EXPERIMENTAL INVESTIGATION ON BEHAVIOR OF BAMBOO REINFORCED CONCRETE MEMBER

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Abstract

The use of bamboo which is fast growing and ecologically friendly material for structural applications is being considered as quite appropriate. The tensile strength of bamboo is quite high and can reach up to 125 MPa. This makes bamboo an pretty alternative to steel in tensile loading applications. The bamboo concrete composite elements can be used as alternate for concrete, steel and wood used in housing and other products required in the day to day applications. In this study it has been attempted to develop engineered bamboo structural elements for use in low cost housing. A bending test was performed on Plain, Steel & Bamboo reinforced members. For example, a total of 4beam (150x150x700mm) were casted using design mix (M25) as per IS code. These beam included 1 beam of steel reinforcement, 1beam of plain concrete, and 4beam of untreated bamboo reinforcement. The load-deformation curves displayed significant nonlinearity, representing that the bamboo has the capacity to absorb energy. Bamboo concrete composite structural members can provide tailored solutions to the eco-housing initiatives at cheaper costs. The results obtained accrue the advantage obtained by the composite members when compared to standard reinforced concrete and plain concrete.

Keywords: *UTM, Composite Member, Bamboo Reinforced Concrete, Experimental Investigation, Tensile Strength.*

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1. INTRODUCTION

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. are common in the globe. However, with sustainability as a key issue in the last decades the environmental load of building materials has also become a more important criterion. The building industry, directly or indirectly causing a considerable part of the annual environmental damage, can take up the responsibility to contribute to sustainable development by finding more environmentally benign ways of construction and building. One of the directions for solutions is to look for new material applications: recycling and reuse, sustainable production of products, or use of renewable resources. Attention has to be given to materials such as vegetable fibres including bamboo, jute, and glass, wastes from industry, mining and agricultural products for engineering applications to control environmental degradation and to minimize cost [15].

Due to the above advantageous characteristics of bamboo, in the last few years, studies have been made on bamboo as structural material and reinforcement in concrete.

1.1 Objectives of the Study

The goal of this paper is to determine the practicability of bamboo reinforcement for concrete beams. Whereas the mechanical properties and behaviour of steel reinforced concrete have been thoroughly studied and well documented, there exists no comprehensive data describing bamboo reinforced concrete. Therefore, the aim of this study is to provide a preliminary contribution toward the collection of the mechanical properties and behaviours of bamboo reinforced beams.

1.2 Property of Bamboo

1.2.1 Physical Structure of Bamboo

Bamboo is commonly compared to wood products due to its similar chemical structure. The physical structure is the aspect that differentiates bamboo from wood. Wood has anisotropic properties and contains grains oriented in the same direction throughout the whole structure. On the exterior edge of each node, branches form creating different types of grass looking leaf structures. Bamboo contains parallel fibres that are reinforced along the axial direction of the Culm.

1.2.2 Shrinkage and Swelling

Bamboo, like wood, changes its dimension when it loses or gains moisture. Bamboo is a hygroscopic material, thus the moisture content changes with the changes in the relative humidity and temperature of the surrounding environment [17].

1.2.3 Bending

Bending is an important parameter, deciding the suitability of bamboo as a construction material. Because of this ability

Bamboo can be used as a substitute for reinforcement in construction of buildings [17].

1.2.4 Elasticity

The enormous elasticity of bamboo makes it to a very good building material for earthquake endangered areas. Another advantage of bamboo is its low weight. It can be transported and worked easily, thus rendering use of cranes and other big machines unnecessary [17].

1.2.5 Fire Resistance

The fire resistance of bamboo is very good because of its high content of silicate acid. Filled up with water, it can stand a temperature of 400° C while the water cooks inside [17].

2. TEST EXPERIMENT

Tests conducted were: Bamboo Compression Strength Testing, tension testing of bamboo and beam bending test. Preparation of test specimens and testing using the following tools: stirring concrete compression machine with a capacity of 2000 kg to test the compression strength of concrete, Universal Testing Machine (UTM) 2 ton capacity used for tension testing of bamboo. Tests performed on the flexural strength of concrete loading frame equipped with hydraulic jacks. The number of specimens for each type of test is shown in Table 1.

Table -1: Type of Testing of Number of Specimens

S.No.	Type of Testing	Specimens
1	Compressive Test of Bamboo	One
2	Tensile Test of Bamboo	One
3	Beam Bending Test	M-25

2.1 Tensile Test

First a bamboo was divided into two pieces length wise with the carpenter's tools like hammer, chisel etc. Each of the two halves was further divided into three pieces. Samples of finished bamboo without GI spiral and 5samples of finished bamboo with GI spiral were taken for tensile test each having the following criteria:

a) Some specimen contained at least 1 knot.
b) Any form of imperfection was avoided.
c) Any undulation was trimmed off.
d) Diameter was measured at four different locations and then the average diameter was calculated.

