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A Study on Bamboo Reinforced Concrete Beams

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Abstract: In today's world construction industry is the highest consumer of the available natural resources, thereby making sustainable development a major issue of concern in order to satisfy the ever increasing demands of the world's inflated population, leading to use of alternate building materials. Bamboo being a natural composite product and due to its many positive aspects such as availability, serviceability, strength and economy can be considered as an alternate building material in place of steel. In this study an attempt has been made to investigate the material properties of locally available species- *Bamboosa Tulda* and its flexural performance in beams as tension reinforcement. An average of 440N/mm^2 of tensile strength was determined experimentally for bamboo splints and a better flexural performance was observed for beams with more numbers of reinforcements and shear links than those without. The test results i.e. flexural strength of 7, 28, and 45 days were taken into consideration for comparison purpose. Moreover remarkable reduction in the mid span deflection in concrete beams was observed when provided with bamboo reinforcements. Hence leaves an option of using bamboo as potential reinforcement in low cost construction.

Key words: *Bamboosa Tulda*, Bamboo reinforced concrete beams, Flexural strength, Tensile strength.

INTRODUCTION

India, one of the most populous countries of the world is house to many sections of people who are below average in case of poverty. Shortage of housing facilities among them due to alarming rate of unaffordability has become a matter of concern in today's Indian scenario. As a matter of fact an attempt has been made to introduce low cost houses which are durable, safe and affordable [3]. Bamboo – one of the oldest construction materials has been considered to have a high tensile strength and is being used as main structural component- reinforcement for these low cost houses.

Bamboo, bearing the scientific name as *BASMBUSA TULDA, BANBUSA BALCONA* etc. is fastest growing woody plant belonging to grass family. Some of these species grow so fast that we can even see them growing. They are capable of growing 60cm or more in a day and can grow up to 30m or more. They can be grown in any climatic condition and soil type which is major factor for considering it. However the growth rate depends on the local climatic condition and soil type. It is considered to be matured after three years of its plantation and it is always advisable to go for matured bamboo for construction purpose. Bamboo is normally considered as organic and to mitigate this problem treatment is given to the bamboo samples to make the free from pest and insect attacks. One of the most important factors to be considered is that it shows its efficiency in climates having at least a little amount of humidity [4].

Many researchers have conducted research on the engineering properties of bamboo and found it suitable to be used as substitution for steel although it has a little less strength than steel.

ENGINEERING PROPERTIES

The mechanical and physical property of bamboo varies from species to species and from soil to soil but still it has average strength properties making it suitable for engineering purpose.

Tensile strength:

Bamboo is very good in tensile strength and it may vary from species to species but an average tensile strength of ¾ to ½ times to that of steel or sometimes even more can be found [2,6,8,9].

Moisture content:

The moisture content in bamboo varies along its height, location and with seasoning period- one of the vital factors in deciding the life of bamboo. The top portion of bamboo has consequently lower moisture content than the middle and the basal portion at any stages of seasoning. Water absorption is inversely proportional to moisture content whereas dimensional changes, tensile and compressive strength is directly proportional to moisture content [11].

Bond strength:

The slippage in reinforcement is prevented by the bond between concrete and the reinforcing material. The factors effecting bond strength are: adhesive properties of the cement matrix, the compressive friction forces appearing on the surface of reinforcing bar due to shrinkage of concrete and the shear resistance of concrete due to surface form and roughness of the reinforcing bar. The dimensional changes of bamboo due to moisture and temperature variation tend to affect all the three bond characteristics severely [1,10].

EXPERIMENATAL PROCEDURE

Locally available species *Bambusa Tulda* was collected and made into splints of 16mm & 20mm respectively. These are then treated with Copper Chrome Boron treatment. And they are then surface dried. Fig 3 shows treatment procedure.

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Fig 2 (a): Plain splints

Fig 2(b) : Tor splints

Fig 1: Cutting of bamboo culms into splints

Fig1, Fig 2(a) and Fig 2(b) shows the cutting and reparation of bamboo splints both in plain and tor formed respectively. Two types of bamboo splints are considered – plain and tor [5].

