Mechanical Properties of Bamboo Fibre Reinforced Concrete

Dr. Shakeel Ahmad, Altamash Raza, and Hina Gupta

***Abstract*—** Concrete is an extensively used construction material for its various advantages such as low cost, availability, fire resistance etc. But it cannot be used alone everywhere because of its low tensile strength. So, generally steel is used to reinforce the concrete. But considering high cost of steel, bamboo is one of the suitable replacements of reinforcing bar in concrete for low cost constructions. Bamboo is natural, cheap, widely available and most importantly strong in both tension and compression. To see the effect of bamboo fibre on compressive and flexure strength, bamboo reinforced Concrete cubes have been tested. On comparing the results with plain concrete cubes, strength becomes double in 50 days testing. Further singly and doubly reinforced beam with bamboo sticks have been cast and tested in flexure. It has been found that there is remarkably increase in the flexural strength and Modulus of elasticity of bamboo reinforced beam.

***Keywords*—**Bamboo fibre, bamboo reinforcement, Bamboo flexural strength, low cost construction.

I. Introduction

BAMBOO is one of the oldest building materials used by mankind. The bamboo culm, or stem, has been made into an extended diversity of products ranging from domestic household products to industrial applications. In Asia, bamboo is quite common for bridges, scaffolding and housing, but it is usually a temporary exterior structural material [7]. In many overly populated regions of the tropics, certain bamboos supply the one suitable material that is sufficiently cheap and plentiful to meet the extensive need for economical housing, a report by [10]. With the advancement of science and technology and the good supply of timber, new methods are needed for the processing of bamboo to make it more durable and more usable in terms of building materials [7]. Reference [4] discussed the mechanical properties of Bamboo, specifically pertaining to Bamboo in concrete. This study showed that the ultimate load of a concrete beam reinforced with Bamboo increased 400% as compared to un-reinforced concrete. Reference [5] studied the mechanical properties of six different types of Bamboo, proper treatments that should be applied to Bamboo, and the methods that should be employed when utilizing Bamboo as concrete reinforcement. Test results showed the ideal value for the percentage of Bamboo in concrete to be 3%f the cross-sectional area of concrete beam, allowing for the highest applied load, and the necessity for drying and water repellant treatments. This study concluded that Bamboo can substitute steel satisfactorily, and that there is a need to establish the characteristic strength of Bamboo for design purposes. Reference [13] suggested not to use green, unseasoned Bamboo for general construction, nor to use un-waterproofed Bamboo in concrete. It concludes that Bamboo reinforced concrete is a potential alternative light construction method at a low cost. Reference [8] gave a detailed description of the mechanical properties of Bamboo in their study. They found that the physical, as well as mechanical properties vary with respect to diameter, length, age, type, position along culm, and moisture content of Bamboo. Reference [2] also investigated the mechanical and physical properties of Bamboo. They conducted a thorough investigation into the structure and purposes of the nodes, which they found to strengthen the Bamboo culm. They also commented on the advantage Bamboo has over other natural building materials with its fast growth rate. Reference [9] found that the Bamboo reinforcement area should be 5 times the typical steel reinforcement area, and that even when fine cracks develop on the surface of Bamboo, the load carrying capacity of the member is not reduced. The only negative properties of Bamboo given are its susceptibility to attack by insects, fungi and dried bamboo is prone to catch fire. Reference [3] studied that the fracture properties of Bamboo depend upon the origin of fracture. Reference [12] researched the remarkable current uses of Bamboo around the world. Bamboo is also still being looked at as a way to clean environmental pollution. It is a consumer of Nitrogen, which could soon be part of a huge effort to prevent air pollution. Reference [11] had done some important work in the area of natural fibre concrete. They had studied the durability of natural fibre concrete composites using mechanical strength and micro structural properties. Naturally and locally available materials such as jute, coir and bamboo fibre can well be used as natural fibre reinforced concrete composites. One more study reported in [6] fashioned a lab manual for determining the physical and mechanical properties of Bamboo. The purpose for publishing this manual is that these methods are available all over the world.

Dr. Shakeel Ahmad (Professor), is with the Civil Engineering Department, Aligarh Muslim, Aligarh, India (corresponding author's phone: 9412877550 ; e-mail: shakeel60in@yahoo.co.in).

Altamash Raza, is with the Civil Engineering Department, King Saud University, Mazahmia branch, phone; 0531279486 (e-mail: altamash.civil@gmail.com).

Hina Gupta, is with the Civil Engineering Department, Aligarh Muslim , Aligarh, India (e-mail: hina15gupta@gmail.com).

