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EXPERIMENTAL INVESTIGATION OF BAMBOO REINFORCED BEAM

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ABSTRACT:

In any construction design, the important thing is economy. Economy is a great thing of concern since past years. Several techniques are being adopted to achieve it. Bamboo can be used as a structural replacement for steel. One of the properties that would make bamboo good substitute to steel in reinforced concrete is its strength. This study aims to determine the mechanical properties of bamboos which can be used as data for construction of a low-cost structure. Two types of bamboo, Dendrocalamus Strictus and Balcooa Bambusa are selected as tested materials. In order to determine the compression and tensile testing we use (IS 6874:2008). According to IS specifications samples are taken from top, middle and bottom location of bamboo. Compressive strength of dry bamboo is greater than that of wet bamboo for both the species, it is adequate to use dry bamboo as structural element. From this finding, it assures that flexural strength of

bamboo is 3/4th of the steel reinforcement. Bamboo cannot be employed as a main structural member in buildings and other heavy engineering works but can be used for partition walls, ceilings, roofs and other areas of light weigh engineering construction that is not heavy load bearing

Keywords- Bamboo, mechanical properties, steel reinforcement, bamboo reinforcement, compressive strength, Tensile strength, flexural strength.

I. INTRODUCTION

Now-a-days, all the buildings and structural components mainly depend on usage of RCC. The steel which is present in RCC structure is responsible for taking the tensile stress that is developed in the structure. Environmental pollution that occurs due to the manufacturing process of steel and an eager need to find out an alternative material in building construction which tends to move our attention towards bamboo, a cheap and economical material. Bamboo is one of the giant grass and an orthotropic material. From the early times bamboo is used as a construction material. The bamboo can be used in both technical and non-technical ways. The bamboo was used in struts, posts, roofs etc. in construction of houses. Now-a-days concrete is used as the basic material in construction. Concrete is good in compression but it is weak in tensile strength. So, steel is used as reinforcement in the concrete to achieve the desired tensile strength. Bamboo is strong in both, compression and tension.

Fiber reinforced composite materials have led to much industrial innovation. Currently composites reinforced by glass fibers and carbon fibers are being used widely for many structural applications. However, there are economic and environmental challenges. Most of the synthetic fibers are crucial to recycle and are produced from chemicals made from refined petroleum. Furthermore, their fabrication procedures are energy-intensive. Composite materials based on synthetic inorganic fibers are thus expensive and environmentally unfitting. A good alternative is to employ natural fibers instead of the synthetic inorganic fibers. Advantages in comparison with synthetic fibers, are their abundance, renewability, biodegradability and low price. Amid various natural fibers, bamboo has shown to be a sustainable yet affordable alternative. Bamboo is one of the locally available natural materials that has gained attention in recent years for manufacture of new category of sustainable bamboo-fiber-reinforced composite materials. Bamboo is a fast growing, low-priced and available natural resource in most developing countries and it has outstanding material qualities. The cultivation and industrial processing of bamboo provide a huge potential for a new generation of building materials fabricated through embedding natural bamboo fibers into a resin matrix for applications in architecture and construction.

2.MATERIALS

Below are the materials that have been used in this study:

2.1 Selection of bamboo

2.1.1 Dendrocalamus strictus:-

Dendrocalmus Strictus is the main specie found in India. Male bamboo or Dendrocalmus Strictus occupies a total of 53 percent total bamboo area in India. It is tall, dull long green-colored bamboo specie, which grows in thickets consisting of loads of heavily branched, closely growing culms. It reaches a height of 6–18 m. Culm sheaths are green when young, and turn brown when mature, and are cylindrical. Internode length varies from 20–30 cm, and diameter is 2.5–12 cm. Culm walls are very thick. Nodes are not prominent. The advantage of bamboo is that it is lightweight, flexible, tough, high tensile, cheap material than the other building materials like steel and can be used in various building works. It has various advantages over the other construction material and it is needed that it should be widely used in construction They are used for making house frames, rafters, tent poles, concrete reinforcement, walls, scaffolding, and fences. The leaves are used for thatching. This specie was used by the British army in India for making lance shafts.

