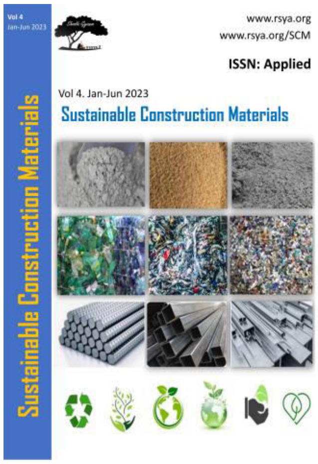

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Utilizing Bamboo as Reinforcement in Structural Concrete Elements

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Abstract: An analysis of the deformation and strength properties of plain and bamboo-reinforced concrete beams. All 150 mm x 150 mm x 700 mm beams with bamboo strips serving as reinforcement in the tension zone have been cast, matured for 28 days, 60 days, and 90 days, and then tested to failure under three-point loading. M25 was the concrete grade used for the inquiry. Flexural strength and deformation tests were performed on plain concrete beams and bamboo-reinforced beams with six different specifications and orientations. The test findings demonstrate that bitumen-coated bamboo reinforcement delivers stronger flexural strength at a younger age (28 days) and almost the same strength at a later age (90 days). In comparison to a simple concrete beam, other modifications have lesser compressive strength. Using bamboo as reinforcement, all beams demonstrate significant ductility before ultimate failure in flexure. When compared to a normal concrete beam, deformation occurs more than twice as often in each variation.

Keywords: Bamboo, Compressive Strength, Sustainability, Cement

INTRODUCTION

Due to the availability of materials including cement, sand, water, coarse aggregate, and industrial wastes, concrete is a frequently utilised construction material. However, concrete cannot be used everywhere by itself due to its weakness in tension. We used steel reinforcement to give concrete tensile strength. Steel usage needs to be restricted because it requires a lot of energy to manufacture and is quite expensive. Therefore, it is imperative to find an appropriate replacement that uses less energy and is good to the environment. For low-cost projects, bamboo is an excellent substitute for reinforcing bar in concrete. [1]. Bamboo is readily available, strong in tension and compression, and reasonably priced. Bamboo is a steel alternative because of its comparatively high tensile strength. Bamboo weighs a lot less than steel, for example. The majority of housing and infrastructure projects during the last two decades have been built with conventional materials like steel and concrete. There are many different ways that the demand for conventional building materials has grown. Massive amounts of CO2 are released during the manufacture of products like steel and cement, destroying the environment. When bamboo is utilised as a reinforcing material in concrete, it adds strength, durability, and flexibility. The best, most affordable, and ecologically friendly substitute material for steel in masonry structures has been determined to be bamboo. [2]. Bamboo is a rapidly growing, environmentally friendly material. During its growth, bamboo absorbs 1 tonne of CO2 from the atmosphere each bamboo culm. It is one of the materials that is most frequently accessible in tropical areas of developing nations like India. [3], [4]. Bamboo strips respond differently depending on the material's elastic modulus. Poor elasticity and a linear stress-strain diagram up to failure without a clear yield point are characteristics of a low quality finite element model of bamboo. [5] The nodes were weaker than inter nodes subjected to tensile loads because it failed without any prior indication of failure. The study came to the conclusion that bamboo might be utilised as a substitute for steel in subpar construction where populations cannot afford steel-reinforced buildings or steel is in scarce supply [6]. After examining the morphological (FTIR and SEM) properties of bamboo dust, it was determined that bamboo is a great alternative to steel since it is a ductile reinforcing material with a high tensile strength. Bamboo can be a great material for members undergoing compression and bending because to its bonding abilities [7]. It is necessary to conduct more study on the use of bamboo for environmentally friendly building materials, quicker implementation, and added value in terms of cost and environmental sustainability. Construction and industrial waste can be used in a way that is more environmentally friendly [8]. Pegs along the beam increase cracking and reduce the beam's maximum load carrying capacity [1]. The durability tests showed that the addition of bamboo splints in concrete beams increased the load carrying capacity of the beams, but not correspondingly. The bamboo reinforced beam is given high strength by wrapping the fibres around it. With age, the strength was seen to increase. When applied to lightweight constructions, bamboo reinforcement can replace steel reinforcement and boost the strength of concrete when compared to plain concrete. [9], According to test results, bamboo has an elastic modulus that is around one-third that of mild steel and a tensile strength that is about half that of mild steel. [11] It has been shown that corrugated bamboo works well to strengthen the bond between bamboo and concrete. Because of this, bamboo-reinforced concrete beams have a larger capacity for bending and can deflect only a little amount. [12] The building material bamboo can be used in place of wood and other materials. Bamboo should be waterproofed when used as reinforcement material to prevent swelling when it comes into touch with concrete. The cost of bamboo reinforcement is lower than that of steel reinforcement. [13] Bamboo is a particularly light material because of its extremely low density. The ability of the nodes to absorb water grows as the number of nodes rises. As the number of nodes increases, tensile stress rises. [14] Bamboo's node, where the majority of failure happens, is weak. Bamboo should be coated with epoxy to increase bond tension because it has a low bond stress. Bamboo cannot be utilised as a shear reinforcement because of its poor shear strength. [15]