II. Experimental Work

In this experimental program two sets of experiment have been conducted one on cubes and other on beams.

1. Concrete cubes reinforced with 1% bamboo fibre by volume have been tested in compression testing machine and stress -strain curve has been plotted. The results have been compared with plain concrete cubes.

2. Concrete beams reinforced with bamboo sticks at top and at top and bottom both have been cast and tested in flexure (pure bending). Four point bending test has been conducted and load deflection curve has been plotted. The results are compared with same dimension beam without any reinforcement.

TABLE I
DIFFERENT SIZES OF BAMBOO FIBRES

S.no.	Size	Code
1	1mmx15mmx5mm	A1
2	1mmx20mmx5mm	A2
3	1mmx25mmx5mm	A3
4	2mmx15mmx5mm	B1
5	2mmx20mmx5mm	B2
6	2mmx25mmx5mm	B3
7	3mmx15mmx7mm	C1
8	3mmx20mmx7mm	C2
9	3mmx25mmx7mm	C3

Tests have been conducted to assess the properties of material used in the experimental program; the results are summarized in Table II.

TABLE II
PROPERTIES OF MATERIAL USED

	Cement	
1	Normal consistency	30%.
2	Initial setting time	32 minutes
3	Compressive strength	32.50 N/mm^2
4	Tensile strength (after 7 days)	2.55 N/mm^2
	Aggregates	
1	Fineness modulus of fine aggregate (Badarpur sand)	3.60
2	Bulk density of 20 mm coarse aggregate	1529 kg/m^3
3	Specific gravity of coarse aggregate	2.68
	Mix Design	
1	Grade of concrete	M20
2	Mix design ratio	1:1.56:3.24
3	Water cement ratio	0.48
	Bamboo	
1	Density of Bamboo fibre	1483.33kg/m^3

Nine different sizes (Table I) of bamboo fibres have been selected to cast 15cm cube with 1% bamboo fibres. 3 samples of concrete cube for each size of fibre have been casted. The bamboo fibres were immersed in different solutions like coal tar, water, grease and lethal solution, minimum deterioration of bamboo was in "Lethal anti termite solution" [1]. Before mixing the fibres in concrete, all fibres were immersed in lethal anti termite solution (Fig.1).

Overall 9 combinations have been taken. For each combination 3 cubes have been casted for testing. Therefore 27 cubes have been casted with different sizes of fibres, and three plain concrete cubes have also been casted for comparison of results. Different sizes of bamboo fibres and their nomenclature are shown in Table I and Bamboo fibres (after treatment with anti-termite solution) of size 3mmx15mmx7mm are shown in Fig 2.

Fig. 1 Bamboo fibres in lethal anti termite solution

Fig. 2 Bamboo fibres of size 3mmx15mmx7mm, after treatment

Testing of Cubes: All cubes have been tested for crushing strength in compression after 28 days of curing and 1 day of drying but two cubes with fibre (A2) and (B3) have been tested after 28 days of curing and 22 days of drying to see the effect of ageing. Load has been applied gradually in the steps of 5KN and longitudinal deflections have been recorded. The experimental sets up are shown in Fig 3.

Fig. 3 Concrete cube with fibres B_1 under compression

Testing of bamboo reinforced concrete beams:

Bamboo sticks of approximate area 200mm^2 have been taken and they have been tested for yield strength in universal testing machine and the average yield strength of bamboo stick is found to be 104 N/mm$^{2.}$

Fig. 4 Bamboo stick under tension in universal testing machine

In this experimental program the bamboo sticks have been first coated with coal tar [4] then sand is poured on it to make bamboo water proof and to improve bond between bamboo and concrete, Fig 5 and Fig 6.

Fig. 5 Bamboo sticks before treatment.

Fig.6 Bamboo sticks after treatment with coal tar.

Beams have been cast in wooden moulds of internal dimension 750mmx150mmx150mm as shown in Fig 7. Three beams without any reinforcements, three beams with bamboo stick as reinforcement at bottom and three beams with bamboo reinforcement at top and bottom both have been cast. Steel stirrups have been used at spacing of 175mm for doubly reinforced beam. These beams have been kept for 28 days curing in curing tank.

Fig.7 Concrete and bamboo stick in the mould

Beams have been tested in pure bending as shown in Fig. 8

Fig.8 Setup for testing of bamboo reinforced beam in pure bending

III. Analysis of Results

The cubes after 28 days of curing is marginally increase in ultimate strength of concrete by reinforcing it with bamboo fibres. The reason for this low strength at early stage may be due to weak bond between bamboo fibres and concrete in early days. The fibres surface friction must be increased to see the effect. Due to lack of time, it could not be done. The stress strain curve for bamboo reinforced concrete cube is almost linear showing the elastic behavior. The results show that modulus of elasticity of concrete increases on addition of bamboo fibres. For plain concrete it has been found to be 23.30kN/mm^2 whereas for fibres reinforced concrete it gains as high as 47.62kN/mm^2. The Stress Strain curve for plain concrete cube and concrete cube with fibres (C_3) are shown in Fig 9 and Fig 10 respectively.

