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Applications of Fibre Reinforced Concrete

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ABSTRACT

One of the commonly used building materials is concrete since it has many advantages. But due to its low tensile strength, it cannot be used alone everywhere. Therefore, steel is widely used to reinforce concrete. But due to its high cost, bamboo is one of the ways to replace reinforcement bar in concrete for low-cost construction. Due to its renewable nature and eco-friendly benefit, it plays a vital effort to prevent air pollution because it absorbs nitrogen. Bamboo grows in a few years and reaches its maximum strength and it is a natural fiber that helps to improve the strength of concrete and thereby used to reinforce concrete materials. In this research work, fiber-reinforced concrete is produced using bamboo as a reinforcing block material. Tests are done with C-25 grade concrete and the compressive strength, tensile strength, and flexibility of bamboo fibers are tested and compared with plain concrete

1. Introduction

Production of iron, steel, glass, etc. pollutes the environment. Biodegradable resources such as plants and fiber have recently been used as a substitute for steel. Concrete with a breakable characteristic with a low value of tensile strength is therefore well-liked with fibers. Fibers have been widely used in the past to provide stability in many types of mortar and concrete. Reinforcement bar is one of the vital materials among materials used in Reinforced concrete and it provides concrete with high tensile strength and flexibility. The idea of

using fibers to enhance the properties of building materials is exact primitive. The modern development of fiber reinforced concrete (FRC) began in 1960s.
There are number of fibers that nature has provided for mankind. Based on the source of origin, these natural fibers can be classified into animal fiber, vegetable fiber and mineral fiber. Figure 1 shows the natural fibers and its classification.

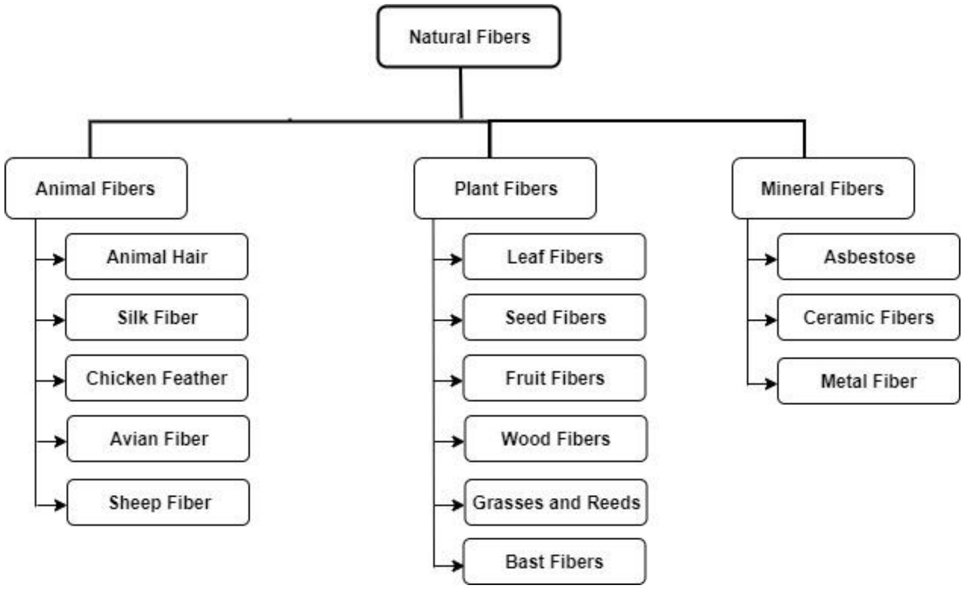

Figure 1. *Natural fibers and its classification.*

Synthetic, natural organic, and natural inorganic fibers are the three different types of fibers. Synthetic fibers are obtained by chemical products and have a high initial cost. They can be harmful to the ecosystem. Compared to all the above fibers, natural organic fibers are renewable, environmentally friendly, and are extracted from minerals, plants, and animal parts. They are economical because of its low production cost. The natural fibers and its properties are given in Table I.

