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Application of Bamboo reinforcement in Structural Concrete elements as a sustainable and green building material

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ABSTRACT

Bamboo is a low-cost, environmentally friendly, and renewable building material that grows abundantly in Indonesia. Bamboo has a high tensile strength but also has flaws, such as being easily attacked by insects and having a high water absorption rate. Because of the increasing unaffordability of housing in urban India, it is logical to consider alternative technologies for their application. The goal of this study is to provide a complete information for a safe and durable house that is affordable to the urban poor using bamboo as one of the primary structural materials. Modular system architecture has the potential to provide increased flexibility in function allocation, lower development costs, and improved maintainability. The utilization of bamboo reinforcement as replacement of steel reinforcement is gaining immense importance today, mainly on account of the improvement in the economical aspect combined with ecological benefits. Bamboo has the advantages of being inexpensive, flexible, and durable (a light weight material).

Keywords: Sustainable Development, Bamboo Architecture, Architecture Modular System Design, Architecture for the Environment

INTRODUCTION

In recent years, steel prices have soared. For developing countries, steel is difficult to obtain because of expensive prices, and for the construction industry, usage of steel is currently limited heavily. The production of steel has high consumption of fossil fuels, so, the steel discharge in the construction of structures has been presented, showing the possibility of drastic reduction by research institutes.

As per the recent report (National Cement Consumption, CAGR 2017-2021), the cement production growth has been reported to be more than 5% in many developing countries across the globe leading to the huge production of greenhouse gases. Cement production alone contributes 4-5% of the total worldwide emission of carbon-dioxide. Similarly, for steel, the demand was observed to be about 1648 million tonnes (Accessed on worldsteel.org) across the globe. Also, the extraction of raw materials causes the degradation of land, loss of agricultural land, dust and noise pollution. In addition to this, the transportation of these raw materials results in vehicle pollution, noise pollution and excessive consumption of fuel further deteriorating the environment.

Thus, there is a requirement for alternative sustainable materials such as bamboo, jute, fly ash, rice husk, straw bales, recycled aggregates, palm oil shell, etc. Considerable research is focused on such unconventional building materials which are cost effective and are sustainable.

Bamboo is one such sustainable building material which has higher than six times the strength by weight ratio comparable with steel (Ghavami, 2005). The amount of CO2 emission in the atmosphere in case of bamboo is 50 times less as compared to steel and cement. Further, bamboo also consumes around 1 tonne of carbon dioxide during its growth phase (Xiao et al., 2013; Sharma et al., 2014). However, there are different issues such as properties variation across species, bond strength development in concrete, treatment processes involved in the application of bamboo in the form of reinforcement in concrete.

BAMBOO AS REINFORCEMENT IN CONCRETE

The United States Naval Civil Engineering Laboratory (1966) reported a study providing a set of instructions on how to properly construct a variety of structures using Bamboo. It was recommended in the report that the amount of Bamboo reinforcement in concrete be 3 to 4% of the concrete's cross-sectional area as the optimum amount.

Advantages of bamboo comparable to mild steel include

- High tensile strength, The tensile strength of bamboo can reach 370 MPa in its outer fibers
- Fast growth rate of up to 91cm per day (Guinness world record)
- Low cost
- Less weight
- Energy efficient

  Bamboo has been used as a building material in village areas from decades.

Out of all the advantages and benefits associated with bamboo, there are also some issues.

- The first one being the durability. The bamboo strips tend to get weak and splits over a considerable period of time due to absorption of water.
- The second disadvantage is the decomposition of bamboo because the aqueous concrete is alkaline in nature.
- The third disadvantage is that the bond strength between bamboo and concrete is not good enough because of the inadequate chemical and mechanical action between the two at the interface (Mali and Datta, 2018).
- It is affected by the fungus and termite attacks as it has a high content of nutrients.

Fig 1-Preparation of grooved bamboo reinforcement

Fig 2-Preparation of plain bamboo reinforcement.

Materials Used

Cement: The binding materials used in concrete are Ordinary Portland cement. This cement is of grades conforming to IS 456-2000 and is having desired properties.

Sand: Fine aggregate used is M-sand. The sand should be free from any impurities such as vegetation, large stones etc.

Coarse aggregate: The coarse aggregate for the work is crushed stone. Angular shape aggregate of size is 20mm and below. The aggregate which passes through 75mm sieve and retain on 4.75mm are known as coarse aggregate. The grading of coarse aggregates should be as per specifications of IS 383-1970.

