International Journal of Applied Engineering Research ISSN 0973-4562 Volume 14, Number 9 (2019) pp. 2198-2202

Experimental Investigation of Bamboo as a Partial Replacement of Rebar in RC Beams

***Sofia N.K.[1] , Dr.Abraham Gebre[2], Xavior Oli Elavan.[3]**

[1] *Lecturer, School of Civil Engineering and Architecture, Dire Dawa Institute of Technology, Dire Dawa, Ethiopia.*

[2] *Assistant Professor, Structural Engineering, Addis Ababa University, Addis Ababa, Ethiopia.*

[3]*Lecturer, School of Civil Engineering and Architecture, Dire Dawa Institute of Technology, Dire Dawa, Ethiopia.*

ABSTRACT

The study discusses about the flexural and load carrying capacity of beams, reinforced with treated bamboo compared to beams reinforced with steel. The bamboo sticks used as reinforcement in the beams were collected from Dilla Zone and tested against compression and tension; its strength found to be 46 & 120 Mpa respectively.

Five beam samples were used for this purpose and singly reinforced and doubly reinforced beams were studied. On singly reinforced beam, bamboo culms were used as a nominal reinforcement in compression zone and steel in tension zone. On doubly reinforced beam, 35% of tension reinforcement was replaced with 85% of bamboo to observe the effect of the replacement on load carrying capacity. As a result, for singly reinforced beam, bamboo replacement increased the load carrying capacity by 8% and for doubly reinforced beam, there was about 10% reduction on the flexural capacity compared with doubly reinforced RC beam but was found to be still safe for the design load**.**

Keywords: RC Beams, Partially Reinforced, Bamboo culms, Flexural capacity, load carrying capacity, DILLA.

1. INTRODUCTION

In most countries, concrete is widely used as the foundation for the infrastructure. Concrete is used largely because it is economical, readily available and has suitable building properties such as its ability to support large compressive loads. However, the use of concrete is limited because it has low tensile strength. For this reason, it is reinforced, and one of the most popular reinforcing bars (rebar) is steel. Steel has a relatively high tensile strength, as high as 115 ksi (792 N/mm2), complementing the low tensile strength of concrete

Problems encountered with the commonly used construction material like steel are rise in cost; degradation of the non-renewable material, the pollution of the environment due to industrial process etc. Scientists and engineers are constantly seeking for new methods and materials for structural systems such as recycling and reuse, sustainable production of products, or use of renewable resources like organic fibers including bamboo, jute and glass.

Bamboo is one of the ecological materials for this purpose having many advantages. Such as, It reaches its full strength in just few months, renewable material, have low weight and cost. Due to the above advantageous characteristics of bamboo, in the last few years, studies have been made on bamboo as structural material; full and partial 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 thesis presents the results of experimental study carried and a concise summary about the strength of bamboo as a partial reinforcement and its interaction with concrete and steel.

2. LITERATURE REVIEW

(Ghavami, 2005) has studied the behavior of bamboo in the reinforcement of beams. The bamboo strips used for this research were 30cm wide rectangular sections which were coated with thin layer of impermeable product and roughed with sand. By varying the percentage of bamboo from 0.75% to 5% flexural tests were performed. The test result had demonstrated that the ultimate applied load increased by more than 400% as compared with concrete beams without reinforcement, for a 3% bamboo reinforcement. **Fikremariam M**. (2010) has studied the flexural and bond strength of Gumero Bamboo on concrete beams. It was found the load carrying capacity of bamboo reinforced sections were 45% with that of RC beams.

(I.K.Khan, 2014) Investigated performance of bamboo reinforced concrete beams in order to reduce the cost of construction. Circular, square and triangular bamboo stick cross sections were used and the square cross section bamboo reinforced beam had higher load carrying capacity.

(NithiPlangsriskul, 2010-2011) Studied about the property of bamboo used as reinforcement in concrete and stated that bamboo swells up when it is used as reinforcement, this cause voids and loss of adhesion between the concrete surface and bamboo, which resulted to failure in the concrete structure .The traditional Asphalt emulsion coating prevents water from penetrating into bamboo surface. Comparing bamboo with node and without node, the pullout strength of bamboo with node in concrete is much greater.

