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Research paper

Strength Characteristics of Bamboo Reinforced Slabs

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Abstract

The construction industry consumes large quantities of composite materials, such as steel, cement and other binding materials. This process emits enormous volume of carbon dioxide leading to global warming and other environmental degradation. As an alternative to steel, bamboo, rattan cane and other agricultural products have been used as reinforcement in different parts of world. However, the application of this non fossil-fuel products has not been exploited to greater extent. In the present study the use of bamboo (bambusa vulgaris) has been adopted as an alternative to steel in fabricating slabs of dimension 1500 mm x 500 mm x 75 mm (length x breadth x thickness). M25 grade with water cement ratio as 0.5 was used. The slabs were tested using Non-Destructive Tests to determine the quality of concrete adopted. Subsequently, destructive tests were carried using a loading frame of capacity 1000 kN. The non-destructive tests and destructive tests were repeated on steel reinforced slabs and control slabs (without any reinforcement). The results indicate that the bamboo reinforced slabs comparatively weaker with respect to steel reinforced slabs and stronger with respect to control slabs. Therefore, it is recommended to adopt BRC slabs for low cost dwellings.

Keywords: *Bamboo, steel, reinforcement, Non-destructive test, control slabs.*

1. Introduction

The pioneering investigation by Glenn (Glenn, 1950) and the subsequent research work by Francis and Paul (1966) have led to significant application of bamboo as an alternative to steel. Manufacturing of one ton of steel generates, two ton of carbon dioxide. It has been observed that producing steel requires 50 times more energy than that required for bamboo (Devi and Nuralinah, 2016). The construction industry is the single most contributor in producing carbon dioxide (CO_2) due to the involvement of fossil fuels (steel and cement). One of the significant advantages of bamboo is that it absorbs carbon dioxide (CO_2) and generates oxygen ?, making it as an environmentally sustainable building material. Among all the varieties of bamboo available all over the world, three types of bamboo are being widely used in the construction industry due to their strength characteristics. These are: (i) bambusa vulgaris (ii) bambusa balcooa and (iii) dendrocalamus strictus. These types of bamboo are harvested for various applications during 3 to 4 years of their age. These varieties are widely grown in south-east Asia, in countries like China, India and Sri Lanka (Suppiah and Venugopal, 2015). Importantly, south-east Asia is one of the most populated region in the world demanding low-cost dwellings to a larger extent.
In the present study, bamboo (bambusa vulgaris) of 3 to 4 years of age was used for casting of 1500 mm x 500 mm x 75 mm (length x width x thickness) slabs. This type of bamboo which is yellow in colour was harvested in Kerala (India).
Preparing slabs with bambusa vulgaris for low-cost dwellings and evaluating the strength characteristics of the panels cast is the main objective of this study. The findings of this investigation will lead to sustainable growth and a reduction in global warming with less demand for fossil fuel and fulfilling the demands of housing requirement to some extent.

2. Previous Studies

Many studies have been performed with bamboo as an alternative to steel which is based on fossil fuel. A few of the pioneering study, worthy of note is Glenn (1950), Francis and Paul (1966), Low (1988), Janssen (1991), Ghavami (1995, 2005). The relationship between water-cement ratio and tensile strength of bamboo has been reported by Terai and Minami (2012). They concluded that the tensile strength increased with aging time when the cement paste was cured at w/c = 80% and 100%. Interestingly, they used untreated bamboo.
Nayak et al (2013) investigated the performance of bamboo reinforced one way slab of size 3000mm by 2000mm and concluded that using bamboo was cheaper by as many as three times when used as an alternative to steel. Different shapes of bamboo culms e.g., circular, square and triangular had been used as reinforcement in testing of slabs of dimensions 1000mm x 1000mm x 50mm by Khan (2014). The important finding was that load carrying capacity of square shaped bamboo reinforcement was higher than the other two shapes. Imbulana et al (2013) conducted a literature survey on the application of bamboo as a reinforcing material in structural applications and concluded that as much as 60% savings had been noticed when compared to steel. A study by Suppiah and Venugopal (2015) shows that bamboo has been used as reinforcement in fence walls.