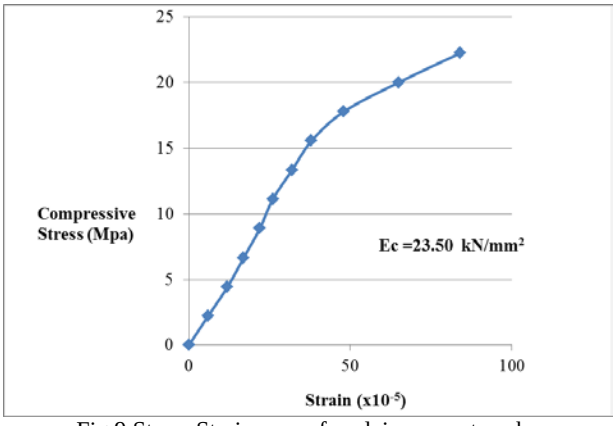

Fig.9 Stress Strain curve for plain concrete cube

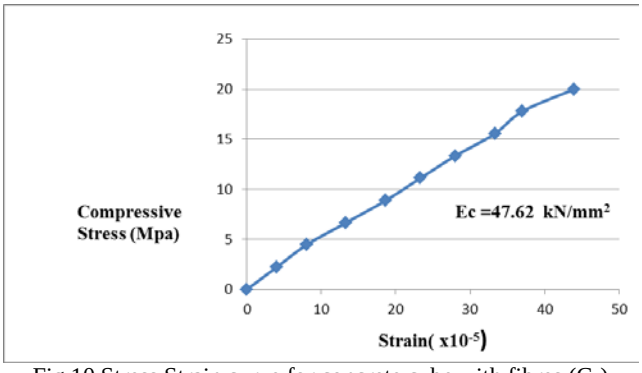

Fig.10 Stress Strain curve for concrete cube with fibres (C_3)

The test results on beam show that the flexural strength of beam increases when we use bamboo stick as reinforcement in concrete. The flexural strength of doubly bamboo reinforced beam reach upto 80MPa as compare to 48MPa for concrete beam without any reinforcements (Table III). The load deflection curve for plain beam, singly reinforced beam and doubly reinforced beam are shown in Fig 11 to Fig 13. The maximum deflection at the mid span reaches up to 1mm approx.