3. OBJECTIVES

1. Determination of the physical and mechanical properties of Bamboo from Dila Zone In Ethiopia.

2. Flexural strength Investigation of Bamboo as a partial reinforcement in concrete beams.

3. Compare the experimental failure load with theoretical values.

4. EXPERIMENTAL PROGRAM

Material Properties

The physical and mechanical properties of bamboo were determined according to IS 6874. This study was carried out to investigate the tensile and compression strength of bamboo mainly in the longitudinal direction In addition, the bottom and middle culm parts were taken for test due to its high strength. For this research test samples were taken from Dila which is Y.Alpina species according to Seyoum Kelemwork (Dr) study on Ethiopian Bamboo (2008).

Specimen Preparation

Six sticks were prepared with node and without node for the Tensile tests. The end part of the specimens were laminated with steel plate in order to avoid grip failure during tensile testing. According to IS6874 recommendation, the length of the test sample was equal to the outer diameter for bamboo which have less than 20mm diameter and twice the outer diameter for bamboo which have greater than 20mm outer diameter Six specimens were prepared for the compressive test of bamboo with diameter (50-60mm), length (100-120mm) and thickness (11.3-16.3mm). The bond strength of bamboo is enhanced by using melted bitumen and applying it to the bamboo strips uniformly with a brush to form thin coats while still hot, the bamboo is covered with coarse sand for 24hours as shown in fig below.

Figure 1. Threated bamboo sticks

Test set up

Tensile tests were conducted using a Universal Testing Machine with model 70-C0807/C. According to ISO 22157-1, the load should be applied continuously throughout the test at a rate of motion of the movable cross head of 0.01mm/s. Six specimens with a length of 60mm, width (15-20mm) and thickness (6-11mm) were prepared and tested for tensile strength.

Compressive Test

The compressive tests were made for a segment of bamboo culm parallel to the fibers for bottom and middle position of a Culm according to IS 6874.

Specimen Preparation

ACI mix design method used for normal steel reinforced concrete is applied in the preparation of mix design for bamboo reinforced concrete specimens.

Concrete slump was made as low as workability will allow minimizing excess water which causes swelling of the bamboo. From sieve analysis 3.0 fineness modulus of sand was obtained and maximum size of 20mm aggregate was used. In order to obtain a 28 day concrete compressive strength 25Mpa the following quantity of material was adopted as shown in table 1 below.

Table 1. Quantity of Material for C-25(kg/m3)

Quantity of Material for C-25(kg/m3)				
Material	Water	Cement	Fine Agg.	coarse Agg.
Quantity	197.4	448.6	752.71	1064.65

From the tests a slump of 27 mm was recorded

The reinforcement used on the beam specimens was checked against corrosion and rust. The tensile strength of steel used in the specimen beam was 300Mpa.

Figure 2. Fresh concrete mix and reinforcement

Flexural Test

Beam Specimen Preparation

In the preparation of test specimen beams, procedure outlined in ASTM standard and U.S Naval Civil Engineering Laboratory was followed. Considering the laboratory conditions and the sizes of bamboo strips a beam length of 1000mm was preferred. According to ASTM standard, which recommend a ratio of length to depth greater than 4, a cross sectional area of 15cmX20cm was used. To be acquainted with the behavior of bamboo & steel in concrete beams different positions of bamboo & steel arrangement were followed .The specimens were designed to resist 50KN load for all conditions of the beam material property detail is shown in the Table3.4 &3.5.

Control Beams

Two Reinforced concrete beams were prepared with length 1000mm, width 150mm and height 200mm as a control beam with single reinforcement and double reinforcement. For

singly reinforced beam, two diameter 10 deformed bars were used on the tensile zone and for doubly reinforced beam two diameter 10 and two diameter 8 deformed bars on the tensile and compression zone, respectively, are used.

Composite Beams

Two bamboo steel reinforced concrete beams with 1000mm, width 150mm and height 200mm were prepared with different percentage of bamboo and steel in compression and tension zone. On the first beam, bamboo was placed in the compression zone as a substitute for nominal reinforcement which was used to support the stirrups as shown in the Figure 3.6a. On the second beam bamboo is used in the tension zone with steel as shown in the Figure 3.6b.