Water: Water is an important ingredient of concrete. It gives strength to cement and workability to the concrete. Potable water is used for casting and curing.

Bamboo: Some species of bamboo have ultimate tensile strength same as that of mild steel at yield point. Experimentally, it has been found that the ultimate tensile strength of bamboo is comparable to that of mild steel & it varies from 140 N/mm2 to 280 N/mm2.

Table 1-Some specific properties of bamboo

Specific gravity	0.575 to 0.655
Modulus of elasticity	1.5 to 2.0 x 105 kg/cm^2
Ultimate compressive stress	794 to 894 kg/cm^2
Safe working stress in tension	160 to 350 kg/ cm^2
Safe working stress in shear	115 to 180 kg/cm^2
Safe working stress in compression	105 kg/ cm^2
Bond stress	5.6 kg/cm^2

TREATMENT OF BAMBOO REINFORCED CONCRETE

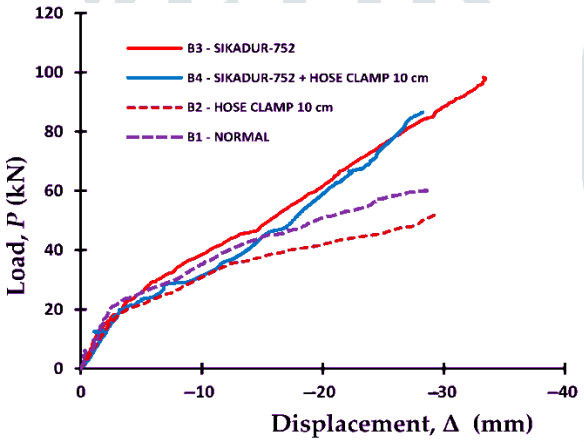
The pull-out of bamboo reinforcement with a layer of Sikadur®-752 and hose clamps embedded in a concrete cylinder, showing an increase in tensile stress of up to 240% compared to untreated bamboo reinforced concrete (BRC).

The various chemical treatments used were Araldite, Araldite with binding wire, Tapecrete P-151, Anti Corr RC, and Sikadur 32 Gel. They also reported that Sikadur 32 Gel gave the highest values of bond strength for bamboo and concrete (Agarwal et al., 2014). In 2016, Javadian et al. observed the bond strength between bamboo and concrete by using water-based epoxy coating, TrueGrip EP, TrueGrip BP, and Exaphen coating.

Drying bamboo is fundamental to its conservation for various reasons. Bamboo with low humidity is less prone to mould attacks especially when humidity content is less than 15%. Physical and mechanical properties of bamboo increase with a decrease in its humidity content. Bamboo to be treated with a preservative needs to be dry to facilitate penetration and obtain a better result and reducing transport costs. Bamboo can be dried in air, green house, and oven or by fire.

Bamboo as a concrete reinforcement must be treated beforehand, such as immersion in water drying in free air applying a waterproof layer and sprinkled with sand, to modify the roughness of the bamboo reinforcement. Usage of the adhesive or waterproof coating can be done in various ways, such as paint Sikadur 32 Gel and Sikadur®-752.

Strengthening of bamboo reinforcement with adhesive or waterproof coating can increase the bond
stress of bamboo reinforcement. Modification of the roughness of the bamboo reinforcement with adhesive, sand, and hose clamp can increase the bond stress and capacity of the bamboo reinforced concrete beam (BRC beam).The relationship between load vs displacement is shown in Figure 3.



Preparation of reinforcement

Step 1. Take bamboo from the soaking.

Step 2. Drying bamboo in free air.

Step 3. Give a waterproof coating

Step 4. Sand sprinkling on bamboo reinforcement.

Figure 5- Stringing the bamboo reinforcement

The bamboo to be used must be treated with the following steps:

(a) The bamboo must be cut and split close to the size of the bamboo reinforcement to be used.
(b) The bamboo must be soaked in water for one to two months to remove the sugar content and prevent termites and insects
(c) It should be dried in free air until the moisture content is approximately 12%
(d) The bamboo reinforcement should be trimmed with a grinding machine according to the specified size
(e) One should provide a waterproof layer to reduce the occurrence of the hydrolysis process between the bamboo and concrete
(f) Do sand sprinkling to modify the roughness of the bamboo reinforcement
(g) Stringing the bamboo reinforcement

CONSTRUCTION PRINCIPLES

In general, techniques used in conventional reinforced concrete construction need not he changed when bamboo is to be used for reinforcement.

