Journal of Civil Engineering and Environmental Technology
p-ISSN: 2349-8404; e-ISSN: 2349-879X; Volume 5, Issue 4; April-June, 2018, pp. 280-284

http://www.krishisanskriti.org/Publication.html

A Study of Bamboo Reinforced Concrete Beams with different Species of Bamboo

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Abstract—*In recent year, the construction industry is one of the main consumer of energy and materials and natural resources in most countries. Any excessive or inefficient consumption of resources is in fact an abuse of the environment. Environmental concerns have broadened during the last two decades. The pursuit of sustainable development has increasing day by day. Emphasis is being placed on technical issues such as materials, building components, construction technologies as well on non-technical issues such as economic and social sustainability. In this study, trials have been made for the use of bamboo as reinforcement in concrete beams which are simple, efficient and economical for rural constructions. This is comparative study of bamboo reinforced concrete beams with four different bamboo species. The BRC beams were of size 15cm x 15cm x 70 cm and bamboo splints of 16mm and 20mm width, and of four different types i.e. Bholuka, Jati, Mokal and Kako were used as reinforcement. Bamboo is excessively prone to insect attacks due to its high content of nutrients. Hence in order to combat this problem it becomes necessary to treat bamboo so as to protect it from the environment. Copper Chrome Boron (CCB) treatment of bamboo has been adopted to prevent bamboo from insect attack. The frictional properties of bamboo reinforced concrete beams have been achieved by rolling the bamboo reinforcements with G.I wire and is made water tight by applying epoxy coating. Flexural strength has been tested in flexure testing apparatus which works on the principle of four-point bend test and values of 28, 45 and 60 days has been taken into consideration for comparison purpose. Also load displacement graphs are obtained for the beams. At failure, it has been observed that beams subjected to higher curing period and greater reinforcement size perform better as compared to beams with lower curing period and smaller reinforcement size. Therefore, it can be suggested that bamboo can act as a good potential reinforcement for low cost housing and can replace steel conveniently thereby saving natural resources to a considerable extent.*

1. INTRODUCTION

India being the second most populous country in the world is also a home to a large section of people who are below average poverty line. With population on the rise, the demand for basic needs increases as well. Shortage of shelter due to unaffordability has become a matter of great concern for our country. As civil engineers, our main aim is to provide shelters and best facilities at an economic cost. Innovations in alternative materials for building technologies are targeted for the low-cost mass housing sector to provide shelter for the poor. Bamboo is one of the oldest construction material has been considered to have high tensile strength and is being used as main structural component for these low-cost houses.

Bamboo has been used in constructions of bridges and houses for thousands of years in Asia. It has been historically used as a building material due to its inherent properties, being regenerating, biodegradable, with high tensile strength, and light weight. -Bamboo is a natural material which is available in bulk and ease of use in the rural areas in the developing countries is bamboo. Bamboo, bearing the scientific name *Bambusa Tulda*, *Bamblusa Balcooa* etc. belongs to grass family. It is the fastest growing woody plant and are capable of growing 60 cm or more in a day and can grow up to 30 m or even more. They can be grown in any climatic condition and soil type. Bamboos occur mostly in tropical and subtropical areas, from sea level to snowcapped mountain peaks, with a few species reaching into temperate areas. The rate of growth of bamboo depends upon the local climatic condition and soil type. Bamboo is considered to be matured after three years of its plantation and it is always advisable to choose matured bamboo for construction purpose. Bamboo is generally considered as organic and to mitigate this problem treatment is being provided to the bamboo samples to make it free from pest and other insect attacks. One of the most important factors to be considered is that bamboo shows its efficiency in least humid. There are studies that have been carried out on the engineering properties of bamboo and it was found suitable to be used as a substitution for steel although it has lesser tensile strength than traditional steel reinforcement. An attempt has been made to introduce bamboo as a structural material in low cost housing structures which are safe durable and affordable.