Table 1*-Natural Fibers And Its Properties*

Fiber	Tensile Strength (MPa)	Young's Modulus (Gpa)	Elongation at break (%)	Density gm/cc
Abacca	400	12	3-10	1.5
Bagasse	290	17	-	1.25
Bamboo	140-230	11-17	-	0.6-1.1
Coir	175	4-6	30	1.2
Flax	345-1035	27.6	2.7-3.2	1.5
Hemp	690	70	1.6	1.48
Jute	393-773	26.5	1.5-1.8	1.3
Oil Palm	248	3.2	25	0.7-1.55
Pineapple	400-627	1.44	14.5	0.8-1.6
Sisal	511-635	9.4-22	2-2.5	1.5
E-glass	3400	72	-	2.5

Bamboo is one of the most abundant plants in India. One of the main air pollutants is nitrogen. Being a renewable, bamboo consumes nitrogen and it plays an important role in preventing air pollution. It grows well in a few years and helps to strengthen concrete materials and enhances the tensile strength of concrete. Its mechanical properties are comparable to that of wood and better than sisal, banana, vakka etc. It can be used in a different form such as long strip, short bamboo fibers, whole bamboo and sections to incorporate a mixed product. The choice of the fiber type depends on the property to be provided in the mixture. The feasibility of using bamboo to reinforce concrete with a smooth surface plays an important role and is used for concrete formwork. This paper is designed to explore the potential use of bamboo fibers in concrete production. Bamboo fiber acts as a reinforcement to enhance the mechanical properties of plain concrete. In doing so, bamboo fiber hollow concrete will resist tensile cracking, bending and fracture. Therefore, it is important to expand the concept of adding bamboo fiber to conventional reinforced concrete because it saves the percentage of reinforcement bars used in the production of steel-reinforced concrete. Experiments are carried out using Highland bamboo (Eushinia albina) species. This work explores the properties of concrete mixtures with bamboo at a water-cement ratio of 0.59 as reinforcement to concrete grades designated as C-25. The goal of this work is to examine the utility of using bamboo concrete reinforcement and to compare its strength with steel.

2. Literature Review

The authors [1] tested with bamboo strips in flexibility tests. They found that the double reinforced beam showed more flexibly and also its load bearing capacity is increased than the single reinforced beam. The authors [2] studied bonding and curvature in concrete with treated and untreated bamboo. They found that the treated bamboo showed improved bonding stress. The authors [3] pointed out that bamboo is used for construction due to its superior properties as a physically strong, hard and inexpensive material. The key finding was that the bamboo’s fracture properties depend on the pretense of the fracture. The authors [4] incorporated the reinforcing properties of bamboo into concrete. To improve the bond strength, three-factor defect treatments such as adhesive properties of the material used in bamboo and concrete, the water repulsive feature, and finally the surface of the interface of bamboo and concrete were used on bamboo. In [5], authors tested the curve for plain, steel and bamboo reinforced constituents. 12 columns are illustrated in their test scheme. These columns include each 3 columns of steel reinforcement, hollow concrete, untreated bamboo reinforcement and treated bamboo reinforcement. Load decay curves showed remarkable straightness, indicates that bamboo absorbs energy efficiently. In [6], authors examined that the processed bamboo has a tensile strength one-third of the steel. The bamboo reinforced concrete (BRC) column has increased load bearing capacity than the non-reinforced concrete. In [7], authors conducted experiments to evaluate the properties of the bamboo and its applicability as a building material. Humidity varies with the height of the green bamboo. The specific gravity decreases from top to bottom based on the dry mass of the oven and is independent of moisture. In [8], authors compared the BRC with reinforced concrete with respect to the fracture characteristic. They found that the behavior of the bamboo is similar to the behavior of a plain steel bar. From the experimental conditions, the authors [9] found that the tensile strength of moso bamboo is one half of the mild steel. And the compressive strength and tensile strength are similar as that of steel. At higher loads, the models without nodes shown superior experience compared to models with nodes. In [10], the authors used Bamboo reinforcement for the main and supply reinforcement and they found that Bamboo reinforcement is three times cheaper particularly for single storey structure. In [11], the authors studied on variable short columns and found that the conventional concrete steel reinforcement experiences higher load bearing capacity than that of coconut shell with bamboo reinforcement. The authors tested a tension on a bamboo [12]. They found that the deflection of the BCSCB beams were more than the NWC and CSCS beams and the deflection of the BCSCB beams were slightly reduced by wrapping with split bamboo binding wire. The authors studied the properties of BRC. They found that Bamboo fibers act as a crack resistor and therefore can withstand higher loads compared to conventional concrete [13 -14]. The authors used concrete beam with bamboo and pumice stone aggregate reinforcement. Sand coated bamboo reinforcement and a type of bamboo called Ori bamboo was used to create the rough surface. It was coated with paint and sand covered. They showed that bamboo fiber has superior beam post-crack load bearing capacity and also the width of the crack is reduced [15]. The authors found that, it increased mechanical properties and they suggested that Bamboo can be replaced partially instead of steel rods in concrete elements [16]. The authors noticed that the bamboo for the foundation was restrained because saplings when in contact with wet ground; if not treated with effective preservatives they can deteriorate and degrade very quickly [17].