1- Concrete Mix Proportions - The same mix designs can be used as would normally be used with steel reinforced concrete. Concrete slump should be as low as workability will allow. Excess water causes swelling of the bamboo. High early-strength cement is preferred to minimize cracks caused by swelling of bamboo when seasoned bamboo cannot be waterproofed.

2- Placement of bamboo- Bamboo reinforcement should not be placed less than 1.5 inches from the face of the concrete surface. When using whole culms, the top and bottom of the stems should be alternated in every row and the nodes or collars, should be staggered. This will insure a fairly uniform cross section of the bamboo. Throughout the length of the member, and the wedging effect obtained at the nodes will materially increase the bond between concrete and bamboo. The clear spacing between bamboo rods or splints should not be less than the maximum size aggregate plus 0.25 inch. Reinforcement should be evenly spaced and lashed together on short sticks placed at right angles to the main reinforcement. When more than one layer is required, the layers

should also be tied together. Ties should preferably be made with wire in important members. For secondary members, ties can be made with vegetation strips.

Bamboo must be securely tied down before placing the concrete. It should be fixed at regular intervals of 3 to 4 feet to prevent it from floating up in the concrete during placement and vibration. In flexural members continuous, one-half to two-thirds of the bottom longitudinal reinforcement should be bent up near the supports. This is especially recommended in members continuous over several supports.

3- Concrete slabs with bamboo permanent shutter forms

Bamboo finds an efficient application in concrete slabs reinforced with half bamboo sections, which work as permanent shutter forms. A half split DG bamboo culm, which works as a tensile reinforcing bar and also as a permanent shutter form, schematically shown in Fig a , was filled with concrete as can be seen in Fig. b In all cases the internal parts of bamboo were treated with a thin coat of Sikadur 32-Gel as shown in Fig. a.

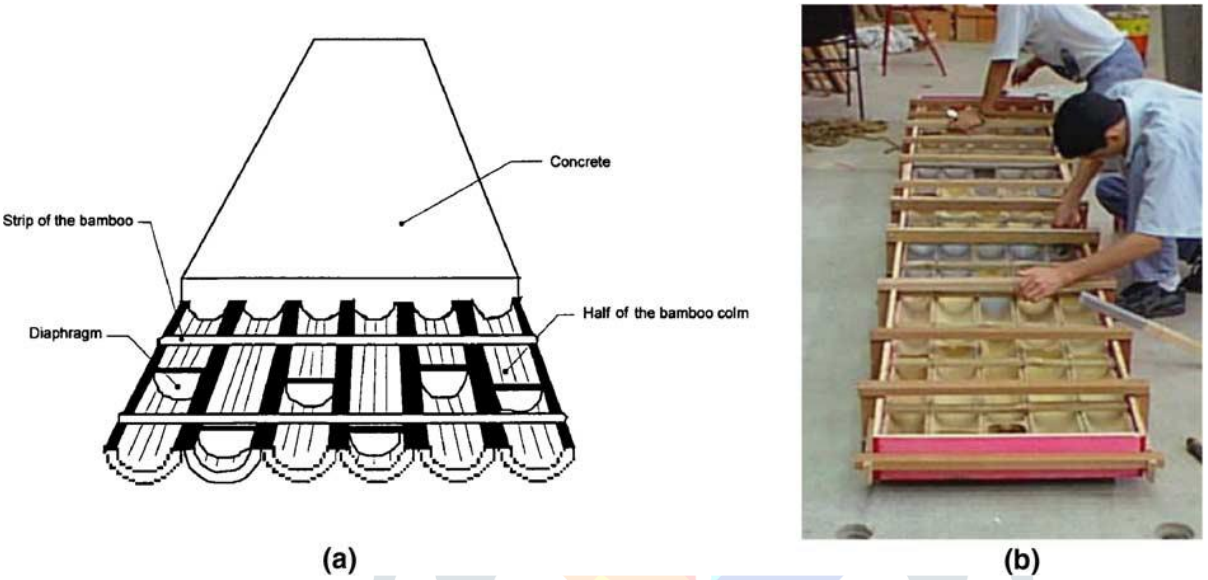


Fig- Concrete slabs reinforced with bamboo permanent shutter forms (a) Schematic set up of the slab. (b) Bamboo of slab during treatment.

