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BAMBOO AS REINFORCEMENT MATERIAL IN CEMENT CONCRETE

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ABSTRACT

From the early times Bamboo is used as a construction material. The Bamboo is used in both technical as well as non-technical ways. The Bamboo was used as the struts, posts, roofs etc in the construction of the houses. Now a day's concrete are used as the basic materials for the construction works. The concrete is good in compression but weak in the tensile strength. So steel is used as reinforcement in the concrete to achieve the tensile strength, the bamboo is strong in both cases compression as well as tension. The use of bamboo as a structural building material is growing as a topic of interest. It is highly renewable, has low-embodied energy, and has the highest strength-to- weight ratio of steel, concrete, and timber. Its primary drawbacks are that it is difficult to connect and is more costly than competing, locally available materials. This paper presents use of bamboo as reinforces in cement concrete and performed tensile and flexural test on specimens.

Keywords- *Bamboo Harvesting and Preservation, Tensile Test, Flexural Test, Advantages*.

INTRODUCTION

The construction materials for building a bamboo house should be readily available and accessible. Traditionally used construction materials are considered. The bamboo based house has a very low weight therefore foundations can be minimized. For wall construction are used wall panels, assembled from split bamboo grids and chicken steel mesh and plastered with cement mortar. Basic materials for house components (bamboo, wire, bolts, chicken mesh, and cement) are inexpensive. Bamboo can tolerate high values of deformations in the elastic range i.e. possesses high elasticity. Therefore bamboo houses when properly constructed are ductile i.e. being able to sway back and forth during an earthquake, without any damage to the bamboo poles. Bamboo is available in commercial quantities using the established supply system.

It is a renewable plant with a short rotation period. Bamboo grows to its full size for about a year. Another two or three years are required for the plant to gain its high strength. Bamboo can be grown even on degraded land. Construction materials from bamboo should be treated in order to achieve longevity. The use of high energy materials, like cement or steel, is minimized. Therefore the adoption of bamboo for house construction helps preserve the environment.

The compressive strength of the Bamboo is less than the tensile strength of the Bamboo. The test on the flexural member was also conducted. The result showed that the treated Bamboo shows slightly higher bond strength than untreated.

Bamboo Harvesting

Bamboo should be harvested during the dry season in the tropics. This reduces beetle attacks, since insects are less active during dry season. Bamboo should be harvested in autumn and winter in subtropical areas. The branches should be carefully removed from the bamboo culms so that the outer skin is not damaged. After harvesting the canes can be stored vertically or horizontally. In the latter case the canes should be frequently supported in order to avoid bending out of shape. Canes should be protected from direct sun, soil moisture and rain. There are two ways for drying the bamboo canes. The bamboo poles can be dried for about 6-12 weeks, by allowing good air-circulation while being stored under a shed. Faster alternative is using kilns for drying the canes. In this way the bamboo canes can be dried for 2- 3 weeks. Workability of the canes is ideal when they are dry.

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Bamboo Preservation
The bamboo should be prevented from insects and fungus. If left untreated, bamboo poles may not survive more than about two years. The following methods for treating bamboo poles:-

Immersion
Freshly cut bamboo poles are immersed in water for period of 4-12 weeks. During this time the nourishment for insects inside the poles is removed. Streams or ponds are suitable. Ponds should allow circulation of water. Immersion in saltwater is not a suitable technique.

Impregnating Coatings
Preservation with borate solution is an efficient technique. The method involves the borate/borax salt solution being pressure-fed in the pole until it is seen at the other end of the pole. The culms treated in this technique should be of mature age. The treatment procedure should be applied on the day of harvesting the bamboo. This is a severe requirement. Information on this method is available through INBAR bamboo research network in India.

Heating
This method consists of heating the canes, for a short time in kilns to 150oC. Alternatively the canes can be placed into a large container and boiled (cooked) for 25 minutes. In Japan a method of boiling the bamboo in caustic ash solution has been used.