In addition, adopting bamboo as reinforcement leads to a saving of cost of the order of 35 to 40%. Interestingly, many varieties of bamboo grow in many parts of the world with least effort. Among the different varieties of bamboo, bambusa vulgaris, popularly known as 'Chinese bamboo' is being widely used as scaffolding in the construction industry due to its strength characteristics.

3. Experimental Investigation

The different stages of construction related to bamboo reinforced slabs are shown in Fig. 1. In the present study, slabs of dimension 1500 mm x 500 mm x 75 mm (length x width x thickness) were cast for light-weight applications, with bamboo (bambusa vulgaris) as reinforcement. This variety of bamboo is also called 'Chinese bamboo' and has been found in the South region of India.

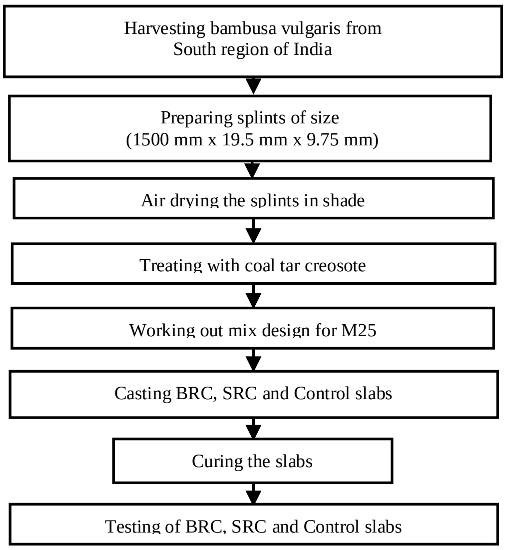

Fig. 1: Flow chart showing the different stages of casting.

Bamboo splints of size 1500 mm x 19.5 mm x 9.75 mm (length x width x thickness) were cut and air-dried in shade without exposing to direct sunlight, for a period of four weeks. Bamboo in its natural state consists of starch and utilizing as reinforcement without any treatment reduces the bond strength and forms fungi (Suppiah and Venugopal, 2015). Thus, the air-dried splints were soaked in coal tar creosote for about 24 hour and excess solution was drained out by keeping the splints in a vertical position.

3.1. Strength Characteristics of Bamboo Splints

The tensile strength of bamboo splints was determined in a Universal Testing Machine (model: TUN 400). Two type of bamboo splints were tested namely, (i) untreated splints and (ii) splints treated with coal tar creosote.

3.2. Preparation of Bamboo Reinforced Concrete (BRC) Slabs

M25 mix ratio was adopted in preparing the BRC panels. The quantity and the characteristics of the various materials used are shown in Table 1. The codal provisions prescribed in IS: 456-2000 and IS: 10262-2009 have been followed in preparing the BRC panels.

Table 1: Details of Mix-Design

Sl. No.	Parameter	Value
1.	Mix-ratio	M25
2.	Type of cement (OPC)	43 grade
3.	Specific gravity of cement	3.15
4.	Specific gravity of fine aggregate	2.65
5.	Specific gravity of coarse aggregate	2.68
6.	28-day compressive strength (N/mm^2)	24
7.	Cement (kg)	383
8.	Fine aggregate (kg)	727
9.	Coarse aggregate (kg)	1103
10.	Water/cement ratio	0.45
11.	Unit weight of BRC (kg/m^3)	2400

3.2.1. Laboratory Tests on Steel Reinforced and Control Slabs

The various tests performed on BRC slabs were repeated on SRC (Steel Reinforced Concrete) slabs and control slabs as well to study the behaviour of all the three types. The control slabs did not have any reinforcement.

4. Results and Discussion

4.1. Tensile Test on Bamboo Splints

The tensile strength values recorded on bamboo splints are presented in Table 2 which shows that the bamboo splints treated with coal tar creosote yielded the tensile strength (mean) value of the order of 195.03 N/mm^2. This value is higher by 10.54% than the strength of untreated splints.