3. About Bamboo

First, The civil engineer should consider all the pros and cons before actual use.

A. Advantages of bamboo

1. Little weight and eco-friendly
2. Cheap and adequately available
3. Grown on the farm

B. Disadvantages of bamboo

1. Bamboo needs preservation over time
2. Bamboo has no uniform shape
3. Coating is needed since it is attacked by fungi
4. Bamboo will always have weak joints
5. Requires guidance, extensive research
6. It is not fire resistant

C. Usees of bamboo

The various uses of Bamboo is shown in Figure.2

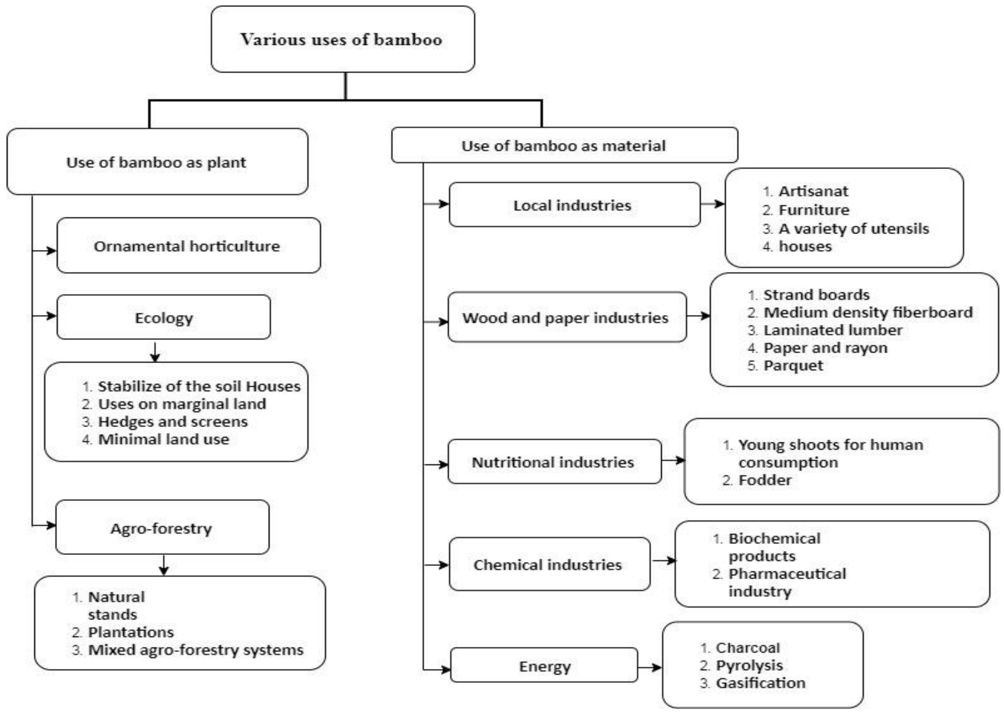

Figure 2. *Uses of Bamboo*

D. Bamboo Anatomy

Bamboo has a natural shape that includes a cylindrical pole (Figure 3). More than 1500 species of bamboo have been identified in the world. It grows very fast and reaches up to 15m to 30m height in 2 to 4 months. The anatomy of bamboo species is shown in figure 2. As the height of the plant increases, the thickness of a bamboo decreases. Similarly, the density increases from the inner to outer wall of the species [18].