Checklist for Obtaining Construction Quality Bamboo Poles
Depending on the species, 3 to 5 year old bamboo is best for construction purposes.
The bamboo should be harvested in dry season in order to avoid fungus attack and excess pole moisture.
Use the appropriate species for the particular application.
Do not expose the bamboo poles to direct sun, moisture and rain.
Use only straight portions from the bamboo culms for construction poles.
Poles should be treated against insects and fungus.

METHODOLOGY
In order to study the performance evaluation of Bamboo as reinforcement in Reinforced Cement Concrete Specimen following tests are executed.

TENSILE TEST ON BAMBOO STRIPS
As the bamboo is used as to take tensile load in the flexural element the tensile test was conducted on the bamboo. The Bamboo strip was of the length 520 mm and the thickness of the Bamboo was average 10 mm. Specimens of such specifications were prepared. The ends of the specimen were roughed at both the ends to have a better grip in Universal Testing Machine. The sample strip of the Bamboo is as shown in Fig.1.

Fig.1 Bamboo Specimens

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Table 1

Sample No.	Sampl Position	Specimen Size		Cross Sectional Area (mm2)		
		Length (mm)	Thickness (mm)	End A	End B	Avg. Area
1	End nodes	520	10	262	256	260
2	End nodes	520	10	142	198	170
3	End nodes	520	10	215	207	211

Test Setup

Tensile test was conducted on Universal Testing Machine model. To have a grip of the Bamboo in the machine the cast iron grips were used. The position of the Bamboo strip in UTM is as shown in Fig.2 and failure of bamboo specimen in fig. 3.

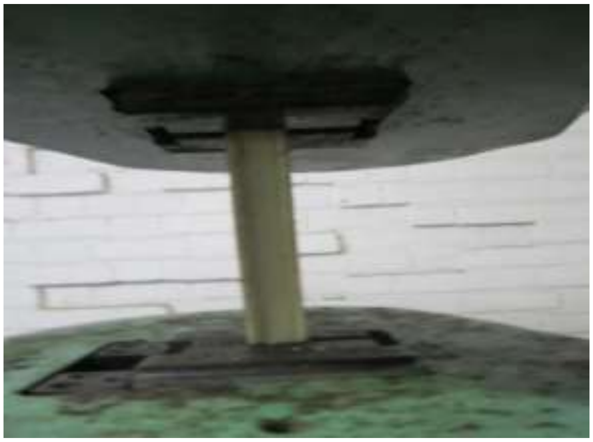

Fig. 2: Position of Bamboo Strip In UTM

Fig. 3: Failure of the Bamboo Specimen in UTM

Tensile Test Results

Tensile tests were conducted on specimens having nodes at the end. Nodes are weak and brittle in resistance to tensile force as referred. This test was performed on specimens with nodes at gauge position and its main purpose was to determine modulus of elasticity of the specified species Bambo. It has been observed that mostly the failure occurred at mid height. The failure occurred looks like the splitting of the fibers as shown in Fig.3. The general tensile test results are summarized in the Table 2.

The graph stress Vs Strain shown in Fig.4.

Table-2

Load P(N)	Elongation(mm)	Strain	Stress (N/mm^2)
0	0.0	0.0000	0.0000
10000	0.1	0.0008	47.300
12000	0.2	0.0015	56.870
14000	0.5	0.0038	66.351
16000	0.5	0.0038	75.829
18000	1.0	0.0075	85.308
20000	2.0	0.0150	94.787
22000	2.5	0.0188	104.265
24000	3.5	0.0263	113.744
26000	5.0	0.0376	123.223
28000	7.0	0.0526	132.701
30000	8.0	0.0602	142.180

