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EXPERIMENTAL STUDY ON BAMBOO REINFORCED CONCRETE

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Abstract

The present project deals with new improvements to bamboo as a reinforcement material instead of steel reinforcement. Like the bond strength of concrete and bamboo using different materials. Flexural test findings indicate a major increase in compressive strength and flexural strength of bamboo-reinforced concrete as compared to plain cement concrete. Also deals with the cost-wise comparison of steel reinforcement with bamboo reinforcement. It is potentially superior to steel in terms of its weight-to-strength ratio. However, the bond strength is a major concern for bamboo to be a reinforcement in structural composites. The goal of this project is to investigate the bonding properties of a newly developed bamboo-reinforcement composite in concrete, through pull-out tests and also flexural strength. Compared with other materials including steel, the tensile resistance property which is the main requirement of reinforcing material is considered appreciable for bamboo. Working on bamboo's weak points and bringing up bamboo innovation as a replacement for structural steel would be a great alternative. The bond strength test is conducted on half-bamboo splints. Bamboo splints are first coated with oil paint and then dry sand is sprinkled on samples. This coating will further ensure that bamboo specimens will remain water-repellent and thus helps in better bonding with concrete. M30 grade concrete mix is used for the entire casting of cubes embedded with prepared half-bamboo splints. The current study basically aims at conducting bond strength through a pull-out test. Further, this study and the outcome of tests are used in evaluating the flexural strength of bamboo-reinforced concrete beams by performing a two-point loading test on

Keywords: Bamboo reinforcement, Bond strength, Flexural strength, Composite materials

1. Introduction

Bamboo is a grass belonging to Gramineae family, distributed in tropical, subtropical and mild temperate zones between approximately 46° north and 47° south latitude [1] belong to

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grass family and are columnar rather than tapering in nature. Fastest growing plants in the world having growth up to 60 cm or more in a day [2]. The height of bamboo plant can go up to 40 m and it still stands against the wind pressure [2]. It is light weight, flexible, tough, high tensile, cheap material than the other building materials like steel. It is potentially superior to steel in terms of its weight to strength ratio. Recently, bamboos are used as reinforcing material in concrete and to make framing, shoring, scaffolding flooring, walls, roofs and trusses

According to the Restructured National Bamboo Mission approved by the Cabinet Committee on Economic Affairs (CCEA) on 25-04-2018. Bamboo covers a 13.96-million-hectare area with 136 species in India

The bamboo culm, or stem, has been made into an extended diversity of products ranging from domestic household products to industrial applications. Bamboo is quite common for bridges, scaffolding and housing, but it is usually used as a temporary exterior structural material. 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.

Steel reinforced concrete has been one of the most successful innovations in the structural industry since its inception in the 19th century. Concrete has remarkable properties that made it the most widely used construction material in the world. Concrete has exceptional compressive strength per unit cost and is durable with low maintenance requirements, and can be cast in a variety of shapes (McCormac and Brown, 2014). The more expensive of the two, steel, is used to compensate for the main weakness of concrete of low tensile strength. Another reason for the success of this combination is the relative affordability of steel in comparison with any metal. Iron, the main constituent of steel, ‘’is the least expensive and most widely used metal’’ (USGS, 2019). While Fibre Reinforced Polymers (FRP) can provide similar mechanical properties and superior durability to steel, it has a prohibitively higher cost (see Burgoyne and Balafas (2007))

The implementation of various technologies used in the field of RCC construction have not been changed since the time steel in the form of reinforcement was introduced and codes were developed to use it in various conditions and in several manners in load bearing structural members. Whatever the reason being behind this trend is surely the immense

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strength of steel but for smaller structures, where little strength is required as compared to 14 the high rise structures to tackle self-weight as well as the loads that amount to a huge magnitude because of numerous floors. The structures that are not meant to be put under loads of magnitudes this high can be built with an alternative of steel that can bear loads up to certain limits safely and is cheaper, easy to avail and eco-friendly. Bamboo happens to be such a material and can be replaced by steel in various parts of a structure. Bamboo can be used extensively in column design. It can also be coupled with steel in beams to tackle strength up to a certain limit where it has to be coupled with steel in doubly reinforced beams. Whenever it has to be put with steel, design principles involved with the setting of steel can be used when coupling bamboo with steel. The major reasons for putting forth the methods in the field of changing reinforcements to bamboo is its Carbon-absorbing property while it grows, so instead of emitting CO_2, unlike steel, while it is in the stages of growing, it would absorb it. It will also help in reducing the self-weight of the structure. Bamboo has a fibrous structure and can also absorb vibrations which can also be very helpful in low magnitude seismic shocks. A great deal of money is spent on projects where steel is bought for seismic proofing and putting them in between the walls for shock absorption, whereas bamboo is much more affordable and can be more easily cut according to the required cross-section and length thus saving the cost of cutting it with heavy machinery moreover, its fibrous structure with giving it an edge over steel in absorbing vibrations.