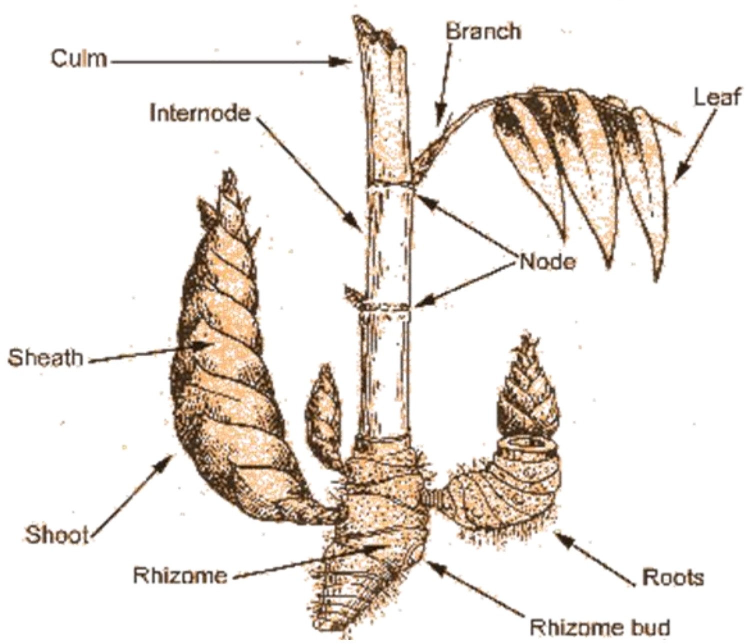

Figure 3. *Bamboo anatomy*

When compared to spruce forests, bamboo forests yields high and it has 4 times the carbon density/ hectare [19] i.e., bamboo absorbs more carbon than wood and grown in short span. Recently, all are showing interest to grow bamboo as a building material in place of timber.
Though it is available in plenty, bamboo is not frequently used as a building material in contrary to other developing countries. One of the reasons for this infrequent use of bamboo is the lack of study on its mechanical properties. The most important property is to withstand the exerted force on it that decides its ability and strength. Its moisture content plays a vital role in determining the strength and performance of the bamboo culm. If the moisture content < 15%, then it has good mechanical properties and is less sensitive to fungal attack [20]. But the percentage varies with species and age. The design life time of untreated bamboo is estimated to be 10-15 years if properly preserved, but it is more for treated bamboo. The suitable bamboo's age should be a minimum of 3-4 years to be used in construction and its strength depends on the age and type of the species. Optimal strength is available for a matured bamboo and it can be used in application of heavy load circumstances. The parameter 'height' decides the compressive strength and it increases from inside to outside of the plant.

4. Materials and methods

E. Material Preparation

In this work, Dendrocalamus asper, Pampusa vulgaris, Schizostachium grande and Gigantoglova scortechini are used and the bamboo are selected and dried for about one month until the bamboo color changed from their original color to yellow. They were treated with boric acid to increase their longevity and resistance to fungal attack. Figure 4 shows the bamboo pile collected before the machine test.

Figure 4. Bamboo pile

F. Materials

- 53 Grade Ordinary Portland cement (Ultratech Cement) was used. Table II shows physical properties of cement.
- Crushed granite having sixty percent passing 20mm and retained on 10mm sieving, forty percent passing 10mm and retained on 4.75mm sieving with a specific gravity of 2.74 is used. The coarse aggregate properties are shown in Table III.
- River sand (zone-II) is used as fine aggregate. The properties of fine aggregate are shown in Table IV.
- Fresh water free from acid concentration/ organic substances is used.

***Table.2**-Properties Of Cement*

S.NO.	Property	Value
1.	Specific Gravity	3.01
2.	Fineness of cement (By sieving)	2.75%
3.	Standard Consistency	33%
4.	Setting Time i) Initial setting time	140 min
	ii) Final setting time	330 min

***Table 3**-Properties Of Coarse Aggregate*

S.NO.	Property	Value
1.	Specific Gravity	2.74
2.	Fineness Modulus	6.76

***Table.4**-Properties Of Fine Aggregate*

S.NO.	Property	Value
1.	Grading of sand	Zone II as per IS 383
2.	Specific Gravity	2.61
3.	Fineness Modulus	2.66

As per IS 10262:2009, M30 grade of concrete has been used for concrete mix and the proportion of mix is shown in Table V.

***Table 5**-M 30 Concrete Materials*

Grade Designation	= M30
Type of cement	= O.P.C 53 grade
Admixture	= Super plasticizer
Fine Aggregate	= M Sand
Coarse aggregate	= 20mm
Cement	= 350 kg/m³
Water	=140 kg/m³
Fine aggregate	= 713 kg/m³
Coarse aggregate	= 1204.27 kg/m³
Chemical admixture	= 7 kg/m³
Water-cement ratio	= 0.4
Water: cement: FA: CA	= 0.4: 1: 2.037: 3.44

G. Compression test on Concrete Block

Concrete cubes measuring 15cm x 15 cm were made with composite design M30 and carried out according to composite design [21]. The concrete cube sample was tested at 7, 14, and 28 days at a standard loading rate using a standard test machine. Table VI gives the results of the compression test on concrete cubes.

Table.6*-Compressive Strength Of Concrete*

Days	Compressive Strength (N/mm^2)
7	26.01
14	32.00
28	36.34

H. Beam Types and their design

Three sizes of beam viz., 230x300x1200 mm, 230x350x1200 mm & 230x400x1200 mm are selected and are designed with Plain Cement Concrete (PCC), BRC, Treated BRC (TBRC, and Steel Reinforced Concrete (SRC). For designing SRC Beam, Fe 415 grade steel rods are selected to reinforce SRC beams in mentioned sizes (Table VII).

