Research Article

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Bamboo as an Alternative to Steel for Green Construction towards Low Cost Housing

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ABSTRACT

In India largest number of population is living in rural areas or they are villagers. These people are working at small scales to fulfill their livelihood and most of them are living in small houses. In such conditions low cost housing could be the best option and usage of bamboo as construction material can play a key role to achieve the goal. Several researchers are working towards the economical and ecofriendly or green construction. To give attention in this regard an experimental study was performed using bamboo as the replacement of steel. In this research paper with the help of experimental investigations the mechanical properties of bamboo reinforced concrete has been presented in terms of compressive strength, split tensile strength and flexural strength.

Keywords: Bamboo reinforced concrete; Compressive strength; Split tensile strength; Flexural strength.

1. INTRODUCTION

As per the area, India is counted one of the largest countries in the world and a large area of the country is under developing stage. The primary need of the people living in rural areas is a shed to live in. Due to low availability of conventional materials (like steel) in remote areas and also because of high costs, it becomes difficult to use this material in construction, also the income of the people living in remote areas is not much and hike in prices of these materials is also a factor which affects their dream to live in good home.

In construction and demolition the use of technology has changed, new methods, advanced equipments are available and also the use of materials has changed which were used from ages. Owing to these factors for economical and green construction, bamboo reinforcement can be one of the major substitutes of steel for concrete reinforcement. The availability and price of this material for remote area people would be affordable. The adaptation of bamboo as reinforcement material in concrete can help in reducing the high demand of steel reinforcement.

In this research paper, bamboo is used as replacement of steel in concrete and the mechanical properties of concrete were compared with traditional concrete. Laboratory experiments were performed to check the reliable use of bamboo as replacement of steel in concrete showing its compressive, tensile and flexural strength by means of bamboo reinforced concrete for green construction.

2. REVIEW OF LITERATURE

Mahzuz *et al.* (2011) Reported that the shear strength of bamboo reinforcement in concrete reveals that concrete members reinforced with sections of bamboo culms, which had been split along their horizontal axes, developed considerably higher load capacities than unreinforced concrete beams of similar sections. The ductility of tension bamboo reinforcement is low and failure of beams is characterized by splitting of concrete from the tension reinforcement and brittle failure. The shear capacity is enhanced by increased amount tension reinforcement and addition of web reinforcement.

Terai and Minami (2012) Investigated that the tensile strength filled with cement paste cured w/c=80% and 100% significantly increase with aging time. The behavior of pull-out test with bamboo is almost the same as the plain steel bar; however, the bond strength with bamboo was higher than the one with plain steel bar. It can be expected that the bond strength covering with full treatment shows the high value 1.2-1.35 MPa. Bamboo reinforced concrete slab: When fresh concrete is poured, its water will moisten the bamboo; then, the concrete will harden and lose water so that the bamboo will again dry out. This drying process will completely break any bond between the bamboo and the concrete. It can be considered that underground humidity is high at any times therefore supply of water to the concrete can be accomplished.

Nayak *et al.* (2013) Concluded that this is a good idea for low cost economical structure. Bamboo reinforcement technique is used for both main and distribution reinforcement as it was same earlier done for steel reinforcement. It is three times cheaper then steel reinforcement technique. It is clear from results that this bamboo reinforcement technique is absolutely cheaper then steel reinforcement technique especially for single story structure.

Ahmad *et al.* (2014) Observed that the strength of concrete cubes with fibre doesn't show much improvement up to 28 days but surprisingly strength become double in 50 days testing. Modulus of elasticity of concrete increases with the increase of bamboo fibre. The flexural strength of bamboo reinforced beam increases as high as nearly doubled, so bamboo reinforced beam can be used in low cost buildings. Bamboo fibre can be used as replacement with concrete which can save the expensive concrete, 10000 cm^3 per 1 m^3 of concrete.

Naznin and Chetiya (2015) Found that 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. 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. A better bond strength has been found in the tor bamboo bars providing an improvement in flexural strength of maximum of 1.81 times and a minimum of 1.19 times to that unreinforced beam sections observed in 28 days strength test.

Ghavami (1995) investigated the mechanical properties of Bamboo, specifically pertaining to Bamboo in concrete. His study showed that the ultimate load of a concrete beam reinforced with Bamboo increased 400% 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 a Modulus of elasticity 1/15 of steel. Bamboo's compressive strength was much lower than its tensile strength, and there was high strength along the fibers, but a low strength transverse to the fibres. He stated that there is a need for the development of a simple design code for the application of Bamboo as a construction material.

Amada *et al.* (1997) studied 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.

Masani (1977) conducted an in-depth study outlining the proper ways to utilize Bamboo in construction. A listing of the positive aspects of Bamboo is given, citing examples pertaining to its economical, mechanical, and environmental properties. When used as reinforcement in concrete, directions are given to insure a better performance, including discussions on waterproofing, pressure-treating, concrete design, and beam design. They 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.