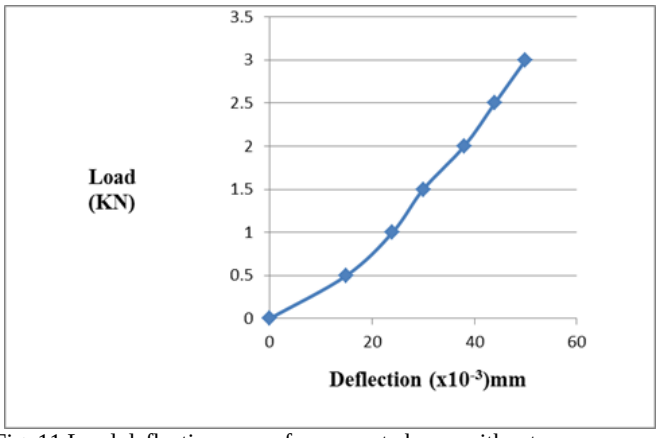

Fig. 11 Load deflection curve for concrete beam without any reinforcement

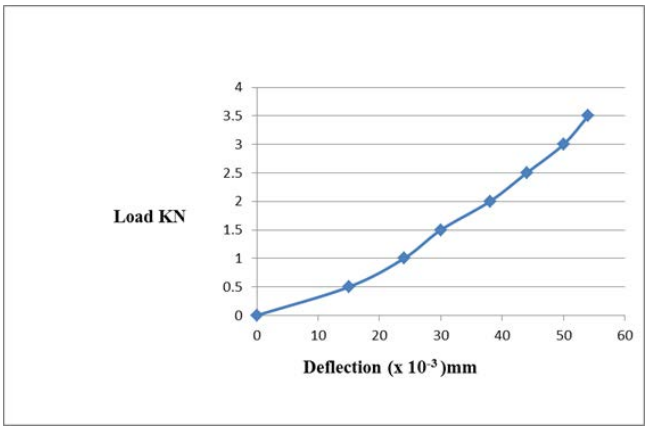

Fig. 12 Load deflection curve for singly bamboo reinforced concrete beam

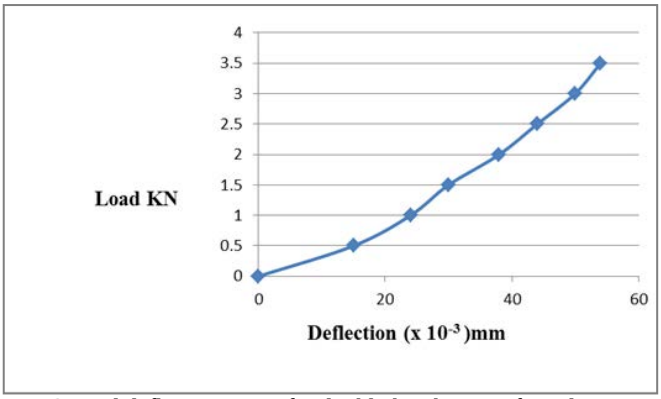

Fig. 13 Load deflection curve for doubly bamboo reinforced concrete beam

TABLE III
RESULTS OF BEAM TESTED IN FLEXURE

Types of beam	Ultimate Load (kN)	Maximum Deflection (x10^{-2})mm	Flexural Strength (MPa)
Plain concrete beam	3.0	56	48
Singly bamboo reinforced beam	3.5	54	56
Doubly bamboo reinforced concrete beam	5.0	98	80

IV. CONCLUSIONS

Based upon the tests conducted, the following conclusions have been drawn:

1) The strength of concrete cubes with fibres doesn't show much improvement up to 28 days but surprisingly strength become double in 50 days testing.
2) Modulus of elasticity of concrete increases by addition of bamboo fibres.
3) The flexural strength of bamboo reinforced beam increases as high as nearly doubled, so bamboo reinforced beam can be used in low cost buildings.
4) Bamboo fibres can be used as replacement with concrete which can save the expensive concrete, 10000cm3 per 1m3 of concrete.

REFRENCES

[1] N. Alam, "Pure friction base isolation system using foundry slag cement mortar" M.Tech thesis presented to Z.H.C.E.T ,A.M.U Aligarh,2011.

[2] S. Amada, Y. Ichikawa, T. Munekata, Y. Nagase, and H. Shimizu, "Fiber Texture and Mechanical Graded Structure of Bamboo", Composites Part B, Vol. 28B, pp 13-20, 1997. http://dx.doi.org/10.1016/S1359-8368(96)00020-0

[3] S. Amada and S. Untao, "Fracture Properties of Bamboo", Composites Part B, Vol. 32, pp 451-459, 2001. http://dx.doi.org/10.1016/S1359-8368(01)00022-1

[4] K. Ghavami, "Ultimate Load Behavior of Bamboo-Reinforced Lightweight Concrete Beams", Cement & Concrete Composites, Vol. 17, pp 281-288, 1995. http://dx.doi.org/10.1016/0958-9465(95)00018-8

[5] K. Ghavami, "Bamboo as Reinforcement in Structural Concrete Elements", Cement & Concrete Composites, 2004.

[6] ISO (International Standard Organization), "Laboratory Manual on Testing Methods for Determination of Physical and Mechanical Designing and Building with Bamboo", TC 165 N315, 1999.

[7] Latif, Tarmeze and. Fauzidah, "Anatomical features and mechanical properties of three Malaysian bamboos". Journal Tropical Forest Science 2(3): 227-234, 1990.

[8] Lo, Cuo and Leung ,"The Effect of Fiber Density on Strength Capacity of Bamboo", Materials Letter, Vol. 58, pp 2595-2598, 2004. http://dx.doi.org/10.1016/j.matlet.2004.03.029

[9] Masani, "Studies on Bamboo Concrete Composite Construction", 1997.

[10] McClure, "The bamboos, A fresh perspective". Harvard University Press. Cambridge, Massachusetts, 1967.

[11] M. Sivaraja, Kandaswamy, N. Velmani and M. Sudhakaran, " Study on durability of natural fibre concrete composites using mechanical strength and microstructural properties". Bull. Mater. Sci., Vol. 33, No. 6. pp. 719–729. Indian Academy of Sciences, 2005.

[12] C. Steinfeld ,"A Bamboo Future", Environmental Design and Construct, pp 1-5, 2001.

[13] U.S. Naval Civil Engineering Laboratory, "Bamboo Reinforced Concrete construction." Bamboo Reinforced Concrete, pp. 1-19, 1966, 2000