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RESEARCH PAPER

Strength analysis of bamboo and steel reinforced concrete beam

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ABSTRACT

Bamboo possesses excellent strength properties that are as good as other building materials like steel, concrete and timber; therefore bamboo is widely used in the construction industry as reinforced material for reinforcement of concrete, for columns and as propping system for supporting structures in construction industry. The average flexural strength of unreinforced concrete beam (mass concrete) after 28 days curing period was found to be 5.73 MPa. The average flexural strength of steel reinforced concrete beam after 28 days curing period was found to be 11.39 MPa. The average flexural strength of singly bamboo strip reinforced concrete beam after 28 days curing period was found to be 8.69 MPa. The average flexural strength of doubly bamboo strip reinforced concrete beam after 28 days curing period was found to be 12.38 MPa. Cracking moment for beam found to be 7.22 kN-m. Flexural strength of bamboo is good and can be used as reinforcement in R.C.C. structure for low cost housing.

KEY WORDS : Strength analysis, Bamboo, Steel reinforced concrete bean

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INTRODUCTION

In India, the enormous diversity of soil and climatic conditions exists in different climatic zones. Thus, it is possible to cultivate various tropical and sub-tropical weeds successfully. The most valuable, strong and fast growing grass among all weeds is bamboo.

Bamboo grows most abundantly in the orient where it is native to China, Burma, India, Japan, Europe and Canada. India has annual bamboo production as 4.5 million tones. In Maharashtra bamboo production is 2,47,239 tones. The Konkan region contributes 70,000 tones of bamboo production (Choudhary, 2008). The two most widely distributed genera in India are *Bambusa* and *Dendrocalamus.*

Bamboo is used to design of scaffolding, for construction of frame work, to manufacture furniture, for making clothing fabrics, for construction of building to withstand earthquake. In addition, bamboo is used for the manufacture of wooden flooring panels, support in traditional housing and for the construction of framework. Among the many uses, bamboo is an important construction material, such as scaffolding, bridges, shelters, towers and for simple and modern engineered structures.

Concrete is widely used as 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. Though steel has a high tensile strength to complement the low tensile strength of concrete, use of steel should be limited since it is very costly and also so much energy consuming in manufacturing process.

Thus, a suitable substitute of this with a low cost, environment friendly and less energy consuming one is a global concern. Addressing all these problems bamboo is one of the suitable replacement for steel. Tensile strength of bamboo is high and can attain 370 MPa, which makes bamboo an attractive substitute to steel in tensile loading applications.

A high demand of owning houses in India is increasing, thus it should be a major concern to provide the people an alternative, which will reduce the cost of houses. Urgent and effective action is required to secure the demand in sustainable basis. To tackle the problem use of bamboo as reinforcement is among the alternatives as the price of steel is increasing high.

This study is prepared to assist field personnel in the design and construction of bamboo reinforced construction mainly for low-cost houses. The tensile strength of bamboo is very high and can reach 370 N/mm^2. This makes bamboo an alternative to steel in tensile loading applications. This is due to the fact that the ratio of tensile strength to specific weight of bamboo is six times greater than that of steel.

The objective of the study was to determine the flexural strength of bamboo reinforced and steel reinforced concrete beam.

Masani (1977) conducted an in-depth study outlining the proper ways to utilize bamboo in construction. It was 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. Ghavami (1995) showed that the ultimate load of a concrete beam reinforced with bamboo increased 400 per cent as compared to un-reinforced concrete. It was found that, compared to steel, there was lower bonding between the bamboo and concrete, and the bamboo had an Modulus of elasticity 1/15 of steel.

Amada and Untao (2001) stated that the tensile strength of bamboo fibres almost corresponds to that of steel. A prototype of bamboo reinforced concrete house was constructed and used an earthquake simulator to find that the house stood sound during a 7.8 (on the Richter scale) earthquake. They found no cracking in the concrete, the bamboo to be extremely resilient to earthquakes, and the cost to be split in half compared to mud-and-brick construction.

Musbau *et al.* (2012) studied that the tensile stress of seasoned bamboo is about 70 N/mm^2, about one third of that of steel, with low ductility and a total strain of 5 per cent compared with an average strain in steel 12 per cent. The use of bamboo-strip as reinforcement in concrete column increased the load carrying capacity of the column compared to unreinforced concrete.

Rahman *et al.* (2011) noted that using bamboo as reinforcement in concrete can increases the load carrying capacity of beam having the same dimensions.

Sakaray *et al.* (2012) found that bond stress of bamboo with concrete is very low compared to HYSD of steel can reduce carbon dioxide emissions.

IS code (456 : 2000) state that, nominal cover for mild steel concrete should be 20 mm. The concrete grade used for reinforced work should be M15 grade and above. As workability of concrete increases with increase in size of coarse aggregates. Coarse aggregates used for reinforced concrete work should be maximum of size 20 mm also fineness modulus of cement should be within 4-5 and that of sand is 3-4.