Figure 1. Dendrocalamus strictus

2.1.2 Bambusa balcooa:-

Bambusa balcooa is also known as female bamboo. It is a tropical clumping bamboo originating from Northeast India. The culms of Bambusa Balcooa are on average between 16-20 m in height and 7-15 cm in diameter. Culms are grayish green in colour and thick walled. Nodes become thicker with a whitish ring above, and have short small hairs below. Culm internodes are on an average between 40 to 45 cm in length. Stems are used as building material in houses, bridges, fishing floats and is much used for scaffolding. The compressive strength of this bamboo ranges from 39.4 to 50.6 N/mm^2 in green bamboo and 51.0 to 57.3 N/mm^2 in air dry condition.

Figure 2. Bambusa balcooa

2.2 Steel bar

High yield steel deformed (HYSD) is used in this study in order to identify the performance of standard reinforcement used in concrete and to make a comparison with the bamboo reinforcement.

2.3 Concrete

The concrete used for these studies are design mix of M20 grade, designed as per Indian standards (IS 10262:2009). The Indian standard specifies (IS 456:2000) the characteristics compressive strength, Young's modulus and flexure strength are given as 20 N/mm^2, 22361 $N/mm^2$and 3.13 N/mm^2.

2.4 Glass fiber

Glass fiber is a material that is made up of several fine fibers of glass. It is one of the most versatile industrial materials known today. It has comparable mechanical properties as compared to other fibers such as carbon fiber and polymers.

2.5 Water proofing material

The characteristic of bamboos showed high water absorption and low bonding strength between bamboo's surface and concrete when used as a reinforcement in concrete. In order to prevent this problem, 'Epoxy coat' has been used to minimize the swelling of bamboo and to increase the bonding strength. This adhesive has very good resistance to water, oil and many other solvents. The coat has been applied on the bamboo 2 days before their beam were casted.

3. Methodology

3.1 Mechanical properties of bamboo

Mechanical properties are very important to identify the characteristic strength of bamboo. All the characteristic values were used in the design calculation. The equation and design procedure can be used to design concrete using bamboo reinforcement if all mechanical properties values were substituted in the reinforcement calculation. The mechanical properties have been determined in this study by conducting few tests such as tensile strength test, compressive strength test and flexural strength test.

3.1.1 Compressive strength test of bamboo.

For the compressive strength test, the sample bamboo with hollow culms of 60-150 mm were prepared with a different type of sample specimen was selected. The sample specimens without nodes were prepared as shown in Figure 4. The dimension of each sample was measured and was placed in the CTM machine.