Fig 3: Bamboo during teatment

These tor splints are then coated with bitumen and sand is sprinkled over them for developing a rough surface to increase the bond strength [3]. Fig 4 and Fig 5 shows the procedure. Caging of the bamboo reinforced beams is prepared providing steel as the stirrup material [7]. Fig 6 shows the caging of the beams.

Fig 4: Providing bitumen coating on bamboo bars

Fig 5: Bitumen coated and sand sprinkled bamboo bars

These samples are then cast in concrete mix of M25 with a water cement ratio of 0.4.

Fig 6: Caging of bamboo reinforced beams

Fig 7: Concreting of bamboo beams.

Fig 8: During casting process

Fig 9: Beams cast

Fig 10: Specimens of bamboo reinforced beams

Fig 7, 8, 9, 10 shows the casting procedure of the prepared bamboo reinforced beams.

TESTS

Tensile Test on bamboo splints

Tensile tests were conducted for the bamboo splints of 16mm and 20mm diameter bars. Due to the problem of slippage the ends of the splints were wrapped in G.I wire, and then they were tested for tension in UTM [8]. Fig11 shows wrapping of G.I wires to the splints. As bamboo splints are not perfectly round, instead of providing the traditional jaws used for HYSD bars flat jaws has been provided in the UTM to get proper grip

Fig 11: Bamboo ends wrapped in wire for tension test

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Fig 12: Failure at the nodal portion

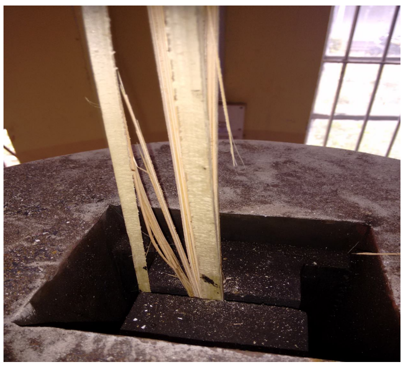

Fig 13: Failure pattern after releasing from grove.

Fig 12 and Fig 13 shows the failure pattern.

Flexure Test

Flexure test were performed on 15 x 15x 70 cm beams and results were tabulated for 7, 28 and 45 days respectively. The beams used for testing were reinforced with 16mm, 20mm bamboo splints both plain and tor. Two different cases – splints without shear links and with shear links were considered [3]. Fig14 shows the four points bent test performed on a flexure testing machine of 100 KN capacities. The midpoint deflection was measured with the help of a deflection dial gauge fitted to an undisturbed horizontal datum bar. Fig 15 shows the failure pattern.

Fig 14: Flexure testing machine

Fig 15: Failure pattern of the beam

Moisture Content Test:

Moisture content of bamboo varies from species to species due to cultivation area, climatic conditions etc. The test for *Bamboosa Tulda* was conducted on treated specimens seasoned for three months [11]. It is found with the following formula:

$$\text{Moisture content (in \%)} = \frac{\text{Initial weight-final}}{\text{Initial weight}}$$

RESULTS AND DISCUSSIONS

Tension Test

From the test it has been evaluated that the tensile strength of bamboo splints were found to be always more than that of mild steel even it extended up to a range of 440 N/mm^2 for a bamboo splint of 16mm diameter. Fig 16 & 17 shows the load versus displacement curve of 16 and 20mm bamboo splints respectively. The corresponding elongations were found to be in the range of 5% to 6%, inevitably this was reflected when beams were cast by providing bamboo reinforcement in different schemes.