2. ENGINEERING PROPERTIES OF BAMBOO

The mechanical and physical properties of bamboo vary from species to species and from soil to soil but still it has adequate strength properties making it suitable for engineering purpose. Bamboo is very good in tension and its tensile strength varies from species to species. An average tensile strength of 50% to 75% of that of steel or sometimes even more can be found in bamboo. The moisture content in bamboo varies along its height, location and seasoning period. It is considered to be one of the vital factors in deciding the life of bamboo. The top portion of bamboo has comparatively lower moisture content than the middle and the base portion at any stages of seasoning. Water absorption is inversely proportional to the moisture content whereas dimensional changes, tensile and compressive strength are directly proportional to moisture content. To prevent the slippage of reinforcement from concrete, a proper bonding between concrete and reinforcing material is necessary. The dimensional changes of bamboo due to temperature and moisture variations tend to affect all the three bond characteristics such as adhesive properties of cement matrix, compression frictional forces appearing on the surface of reinforcing bar due to shrinkage of concrete and shear resistance of concrete due to the surface form severely.

2.1 Characteristics of Bamboo

The bamboo culm, in general, is a cylindrical shell, which is divided by transversal diaphragms at the nodes. The fiber density of bamboo in cross section varies with the thickness as well as height. The thickness, however, decreases from the base to the top of the bamboo shell. The distribution of fibers is more uniform at the base than at the top or middle of the bamboo. The fibers are concentrated in regions closer to the outer skin. Bamboo shells are orthotropic materials with high strength in the direction parallel to the fibers and low strength perpendicular to the fibers respectively. Although bamboo partially in wooden family yet it has strength which is greater than most of its correlates. The main drawback however is its susceptibility to insect attack which makes it unsuitable to use in construction.

2.2 Selection of Bamboo

Only those bamboos which are at least three or more years old and are matured are to be used for construction purposes. Matured bamboo will be brownish green in color. Selection is made is such a manner that longest and largest diameter culms are obtained. The culms are generally smaller in diameter as well as thickness and less intermodal distance at the top portion of bamboo. The internodal length is larger in the middle of the culm. Generally, culms from the base portion of the bamboo are preferable. Also cutting of bamboo should be avoided during spring and early summer as during these times the fiber moisture content is high.

Among the wide range of available bamboo species, we have chosen the four types of bamboo species based on their availability, cost effectiveness and performance based on this region. They are

i) Bholuka (Bambusa balcooa)

ii) Jati (Bambusa tulda)

iii) Mokal (Bambusa nutans)

iv) Kako (Dendrocalamus hamiltonii)

2.3 Necessity of Bamboo Treatment

Just like timber, bamboo is vulnerable to environmental degradation and attacks by insects and moulds. Bamboo is excessively prone to insects than other trees and grasses because of the fact that bamboo contains high content of nutrients. Hence in order to combat this problem it becomes necessary to treat bamboo so as to protect it from the environment. Copper Chrome Boron (CCB) treatment of bamboo has been adopted to prevent bamboo from insect attack. The content of various chemicals is in the ratio- Boric acid: Copper Sulphate: Sodium Dichromate- 1.5:3:4 and its recommended concentration is 8-10% for outdoor use (structures exposed to weather and in ground contact)

Figure 1 Bamboo in CCB treatment tank

Figure 2 Bamboo splints treated in CCB tank

2.4 Protection of Bamboo during concreting

One of the main shortcomings of bamboo is water absorption when it is used as reinforcement in concrete. Bamboo has a high-water absorption capacity. The dimensional variation of untreated bamboo due to water absorption pushes the concrete away. Then at the end of the curing period, the bamboo loses the moisture and shrinks back almost to its original dimensions leaving voids around itself. (Figure 3) This leads to the formation of micro cracks or even macro cracks which is not desirable in concrete. The swelling and shrinkage of bamboo in concrete is very harmful to concrete strength. To improve the bond between bamboo reinforcements and concrete, an effective water-repellent treatment is necessary so that bamboo do not get in contact with water. To overcome this, one effective treatment is the application of thin layer of epoxy. (Figure 4) shows the application of epoxy in bamboo splints.