2. Materials

Through research, it has been found that 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/mm^2 to 280 N/mm^2. Bamboo is a versatile material because of its high strength to weight ratio easy workability & availability bamboo needs to be chemically treated due to their low natural durability. It can be used as bamboo trusses, bamboo roofs, skeleton, bamboo walling/ceiling, bamboo doors & windows, bamboo flooring, scaffoldings, etc. It has been found that bamboo acts very well in buckling but due to low stresses then compare to steel 15 and due to it not being straight, it may not be very good further it has been established that in seismic zone the failure of bamboo is very less as the maximum absorption of the energy is at the joints. Cellulose is the main component present in bamboo which is the main source of mechanical properties of bamboo. Bamboo reinforced concrete construction follows same

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design, mix proportion and construction techniques as used for steel reinforced. Properties of bamboo reinforcement are similar to that of STEEL REINFORCEMENT. Bamboo has used for scaffolding works, formwork supporting stands and many in building construction work. These are limited to medium- large projects. Even though the existence of bamboo has been found from centuries, bamboo as reinforcement material is an innovation in the civil engineering construction field. Bamboo is a bio-degradable and renewable. It is energy efficient as it is of natural origin & environmentally sustainable in nature.

Table 1: Specific properties of bamboo: [3]

Specific property	Value	Units
Specific gravity	0.575 to 0.655	
Modulus of elasticity	1.5 to 2.0 x 105	kg/cm2
Average weight	0.625	kg/m
Ultimate compressive stress	794 to 864	kg/cm2
Safe working stress in compression	105	kg/cm2
Safe working stress in tension	160 to 350	kg/cm2
Safe working stress in shear	115 to 180	kg/cm2
Bond stress	5.6	kg/cm2

The steel as a reinforcing material is a demand that is increasing day by day in most of the developing countries. There is a situation when the production is not found enough to face the demand for steel. So, in order to counter the scarcity of steel, it is quite imperative to have an alternative which has the same properties as that of steel when it comes to concrete reinforcement.

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Fig. 1 Bamboo reinforcement in columns

Bamboo is the most desirable one in this case and it is found in abundance, they are resilient these can face the demand as a reinforcing material and can be proved as an ideal replacement for steel. The tensile strength property which is the main requirement of a reinforcing material is seen appreciable for bamboo the hollow tubular structure has high resistance against wind forces when it is in natural habitat

3. Mechanical behaviour of bamboo

The mechanical properties most important in a tensile reinforcement are the modulus of elasticity and the tensile strength. The tensile strength of the reinforcement is directly responsible for the moment capacity of reinforced concrete elements while the MOE is indirectly linked to the moment capacity. More importantly, the modulus of elasticity of reinforcement directly influences cracking and deflection in reinforced concrete. Relativeto other organic materials, bamboo fibres have a high modulus of elasticity and high tensile strength (see Table 2.1). The MOE of bamboo fibre is comparable to GFRP at 40 GPa; however, significantly smaller relative to steel at 200 GPa

Table 2: Parameters of natural materials fibre

Fibre	Ultimate tensile stress (MPa)	Modulus of elasticity, E (GPa)
Wood[1]	160	23
Bamboo[1]	550	36
Jute[1]	580	22
Cotton[1]	540	28
Wool[1]	170	5.9
Coir[1]	250	5.5
Asbestos[1]	1700	160

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Bamboo can be potentially used in its natural form or as a composite material in engineered bamboo. The following two subsections review the properties of natural bamboo and engineered bamboo. In addition, their relative advantages and disadvantages are discussed.

4. Methodology

Collection of materials → Primary test → Tests on bamboo → Mix design, casting and testing → Pull out test → Flexural strength test → Results and analysis

5. Mix design, Casting and testing

Table 3 Concrete Mix Design

A-1	**Stipulations for Proportioning**	
1	**Grade Designation**	**M30**
2	Type of Cement	OPC 53 grade confirming to IS-12269-1987
3	Maximum Nominal Aggregate Size	20mm
4	Minimum Cement Content	320kg/m^3
5	Maximum Water Cement Ratio	0.45
6	Workability	50-75mm (Slump)
7	Exposure Condition	Severe
8	Type of Aggregate	Crushed Angular Aggregate
9	Maximum Cement Content	540kg/m^3
10	Chemical Admixture Type	Super plasticizer Confirming to IS-9103
A-2	**Test Data for Materials**	
1	Cement Used	Penna Cement OPC 53 grade