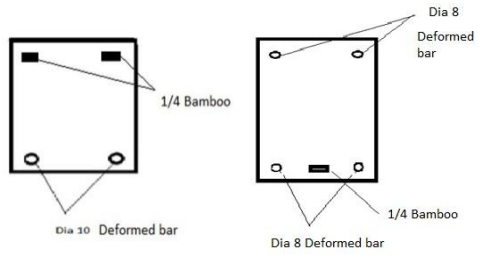

Figure 3. Bamboo reinforced beams

Bamboo Reinforced Beam

A bamboo reinforced beam specimen was prepared to see if full replacement of reinforcement was possible. The beam is composed of four bamboos ¼ culm from bottom and middle part with a length of 1000mm,width 150mm and height 200mm

Test Setup

Flexural tests were conducted on Universal Testing Machine with model 70-C0807/C. The test was conducted with one point loading. Test procedure listed on ASTM C 78-02 was used to perform flexural test. The loading was applied at a distance of 500mm at the center of the beam specimen and the support was indented 100mm from left and right side of the beam as shown in the figure 3.7 below.

Figure 4. Beam set up on universal Testing Machine

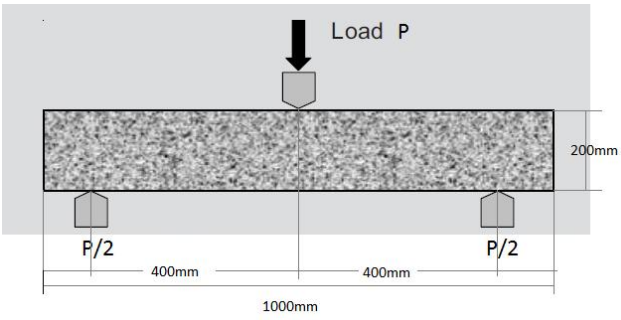

Figure 5. Test set up

5. RESULTS

Tensile strength Test

Tensile tests were conducted on specimens with nodes. Nodes are weak and brittle in resistance to tensile force as referred in ISO-22157.From the test results of six specimens an average tensile strength 119.9 Mpa obtained from four specimens with a standard deviation of 8.6.In the experimental test failures in most of the specimens occurred at the node. A few numbers of test specimens failed by splitting in to two parts and then followed by node failure.

Compressive strength Test

From the test the ultimate compression resistance of the Node splitting type failure, Splitting Failure, Node failure in specified species was recorded. Brooming or end-rolling type of failure was observed in most of the test specimen. All the specimens with nodes failed with the end rolling type of failures. This type of failure is usually associated with excess moisture at the ends of the specimen or improper cutting of the specimen which is usually associated with reduced load. The other type of failures which were observed in most of the specimens were splitting and shearing. Most samples failed by dividing in to two parts which is a splitting type of failure.

the mean value of the sample specimen result of compressive strength was 46Mpa with a standard deviation of 10.6.

Concrete test

Concrete is a composite material consisting of cement, gravel, sand and water. After hardening of this composite material the material can be regarded as a mortar mix including distributed aggregates. Concrete showed a very brittle behavior after reaching its ultimate load. Generally the concrete workability is measured with a slump test which was recorded as 27mm for the mix design and the average concrete compressive strength obtained to be 24.8Mpa after curing for 28 days.

6. DISCUSSION

Failure modes and failure mechanism

The flexural failure mode was observed for all types of beam specimens as shown in figure 5.1.The yielding of steel, bamboo took place and this was followed by crushing of

concrete in the compression zone. Since all the beams were designed as under-reinforced, the failure started by yielding of the tension steel bar before the compression failure of concrete as expected.Also,the stirrup spacing was kept at 100mm center in the shear zone and thus all beams failed in typical flexural mode. For all types of beam specimens, failure started with flexural crack which extended up to the neutral axis and finally crushing of concrete took place.

Figure 6. Failure Mode of Beam-3

Ultimate Load Capacity

The theoretical ultimate moments were calculated using the ultimate strength of the reinforcement, while that of bamboo were calculated using the ultimate strength of bamboo without a material factor of safety for all cases. Chart 5.2 shows the load carrying capacity of Beam-1, Beam-2, Beam-3, Beam-4 and Beam-5 tested under center point loading.

