Utilization of Bamboo in Concrete as A Reinforcement

L Bhanu[1], A.S S Vara Prasad[2], S Ashok Kumar[3]
[1, 2, 3] Department of Civil Engineering
[1, 2, 3] Kakinada Institute of Technology & Science, Divili

Abstract- *Concrete is the most common used material for construction and their design consumes almost the totals cement production in the world. On other hand due to ever increasing quantities of waste materials and industrial by-products, solid waste management is the prime concern in the world.. There are several types of industrial by-products and waste materials. The utilization of such materials in concrete not only makes it economical, but also helps in reducing disposal concerns. As a part of that this paper discuss about the utilization of bamboo as a reinforcement in concrete.*

Keywords- Bamboo, Reinforcement, compressive strength.

I. INTRODUCTION

The use of bamboo as reinforcement in Portland cement concrete has been studied extensively by Clemson Agricultural College. Bamboo has been used as a construction material in certain areas for centuries, but its application as reinforcement in concrete had received little attention until the Clemson study.

A study of the feasibility of using bamboo as the reinforcing material in precast concrete elements was conducted at the U.S. Army Engineer Waterways Experiment Station in 1964. Ultimate strength design procedures, modified to take into account the characteristics of the bamboo reinforcement were used to estimate the ultimate load carrying capacity of the precast concrete elements with bamboo reinforcing.

Bamboo was given recent consideration for use as reinforcement in soil-cement pavement slabs in which the slabs behave in elastically even under light loads. For this case ultimate load analysis was shown to be more economical and suitable for use.

The results of these investigations form the basis of the conclusions and recommendations presented in this report. Further studies will be required before complete confidence can be placed theoretical designs based on the material presented here.

II. LITERATURE RIEVIEW

SELECTION AND PREPARATION OF BAMBOO:

Selection:

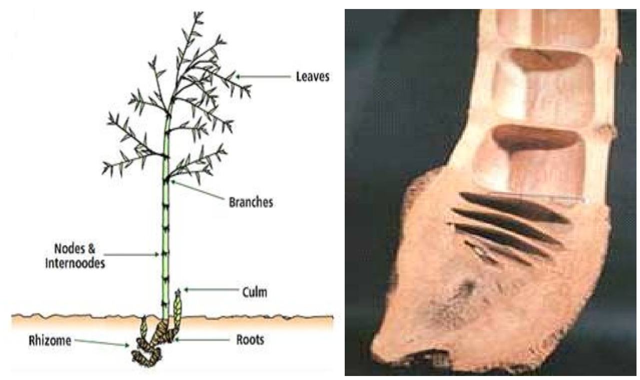


Fig.2.1: Structure of Bamboo Plant

The following factors should be considered in the selection of bamboo culms (whole plants) for use as reinforcement in concrete structures:

- Use only bamboo showing a pronounced brown colour. This will insure 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 weaker due to increased fiber moisture content.

Preparation:

Sizing :

Splints (split culms) are generally more desirable than whole culms as reinforcement. Larger culms should be split into splints approximately 3/4 inch wide. Whole culms less than 3/4 inch in diameter can be used without splitting. (See Fig 4)

Splitting the bamboo can be done by separating the base with a sharp knife and then pulling a dulled blade through the Culm. The dull blade will force the stem to split open; this is more desirable than cutting the bamboo since splitting will result in continuous fibers and a nearly straight section. Table II shows the approximate net area provided by whole culms and by 3/4-inch-wide splints, as well as the cross-sectional properties of standard deformed steel bars and wire mesh.

Seasoning:

When possible, the bamboo should be cut and allowed to dry and season for three to four weeks before using. The culms must be supported at regular spacing to reduce warping.

Bending:

Bamboo can be permanently bent if heat, either dry or wet, is applied while applying pressure. This procedure can be used for forming splints into C-shaped stirrups and for putting hooks on reinforcement for additional anchorage.

Water proof Coatings:

When seasoned 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 concrete has developed sufficient strength 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 materials available. A brush coat or dip coat of asphalt emulsion is preferable. Native later, coal tar, paint, dilute varnish, and water-glass (sodium silicate) are other suitable coatings. In any case, only a thin coating should be applied; a thick coating will lubricate the surface and weaken the bond with the concrete.