Table.7*-Src Beam Design*

Type of beam		SRC1 beam	SRC2 beam	SRC3 beam
Size of beam		230x300 x1200mm	230 x 350 x1200mm	230x400x1200mm
Grade of concrete		M30	M30	M30
Grade of Steel		Fe-415	Fe-415	Fe-415
Limiting percentage tensile steel	Pt,lim	1.681%	1.681%	1.681%
Limiting moment of resistance	Mu,lim/bd2 (MPa)	4.166	4.166	4.166
Limiting value of depth of neutral axis	xu,lim	0.48d	0.48d	0.48d
Percentage reinforcement provided	Pt	1.68 %	1.68 %	1.20 %
Type of section		Balanced	Balanced	Under-reinforced
Reinforcement provided		2 no. 12mm diameter bars	2 no. 12mm diameter bars	2 no. 12mm diameter bars
Cover		25 mm	25 mm	25 mm

I. BRC beam

The bamboo sticks are selected and dried for about one month until the bamboo color changed from their original color to yellow. They were treated with boric acid to increase their longevity and resistance to fungal attack. The BRC design is shown in Table VIII.

Table.8*-BRC Beam Design*

Type of beam	BRC1 beam	BRC2 beam	BRC3 beam
Size of beam	230x300 x1200mm	230 x 350 x1200mm	230x400x1200mm
Grade of concrete	M30	M30	M30
Type of reinforcement bars	Bamboo sticks	Bamboo sticks	Bamboo sticks
Percentage reinforcement provided	1.68 %	1.68 %	1.20 %
Reinforcement provided	2 bamboo sticks of about 12 mm diameter	2 bamboo sticks of about 12 mm diameter	2 bamboo sticks of about 12 mm diameter
Cover	25 mm	25 mm	25 mm

J. TBRC beam

The bamboo sticks after processing in above section is taken and its surface body is then hardened with a knife before applying coal tar paint on its surface. Then sand is sprayed and glued on the painted surface. This improves the effect of bonding between the bamboo sticks and the TBRC beams. Then the sticks are dried for 2 days, after which these sticks are utilized in the design of TBRC beams in three variable sizes. The TBRC beam design is shown in Table IX.

Table.9*-TBRC Beam Design*

Type of beam	TBRC1 beam	TBRC2 beam	TBRC3 beam
Size of beam	230x300 x1200mm	230x350x1200mm	230x400x1200mm
Grade of concrete	M30	M30	M30
Type of reinforcement bars	Treated Bamboo sticks	Treated Bamboo sticks	Treated Bamboo sticks
Percentage reinforcement provided	1.68 %	1.68 %	1.20 %
Reinforcement provided	2 treated bamboo sticks of about 12 mm diameter	2 treated bamboo sticks of about 12 mm diameter	2 treated bamboo sticks of about 12 mm diameter
Cover	25 mm	25 mm	25 mm

K. Experimental setup of flexural strength test

The test measured 230x300 x1200 mm, 230x350x1200 mm, and 230x400x1200 mm in accordance with IS: 516-1959 and cured under the flexibility test machine after 7 and 28 days. Its typical arrangement is shown in Figure 5.

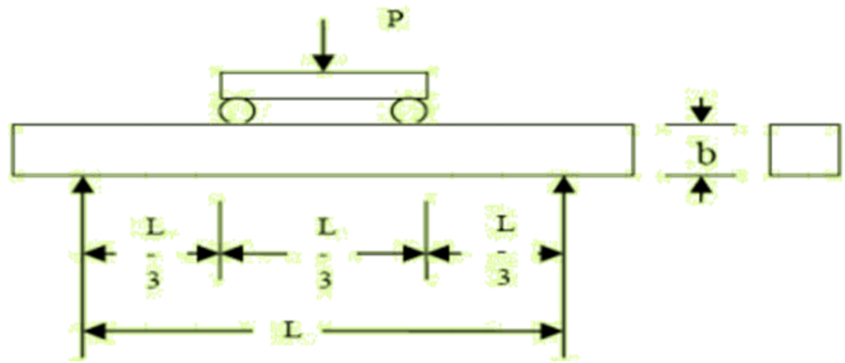

Figure 5. *Calculating of flexural strength with a typical arrangement*

Flexural strength (N/mm^2), $f = \frac{PL}{bd^2}$ and Bending moment, $M = \frac{PL}{6}$ Where, P = maximum load, L = Span of beam, b = Width of the beam, d = Depth of beam

