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Study on Bamboo as Reinforcement 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. Our ancestors used Bamboo in the construction of the houses. 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. Problems encountered with the commonly used construction material like steel are high in cost, corrosion, etc. Due to the advantageous characteristics of Bamboo, in the last few years, studies have been made on the use of Bamboo as structural material and reinforcement in concrete. The main obstacle for the application of Bamboo as a reinforcement is the lack of sufficient information about its interaction with concrete, strength and durability.

This study presents the evaluation of the feasibility of the use of Bamboo as reinforcement in concrete members. In this study the Bamboo was used as a reinforcing material without any treatment and stirrups.

Keywords- Bamboo Strips, Concrete, Crack, Flexure Test, Tensile Test

1. INTRODUCTION

Bamboos are giant grasses belonging to the family of the *Bambusoideae*. It is estimated that 60–90 generae of Bamboo exist, encompass approximately 1100–1500 species and there are also about 600 different botanical species of Bamboo in the world. Bamboo mainly grows in tropical and sub-tropical regions of Asia, Latin America and Africa. Bamboo is versatile resource characterized by high strength to weight ratio and ease in working with simple tools.

Bamboo is the fastest growing, renewable natural resource known to us. It is a small wonder, therefore, that this material was used for building extensively by our ancestors. It has a long and well established tradition as a building material throughout the tropical and sub-tropical regions. It is used in many forms of construction, particularly, for housing in rural areas. But, enough attention had not been paid towards research and development in Bamboo as had been in the case with other materials of construction including timber [6].

Due to the advantageous characteristics of Bamboo, in the last few years, studies have been made on Bamboo as structural material and reinforcement in concrete. Fikremariam Mengistu Assaminew[1] has conducted the tension test and compression test on the Bamboo specimen. He concluded that 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. Khosrow Ghavami[2] has described about the test on the beams and columns. He has shown the whole procedure of the beam and column test and its behaviour. He finally concluded that the Bamboo can satisfactorily substitute the steel. The various element produced by Bamboo can very well be used in the construction. Markos Alito[3] mentioned about the physical and the mechanical properties of the Bamboo and its various test. He has presented his study on the test performed on the R.C.C beam reinforced with the Bamboo. The mid span test was performed. He concluded that the Bamboo reinforced concrete design is similar to steel reinforced concrete design if its mechanical properties are properly utilized. Musbau Ajibade Salau[4] has shown his work about the structural strength of the concrete column reinforced with the Bamboo strips. The number of the Bamboo stirrups is varied. The results showed that the load carrying capacity of the column increased with increase in percentage of Bamboo stirrup reinforcement but the increase is not proportional to the percentage of reinforcement. Satjapan Leelatanon, Suthon Srivaro and Nirundorn Matan[5] has stated about the test on the axial force element such as column. Paper shows that the Bamboo was used as the reinforcement in the concrete without any surface treatment. They concluded that for the column reinforced with the Bamboo without any surface treatment, strength capacity was found to be sufficient for carrying the axial load while the ductility was found low. Youngsi Jung[7] has performed the pull out test.

Various types of the Bamboo used are solid and the moso. The Bamboo with nodes and without nodes was also used. At the end he concluded that the moso Bamboo shows higher strength and ductility than that of the solid Bamboo. In general the node was found to be failure point for the Bamboo having nodes. Thus moso Bamboo shows higher grip and strength than that of the solid Bamboo.

Table1: List of Abbreviation

Symbol	Description
A_{bt}	Area of Bamboo in Tension
A_{bc}	Area of Bamboo in Compression
E	Modulus Of Elasticity
σ	Stress
ε	Strain

2. METHODOLOGY

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

1. Tensile test on Bamboo strips.
2. Compression test on Cement Concrete Cubes.
3. Flexural strength test of Bamboo Reinforced Concrete Beams.

2.1. 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 Specimen.

Table 2: Description of Tensile Test Specimen

Sample No.	Sample Position	Specimen Size		Cross Sectional Area (mm^2)		
		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

2.1.1 Test Setup

Tensile test was conducted on Universal Testing Machine model TUN 600. 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.