Water proof material:

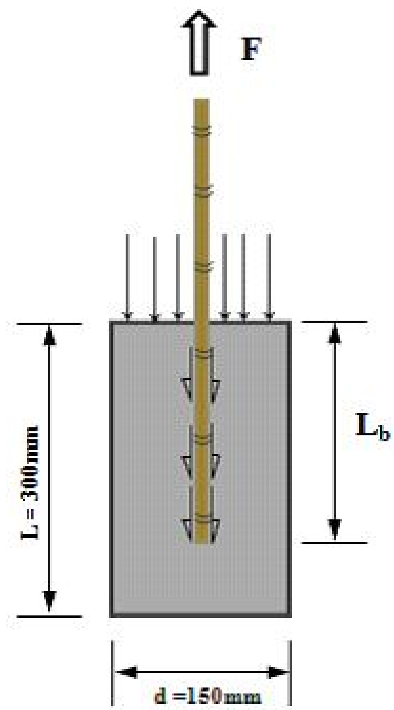
When bamboo is used as reinforcement in concrete it gets swelling, it should receive a waterproof coating to minimise swelling. “ALGICOAT RC-104” is used as a water proofing agent in present research.

Steel bars:

HYSD bars are used in this study, for determining bond stress. These values are compared with bamboo bond stress as per IS-456:2000 specifications.

Concrete:

M-30 grade mix concrete used in the present study as per IS-456:2000 specifications. The concrete mix proportion (cement: fine aggregate: course aggregate) is 1:1.5:3 with a 0.54 Schematic diagram of specimen water-cement ratio for cast cylinders for pull out test.



CONSTRUCTION PRINCIPLES:

In general, techniques used in conventional reinforced concrete construction need not he changed when bamboo is to be used for reinforcement.

Concrete Mix Proportions:

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

Placement of bamboo:

Bamboo reinforcement should not be placed less than 1-1/2 inches from the face of the concrete surface. When using whole culms, the top and bottom of the stems should be alternated in every row and the nodes or collars, should be staggered. This will insure a fairly uniform cross section of the bamboo throughout the length of the member, and the wedging effect obtained at the nodes will materially increase the bond between concrete and bamboo.

The clear spacing between bamboo rods or splints should not be less than the maximum size aggregate plus 1/4 inch. Reinforcement should be evenly spaced and lashed together on short sticks placed at right angles to the main reinforcement. When more than one layer is required, the layers should also be tied together. Ties should preferably be made with wire in important members. For secondary members, ties can be made with vegetation strips.

Bamboo must be securely tied down before placing the concrete. It should be fixed at regular intervals of 3 to 4 feet to prevent it from floating up in the concrete during placement and vibration. In flexural members continuous, one-half to two-thirds of the bottom longitudinal reinforcement should be bent up near the supports. This is especially recommended in members continuous over several supports. Additional diagonal tension reinforcement in the form of stirrups must be used near the supports. The vertical stirrups can be made from wire or packing case straps when available; they can also be improvised from split sections of bamboo bent into U-shape, and tied securely to both bottom longitudinal reinforcement and bent-up reinforcement. Spacing of the stirrups should not exceed 6 inches.

Anchorage and Splicing of Reinforcements:

Dowels in the footings for column and wall reinforcement should be imbedded in the concrete to such a depth that the bond between bamboo and concrete will resist the allowable tensile force in the dowel. This imbedded 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 will not be this deep; therefore, the dowels will have to be bent into an L-shape. These dowels should be either hooked around the footing reinforcement or tied securely to the reinforcement to insure complete anchorage. The dowels should extend above the footings and be cut so that not 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 well tied.

- Splicing reinforcement in any member should be overlapped 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 location.

III. DESIGN PRINCIPLES

Bamboo reinforced concrete design is similar to steel reinforcing design. Bamboo reinforcement can be assumed to have the following mechanical properties:

Table I. Mechanical properties of bamboo reinforcement:

Mechanical Property	Symbol	Value (psi)
Ultimate compressive strength	$\sigma_{c\ ult}$	8,000
Allowable compressive stress	$\sigma_{c\ allow}$	4,000
Ultimate tensile strength	$\sigma_{t\ ult}$	18,000
Allowable tensile stress	$\sigma_{t\ allow}$	4,000
Allowable bond stress	U	50
Modulus of elasticity	E	$2.5x10^6$

When design handbooks are available for steel reinforced concrete, the equations and design procedures can be used to design bamboo reinforced concrete if the above mechanical properties are substituted for the reinforcement.