Figure 3. Compressive strength test of bamboo

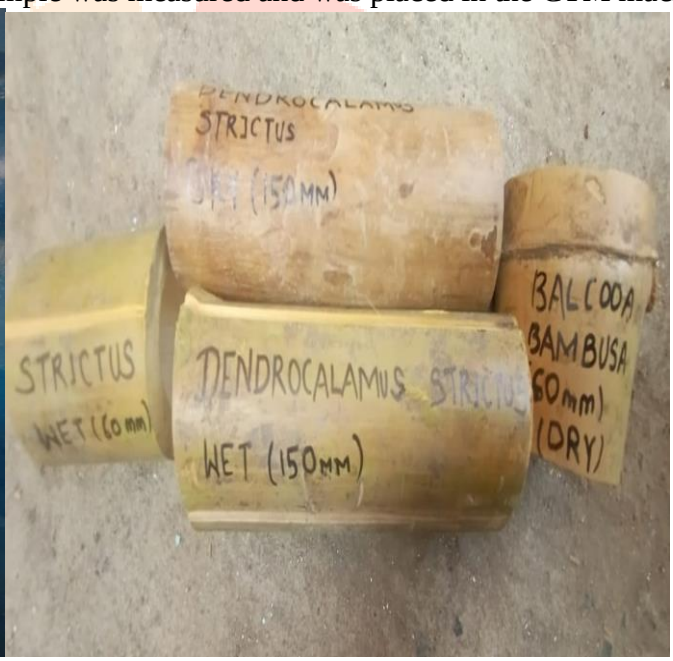


Figure 4. Bamboo samples in compressive strength test

3.1.2 Tensile test of bamboo strip

Bamboo sample with 12 inches and 16 inch length were prepared by cutting from the main Bamboo according to IS 6874. The specimens were cut such that they had no node across the length of bamboo strip. The test was conducted for different diameter of strips of bamboo that is for 1, 2, 3, 4, 5 and 6mm. During the good grip a covering of 4mm of saagwan beeding was provided at both ends of sample bamboo strip.

Figure 5.Tensile strength test of bambo

3.1.3 Flexural strength test of bamboo concrete beam.

3.1.3.1 **Beam specimen**

Concrete beams of size 600mm x 150mm x 150mm with bamboo as reinforcement were casted for the test. Steel reinforcement of diameter 12mm was used. Test were done on three types of sample beams namely concrete beams with reinforcement and stirrups of bamboo (BB), concrete beams with reinforcement of bamboo and steel stirrups (BS), and concrete beams with steel reinforcement and steel stirrups (SR). The beams specimen has been designed for doubly supported to determine the feasibility of the bamboo reinforced in concrete reinforcement.

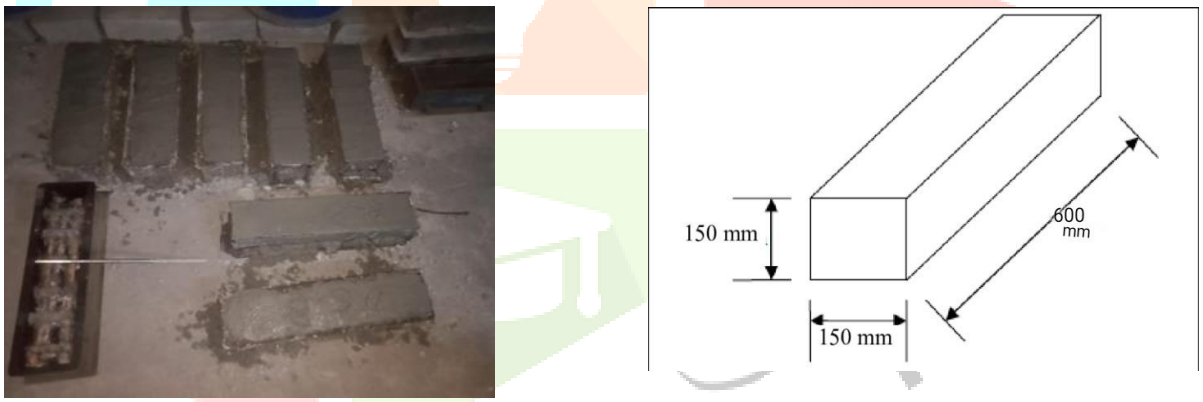


Figure 6. Dimensions of sample beam.

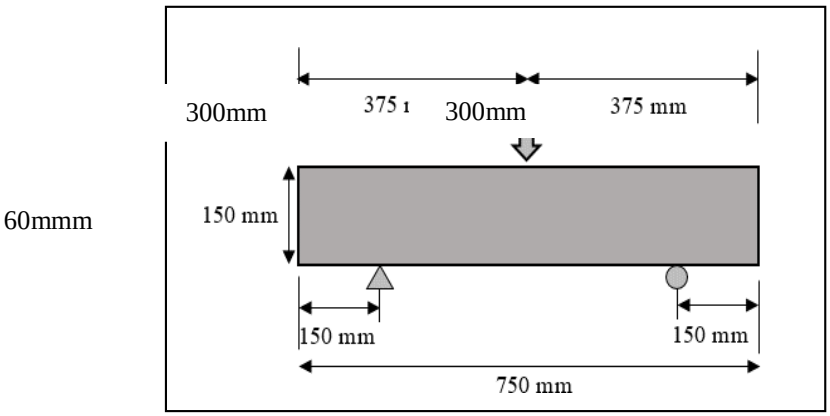


Figure7. Test setup for flexural test of the beam.