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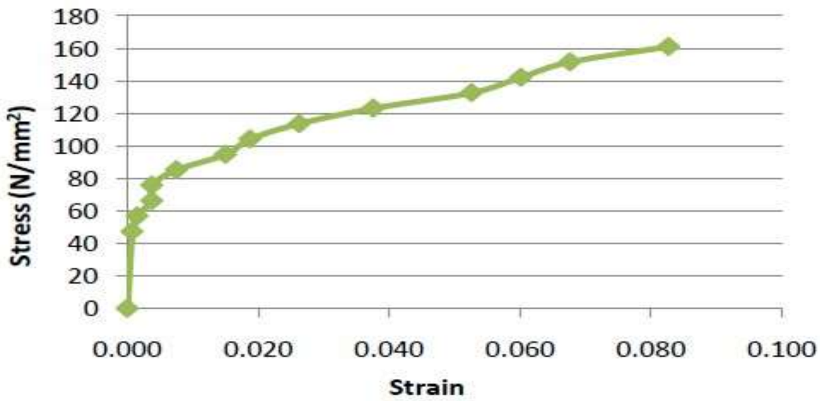


Fig. 4: Stress Vs Strain Curve of Tensile Test on Bamboo Strip.

FLEXURAL STRENGTH TEST OF BAMBOO REINFORCED CONCRETE BEAMS

In order to check flexural strength of Bamboo Reinforced cement concrete, beam specimens are casted with dimension 130*130*750 mm. The Bamboo strips of the length 730 mm were used as reinforcement.
The area of the Bamboo specimen used in the singly and doubly Reinforced Beam are shown in Table 3.

Table-3

Type of Beam	Length of Bamboo Specimen (mm)	Area (mm2)		
		End A	End B	Avg. Area
Singly Reinforced Beam	730	226	153.0	190.0
	730	170	202.0	186.0
Doubly Reinforced Beam	730	156.8	156.1	156.45
	730	130.3	108.6	119.45
	730	166.1	145.9	156.0
	730	177.6	144.6	161.10

Test Setup: -Flexural tests were conducted on Universal Testing Machine. The test was conducted with two points loading. Test setup to perform flexural test on Bamboo reinforced Concrete Beam is as shown in Fig.5

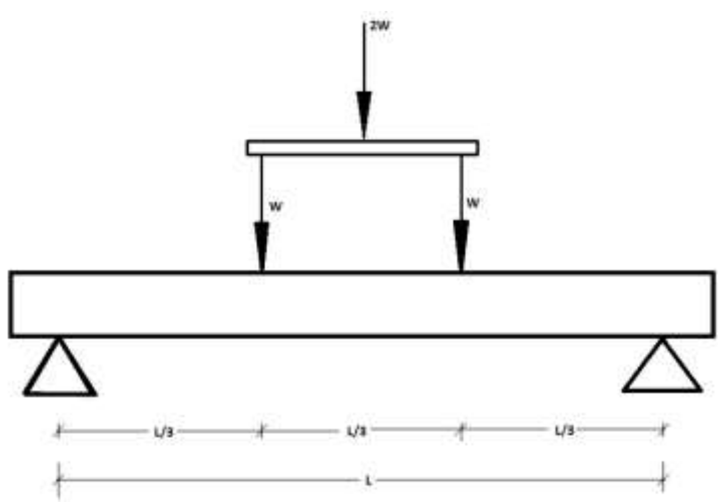


Figure 5. Flexural Test on Bamboo Reinforced Concrete Beam

To be acquainted with the behavior of Bamboo in concrete, different Bamboo reinforced concrete beam specimens were prepared. The different types of flexural beam specimen were:

CASE-1 Plain Cement Concrete Beam without Bamboo Strips

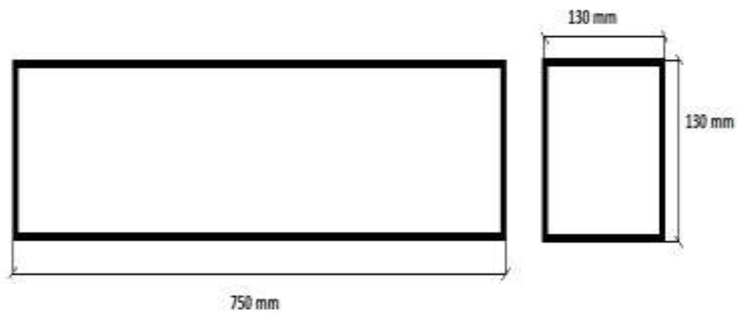
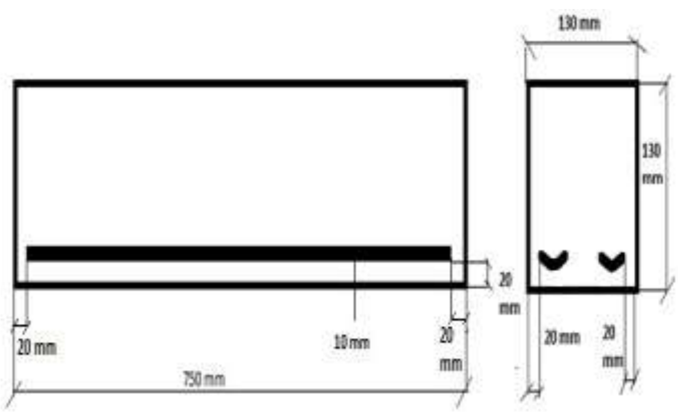


Fig.6: Plain Cement Concrete Beam

In the plain beam test specimen, the first crack occurred vertically from the point of load application which was flexure crack and the crack was widened. Then, crushing of concrete at the point load application was observed. Finally, the beam failed ultimate load of 11.65 kN. Plain concrete beam specimen failed suddenly and hence showed the brittle failure. The failure occurred in the Cement Concrete Beam is as shown in the Fig.7.

Fig.7: Cement Concrete Beam Failure

CASE-2 Singly Reinforced Cement Concrete Beam having two Bamboo strips without any treatment at the bottom with 20mm clear covers. Beam specimens have no stirrups:-



$A_{st} = 1.377\%$

Fig.8: Singly Reinforced Concrete Beam

In singly reinforced concrete beam initially the crack developed vertically in middle third portion, on further loading crack widened as shown in figure 10. Then the crack got widened. The crack was rising very smoothly and slowly. From the failure of the beam it was observed that the there was very less bonding between the concrete and the Bamboo as it was untreated Bamboo. The beam failed at a load of 11.6 kN. Result obtained is as shown in Table 4. The graph of load Vs deflection is plotted.
The Fig.10 shows the failure of the beam.

Table-4

Sr. No.	Deflection (mm)	›ad (N) (2W)	ad (N) (W)
1	0.00	0	0
2	0.01	1000	500
3	0.02	1800	900
4	0.03	2800	1400
5	0.04	4500	22500
6	0.05	5800	2900
7	0.10	8000	4000
8	0.15	11000	5500
9	0.20	11600	5800
10	0.25	11600	5800
11	0.30	11600	5800
12	0.35	11600	5800

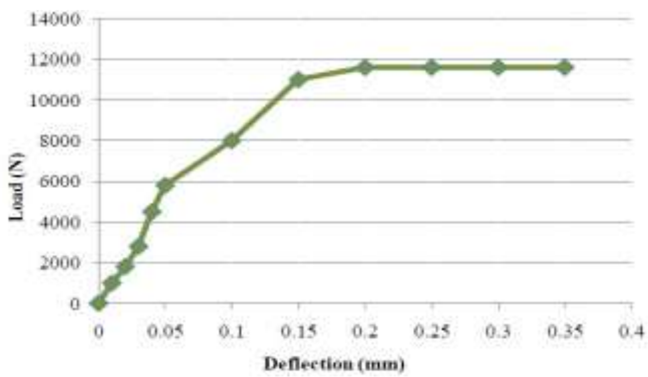


Fig.9: Load Vs Deflection Graph for Singly Reinforced Beam

Fig.10: Failure of Singly Reinforced Beam

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Modulus of elasticity for Singly Reinforced Beam is 3,762.9395N/mm2. By using following data:-