Fig. 2: Position of Bamboo strip in UTM

2.2. Compression Test On Cement Concrete Cubes

The compression test was performed on the cement concrete cubes to check the compressive strength of the concrete & hence to justify the proportion of ingredients to have specific strength of concrete. The resulting concrete was poured in moulds of size 150*150*150 mm. After casting concrete samples were kept in wet place and demoulded at 24 hours age they were submerged in open water tank for curing up to 28 days as required for test.

Table 3: Details of Cube Specimen

Size Of Cube specimen(mm)	Weight of the Cube Specimen(Kg)	Density (kg/m^3)
150*150*150	8.52	25.2
150*150*150	8.36	24.7
150*150*150	8.41	24.91
150*150*150	8.11	24.02
150*150*150	8.24	24.41
150*150*150	8.56	25.36

2.2.1 Test Setup

A specimen was centred on the lower block in relation to the upper plate. The maximum load was recorded after the concrete cubes failed to take further load.

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

- Plain Cement concrete beam without bamboo strips.
- Singly Reinforced Cement Concrete Beam having two Bamboo strips without any treatment at the bottom with 20mm clear covers. Beam specimens have no stirrups.
- 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.

The area of the Bamboo specimen used in the singly and doubly Reinforced Beam are shown in Table 4.

Table 4: Details of bamboo strips used as reinforcement in Beam

Type of Beam	Length of Bamboo Specimen (mm)	Area (mm^2)		
		End A	End B	Avg. Area
Singly Reinforced Beam	730	226.0	153.0	190.00
	730	170.0	202.0	186.00
Doubly Reinforced Beam	730	156.8	156.1	156.45
	730	130.3	108.6	119.45
	730	166.1	145.9	156.00
	730	177.6	144.6	161.10

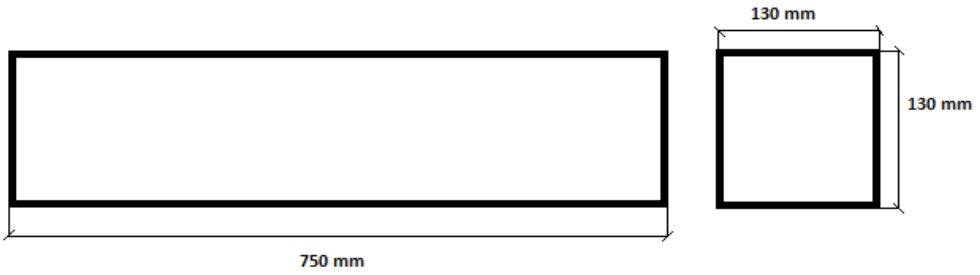
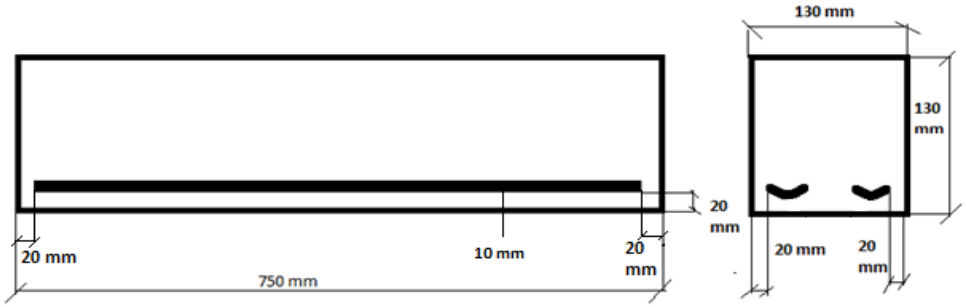
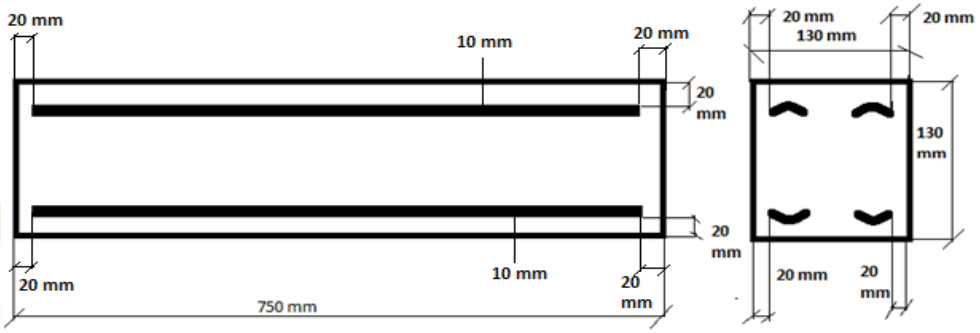