3.1.3.2 Methodology of flexural strength test

The beam was carefully placed under the testing machine and support was placed at 150 mm towards inner side from each end. The deflection of the beam at mid-span was checked at regular interval of loading. The peak load for which the cracks developed was noted. From the flexural strength test, the performance of reinforcement and bamboo beams has been identified for the three types of samples.

Figure 8. Test setup for flexural test of the beam.

4. RESULTS AND DISCUSSION

Below are the result and discussion for this study.

a. Tensile strength test of bamboo strip

The tensile strength test was conducted using Universal Testing Machine (UTM). Specimen was positioned in the machine and tensile load was applied until breaking point. The result for tensile strength test can be seen from the Table 1.

Table 1. Result of Tensile strength stress of bamboo specimen.

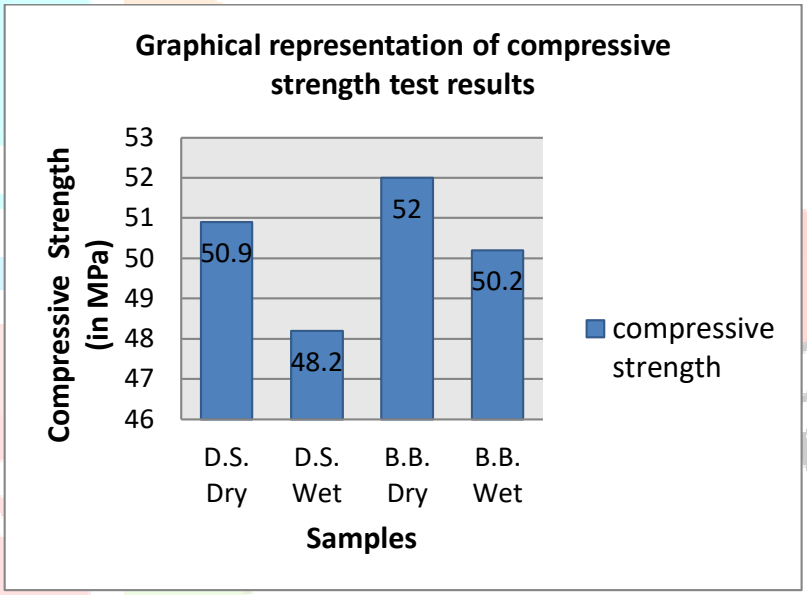
Species		Samples	Load (in kN) for specific width					
			1mm	2mm	3mm	4mm	5mm	6mm
Dendrocalamus strictus	Dry bamboo	1^{st}	1.8	1.9	1.8	2.1	2.1	2.2
		2^{nd}	1.7	1.8	2.1	2.0	2.3	2.4
		3^{rd}	1.6	1.8	1.9	2.1	2.3	2.5
	Wet bamboo	1^{st}	2.1	2.3	2.2	3.0	3.1	3.4
		2^{nd}	2.1	3.2	3.5	2.8	3.0	2.7
		3^{rd}	2.3	2.3	3.0	2.1	2.6	2.7
Bambusa balcooa	Dry bamboo	1^{st}	2.8	2.9	3.0	3.4	3.3	3.6
		2^{nd}	2.7	3.1	2.9	3.4	3.6	3.8
		3^{rd}	2.9	3.0	2.9	3.5	3.2	3.6
	Wet bamboo	1^{st}	2.1	2.0	2.2	2.1	2.2	2.3
		2^{nd}	2.0	2.1	2.3	2.2	2.4	2.6
		3^{rd}	1.8	2.0	1.9	2.0	2.3	2.5

b. Compressive strength test of bamboo

The compressive strength test was conducted using compressive testing machine (CTM). Specimen was positioned in the machine and then load was applied until breaking point. The results of the compressive strength test can be seen in Table 2.

Table 2. Result of compressive strength test for bamboo specimen.