Fig -1: Specimens used for tensile testing

2.2 Compressive Test

Bamboo cylinders were prepared of 10 cm length throughout the length of bamboo with varying diameter it is to be noted that bamboo samples must be well seasoned and well finished before placing it on UTM for compressive strength of bamboo and about 30 of such samples were created.

Fig -2: Specimens used for Compressive test

2.3 Beam Specimen

Concrete is poured in moulds of 150 mm width, 150 mm depth and 750 mm length. In this research, three types of beam are used namely plain concrete beam, doubly reinforced beam and steel reinforced beam having same dimensions. In plain concrete beam, no bamboo stick is used. Two bamboo sticks are placed at the top and bottom with 1 inch clear cover in the case of doubly reinforced beams. Figure show the dimensions and cross section of sample beams. The resulting concrete is poured in cylindrical moulds of 150 mm diameter and 300 mm height. After casting, the concrete samples are kept in wet place and de-moulded at 24 hours age. They were submerged in open water tank for curing up to 28 days as required for test.

Fig -3: Actual Beam under 3 point bending.

2.4 Concrete Mix Design

IS mix design method used for normal steel reinforced concrete is applied in the preparation of mix design for bamboo reinforced specimens. However, concrete slump are made as low as workability will allow minimizing excess water which causes swelling of the bamboo. Following material used in project.

2.4.1 Water

Water from municipality was used to prepare concrete mix and cure the test specimens.

2.4.2 Cement

Through the investigation, Ordinary Portland Cement (OPC) of Vikrant Cement Factory was used for the concrete mix.

2.4.3 Aggregates

Natural sand and coarse aggregates were used in this test preparation. The sand the aggregate were first washed and dried. Maximum size of 20mm aggregate was used for this test. By sieving the aggregate on 25mm and 4.75mm sieve, the aggregate, that were retained on 25mm and pass 4.75mm sieves were rejected. Similarly the sand was sieved on 9.5mm sieve which were rejected all retained. In the determination of the fineness modulus, gradation, specific gravity, absorption capacity, and compacted unit weight of aggregates procedures outlined in Indian standard were followed.

Procedure for Mixing the Concrete

Concrete mixing operation is performed following Procedure which can be summarized as follows;

1. Coarse aggregate was placed in the mixer,
2. Cement was placed next,
3. Fine aggregate followed and
4. Dry mixing was made for one minute,
5. The water was added continuously as the mixer was rotating,
6. The mixer was operated for about two to three minutes and then finally the mix was stopped and preparation of test specimens was made.

3. TEST RESULT

3.1 Introduction

The results of the tensile tests, compression tests, pullout tests and three point flexural tests performed with Bamboo reinforced concrete for different percentage.

3.2 Tensile Test Results

The first sets of tensile tests are conduct on different species of Bamboo to find a pattern of behaviour based on the structure of Bamboo as a plant. These tests are performing on several specimens with and without nodes. The results two vague patterns. The first pattern observed was that if a node was present, the failure often occurred at the node as shown in Figures 4, which shows test specimens after failure at the nodes. The second pattern observed was that specimens with nodes often held a larger load before reaching failure in contrast to those without a node. Examination of the node structure shows that the fibres in the nodes are much denser than those of the inter-nodal regions. Tensile tests were conducted on Bamboo, which was used as the Main Reinforcement and stirrup reinforcement in the concrete beams. Moso Bamboo was used in the beam tests, so the remainders of the tensile tests are conducted on these types. Some of these samples failed at their nodes while others failed near the grips. Chart 1 displays a load-elongation curve of moso Bamboo samples consisting of both noded and un-noded samples .

Table – 2: Tensile stress of bamboo specimen

Serial	Type	Peak Load(N)	Area (mm2)	Tensile Strength(mpa)
1	I	30730	245	125.40
2	I	30710	245	125.30
3	I	24530	245	100.12
4	I	25970	245	106.00
5	I	24530	245	100.12
6	I	24960	245	101.87

Table – 3: Results of tensile test

Type	Characteristic Strength (Mpa)	Mean Strength (Mpa)	Standard Deviation (Mpa)
I	108.80	114.56	33.04

Fig – 4: splitting failed specimen in tension test

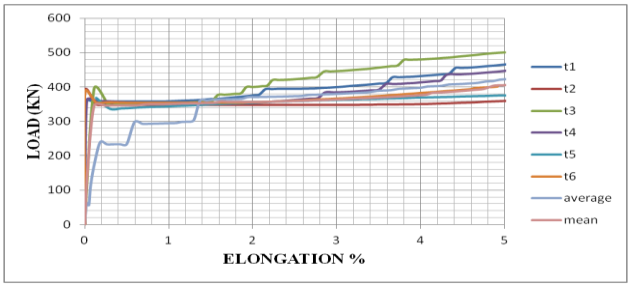

Chart -1: Load v/s Elongation of Tensile Strip

3.3 Compressive Strength Result

Table 05 shows the compressive strength results of cylindrical of 25-30 mm diameter and 100 mm height.

