements between 4-5% of the cross-sectional area of beam but a less compressive strength recorded the much higher values when compared with other beam groups (BBR1-BBR4, BBR5-BBR8 and BB1-BB4) [7].

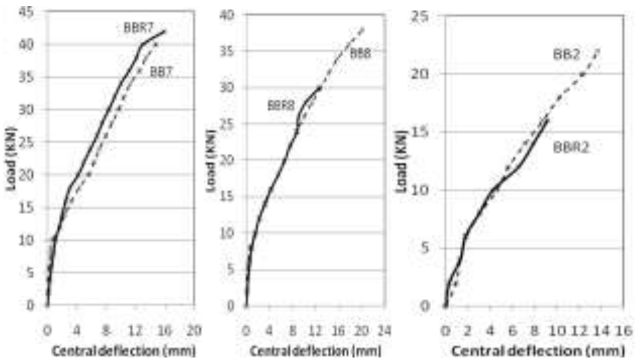

Fig 2 : Load Deflection Curves of a Tested Bamboo Beam

6. CONCLUSION

A thorough study of the shear strength of bamboo reinforcement concrete reveals that concrete members which are reinforced with sections of bamboo culms, which had been split along their horizontal axis, developed a considerably higher load capacity than unreinforced concrete beams of similar cross sections. The ductility of tension bamboo reinforcement is low enough and failure of beams is characterized by splitting of concrete from the tension reinforcement. The shear capacity is enhanced greatly by increased amount of tension reinforcement and addition of web reinforcement to the concrete. The very strength of concrete influences the shear capacity and the failure mode of the concrete in such a way that low strength concrete cause concrete to crush before the full shear capacity is even reached. The predominant failure mode of bamboo reinforced concrete beams and columns was shear even though they were all full enough theoretically in shear capacity.

The highest and lowest failure loads were also recorded for the cases of steel stirrups and no stirrups respectively. The cheapest and most affordable way of providing shear reinforcement for bamboo-reinforced beams and columns according to the BPI derived in this research is steel stirrups and the most expensive method is rattan stirrups irrespective of the grade of concrete. Therefore, it is recommended that bamboo reinforced concrete beams are to be reinforced with steel stirrups to cut the effective high cost improve its load carrying behavior.

REFERENCES

(1) Masakazu TERAI & Koichi MINAMI, FUKUYAMA UNIVERSITY, Japan, “Research and Development on Bamboo Reinforced Concrete Structure”, WCEE, IIT Kanpur, 2012.

(2) Anurag Nayak, Arehant S Bajaj, Abhishek Jain, Apoorva Khandelwal, “Replacement of Steel by Bamboo Reinforcement” *IOSR Journal of Mechanical and Civil Engineering, Vol. 8, No. 1 , pp 50-61, 2013.*

(3) Khosrow Ghavami, 2005, Bamboo as reinforcement in structural concrete elements, Cement and composites, Vol. 27, pp 637-649.

(4) Chariar V.M., “Fabrication and Testing of Jute Reinforced Engineered Bamboo Structural Elements.” IIT, Delhi, 2009.

(5) Francis E. Brink and Paul J. Rush, “Bamboo Reinforced Concrete Construction” *U.S. NAVAL CIVIL Engineering Laboratory Port Hueneme, California.*

(6) Harish Sakaray, N.V. Vamsi Krishna Togati and I.V. Ramana Reddy, “Investigation on properties of bamboo as reinforcing material in concrete”, *International Journal of Engineering Research And Applications (Ijera) Vol. 2, No. 1,* pp *077-083, 2012.*

(7) Adom-Asamoah Mark, Afrifa Owusu Russell, “A Comparative Study of Bamboo Reinforced Concrete Beams Using Different Stirrup Materials for Rural Construction” *INTERNATIONAL JOURNAL OF CIVIL AND STRUCTURAL ENGINEERING*
Volume 2, No 1, 2011

(8) Abhijeet Dey[a], Dr.(Mrs) Nayanmoni Chetia[b], “Experimental study of Bamboo Reinforced Concrete beams having various frictional properties”, PMME, 2016.