Species	Type	Diameter (in mm)	Length (in mm)	Compressive Strength (in kN/mm^2)
Dendrocalamus Strictus	Dry bamboo	56	60-150	50.9
	Wet bamboo	58	60-150	48.2
Bambusa balcooa	Dry bamboo	71	60-150	52
	Wet bamboo	71.5	60-150	50.2



4.3 Flexural strength test of concrete beam

In this research, for flexural strength testing three types of sample specimens have been used which are discussed in previous section.

Tables below tells the strength obtained for ultimate load on specimens after 7th,14th and 28th day curing. Based on the graph, concrete beam with steel reinforcement have shown highest value of flexural strength which is 14.43 kN (for 7th day) ,15.22KN (for 14th day) and 16.078 kN (for 28th day) compared to the other two types of beam.

The flexural strength has been conducted with three beam of each sample for a single day. A total of 33 beams were casted.

The average of strength of three samples for 7th, 14th and 28th day was calculated for more accuration.

Table 3. Result of flexural strength test for bamboo (dendrocalamus) specimen

Dendrocalamus Strictus {D.S.}							
Testing Day	Sample	Length (in mm)	Width (in mm)	Height (in mm)	Load (in kN)	Flexural strength (in kN/mm^2)	Average Flexural strength (in kN/mm^2)
7^{th}	D.S. 7.1	600	150	150	40.40	7.18	7.46
	D.S. 7.2	600	150	150	42.43	7.54	
	D.S. 7.3	600	150	150	43.19	7.67	
14^{th}	D.S. 14.1	600	150	150	57.33	10.19	10.48
	D.S. 14.2	600	150	150	58.48	10.39	
	D.S. 14.3	600	150	150	61.13	10.86	
28^{th}	D.S. 28.1	600	150	150	65.33	11.61	11.75
	D.S. 28.2	600	150	150	66.14	11.75	
	D.S. 28.3	600	150	150	66.89	11.89	

Graphical representation of flexural test results for Dendrocalamus Strictus

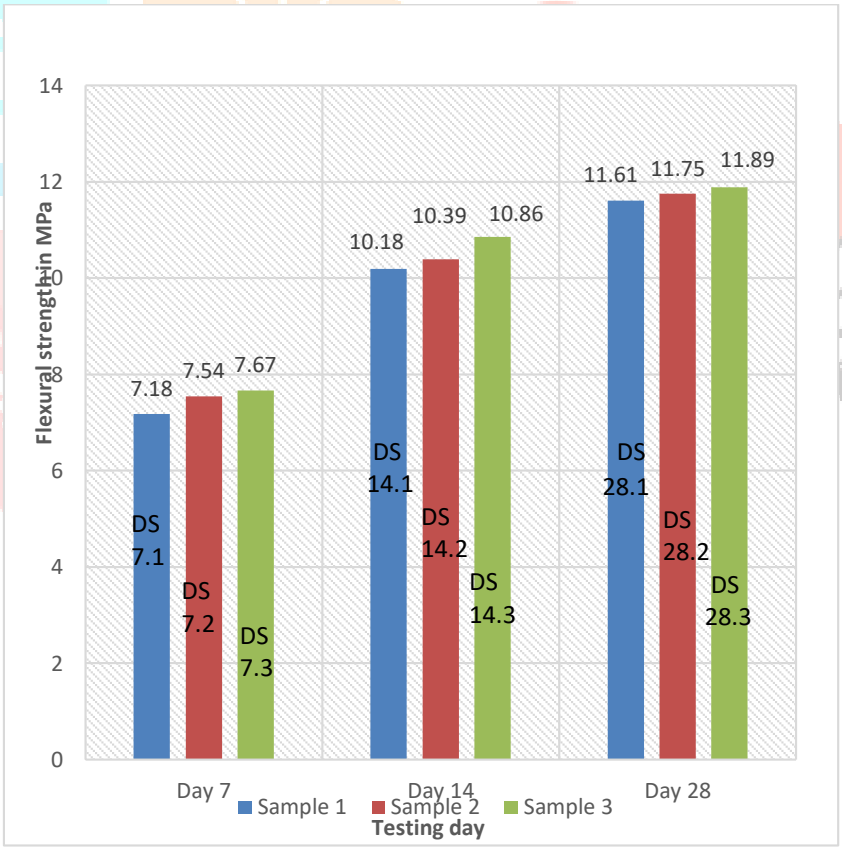


Table 4. Result of flexural strength test for bamboo(bambusa) specimen.