Mardjono (1998) provided research with the effort to give some sort of organization of a system to building with Bamboo between cultures, species, and countries having varying designs. The objective of their research was to improve the functions of Bamboo buildings by this organization to provide privacy, safety, comfort, durability, and accessibility. Overall Bamboo used as a structural material suffers from an incredible disadvantage due to inadequate applied scientific research. They do feel that Bamboo products should be brought to the level of acknowledged and received building materials. The results of their research will be published as a thesis and guide for designing Bamboo structures to be dispersed to people in developing countries.

3. MATERIALS & METHODS

With the aim to investigate the compressive strength, split tensile strength and flexural strength of bamboo reinforcing, 9 beams of size 150 mm x 150 mm x 750 mm were cast for the testing of flexural strength after moist curing at 7, 14 and 28 days respectively. 36 cylinders of size 150 mm diameter and 500 mm height were cast to study the compressive and split tensile strength after moist curing at 7, 14 and 28 days respectively.

M 20 grade of concrete was prepared with the proportion of 1:1.5:3 using Pozzolana Portland Cement of prism brand obtained from single batch throughout the investigation. Fine aggregate which is passes through 4.75 mm sieve and with specific gravity 2.2 and fineness modulus 2.84 were used. Course aggregate of 10 mm and 20 mm size were used with specific gravity 2.66. The water cement ratio (w/c) was taken as 0.54. The concrete mix design was nominal mix in accordance with IS 10262 (1982), cement content was 380 kg/m^3. The shape and size of bamboo available is quite large and needs to be reduced therefore it is cut down into rectangular

sections of size 20 mm wide, 10 mm thick and 710 mm length for beams and 20 mm wide, 10 mm thick and 280 mm length for cylinders respectively.

In traditional reinforced concrete, placement of steel bars is arranged as per the bar bending schedule and are binded to each other with binding wires thus replacing it with bamboo also requires proper arrangements and are required to bind with each other.

4. RESULT & DISCUSSION

In this section, a comparative studies has been demonstrated in terms of compressive, split tensile and flexure strength of PCC as well as bamboo reinforced concrete.

Average compressive strength of bamboo reinforced concrete at 28 days, 14 days and 7 days were found as 23.21 N/mm^2, 21.5 N/mm^2 and 20.38 N/mm^2 respectively. However, the average compressive strength for PCC at 28 days, 14 days and 7 days were obtained as 20.9 N/mm^2, 19.7 N/mm^2 and 18.5 N/mm^2 respectively. The result shows a plunging rise in the compressive strength of approximately 10 to 15 % when the concrete is reinforced with bamboo (Fig. 1). This alarming emanation provided an approach to work towards making a low cost and environment friendly construction building using bamboo reinforcement as well which may result into an enhanced strength parameters along with their reduced construction cost.

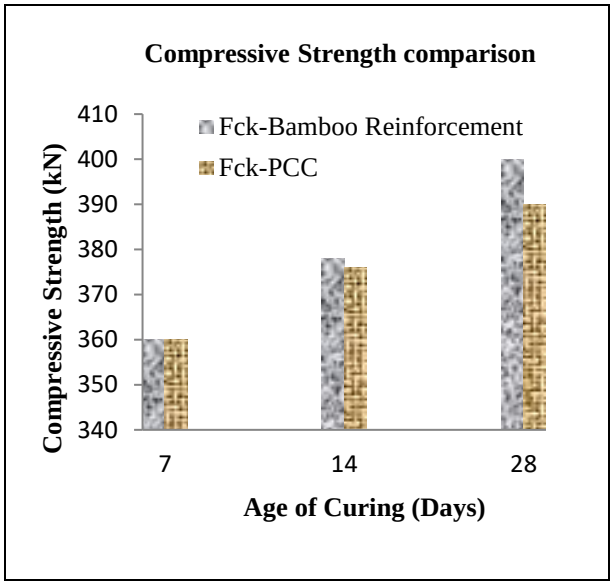

Fig. 1: Compressive Strength comparison for Bamboo as well as PCC concrete.

Table 1. Compressive strength for PCC as well as bamboo reinforced concrete.

S. No.	Compressive strength of bamboo reinforcement (kN)			Compressive strength of PCC (kN)		
	7 days	14 days	28 days	7 days	14 days	28 days
1.	360	380	410	322	348	360
2.	350	376	400	326	446	364
3.	370	384	420	330	350	378
Average	360	380	410	326	348	368

Table 2. Split tensile strength for PCC as well as bamboo reinforced concrete.