W= 2900 N, L= 750 mm, δ = 0.050 mm, I =1/12 (b*d3) =23800833.33 mm4

CASE-3 Doubly Reinforced Cement Concrete Beam having two Bamboo strips at the top and two strips at the bottom of the beam with 20mm clear covers. Bamboo specimen used without any treatment. Beam specimens have no stirrups:-

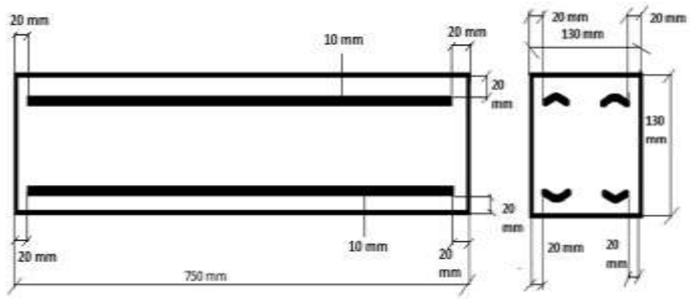

Fig.11: Doubly Reinforced Concrete Beam

In Doubly Reinforced Beam the crack developed in flexure. Two cracks were generated in the beam. The cracks developed at a very slow rate. The cracks formed triangular shaped. During the failure the Bamboo in the bottom was failed by a node failure. The upper Bamboo also failed at node. The failure type is node split failure. The beam failed at load of 15 kN Lack of gripping between the Bamboo and the concrete was observed. The failure pattern is shown in the Fig.13. The load Vs deflection graph is also obtained and the readings observed are shown in the Table 5.

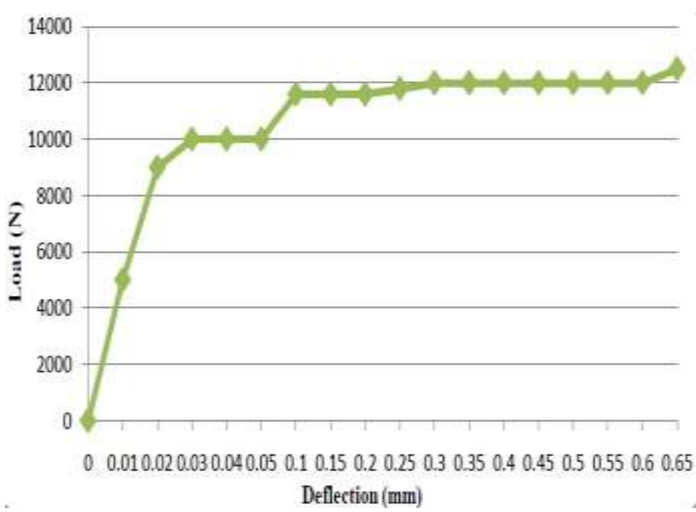

Fig.12: Load Vs Deflection Graph for Doubly Reinforced Beam

Fig.13: Failure of Doubly Reinforced Beam

Table-5

Sr. No.	Deflection (mm)	Load (N) (2W)	Load (N) (W)
1	0.00	0	0
2	0.01	5000	2500
3	0.02	9000	4500
4	0.03	10000	5000
5	0.04	10000	5000
6	0.05	10000	5000
7	0.10	11600	5800
8	0.15	11600	5800
9	0.20	11600	5800
10	0.25	11800	5900
11	0.30	12000	6000
12	0.35	12000	6000
13	0.40	12000	6000
14	0.45	12000	6000
15	0.50	12000	6000
16	0.55	12000	6000
17	0.60	12000	6000
18	0.65	12500	6250