Due to the low modulus of elasticity of bamboo, flexural members will nearly always develop some cracking under normal service loads. If cracking cannot be tolerated, steel reinforced designs or designs based on unreinforced sections are required.

Experience has shown that split bamboo performs better than whole culms when used as reinforcing. Better bond develops between bamboo and concrete when the reinforcement is-split in addition to providing more compact reinforcement layers. Large-diameter culms split into 3/4-inch- wide splints are recommended. (References to splints in the following examples will be understood as meaning 3/4-inch-wide splints of a specified thickness unless otherwise stated.

Design principles for the more common structural members are presented in the following sections. Examples of the use of these principles for each member discussed are included.

Beams and Girders:

Flexural members reinforced with bamboo can be designed with the use of Figure 1. Bamboo longitudinal reinforcement should be between 3 and 4 percent of the concrete cross section.

Figure 2 can be used to convert existing designs for steel reinforced beams to equivalent bamboo reinforced designs. The curve provides the cross-sectional dimensions of a bamboo reinforced beam that will have the same bending moment resistance coefficient as a balanced steel reinforced beam, singly reinforced. Economy of concrete increases going to the left on the curve; therefore, deeper, narrower replacement beams are recommended.

The number and size of bamboo reinforcing rods (culms or splints) can be selected from Figure 2(b). These curves are drawn for 3 percent of the concrete cross section as bamboo reinforcement which is in the optimum range for flexural members. Other reinforcement percentages can be used as noted on the figure. A minimum number of rods should be used to provide adequate spacing. The bamboo stirrup area should always be about 4 times the steel stirrup area.

IV. RESULTS AND DISCUSSION

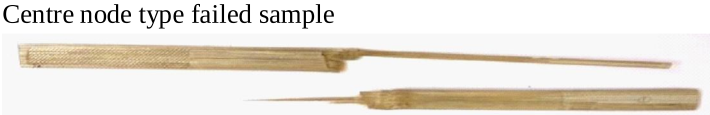
Mechanical Properties of Bamboo:

The mechanical properties are very important for using any material in construction and design. Mechanical properties of bamboo were determined by conducting the following tests:

Tensile Test:

Fig.4.1: Tensile test

Centre node type failed sample



Combined node and splitting type failed sample in tensile test

Splitting type failed sample in tensile test:

Moso type of Bamboo samples of length 600mm was used. Three types of specimens are used, first type with centre node, second type specimens contains nodes at 1/4th of length from each ends and third type of specimen contains random nodes. The test procedure followed for bamboo is same that of steel. Load and elongation readings for sample placed in UTM are recorded.

The relevant Stress Strain graph were developed as shown is the Fig 5 Ultimate stress values for different specimens obtained are tabulated.

Tensile Test Results for Bamboo

Ultimate Tensile stress of Bamboo (N/mm2)

S.No	End nodes Stress	Center node Stress	Random nodes Stress
1	244	201	127
2	119	151	128
3	106	102	142
4	90	93	177
5	108	117	180
6	85	113	134
7	125	140	118
8	155	180	108
9	133	135	125
Avg	**120**	**115**	**128**

Compressive Test:

Fig 4.2: Failed bamboo samples in compression test

The Hollow culms of 152mm length are cut for compressive test. Three different types of specimens are selected for the test. The first type of specimens contains central node; second type contains end node and third type without nodes. The dimensions of samples are measured and samples were placed in compressive testing machine of capacity 2000KN. The load is applied parallel to fibers of bamboo in gradual increments until the sample failure. From the ultimate load, compressive strength is determined.

Modulus of Elasticity:

Modulus of elasticity test procedure followed for moso bamboo is same as that of steel. Two types of moso bamboo specimens of length 600mm are used for test, first type of specimen with centre node and second type of specimen contains nodes at 1/4th of length from each end. The samples are placed in setup for simply supported action and loads were applied at centre and deflections are recorded at 1/3rd and 1/4th form any one direction of sample. Considering Load vs. Deflection graphs and simply supported beams deflection formula, modulus of elasticity of bamboo were determined and the results are tabulated.