Fig.3: Plain Cement Concrete Beam



$A_{bt} = 1.377\%$

Fig.4: Singly Reinforced Concrete beam



$A_{bc} = 1.009\%$ $A_{bt} = 1.159\%$

Fig.5: Doubly Reinforced Concrete beam

2.3.1 Test Setup

Flexural tests were conducted on Universal Testing Machine with model TUN 600. The test was conducted with two point loading. Test setup to perform flexural test on Bamboo reinforced Concrete Beam is as shown in Fig.6.

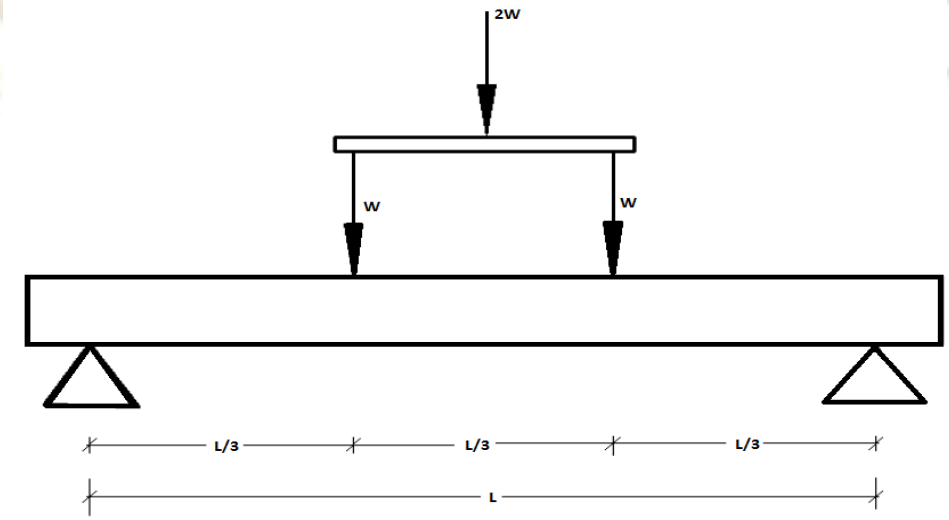


Fig.6: Two Point Loading System

Fig.7: Test Setup to check flexural strength of Beam

3. RESULTS

3.1 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 Bamboo. It has been observed that mostly the failure occurred at mid height. The failure occurred looks like the splitting of the fibres as shown in Fig.9. The general tensile test results are summarized in the Table 5 shown below. The graph stress Vs Strain shown in Fig.8.

Table 5: Results of the Tensile Test

Load P(N)	Elongation(mm)	Strain	Stress (N/mm²)
0	0.00	0.0000	0.0000
10000	0.10	0.0008	47.300
12000	0.20	0.0015	56.870
14000	0.50	0.0038	66.351
16000	0.50	0.0038	75.829
18000	1.00	0.0075	85.308
20000	2.00	0.0150	94.787
22000	2.50	0.0188	104.265
24000	3.50	0.0263	113.744
26000	5.00	0.0376	123.223
28000	7.00	0.0526	132.701
30000	8.00	0.0602	142.180
32000	9.00	0.0677	151.659
34000	11.00	0.0827	161.137

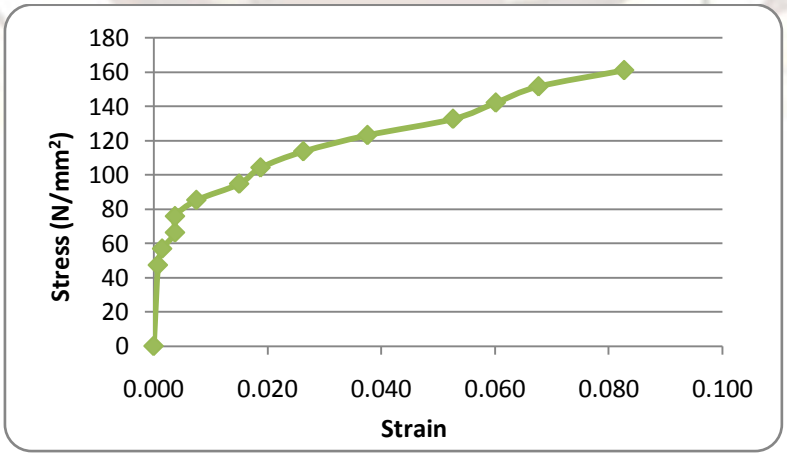


Fig. 8: Stress Vs Strain Curve of tensile test on Bamboo Strip.