5. Results And Discussion

L. Flexural strength

PCC, BRC Beams, TBRC, and Steel-Reinforced Concrete Beams (SRC) of sizes 230x300x1200 mm, 230x350x1200 mm, and 230x300xx1200 are selected to perform the flexural strength tests. During the test run, the load-bearing capability of the beam and its failure pattern are examined. The failure loads are recorded. In the interim, using dial gauge fitted in the test system, the deflection of the beams under loads was recorded. The load-deflection curve was then projected and the maximum bending moment was obtained. Flexural test results of 230x300x1200 mm, 230x350x1200 mm, and 230x300xx1200 beams at 7 and 28 days are shown in Table X, Table XI and Table XII respectively for PCC, BRC, TBRC and SRC. Flexural strength graph of beams 230x300x1200 mm, 230x350x1200 mm, and 230x300xx1200 at 7 and 28 days are shown in Figure 5, 7 and 9 respectively for PCC, BRC, TBRC and SRC. Load-deflection graph of beams 230x300x1200 mm, 230x350x1200 mm, and 230x300xx1200 at 7 and 28 days are shown in Figure 5, 7 and 9 respectively for PCC, BRC, TBRC and SRC.

Table.10*-Pcc1, Brc1, Tbrc1 And Src1 Beams*

Beam designation for beam of size 230x300x1200mm	Avg. Flexural strength at 7 days (N/mm²)	Percentage variation in flexural strength with respect to PCC1 beam	Avg. Flexural strength at 28 days (N/mm²)	Percentage variation in flexural strength with respect to PCC1 beam (N/mm²)
PCC1 beam	2.78	0%	3.69	0%
BRC1 beam	3.58	37.68%	5.98	55.28%
TBRC1 beam	4.32	58.43%	6.62	68.69%
SRC1 beam	10.45	290.78%	14.81	288.46%

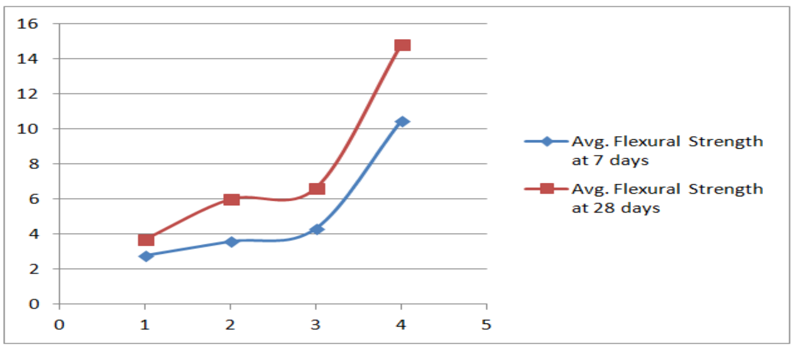

Figure 6. *Flexural strength graph of beams of size 230x300x1200mm at 7 & 28 days*

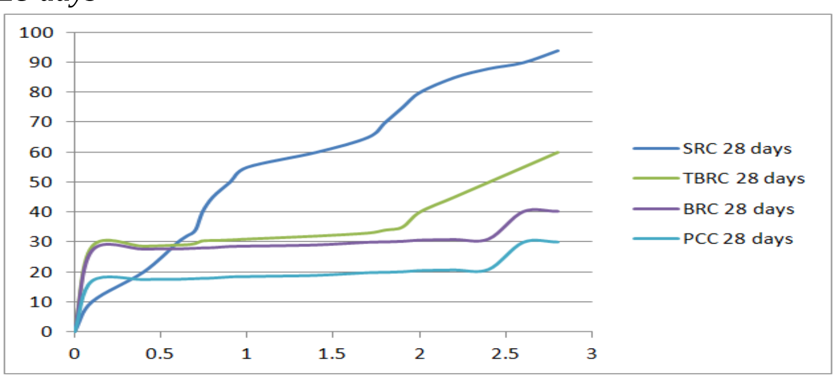

Figure 7. *Load-deflection graph of beams of size 230x300x1200mm mm at 28 days*

From Table X and Figure. 6, the flexural strength of PCC1 beam at 28 days is 3.69 and flexural strength of BRC1, TBRC1 and SRC1 beams at 28 days are 5.98, 6.62 and 14.81 respectively. From Figure. 7, the maximum deflection of the samples of PCC1, BRC1, TBRC1 and SRC1 beams at 28 days are 2.13, 2.22, 2.52 and 2.96 respectively.