Table 2: Tensile strength of bamboo splints

Sl. No.	Tensile strength of splints (N/mm^2)	
	Untreated	Treated with coal tar creosote
1.	152.08	176.56
2.	194.52	212.91
3.	176.83	195.54
Mean	*174.47*	*195.03*

4.2. Non-Destructive Tests

4.2.1. Ultrasonic Pulse Velocity Tests

This type of test (make: PUNDIT) was performed on all the three types of slabs to assess the quality of the concrete used. The velocity values were measured by 'direct method'. This method ensures the maximum transmission of signal between the transducers (Proceq, 2011). The velocity values recorded are shown in Table 3

Table 3: Ultrasonic Pulse Velocity Values

Sl. No.	**Ultrasonic pulse velocity** (m/sec)		
	BRC slab	SRC slab	Control slab
1.	4241	4383	3849
2.	4250	4454	3856
3.	4248	4355	3819
Mean	*4246.3*	*4397.3*	*3841.3*

Among all the slabs tested the minimum velocity of the order of 3841.3 m/sec in control slab and the maximum value of 4397.3 m/sec in SRC slab were recorded. The velocity values indicate that 'good' quality of concrete has been used in fabricating all the type of slabs (Shetty, 2012).

4.2.2. Rebound Hammer Tests

As part of NDT, rebound hammer was used to assess the compressive strength. The compressive strength values recorded for the three type of slabs are shown in Table 4. From this table it can be observed that the lowest value of the order of 15.39N/mm^2 was recorded on control slabs and the highest value of the order of 21.56N/mm^2 recorded on SRC slabs. Interestingly, BRC slabs yielded intermediate value of the order of 17.42N/mm^2.

Table 4: Rebound Hammer Test Values

Sl. No.	Compressive strength (N/mm^2)		
	BRC slab	**SRC slab**	**Control slab**
1.	25.44	27.38	22.56
2.	24.71	27.71	22.20
3.	25.98	28.43	22.66
mean	***25.37***	***27.84***	***22.47***

4.2.3. Compression Tests on Slabs

The compression tests performed on all type of slabs using UTM showed that cracks emanated from any one corner and extended towards the centre of the slab. The maximum load and the corresponding deflection values recorded are given in Table 5. The flexural strength values presented show that BRC slabs yielded intermediate (mean) value of the order of 4.35N/mm^2.[22]

Table 5: Maximum Values of Load Versus Deflection

Sl. No.	Type of reinforcement	Unit weight (kN/m^3)	Maximum deflection (mm)	Load at maximum crack (kN)	Flexural strength (N/mm^2)
1.	Bamboo	2225	26	24.5	3.77
2.		2256	28	25.3	3.89
3.		2215	29	26	4.00
5.	Steel	2426	28	22	4.37
6.		2478	29	24	4.34
7.		2492	27	26	4.46

4.2.4. Load versus Deflection

The load versus deflection curves of all the three types of slabs are presented in Fig. 2. From which it can be seen that SRC slabs have the lowest deflection value and the highest load values whereas the control slabs yielded the highest deflection and the lowest load carrying capacity. The BRC slabs yielded the intermediate values of load and deflection.[23]

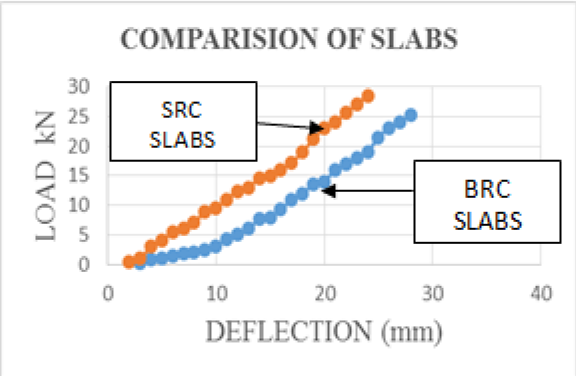

Fig. 2: Load versus deflection for all type of slabs

5. Conclusion

Bamboo is being used a construction material since prehistory days mostly for scaffolding work. Nevertheless, bamboo as a replacement for steel is meagre in application. This paper presents the feasibility of adopting bamboo (bambusa vulgaris) as an alternative to steel in construction, such as partition wall, cow barn, and other low cost applications. Based on the extensive testing work the following conclusions are drawn at:

1. Bambusa vulgaris family can be successfully used a replacement for steel in low cost construction.
2. Treating of bamboo with coal tar creosote increases the strength characteristics and retards the attack of fungi.
3. Bamboo reinforced panels yield higher deflection and lower load carrying capacity values than the steel reinforced panels of the same dimensions.

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