S. No.	Split Tensile strength of bamboo reinforcement (kN)			Split Tensile strength of PCC (kN)		
	7 days	14 days	28 days	7 days	14 days	28 days
1.	370	378	390	350	370	390
2.	360	376	400	370	376	386
3.	350	380	410	360	382	394
Average	360	378	400	360	376	390

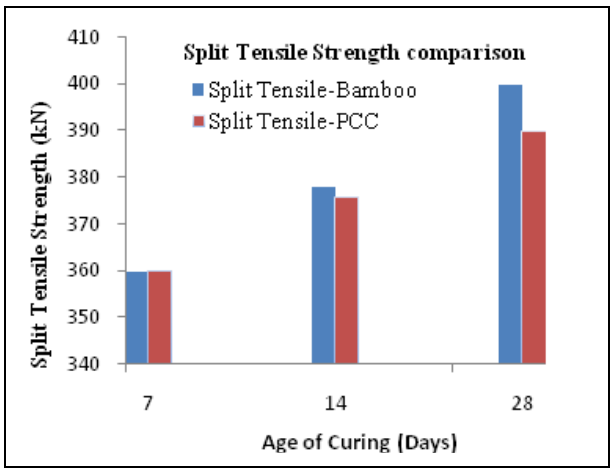

Fig. 2: Split Tensile strength comparison for bamboo as well as PCC concrete.

Average Split Tensile strength at 28 days, 14 days and 7 days are 1.69 N/mm^2, 1.61 N/mm^2 and 1.53 N/mm^2 respectively for bamboo reinforcement. Average Split Tensile strength at 28 days, 14 days and 7 days are 1.67 N/mm^2, 1.59 N/mm^2 and 1.53 N/mm^2 respectively for PCC (Fig. 2).

However the results of split tensile strength for both the cases are almost similar but are distinct in their magnitudes which clearly distinguish about the dominant effects of bamboo reinforcement in the concrete. To some extent the values have been magnified.

Table 3: Flexural strength for bamboo reinforced concrete.

S. No.	Flexural strength of bamboo reinforcement (kN)		
	7 days	14 days	28 days
1.	32	40	50
2.	30	45	55
3.	28	35	45
Average	30	40	50

Average Flexure strength at 28 days, 14 days and 7 days were found as 16.66 N/mm^2, 13.33 N/mm^2 and 10 N/mm^2 respectively for the concrete formed using bamboo reinforcement (Fig. 3).

These results show the significant enhancement in compressive strength and flexural strength of bamboo reinforced concrete as compared to plane cement concrete. The split tensile strength was slightly same in bamboo reinforced concrete and plane concrete, the reason for slightly same result due to failure is taking place in concrete others wise the tensile strength of the bamboo is also high.

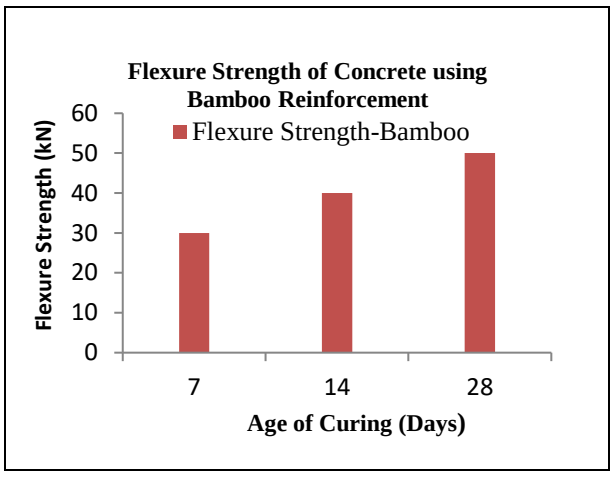

Fig. 3: Flexure strength of concrete using bamboo reinforcement.

4. CONCLUSIONS

Given results shows the satisfactory anticipation and possibilities of using bamboo reinforcement as a replacement of steel reinforcement in concrete structures may be feasible in terms of low cost green construction. Other factor like strength of the bamboo reinforced concrete is also increasing with the age. In the field of green construction use of bamboo as steel replacement where the availability of steel material is low and also the cost is high can be the better solution. It is also suggested that the involvement of bamboo in green construction can lower the use of steel and can become one of the best solution with limited resources in remote areas for needy people.

Despite of the long tradition of building with bamboo, the material is not used frequently in modern building constructions. In the past years architects have been using bamboo in different ways in their designs. From interior finishes to bamboo constructions the application of bamboo in design is still developing and there are more new applications to be expected. Materials that are used in green design are always assessed for their environmental impact. Bamboo can replace concrete, steel or wood, depending on the situation and the application, although more built examples and dissemination is needed. Bamboo has been proved to be a versatile material because of its high strength-to-weight ratio, easy workability and availability. The positive attributes of Bamboo are its environment-friendly nature. But there are some negative attributes of Bamboo which has also been identified in the past researches, focusing on its tendency to absorb water. Of those, the bonding between the Bamboo and concrete is considered the biggest problem due to absorption of water and smooth wall of the Bamboo Culm. This aspect can be a source of future research and there is a need for the development of a simple design code for the application of Bamboo as a Construction material.

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CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

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