Modulus of Elasticity (E) of Bamboo (N/mm2)		
S No	Center node Stress	End node Stress
1	2.9473 x 104	1.5898 x 104
2	1.9347 x 104	1.40153 x 104
3	1.4218 x 104	1.3379 x 104
4	1.3476 x 104	1.14435 x 104
5	2.1804 x 104	0.9535 x 104
6	1.6402 x 104	1.27188 x 104
7	2.7989 x 104	1.7498 x 104
8	2.16365 x 104	0.9998 x 104
9	2.16760 x 104	1.9818 x 104
10	2.78404 x 104	1.0638 x 104

Shear Test:

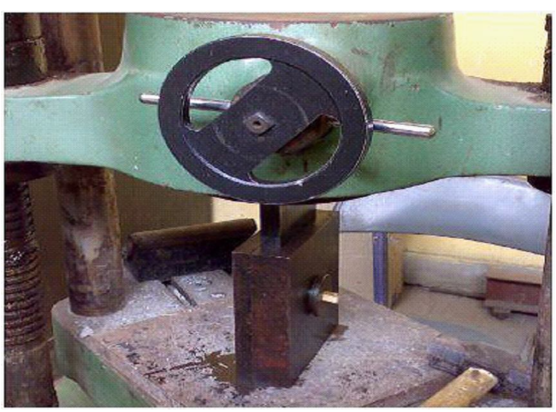


Fig 4.3:. Test setup of Shear shackle arrangement in U.T.M

The samples used for shear test are moso bamboo of 50mm length. Three different types of specimens, the first with central node, second type with end node and third type of specimens without nodes are used in this test. The test procedure followed for bamboo is same as that of steel. The shear shackle used is of double shear action the test is called as double shear test. The test setup consists of placing shear shackle in Universal Testing Machine (UTM) of 400KN capacity and load is applied gradually until the specimen fails as shown in figure. The ultimate load at failure is noted. Shear Stress is determined using formula given below from ultimate load and results are tabulated in Table. Shear stress=load/2*area=L/2A

Shear Strength of Bamboo			
S.No	Area of specimen (mm2)	Ultimate load (kg)	Shear Strength (N/mm2)
1	101.29	597	29.47
2	81.86	538	32.86
3	96.2	520	27.03
4	160.6	938	29.20
5	162.85	993	30.49
6	142.79	646	25.62
Average		29.12	

Water absorption Test:

Six samples of uncoated moso bamboo with 1 and 2 nodes samples with different dimensions were selected for determining water absorption capacity. Dry weights of samples were noted and placed in water. The weights were recorded after 1, 3, 9, 15 and 25 days the samples were removed from water and wiping the surface with a cloth.

V. CONCLUSIONS

The constitutive relationship of the nodes differs from those of inter-nodal regions. Further the nodes possess brittle behavior and the inter-nodal regions possess ductile behavior. The average tensile strength of moso bamboo from present study is 125N/mm^2, which is half the strength of mild steel. There is no failure pattern followed by samples in tensile test. However, the samples with nodes generally failed at higher loads than those samples without nodes. The compressive strength of bamboo is nearly same as the tensile strength of bamboo and this behavior is similar to steel. Bond stress of bamboo with concrete is very low compared HYSD steel bars, due to surface smoothness of bamboo. Water absorption of bamboo is very high and waterproofing agent is recommended. From the test conditions, bamboo can potentially be used as substitute for steel reinforcement. As bamboo is eco-friendly material, limiting the use of steel can reduce carbon dioxide emissions. In the green building concept use of bamboo reinforced concrete may be recommendable.

REFERENCES

[1] H. E. Glenn. "Bamboo reinforcement in Portland cement concrete," Engineering Experiment Station, Clemson Agricultural College, Clemson, South Carolina, Bulletin No. 4, May 1950.

[2] U. S. Army Engineer Waterways Experiment Station. Technical Report No. 6-646: "Precast concrete elements with bamboo reinforcement," by E. F. Smith and K. L. Saucier. Vicksburg, Mississippi, May 1964.

[3] S. R. Mehra and R. G. Ghosh. "Bamboo-reinforced soil-cement," Civil Engineering and Public Works Review, Vol.60, no.711, October 1965; vol. 60, no. 712. November 1965.

[4] "Concrete floors on ground," Portland Cement Association Concrete Information, ST-51.

[5] American Concrete Institute. "Building code requirements for reinforced concrete," (ACI 318-56). May 1956