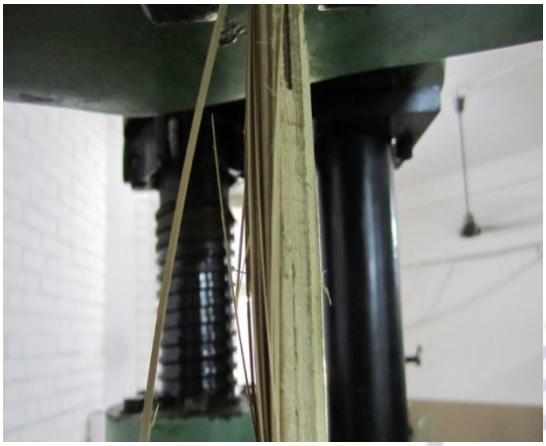


Fig.9: Failure of the Bamboo Specimen in Tension Test

Fig.10: Split Failure of Bamboo Strip

3.1.1 Calculation of Modulus of Elasticity.

The yield stress of the Bamboo strip is 56.870 N/mm^2.

The equation to calculate the Modulus of Elasticity is as mentioned below:

$$E = \frac{\sigma}{\varepsilon}$$

Where,

σ = Stress.

ε = Strain.

E = Modulus Of Elasticity.

The data are

σ = 56.87 N/mm^2.

ε = 0.0015

Thus,

$$E = \frac{56.87}{0.0015}$$

E= 37,913.33 N/mm^2

The Modulus of Elasticity of the Bamboo strip is 37,913.33 N/mm^2.

3.2 Compression Test Results

Compression test was carried out on the cubes of grade M20. Total six cube testing was carried out three cubes were tested after 7 days and the other three cubes were tested on 28 days. The results obtained are shown in the Table 6.

Table 6: Cube tests results

Sample No.	Dimension (mm)	Days	Load (kN)	Compressive Strength (N/mm^2)
1	150*150*150	7	421	18.71
2	150*150*150	7	310	13.77
3	150*150*150	7	306	13.66
4	150*150*150	28	575	25.56
5	150*150*150	28	595	26.44
6	150*150*150	28	451	25.36

3.3 Flexural Test Results

From the experimental test the load deflection graph, ultimate carrying capacity and the type of failure were recorded. The deflection at first crack was recorded from the load and deflection curve which was found at the point where the stiffness of the beam changed. In addition the maximum deflection was read from this curve. Generally Flexure failure was seen.

3.3.1 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.11.

Fig.11: Cement Concrete Beam Failure

3.3.2 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 7. The graph of load Vs deflection is plotted. The Fig.13 and Fig.14 shows the crack development and the failure of the beam.

Srno.	Deflection(mm)	Load(N) (2W)	load (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	2250
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