Bambusa Balcooa {B.B.}							
Testing Day	Sample	Length (in mm)	Width (in mm)	Height (in mm)	Load (in kN)	Flexural strength (in kN/mm^2)	Average Flexural strength (in kN/mm^2)
7^{th}	B.B. 7.1	600	150	150	61.00	10.84	10.89
	B.B. 7.2	600	150	150	60.14	10.69	
	B.B. 7.3	600	150	150	62.39	11.09	
14^{th}	B.B. 14.1	600	150	150	62.10	11.04	11.24
	B.B. 14.2	600	150	150	63.43	11.27	
	B.B. 14.3	600	150	150	64.19	11.41	
28^{th}	B.B. 28.1	600	150	150	68.71	12.21	12.25
	B.B. 28.2	600	150	150	69.00	12.26	
	B.B. 28.3	600	150	150	69.11	12.28	

Graphical representation of flexural test results for Bambusa Balcooa

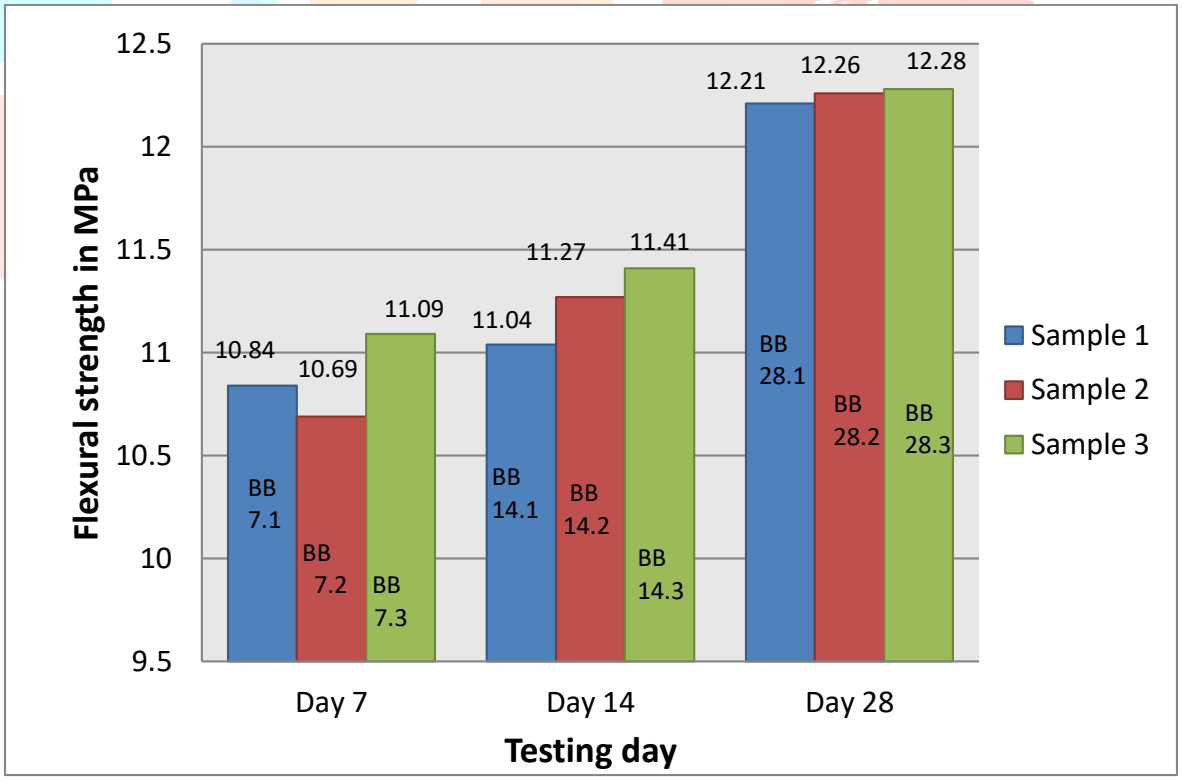
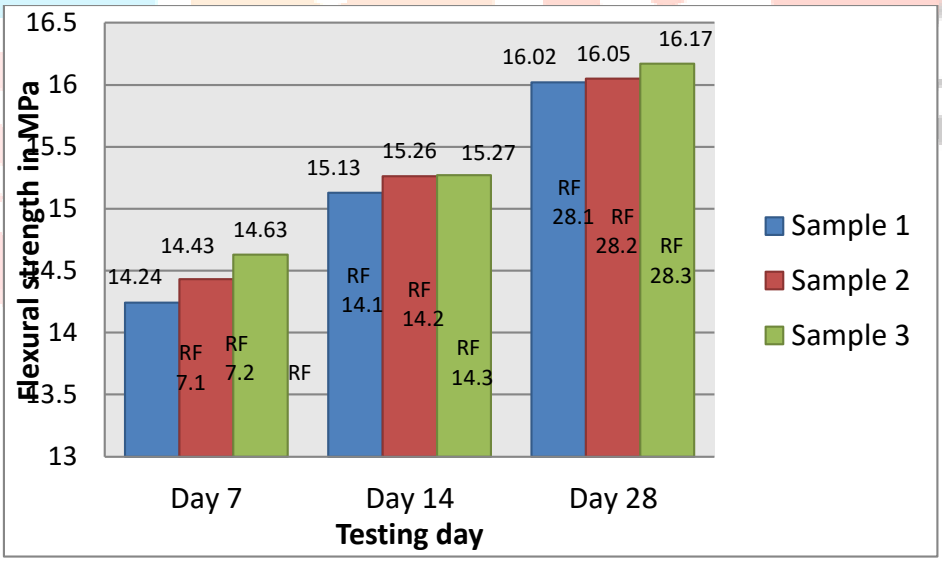