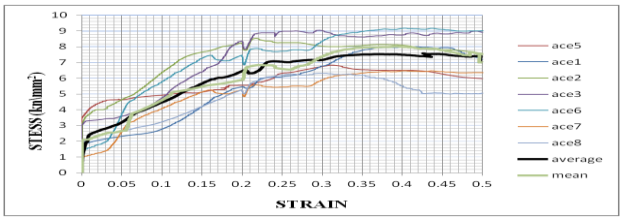

Chart -2: Strain v/s Stress of ACE

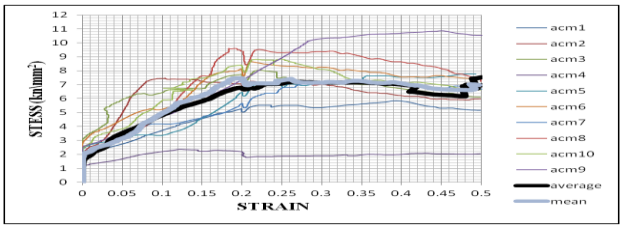

Chart -3: Strain v/s Stress of ACM

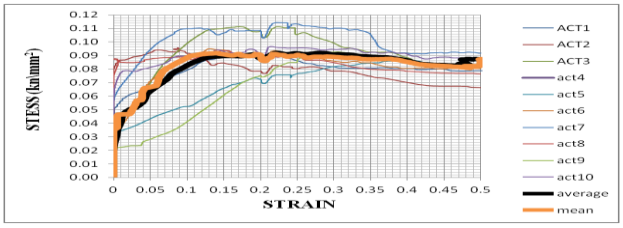

Chart -4: Strain v/s Stress of ACT

Table -4: Mean Results of Compression Test

Type	Characteristic Strength (Mpa)	Mean Strength (Mpa)
TOP	113.04	87.7
MIDDLE	103.8	66.3
BOTTOM	89.90	56.5

3.4 Beam Test Result:

The beam was carefully placed under the testing machine and supports were placed at the measured location of 125 mm inside from each end. After placing the beam, one point loading at the mid-span of the beam was applied gradually by controlled pumping unit. The deflection of the beam at mid-span was measured at regular interval of loading. 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 bond, pure flexural, shear and a combination of shear and flexure types of failures were observed. The flexure and shear combination failure were the most dominating occurrence.

Fig -5: Bamboo Reinforcement Failed Test Specimen-A

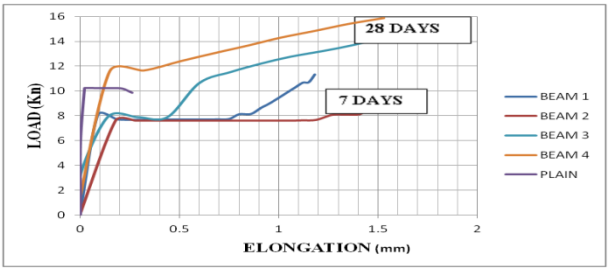

Chart -5: Load v/s Elongation of all Reinforced and plain beam

Table -5: Ultimate load carrying capacity and maximum deflection of Beam specimens

Sample	Ultimate load(KN)	Maximum Deflection(mm)
Plain Concrete	10.25	0.88
Bamboo-1	35.02	1.07
Bamboo-2	45.78	2.03
Bamboo-3	19.06	0.90
Bamboo-4	22.05	0.80
Steel	102.67	5.54

Table -6: Stress and moment of Beam specimens

Sample	Stress (N/mm^2)	Moment (KN-mm)
Plain Concrete	14.80	1.7 x 10^6
Bamboo-1	50.84	6.1x10^6
Bamboo-2	66.40	8.1x10^6
Bamboo-3	27.67	2.7 x10^6
Bamboo-4	32.01	3.2 x10^6
Steel	149.06	17.9x10^6

4. CONCLUSIONS

This work provides bamboo as a potential reinforcement in concrete. From stress-strain curves of bamboo, it can be seen that bamboo possesses low modulus of elasticity compared to steel. So, it cannot prevent cracking of concrete under ultimate load. But from the flexural test of bamboo reinforced beam, it has been seen that using bamboo as reinforcement in concrete can increase the load carrying capacity of beam having the same dimensions. For bamboo reinforced concrete beam, the load carrying capacity increased about 3 times that of plain concrete beam having same dimensions. The maximum deflection of bamboo reinforced concrete beam is about 1.5 that of plain concrete. This thesis concludes that it is possible to use bamboo as reinforcing for masonry structure. Though the tensile strength is about 1/3rd that of steel, this is sufficient for masonry structure and provides a more economical and environment- friendly alternative that is accessible to every section of the society. However, there is still ample scope for research on the subject.

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