***Table.11**-PCC2, BRC2, TBRC2 And SRC2 Beams*

Beam designation for beam of size 230x350x1200mm	Avg. Flexural strength at 7 days (N/mm^2)	Percentage variation in flexural strength with respect to PCC1 beam	Avg. Flexural strength at 28 days (N/mm^2)	Percentage variation in flexural strength with respect to PCC1 beam
PCC2 beam	2.89	0%	4.26	0%
BRC2 beam	3.82	30.28%	6.32	51%
TBRC2 beam	4.53	50.33%	6.89	64.19%
SRC2 beam	10.91	266.68%	14.98	257.16%

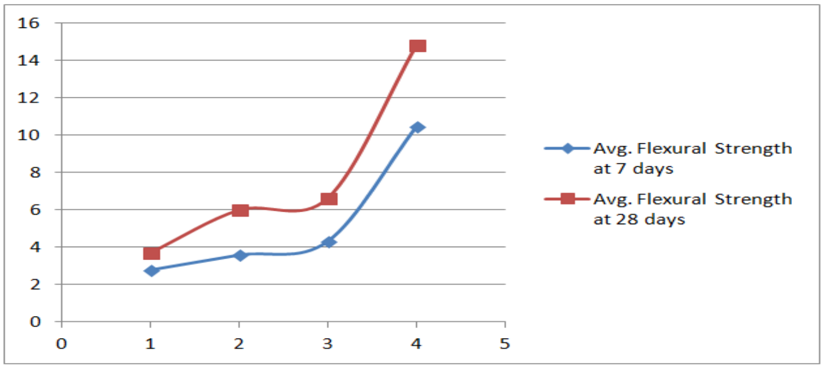

Figure 8. *Flexural strength graph of beams of size 230x350x1200mm mm at 7 &28 days*

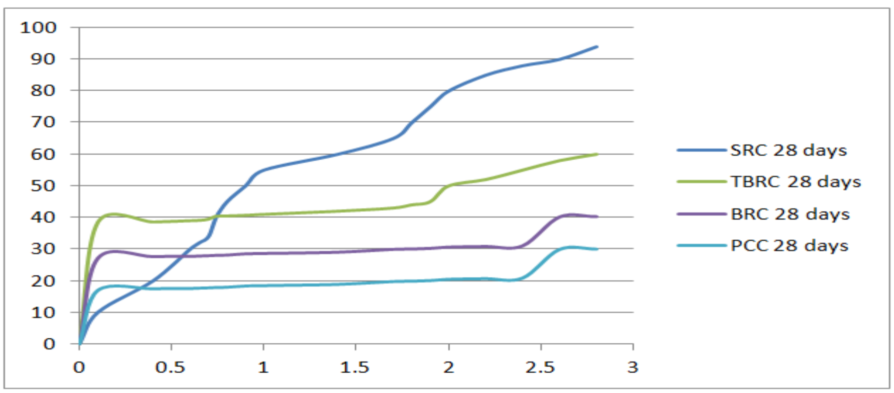

Figure 9. *Load-deflection graph of beams of size 230x350x1200mm at 28 days*

From Table XI and Figure. 8, the flexural strength of PCC2 beam at 28 days is 4.26 and that of BRC2, TBRC2 and SRC2 beams at 28 days are 6.32 , 6.89 and 14.98 respectively. From Figure9, the maximum deflection of the samples of PCC2, BRC2, TBRC2 and SRC2 beams at 28 days are 1.78, 1.89, 2.01 and 2.32 respectively.

***Table.12**-Pcc3, BRC3, TBRC3 And SRC3 Beams*

Beam designation for beam of size 230x400x1200mm	Avg. Flexural strength at 7 days (N/mm^2)	Percentage variation in flexural strength with respect to PCC1 beam	Avg. Flexural strength at 28 days (N/mm^2)	Percentage variation in flexural strength with respect to PCC1 beam (N/mm^2)
PCC3 beam	2.91	0%	4.56	0%
BRC3 beam	3.92	30.58%	6.42	52%
TBRC3 beam	4.83	50.63%	6.92	65.39%
SRC3 beam	10.98	266.88%	14.92	258.46%

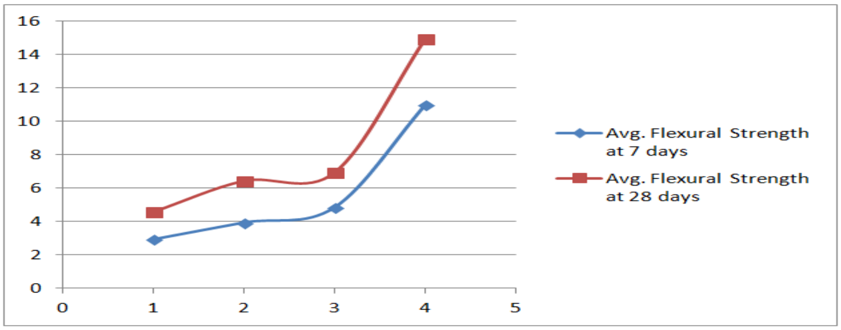

Figure 10. *Flexural strength graph of beams of size 230x400x1200mm at 7 &28 days*