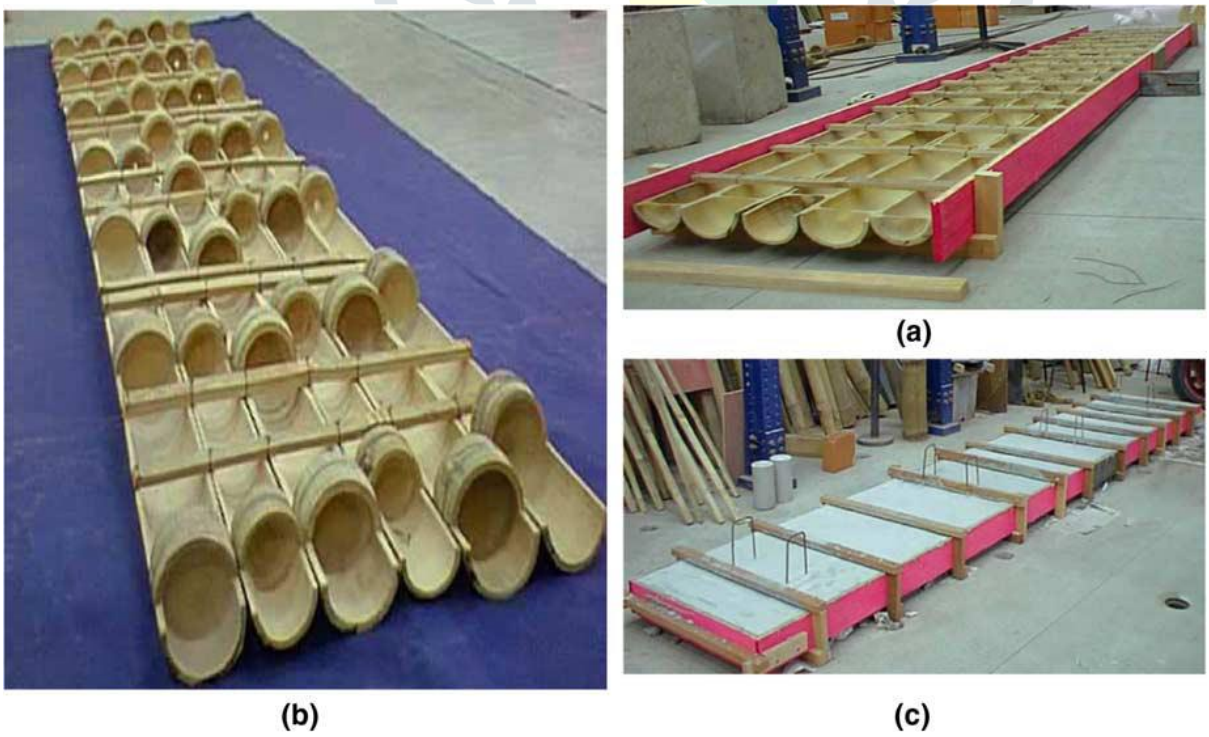


Fig- Concrete slabs reinforced with bamboo permanent shutter forms. (a) Half bamboo diaphragm as connector. (b) Second type of connector (c) Slab before testing

The shear resistance of whole and half bamboo diaphragms of specie DG has been studied. For the half bamboo its shear strength has been found to be 10.89MPa with a standard deviation of 2.56MPa.
Although the bamboo diaphragm creates a composite interaction between bamboo and concrete, its shear resistance is not sufficient enough to prevent its shear failure.

SPECIFICATION

Providing & Fixing Bamboo reinforcement with Adhesive layers of Sikadur®-752 for BRC including material, fabricating as required, transporting, storing, straightening, cutting, bending, spirally hooping and placing in position at all levels, including all labour, equipments, supplies, incidentals, sampling and testing as prescribed including all charges thereon for requisite tests, supervision and binding with approved quality steel rebar ties. Bamboo shall be in approved color, texture and finish, having Performance Appraisal Certificate (PAC) issued by Building materials & Technology Promotion Council (BMTPC). Hose-clamp d = 0.75 attached to the end of the bamboo reinforcement instead of hooks. Bamboo wood shall have minimum density of 1000 Kilogram/cum & minimum Hardness 1000 Kilogram with Eco friendly UV coating, all complete as per direction of Engineer in-charge.

CONCLUSION

Environmental concerns have broadened during the last two decades. Initially it meant to analyse visible catastrophes such as a dying forest or dead fish on a shore and we slowly came to realize that any excessive or inefficient consumption of resources is in fact an abuse of the environment.
Bamboo is a versatile material because of its high strength-to-weight ratio, easy workability and availability. The replacement of steel with bamboo as reinforcement shows that reinforcement with bamboo is quite cheaper than that of steel reinforcement. 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. 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 1.2-1.35MPa.

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