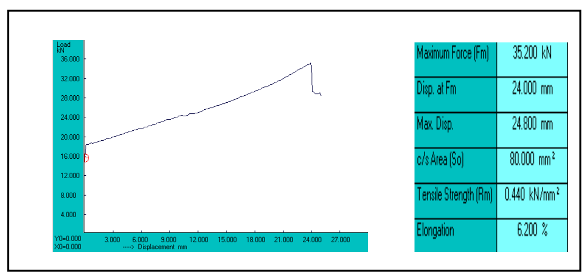

Fig 16: Load vs Displacement curve for 16mm bamboo splints

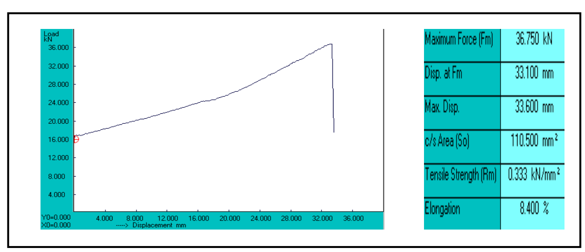

Fig 17: Load vs Displacement curve for 20mm bamboo splints

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Flexure Test

Fig 18 and 19 shows that the more the number of reinforcement the better is the flexural strength even an increase in diameter and addition of shear links also results in better flexural performance. Both plain and tor splints were tested for flexure. The tor bars performed well due to better bond strength with a maximum improvement of flexural strength in 28 days i.e. 1.8 times and minimum improvement of 1.19 times to that of plain unreinforced concrete beam sections.

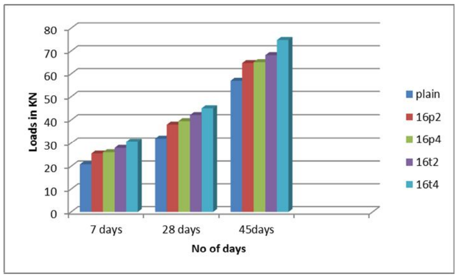

Fig 18: Strength comparison of 16mm bars with respect to plain concrete beams.

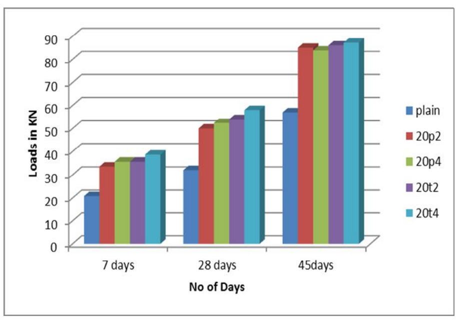

Fig 19: Strength comparison of 20mm bars with respect to plain concrete beams.

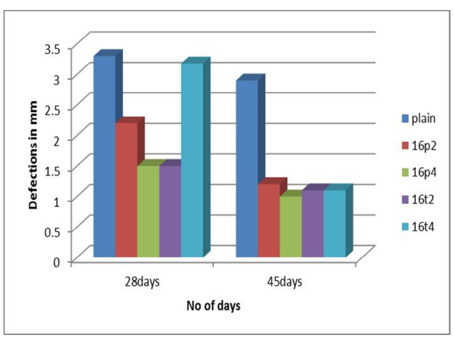

Fig 20: Deflections of beam with 16mm bamboo splints with respect to plain concrete beams

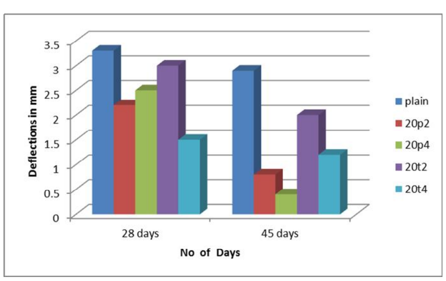

Fig 21: Deflections of beam with 20mm bamboo splints with respect to plain concrete beams

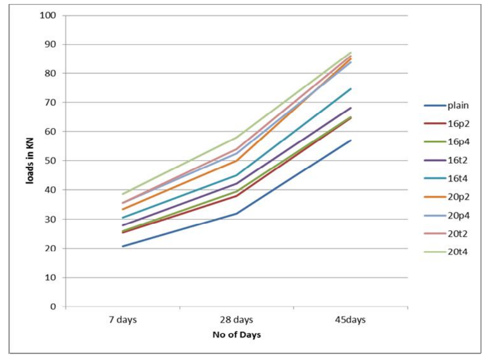

Fig 22: Increase of load pattern with respect to plain concrete beam.