Table 7: Singly Reinforced Beam Results

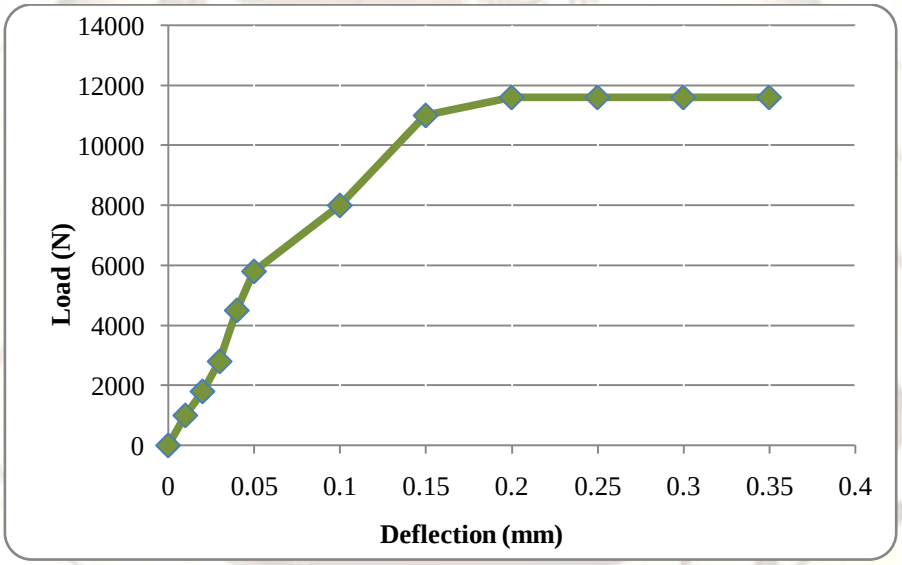


Fig.12: Load Vs Deflection Graph for Singly Reinforced Beam

Fig.13: Development of crack

Fig.14: Failure of Singly Reinforced Beam

3.3.2.1 Calculation of Modulus of Elasticity Of Singly Reinforced Beam

The Modulus of Elasticity (E) is given by the following equation:

$$E = \frac{23*W*L^3}{648*\delta*I}$$

Where,
W = load.
L = Length of the Beam
δ = Deflection
I = Moment of inertia.
Now,
$I = 1/12\ (b*d^3)$
Where,
b = Width of the beam
d = Depth of the Beam.
$I = 1/12*(130*130^3)$
$I = 23800833.33\ mm^4$

3.3.3 Doubly Reinforced Beam

Singly Reinforced Beam in elastic behaviour has the following data:
W= 2900 N
L= 750 mm
δ = 0.050 mm
$I = 23800833.33\ mm^4$
Thus,

$$E = \frac{23*2900*750^3}{648*0.050*230800833.33}$$

$E = 3{,}762.9395\ N/mm^2$
Modulus of elasticity for Singly Reinforced Beam is $3{,}762.9395 N/mm^2$.

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 and the development of the crack are shown in the Fig.16. The load Vs deflection graph is also obtained and the readings observed are shown in the Table 8. The failure pattern is shown in the Fig.17.

Table 8: Doubly Reinforced Beam results

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

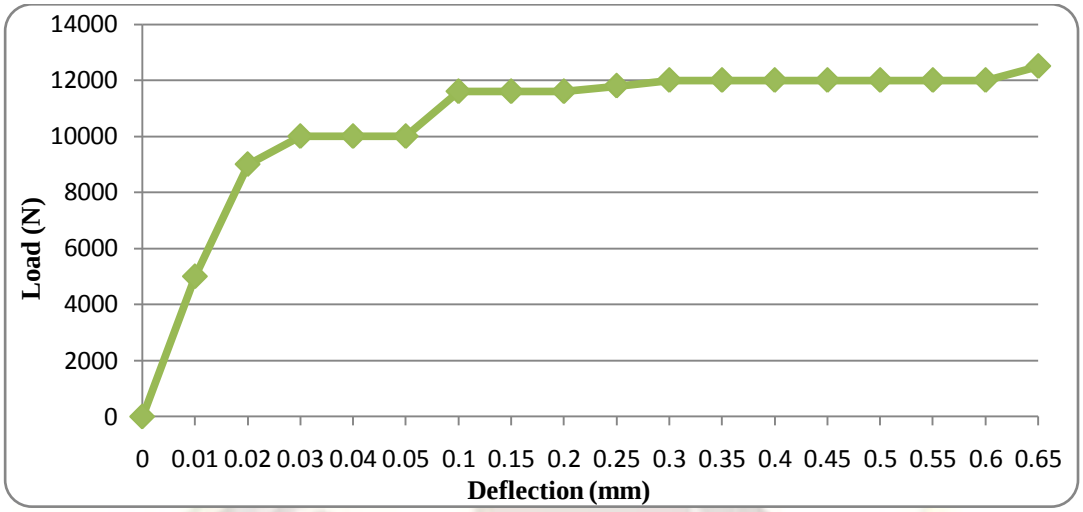


Fig.15: Load Vs Deflection Graph for Doubly Reinforced Beam

Fig.16: Failure Pattern of Doubly Reinforced Beam

Fig.17: Failure of Doubly Reinforced Beam

3.3.3.1 Calculation of Modulus Of Elasticity Of Doubly Reinforced Beam

The Modulus of Elasticity (E) is given by the following equation:

$$E = \frac{23 * W * L^3}{648 * \delta * I}$$

Where,
W = load.
L = Length of the Beam
δ = Deflection
I = Moment of inertia.
Now,

$I = 1/12 (b*d^3)$
Where,
b = Width of the beam
d = Depth of the Beam.