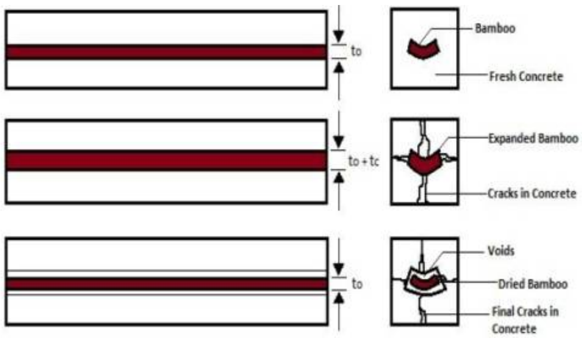


Figure 3 Expansion and Contraction of Bamboo in concrete

Figure 4 Application of Epoxy coating

3. BAMBOO REINFORCED CONCRETE BEAMS

Simply supported beam subjected to four-point bend test with its middle third portion subjected to maximum uniform bending and zero shear force and assuming that the self-weight of the beam is negligible has been tested. The beams have been fabricated with coarse aggregates of sizes 20mm down respectively. Ordinary Portland cement of 43 grade and naturally washed river sand have been used. Sieve analysis have been done on fine aggregates and have been found to belong in Zone II as specified in IS 383-1970. The normal weight concrete has been proportioned in the ratio 1:1.5:3 for M20 grade and the mix proportion has a water-cement ratio of 0.45. The bamboo splints were of 16mm and 20mm width, and of four different types i.e. *Bholuka*, *Jati*, *Mokal* and *Kako*. Before casting a thin impermeable layer of epoxy has been applied so as to prevent the penetration of water into the bamboo and avoid dimensional variation in it. After application of epoxy coating the bars have been subdivided into the four species and two different widths. The bars are then caged with steel stirrups and then cast in the mould of dimension 15cm x 15cm x 70 cm with concrete to obtain bamboo reinforced concrete beams. Finally, these beams are being tested in the flexure testing apparatus which works on the principle of four-point bend test. The results obtained are illustrated in the next heading.

Figure 5 Four Point Load test machine in JEC lab

4. RESULTS AND DISCUSSIONS

The test procedure began with placing under the universal testing machine as shown in Figure 6. The beam was carefully placed to provide the supports at the measured placement of 400 mm from each end. The concrete beam and steel support beam were pushed sideways into place above the base plate and between the frame of the hydraulic compression machine being used for the four-point bending test. The load cell measures the load transferred through it and transmitted it to the precise digital controller which is connected to a computer which gives us the desired output in both tabulated and graphical form. The laser deflection sensor measures the deflection at the center of the beam and transmitted these measurements as electronic signals to the INSTRON system computer. The Universal Testing Machine available at NEIST- Jorhat is manufactured by INSTRON (Model 5594 and Serial no 3351) is shown in Figure 7

Figure 6 Set up for four-point load test in UTM

Figure 7 UTM at NEIST Jorhat

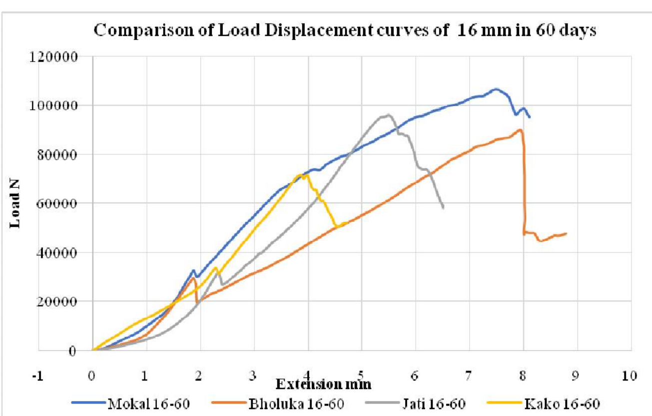
The four-point bend test results of BRC beams obtained have been tabulated below in table 1.