Fig 20 and 21 show comparison of deflections of bamboo reinforced beams with plain unreinforced beam sections. Fig 22 shows a uniform trend has been noticed in the increase in load pattern with respect to that of the plain concrete beam in the corresponding days- 7, 28 and 45 days .

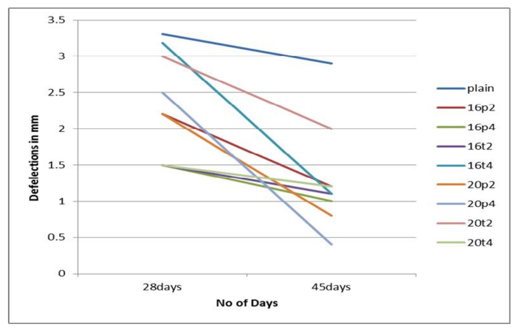

Fig 23: Deflection pattern with resect to plain concrete beam

Fig 23 shows that there is a reduction in the defelection pattern at the mid span section of the beam, thereby showing another positive aspect about the work. However no uniform trend has been observed but the reduction in deflection pattern has been noticed upto 13.7 % of that of original plain concrete beams.

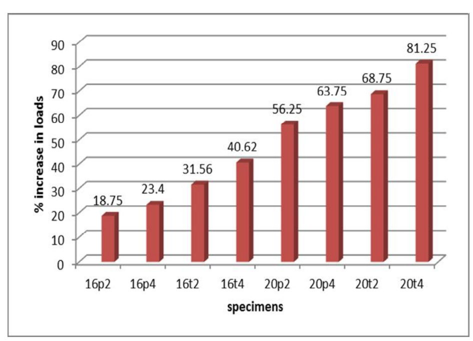

Fig 24: % increase in loads for 28 days

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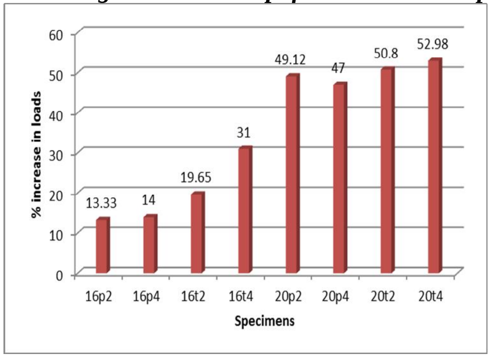

Fig 25: % increase in loads for 45days

Fig 24 and 25 show the increased load pattern with increased in the area for 28 and 45 days.

Moisture Content Test

Initial weight = 16.620g
Final weight =14.760g

$$\text{Moisture content} = \frac{16.620 - 14.720}{16.620}$$

=11.432%

Since moisture content of 11.432% was observed it can be interpreted that the specimen was extracted from top portion of the bamboo.

CONCLUSION

From the results of this experimental work the following conclusion were made:

a) While studying the failure pattern of bamboo splints in tension a sharp peak followed by a sudden fall in the graph has been observed which is due to lack of ductility in bamboo unlike steel – provided by molecular slippage resulting in more elongation percentage. Nevertheless bamboo provides a high tensile strength of about 440 N/mm^2 which actually depends on the species, cultivation area and the cross sectional area.

b) A better flexural performance has been observed with increase in number of reinforcement, diameter of the bars and addition of shear links to the bamboo reinforced beams.

c) A better bond strength has been found in the tor bamboo bars providing an improvement in flexural strength of maximum of 1.81times and a minimum of 1.19 times to that unreinforced beam sections observed in 28 days strength test.

d) Though the prime study was increase in flexural strength but in practical case as the span of beams is more, mid span deflection is an important criterion when serviceability limit state is considered.

Hence the study of bamboo reinforced concrete also illuminates this field – reduction in mid span defection as well as increased flexural strength.

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