Table 5. Result of flexural strength test for steel reinforcement specimen.

Reinforcement {R/F}							
Testing Day	Sample	Length (in mm)	Width (in mm)	Height (in mm)	Load (in kN)	Flexural strength (in kN/mm^2)	Average Flexural strength (in kN/mm^2)
7^{th}	R/F 7.1	600	150	150	80.11	14.24	14.43
	R/F 7.2	600	150	150	81.22	14.43	
	R/F 7.3	600	150	150	82.33	14.63	
14^{th}	R/F 14.1	600	150	150	85.11	15.13	15.22
	R/F 14.2	600	150	150	85.86	15.26	
	R/F 14.3	600	150	150	85.91	15.27	
28^{th}	R/F 28.1	600	150	150	90.12	16.02	16.08
	R/F 28.2	600	150	150	90.30	16.05	
	R/F 28.3	600	150	150	91.00	16.17	

Graphical representation of flexural test results for reinforcement



5. Conclusion

5.1 The compressive strength of dry bamboo is greater than that of wet bamboo.
5.2 The compressive strength of bamboo is however less than that of steel. Housing where the structural loads are very low bamboo can be adopted.
5.3 This also proved that bamboo as a replacement of steel which can be used for masonry work instead of plain concrete.
5.4 From flexural strength it can be conceived that bamboo beams could resist cracking up to certain limit.
5.5 as per the results, flexural strength of bamboo is 3/4th of the steel reinforcement.
5.6 It is not that everywhere bamboo could give the same desired value. But can be used where the availability of bamboos is good quantity.

5.7 Bamboo reinforcement technique can be used for both main and distribution reinforcement as it was earlier done for steel reinforcement. However, this bamboo reinforcement technique is costlier than steel reinforcement technique

5.8 Overall in this research, bamboo proved to be a good and possible replacement for steel in construction industry.

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