Preparation of beam samples :

The testing was conducted on three different types of specimens and three specimens were prepared for each type. The dimension of each specimen was 500 mm × 100 mm × 100 mm and M15 grade concrete (1:2:4) grade was used. The three types of test specimens were;

- Specimens consisting of no reinforcement (mass concrete).
- Specimens consisting of 6 mm diameter steel reinforcement.
- Specimens consisting of 18 mm width bamboo reinforcement.

Flexural strength test :

Flexural strength test will be conducted on specimens of bamboo to obtain the ultimate bending strength. A mid

span loading method was conducted by using Universal testing machine. The ultimate bending strength of the test given by :

$$\sigma Z \frac{My}{I}$$

where,

σ = the ultimate bending strength in MPa

M = bending moment, N-mm

y = distance between neutral axis and extreme

I = the moment of inertia in mm^4.

EXPERIMENTAL PROCEDURE

The *Dendrocalamus stocksii* (Mes) variety of bamboo samples was used for present study. Bamboo splits used for the project having thickness 16 mm and 28 mm wide.

Coarse aggregates used for this project of size 20 mm. As per IS 456:2000 coarse aggregates used in reinforced concrete work should be of size 20 mm.

Sand used for this project is natural river sand. Ordinary Portland cement is used for this concrete work. Steel reinforcement is generally in the form of round bars of mild steel. Diameter of bar used is of 5 mm of grade Fe250. Reinforcement is placed in cement concrete to take up tensile forces. The water which is used for making concrete should be clean. Used with 1:2 ratio while preparing concrete mixture.

Universal testing machine (Fig. A) was used for measurement of Flexural strength of reinforced beam samples (Fig. B).

Universal testing machine :

The concrete surfaces are kept wet for a certain period after placing of concrete so as to promote the hardening

Fig. A : Universal testing machine

Fig. B : Singly reinforced beam and testing

of cement. It consists of control of temperature and of the moisture movement from and into concrete. The strength of concrete gradually increases with age with proper curing. Prepared samples are kept in curing for 28 days period.

EXPERIMENTAL FINDINGS AND ANALYSIS

The findings of the present study as well as relevant discussion have been presented under following heads :

Performance evaluation of concrete specimens :

The observations were recorded after 28 days from concrete beam making. Data was analyzed to find suitability of bamboo as reinforcement in the concrete work.

Specimens consisting of no reinforcement (Mass concrete) :

It is also observed from this test that unreinforced specimens failed suddenly at a very small load. Because concrete is weak in tension and when the load is gradually applied it fails suddenly. The observations of load applied are presented in Table 1.

It was found that flexural strength for mass concrete beam was 5.73 MPa. Also failure obtains at very low load. It was also observed from this test that steel reinforced specimens take time for failure. Due to gradual application of load on the steel reinforced beam it bends after load applied which is beyond its limit. Concrete is weak in tension but reinforced steel is good in tension hence load is distributed to the steel. The average flexural strength for steel

Table 1 : Flexural strength

Replications	Mass concrete	Flexural strength, MPa		
		Steel reinforced concrete beam	Singly bamboo reinforced concrete beam	Doubly bamboo reinforced concrete beam
1.	5.18	11.12	8.24	12.95
	5.76	12.42	8.95	12.12
	6.12	11.77	10.77	11.65
2.	5.06	7.41	8.12	11.18
	5.65	12.48	8.59	14.00
	6.59	13.13	7.47	12.36
Average	5.73	11.39	8.69	12.38

reinforced beam was obtained 11.39 MPa. Also the load require for failure of beam is higher than mass concrete. During test it was seen that the singly reinforced bamboo concrete specimens remain uncracked and have large stiffness until the moment reaches the cracking moment. When the cracking moment is reached the member cracked and the stiffness at the cracked section is reduced. As the load is increased further; the more cracks occurred and existing cracks increased in size. Eventually, the reinforcement yielded. It was observed that mean flexural strength of singly reinforced concrete beam is 8.69 MPa. During test it was seen that doubly bamboo reinforced concrete specimen remains uncracked and have a large stiffness until the moment reaches the cracking moment. In this type of beam bamboos are embedded in the concrete in such a way that tension forces needed for the moment equilibrium after the concrete cracks can be taken care by in the bamboo bars and it showed better result while loading. Flexural strength relies on the transfer of tensile force. It is observed that the average flexural strength of doubly reinforced concrete beam is 12.38 MPa.

Conclusion :

The study concluded that bamboo cannot prevent cracking of concrete under ultimate load but from flexural test of bamboo reinforced beam, it has been seen that using bamboo reinforcement in concrete can increase the load carrying capacity of beam having same dimensions. The singly bamboo reinforced concrete beam the load carrying capacity increased by 1.5 times and that for doubly bamboo reinforced concrete beam 2 times than that of mass concrete beam having same dimension. Thus, flexural strength of bamboo is good and can be used as reinforcement in R.C.C. structure for low cost housing.

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