The idea of sustainability in architectural design has also changed over time. The topic that drew the most attention was how to lessen the impact on the environment and the issue of few resources, particularly energy. [16] Reformed bamboo, which has a high strength-to-weight ratio, can greatly strengthen fiber-reinforced mortar while lowering the overall weight of the composite. [17] The experimental failure loads for conventional concrete beams reinforced with bamboo are typically 2.40 times higher than the theoretical failure loads, whereas the corresponding values for blended concrete beams reinforced with bamboo that include fly ash and blast furnace slag in place of 15% of the cement and 30% of the coarse aggregate, respectively, are 2.43 times higher. All beams had linear elastic properties prior to breaking, but as cracks developed, inelastic response was seen. [18] Many scientists and engineers are looking for a natural substance to replace steel in the construction industry during an energy crisis. One of the most intriguing materials is bamboo, which has special qualities like quick growth, a high tensile strength to weight ratio, and widespread accessibility in tropical areas. The results of this analysis indicated that the bamboo-reinforced column had a strength capacity that was sufficient to sustain the maximum axial force [19].

OBJECTIVES OF THE RESEARCH

The study's goal is to figure out how strong bamboo-reinforced concrete beams can flex. In order to compare the outcomes of bamboo strips used as reinforcement in concrete beams with and without bitumen coating, the study's goal was to employ bamboo strips as reinforcement in concrete beams.

Table 1: Material properties

Properties	Standard consistency	Initial setting time (Min.)	Final setting time (Min.)	Specific gravity of Cement	Fineness Modulus of FA	Specific gravity of FA	Zone of FA	Specific gravity of CA	Fineness Modulus of CA

Results	33 %	43	252	3.12	2.78	2.64	III	2.59	7.48

EXPERIMENTAL PROGRAM

Flexural testing of bamboo-reinforced concrete beams is the focus of this study's experimental plan. Flexural tests are performed using test setup, instruments, epoxy application to the specimens, and specimen preparation. Designing a concrete mix, preparing bamboo, preparing reinforcement, and casting concrete are all steps in the beam testing process. The instruments and beam test setup are fully detailed.

SAMPLE PREPARATION

Bamboo

Bamboo culms had cylindrical shells that were divided into solid transversal diaphragms by nodes. The thickness of the sample varied along its length because it is a natural material whose properties cannot be strictly controlled. To calculate the average dimension of the sample, the dimensions were measured at five points along its length.

Bamboo strips

Whole bamboo culms are less frequently utilised in building than bamboo strips. Before being used, the bamboo plant was chopped and let to dry and season for three to four weeks. Prior to conducting the flexural strength test, the bamboo sample needed to be prepared. 650 mm long by 30 mm wide bamboo strips were cut, as illustrated in the image, and cured for 30 days.

Figure 1: Bamboo strips.

Preparation of concrete beams for flexural strength test

There were 108 beam specimens overall, each measuring 150 mm by 150 mm by 700 mm. Each specification had a total of nine beams. The seven standards that were chosen are listed in the table below.

Beam Specimen and curing

Concrete is poured into a 700 mm long by 150 mm wide mould. The plain concrete beam did not contain any bamboo strips. Two bamboo strips were inserted at the bottom and covered with a 30 mm clear cover. The test samples were stored for 24 hours at room temperature and without vibration. After this time, the specimens were taken out and marked. For 28, 56, and 90 days, the specimens were submerged in water in a curing tank that was kept at room temperature. For 28, 56, and 90 days, three samples from each mix were cured and evaluated.

TEST RESULTS AND ANALYSIS

Mix Design of M25 Grade Concrete (OPC 43) has been made as per IS code 10262:2009. Proportion of cement sand and coarse aggregate was 1:1.34:2.5. Cement, water, fine aggregate and coarse aggregate in proportion in one cubic meter was 438.13 kg, 197.16 kg, 1097 kg and 591.03 kg respectively.

TEST RESULTS AND DISCUSSION

Arithmetic mean, standard deviation, kurtosis, skewness, lowest value, and maximum value were all included in the statistical summary. Data sets' variability was measured using SD. SD quantifies how widely distributed data are from their mean. It is variance squared and has far greater significance than variance. While SD displays the result in the original unit, variance does it in squared units.