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2	Sp. Gravity of Cement	3.15
3	Sp. Gravity of Water	1.00
4	Chemical Admixture	
5	Sp. Gravity of Coarse Aggregate	2.6954
6	Sp. Gravity of Sand	2.6586
7	Water Absorption of Coarse Aggregate	0.59%
8	Water Absorption of Sand	0.90%
A-3	**Target Strength for Mix Proportioning**	
1	Target Mean Strength	38N/mm^2
2	CharacteristicStrength@28days	30N/mm^2
A-4	**Selection of Water Cement Ratio**	
1	Maximum Water Cement Ratio	0.45
2	Adopted Water Cement Ratio	0.43
A-5	**Selection of Water Content**	
1	Maximum Water content (10262-table-2)	186Lit.
2	Estimated Water content for 50-75 mm Slump	171.58Lit.
3	Super plasticizer used	1 % by wt. of cement
A-6	**Calculation of Cement Content**	
1	Water Cement Ratio	0.43
2	Cement Content (171.58/0.43)	399.02kg/m^3
		Which is greater then 320 kg/m^3
A-7	**Proportion of Volume of Coarse Aggregate & Fine Aggregate Content**	

1	Vol. of C. A. as per table 5 of IS10262	64.00%
2	Adopted Vol. of Coarse Aggregate	64.00%
	Adopted Vol. of Fine Aggregate (1-0.64)	36.00%
A-8	**Mix Calculations**	
1	Volume of Concrete in m^3	1.00
2	(Mass of Cement)/(Sp. Gravity of Cement)x1000	0.12
3	(Mass of Water)/ (Sp. Gravity of Water) x1000	0.128
4	VolumeofAdmixture@1%inm^3	0.00160
5	Volume ofAllinAggregateinm^3	0.708
6	VolumeofCoarseAggregateinm^3	0.453
	Sr. no. 5 x 0.64	
7	Volume of Fine Aggregate in m3	0.255
	Sr. no. 5 x 0.36	
A-9	**Mix Proportions for One Cum of Concrete (SSD Condition)**	
1	Mass of Cement in kg/m^3	399.02
2	Mass of Water in kg/m^3	128.65
3	Mass of Fine Aggregate in kg/m^3	687.57
4	Mass of Coarse Aggregate in kg/m^3	1177.07
5	Mass of 20m min kg/m^3	706.242
6	Mass of 10m min kg/m^3	470.82
7	Mass of Admixture in kg/m^3	1.90
8	Water Cement Ratio	0.43

6. Result and analysis

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Table 4 Sieve Analysis of Coarse Aggregate

Sieve size	Sample-1(gm)	Sample-2(gm)	Sample-3(gm)
63mm	0	0	0
50mm	0	0	0
40mm	190	210	200
31.5mm	305	295	280
25mm	280	290	300
20mm	1845	1850	1840
16mm	825	835	820
12.5mm	1235	1100	1210
10mm	180	250	200
6.3mm	50	90	80
4.75mm	40	60	50
pan	35	10	10
Total	4985	4990	4990

Table 5: Mix Design Results(M30)

Content name	Kg/m3	Content for one cube(m3)
Water content	128.68	0.434295
Cement content	381.28	1.28682
Fine aggregate content	687.57	2.320549
Coarse aggregate content	1177.078	3.972639
MIX RATIO: 1:1.8:3.10:0.43		

Table 6: Mix design results

Contents for 3 cubes	Total content (Kg)	Total with extra 20% wastage (Kg)	Total content with extra (Kg)

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Water content	1.3028	0.5211	1.5634
Cement content	3.8604	1.5441	4.6325
F. A content	6.9616	2.7846	8.3539
C. A content	11.9179	4.7671	14.3015

Table 7: Mix design results

Cube Sample	**Date of test**	**Load (KN)**	**Compressive strength(N/mm2)**
Sample-1	21-03-2022 (7-days test)	563.50	25.044
Sample-2		567.79	25.235
Sample-3		565.12	25.116
Sample-4	06-04-2022 (14-days test)	760.22	33.788
Sample-5		757.81	33.680
Sample-6		763.00	33.911
Sample-7	20-04-2022 (28-days test)	832.22	36.988
Sample-8		840.26	37.345
Sample-9		839.40	37.307

(a) (b)

Fig 2. Pull out test-1

7. Conclusions

Bamboo splints and half clums were tested for material properties, like compressive strength (77MPa), tensile strength of (387.6MPa) which were correlating with standard bamboo properties. Bamboo samples were also tested for water absorption (33.06%) and specific gravity of 0.77.Pull out test carried out in present experimental study shows the interfacial bond strength is highest for bamboo sprinkled with fine sand and wrapped with cross GI wire.

For half culm bamboo sprinkled with sand wrapped with GI wire (0.83MPa) the bond strength enhances to 1.22 times than sand sprinkled half clum bamboo (0.68MPa), 1.97 times than sand sprinkled bamboo splints (0.42MPa) and 1.66 times than sand sprinkled bamboo splints wrapped with GI wire (0.5MPa). From the current study on bond strength behavior of bamboo reinforced concrete it was concluded that culm bamboo sprinkled with sand wrapped with GI wire will give better bond strength and may be used for light loading structures.

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