$I = 1/12*(130*130^3)$
$I = 23800833.33 \text{ mm}^4$
Doubly Reinforced Beam in elastic behaviour has the following data:
W= 4500 N
L= 750 mm
δ = 0.020 mm
$I = 23800833.33 \text{ mm}^4$
Thus,

$$E = \frac{23*4500*750^3}{648*0.020*230800833.33}$$

$E = 14597.6103 \text{ N/mm}^2$

Modulus of elasticity for Doubly Reinforced Beam section is 14,597.6103 N/mm^2.

3.3.4 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.18.
Modulus of elasticity for Singly Reinforced Beam is 3,762.94 N/mm^2.
Modulus of elasticity for Doubly Reinforced Beam is 14,597.70 N/mm^2.

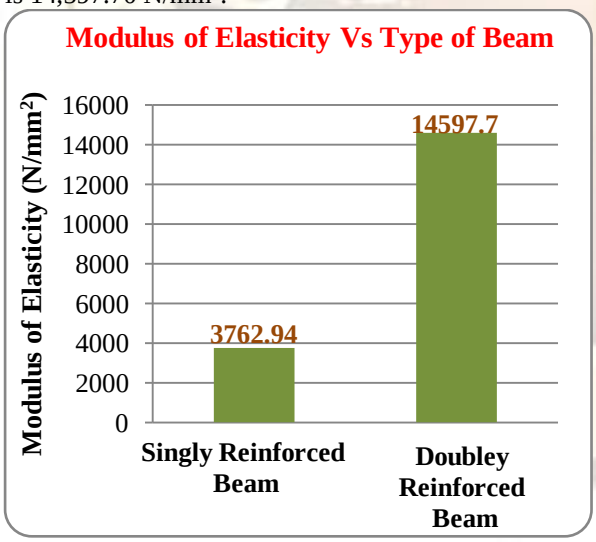


Fig.18: Comparison of Modulus of Elasticity of Singly Reinforced And Doubly Reinforced Beam

4. CONCLUSIONS

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

Based on the experimental study, the following conclusions are made,

- Tension test performed on Bamboo strip revealed elastic behaviour as it can be seen from Fig.8.
- Both Singly and Doubly Reinforced Beam has shown elastic behaviour while performing flexural tests on them as it can be seen from Fig.12 and Fig15.
- 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.
- 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.18.

REFERENCES

1. Fikremariam Mengistu Assaminew, *Investigation Of The Flexural And Bond Strengths Of Bamboo Using Different Splits (Forms) In Concrete Mem*bers, Addis Ababa University School Of Graduate Studies, 2010
2. Khosrow Ghavami, Bamboo as Reinforcement In Structural Concrete Elements, *Cement & Concrete Composites 27*, 2005, 637–649.
3. Markos Alito, *Bamboo Reinforcement As Structural Material For The Construction Of Low-Cost Houses In Ethiopia*, Addis Ababa University, 2005
4. Musbau Ajibade Salau (2012), Characteristic Strength Of Concrete Column Reinforced With Bamboo Strips, *Journal Of Sustainable Development Vol. 5, No. 1*, 2012, 133-143.
5. Satjapan Leelatanon, Suthon Srivaro And Nirundorn Matan , Compressive Strength And Ductility Of Short Concrete Columns Reinforced By Bamboo, *Songklanakarin J. Sci. Technol. 32 (4)*, 2010, 419-424.
6. Sreemathi Iyer, *Guidelines For Building Bamboo-Reinforced Masonry In Earthquake-Prone Areas In India*, University Of Southern California, 2002
7. Youngsi Jung, *Investigation of Bamboo as Reinforcement in Concrete*, The University Of Texas, Arlington, 2006.