Table 3: Statistical summary Data

PCB	***28 Days***		***56 Days***		***90 Days***	
Statistical Summary	***Load(KN)***	***Displace-ment(mm)***	***Load(KN)***	***Displace-ment(mm)***	***Load(KN)***	***Displace- ment(mm)***
Mean	43.22	2.94	44.74	3.05	44.40	3.07
SD*	1.70	0.27	2.15	0.35	2.18	0.27
Kurtosis	-3.10	-2.91	-3.23	-3.04	-0.98	1.24
Skewness	-0.45	0.15	-0.55	0.44	-0.44	1.12
Minimum	41.30	2.65	42.30	2.70	41.40	2.80
Maximum	44.80	3.23	46.60	3.45	46.90	3.50

BRCB1	***28 Days***		***56 Days***		***90 Days***	
Statistical Summary	***Load(KN)***	***Displace-ment(mm)***	***Load(KN)***	***Displace-ment(mm)***	***Load(KN)***	***Displace- ment(mm)***
Mean	40.82	2.70	42.01	2.91	41.92	3.04
SD	1.85	0.67	2.47	0.83	3.20	1.04
Kurtosis	-0.90	4.73	-1.29	2.74	-0.46	2.64
Skewness	0.26	-2.16	-0.56	-1.70	-0.82	-1.67
Minimum	38.70	1.50	38.60	1.50	37.20	1.30
Maximum	43.36	3.10	44.70	3.52	45.10	3.80

BRCB2	***28 Days***		***56 Days***		***90 Days***	
Statistical Summary	***Load(KN)***	***Displace-ment(mm)***	***Load(KN)***	***Displace-ment(mm)***	***Load(KN)***	***Displace- ment(mm)***
Mean	41.02	2.58	41.20	2.45	41.96	41.96
SD	0.54	0.22	0.78	0.11	1.16	1.16
Kurtosis	-0.68	-2.45	-1.89	-0.09	-0.16	-0.16

Skewness	-0.18	-0.59	-0.31	-0.06	-1.02	-1.02
Minimum	40.30	2.30	40.20	2.30	40.20	40.20
Maximum	41.70	2.80	42.10	2.60	43.00	43.00

BRCB3	***28 Days***		***56 Days***		***90 Days***	
Statistical Summary	***Load(KN)***	***Displace-ment(mm)***	***Load(KN)***	***Displace-ment(mm)***	***Load(KN)***	***Displace- ment(mm)***
Mean	40.42	2.48	43.14	3.02	42.28	2.95
SD	0.50	0.24	0.53	0.26	0.61	0.29
Kurtosis	1.30	-1.12	-1.30	-2.41	-2.33	-2.55
Skewness	1.02	0.21	-0.60	-0.36	-0.37	-0.26
Minimum	39.90	2.20	42.40	2.70	41.50	2.60
Maximum	41.20	2.80	43.70	3.30	42.90	3.26

BRCB1*	***28 Days***		***56 Days***		***90 Days***	
Statistical Summary	***Load(KN)***	***Displace-ment(mm)***	***Load(KN)***	***Displace-ment(mm)***	***Load(KN)***	***Displace- ment(mm)***
Mean	41.66	4.88	41.68	5.01	41.82	5.46
SD	0.30	1.13	0.60	0.70	0.40	0.55
Kurtosis	1.45	4.84	-2.23	-2.56	0.88	4.14
Skewness	-0.88	2.19	-0.50	-0.29	-1.09	-1.99
Minimum	41.20	4.28	40.90	4.20	41.20	4.50
Maximum	42.00	6.90	42.30	5.80	42.20	5.84

BRCB2*	***28 Days***		***56 Days***		***90 Days***	
Statistical Summary	***Load(KN)***	***Displace-ment(mm)***	***Load(KN)***	***Displace-ment(mm)***	***Load(KN)***	***Displace- ment(mm)***
Mean	41.28	2.79	41.32	2.98	41.28	3.04
SD	0.32	0.34	0.46	0.27	0.29	0.19
Kurtosis	-1.34	-2.80	1.13	-1.45	-1.54	-1.74
Skewness	0.30	0.64	-1.03	-0.80	-0.31	-0.01
Minimum	40.90	2.50	40.60	2.60	40.90	2.80
Maximum	41.70	3.23	41.80	3.22	41.60	3.26

BRCB3*	***28 Days***		***56 Days***		***90 Days***	
Statistical Summary	***Load(KN)***	***Displace-ment(mm)***	***Load(KN)***	***Displace-ment(mm)***	***Load(KN)***	***Displace- ment(mm)***
Mean	43.88	6.66	44.14	6.94	44.14	6.99
SD	0.26	0.11	0.40	0.19	0.21	0.26
Kurtosis	-2.41	-2.71	-2.71	-2.41	-1.96	-3.09
Skewness	0.36	0.58	0.12	0.18	0.24	-0.43
Minimum	43.60	6.56	43.70	6.72	43.90	6.70
Maximum	44.20	6.80	44.60	7.16	44.40	7.25