Modulus of elasticity for Doubly Reinforced Beam section is 14,597.6103 N/mm2. By using following data:- W= 4500 N, L= 750 mm, δ = 0.020 mm, I = 1/12 (b*d3) = 23800833.33 mm4

COMPARISON OF MODULUS OF ELASTICITY OF SINGLY REINFORCED AND DOUBLY REINFORCED BEAM

Based on the experimental study the modulus of elasticity of Doubly Reinforced Beam is more than twice of the Singly Reinforced Beam. The comparison is shown in Fig.14. Modulus of elasticity for Singly Reinforced Beam is 3,762.94 N/mm2. Modulus of elasticity for Doubly Reinforced Beam is
14,597.70 N/mm2.

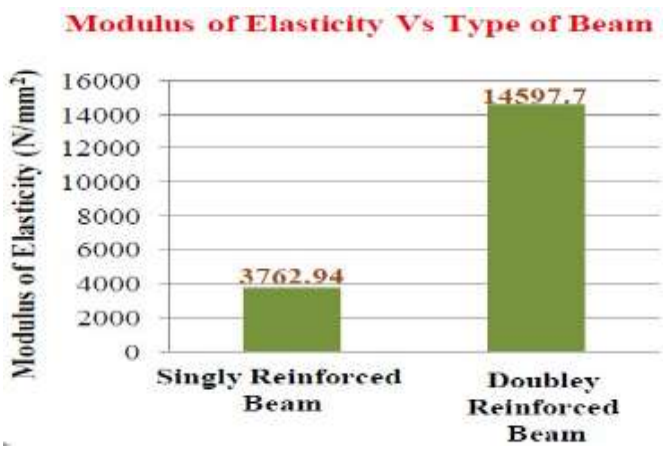

Fig.14: Comparison of Modulus of Elasticity of Singly Reinforced and Doubly Reinforced Beam

ADVANTAGES OF BAMBOO CONSTRUCTION

Lightweight- Bamboo is extremely lightweight. Consequently, building with bamboo can be accomplished faster with simple tools than building with other material. Cranes and other heavy machinery are rarely required.
Cost-Effective- Economical, especially in area where it is cultivated and is readily available. Transporting cost is also much lesser.
Durability- As long-lasting as its wooden correlates, when properly harvested and maintained**.**
Strength- Bamboo is an extremely strong natural fiber, on per standard hardwoods, when cultivated,
Harvested, prepared and stored properly.
Flexibility- Bamboo is highly flexible. During its growth, it may be trained to grow in unconventional shapes. After harvesting, it may be bent and utilized in archways and other curved areas.
Earth-Quake Resistance- It has high residual strength to absorb shocks and impacts.
Few considerations currently limit the use of bamboo as a universally applicable construction material -
Jointing Techniques- Although many traditional joint types exist, their structural efficiency is low. Considerable research has been directed at the development of more effective methods.
Flammability- Bamboo structure are not fire-resistant, and the cost of treatment, where available is relatively high.
Lack of Design Guidance and Codification- The engineering design of bamboo structure has not yet been fully addressed. There is little or no data containing specifications of bamboo.

CONCLUSIONS

Plain Cement Concrete Beam failed suddenly without any prior notice. Hence, it is to be said that it has shown brittle failure.

Tension test performed on Bamboo strip revealed elastic behavior as it can be seen from Fig.4.
Both singly and doubly Reinforced Beam has shown elastic behavior while performing flexural tests on them as it can be seen from Fig.9 and Fig12.

Doubly Reinforced Beam has performed more elastically than Singly Reinforced Beam while performing flexural tests.

Load carrying capacity in Doubly Reinforced Beam increased by 29.31 % as compared to Singly Reinforced Beam.

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Vertical cracks are developed, on failure of the beam, within middle third region of the beam. This type of failure is a proof existence of pure moment without any shear.

Modulus of Elasticity of the Doubly Reinforced Beam is more than twice of Modulus of Elasticity of the Singly Reinforced Beam as it can be seen from Fig.14.

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