Case-1

The control beam specimen is designed to resist 50KN load reinforced only in the tensile zone but most of the time nominal reinforcement at the top was provided for stirrup tying.therefore,in this study the nominal reinforcement was replaced by ¼ two bamboo culms and its load carrying capacity was investigated in the laboratory. The result showed that bamboo reinforced concrete had 8.7% more load carrying capacity than singly reinforced beam.

Case-2

The reference RC beam is designed to resist a load of 55KN as a double reinforcement beam with two diameters 10 and diameter 8 deformed bars as a bottom and top respectively. The reinforcements in the compression zone were replaced by two ¼ bamboo culms each with an average area of 134mm2.The result showed bamboo reinforced concrete beam specimen can carry 105% of the design load and 78.3% of the respective double reinforcement concrete beam with steel.

On the other beam,35.9% of the tension reinforcement area was replacement by 85% of bamboo reinforcement and the compression reinforcement kept the same. The load carrying capacity of steel bamboo reinforced concrete beam (beam-4) was 10.% below from the reference beam(beam-2) but still can withstand the design load with 119%.

Case -3

The control beam is designed to resist a load of 65KN as a doubly reinforced beam with diameter 10 and diameter 8 deformed bar at the bottom and top respectively. From the reinforcement area at the tension zone 36% was replaced by bamboo with an average area of 134mm2 and compression zone reinforcement remained the same. This arrangement of reinforcement and bamboo carried the design load around 100%.

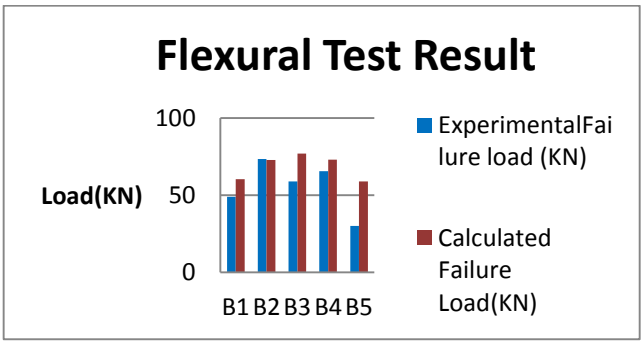

Chart 1. Flexural test results

The ultimate load capacity on Beam-5 showed a great difference between the experimental and theoretical value due to the following reasons.

Theoretical value was calculated based on RC design procedure the only difference was material property and perfect bond between bamboo and concrete was assumed.

7. CONCLUSION

Summarized below are the results of the study:

1. Bamboo can be used as reinforcement in nominal reinforcement places for singly reinforced beam.
2. when using bamboo as a reinforcement higher factor of safety should be considered
3. The experimental results showed that replacing bamboo in place of steel requires large area of bamboo.
4. Considering the ultimate load capacity as a measurement ; bamboo reinforced sections have less load carrying capacity when used as a main reinforcement on doubly reinforced beam , compared with RC beams but still can with stand the design load

8. RECOMMENDATIONS

This study initiate use of bamboo as reinforcement complement to previous studies but would recommend to be studied in detail.

1. Development of factor of safety to calculate the allowable stress of bamboo for use in design calculation on basis of statically data.
2. Experimental study should be carried out on different percentage of bamboo reinforced concrete columns to investigated bond strength, buckling behavior, carrying capacity and type of failures
3. Long term studies on the durability, fatigue of bamboo reinforced concrete beam and Thermal

effect of bamboo by conducting pullout tests on different gradient of temperature.

4. Experiment with other types of coating and compared the bonding strength with the traditional asphalt emulsion coatings.

REFERENCE

1. Ghavami, K. (2005). Bamboo as reinforcement in structural concrete elements. ELSEVEIR.
2. I.K.Khan. (2014). Performance Of Bamboo Reinforced Concrete Beam. ISSN , 2278-3687.
3. Mengistu, F. (2010). Investigation of the flexural and bond strength of bamboo different split in concrete.
4. NithiPlangsriskul, N. D. (2010-2011). Materials Characterization of Bamboo and Analysis of Bonding Strength And Internal Strength as a Structural Member in Reinforced Concrete. California Polytechnical State University San Luis Obispo .