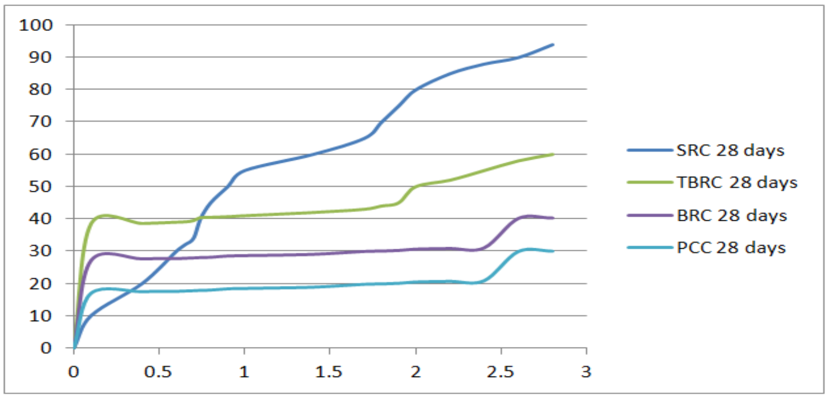

Figure 11. *Load-deflection graph of beams of size 230x400x1200mm at 28 days*

From the Table XII and Figure 10, the flexural strength of PCC3 beam at 28 days is 4.56 and that of BRC2, TBRC2 and SRC2 beams at 28 days are 6.42, 6.92 and 14.92 respectively. From Figure11, the maximum deflection of the samples of PCC3, BRC3, TBRC3 and SRC3 beams at 28 days are 1.78, 1.91, 1.97 and 2.31 respectively.

M. Mode of Failure

The nature of failure of beams in the test of Flexural strength is provided in Figure. 12.

(a) (b) (c) (d)

Figure 12. *(a) Failure of PCC beam (b) Failure of BRC beam (c) Failure of TBRC beam (d) Failure of SRC beam*

From Figure12, the failure pattern of PCC beams at 28 days acted as a brittle material but BRC and TBRC beams shows flexible nature. According to the test results, the flexural strength of the TBRC is higher than the elasticity of the BRC. The bamboo surface is rough due to water-resistant and sand coating by painting its surface with bamboo. Due to this, the binding capacity is increased.

6. Conclusion

The following conclusions can be drawn based on the work made in the laboratory:

1) Based on the test results it has been found that the load-bearing capacity of BRC and TBRC beams is very high with respect to the dimensions of plain cement concrete beams (230x300x1200 mm, 230x350x1200 mm, and 230x300xx1200).

2) The flexural strength of the SRC beam is higher than all other types of beams. The flexural strength of the PCC beam has been found to be low. This applies to three sized beams.

3) For beams measuring 230x300x1200 mm, the bending strength of BRC and TBRC beams is approximately 37.78% and 58.39% higher than PCC beam in 7 days. At 28 days, the bending strength of the BRC and TBRC beams was 53.43% and 68.79% higher than the PCC beam, respectively.

4) Test results of beams measuring 230x350x1200 mm indicate that the bending strength of BRC and TBRC beams is 30.26% and 50.37% higher than the PCC beam in 7 days respectively. However, at 28 days, the regression of the BRC and TBRC beams was found to be 53% and 64.41% higher than the regression of the PCC beam, respectively.

5) For beams measuring 230x400x1200 mm, the bending strength of BRC and TBRC beams is approximately 30.17% and 50.39% higher than PCC beam in 7 days. At 28 days, the bending strength of the BRC and TBRC beams was 52% and 67% higher than the PCC beam, respectively.

6) At the similar load, the PCC beam deflection is higher than BRC and TBRC beams but the deflection of the SRC beam is found to be very low.

7) For beams measuring 230x300x1200 mm, the regression of the TBRC beam was found to be 15.01% and 10.89% higher than the regression of the BRC beam at 7 and 28 days, respectively. For beams measuring 230x350x1200 mm, the regression of the TBRC beam was found to be 15.68% and 9.48% higher than the regression of the BRC beam at 7 and 28 days, respectively. Similarly, for beams measuring 230x400x1200 mm, the regression of the TBRC beam was found to be 14.98% and 9.12% higher than the regression of the BRC beam at 7 and 28 days, respectively.

8) The flexural strength of beams measuring 230x300x1200 mm is better than the flexural strength of beams measuring 230x350x1200 mm. Deviations of 230x300x1200 mm beams are less common compared to 230x300x1200 mm beams.

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