*Standard Deviation

Comparison of Flexural strength and Displacement for various days of testing

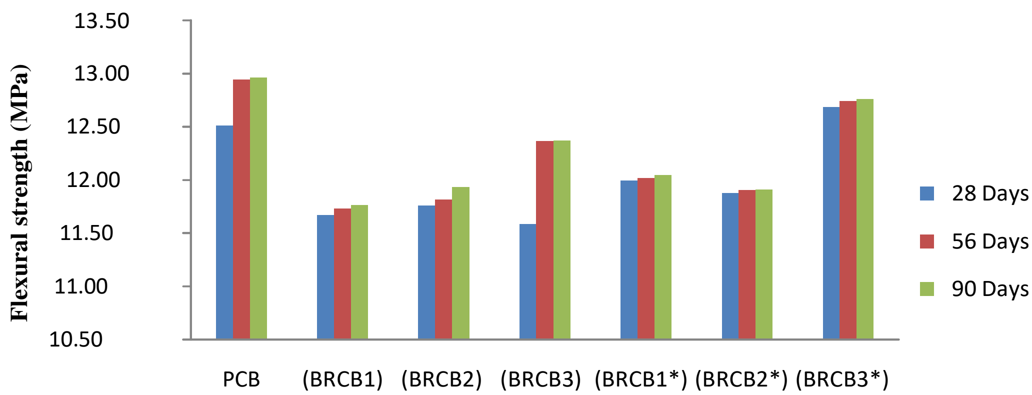

Figure 2: Flexural Strength at various Days of Testing

The graph shows that compared to other types of bamboo reinforced beams, bitumen-coated strips facing each other on a bamboo reinforced beam have a higher flexural strength. This criterion also demonstrates a 1.44 percent greater strength compared to a concrete beam placed and tested for 28 days. Other beam specifications indicate a weaker flexural strength than a concrete-supported beam.

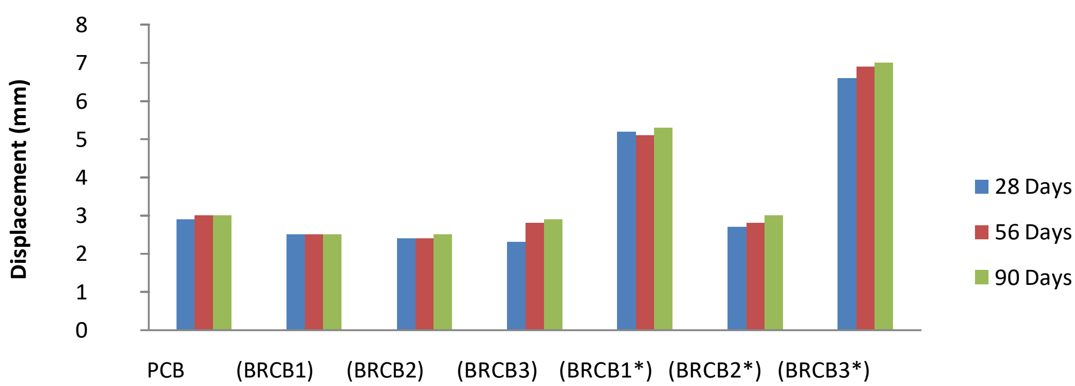

Figure 3: Displacement at various Days of Testing

The graph shows that for all testing days, the displacement is greater for bamboo-reinforced beams than for plain concrete beams. Maximum displacement is shown by a bamboo reinforced concrete beam with strips facing one another and coated in bitemen. When bamboo is employed as reinforcement, the brittle behaviour of a concrete beam is contrasted with its ductile behaviour.

CONCLUSION

It was revealed, after comparing the specimens with and without a bitumen coating, that bitumen strengthens the link between concrete and the specimens, hence increasing their capacity to withstand larger loads. This was established after comparing the specimens with and without a bitumen coating. The ductility of concrete beams can be significantly improved by the addition of bamboo as a reinforcement. These characteristics have the potential to become one hundred percent better. The use of bamboo as reinforcement in concrete increases not only the tensile strength of the beam but also its flexural strength. The addition of bamboo reinforcement to a concrete beam also results in an increase in the beam's flexural strength. A further benefit of using bitumen coating is that it strengthens the link between the bamboo reinforcement in the concrete. As a direct consequence of this, the load-bearing capability of the bitumen-coated bamboo beam specimen improves.

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