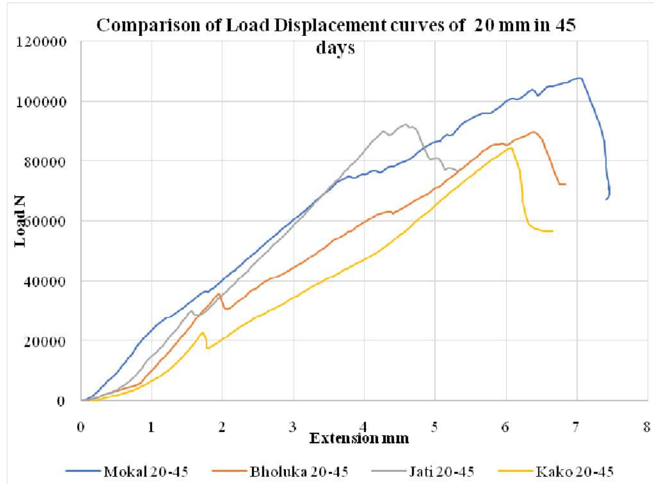
Table 1 Test Results for BRC beams

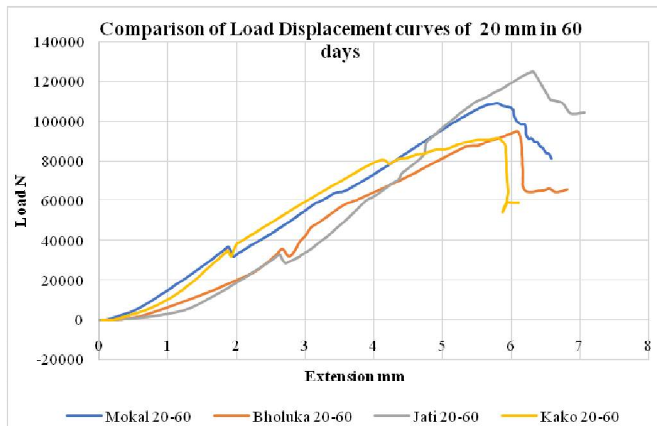
Sl no	BRC type	Bar Size	Curing period	Max Load (kN)	Max deflection (mm)
1	Bholuka		28	79	12.57
2	Bholuka	16	45	82.56	10.32
3	Bholuka		60	89.89	7.93
4	Bholuka		28	85	7.60
5	Bholuka	20	45	89.63	6.46

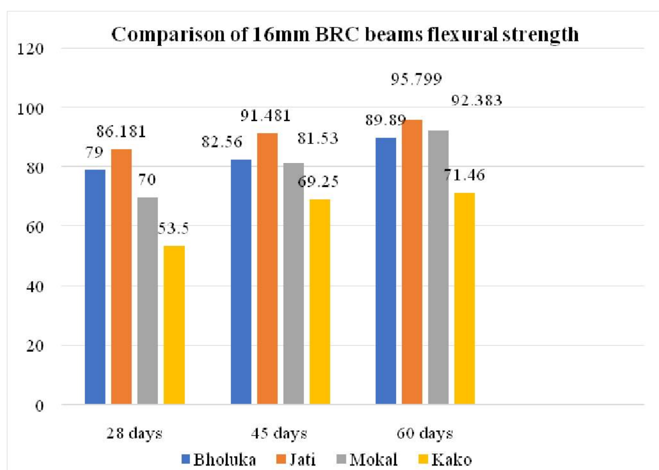
6	Bholuka		60	94.86	6.09
7	Jati		28	86.181	7.13
8	Jati	16	45	91.481	5.8
9	Jati		60	95.799	5.47
10	Jati		28	88	9.24
11	Jati	20	45	106.22	7.52
12	Jati		60	125.199	6.31
13	Mokal		28	70	10.34
14	Mokal	16	45	71.53	4.59
15	Mokal		60	92.383	3.87
16	Mokal		28	90.34	9.42
17	Mokal	20	45	107.95	7.02
18	Mokal		60	109.338	5.78
19	Kako		28	53.5	7.23
20	Kako	16	45	69.25	4.86
21	Kako		60	71.46	3.98
22	Kako		28	76	7.10
23	Kako	20	45	78.84	6.08
24	Kako		60	84.201	5.08

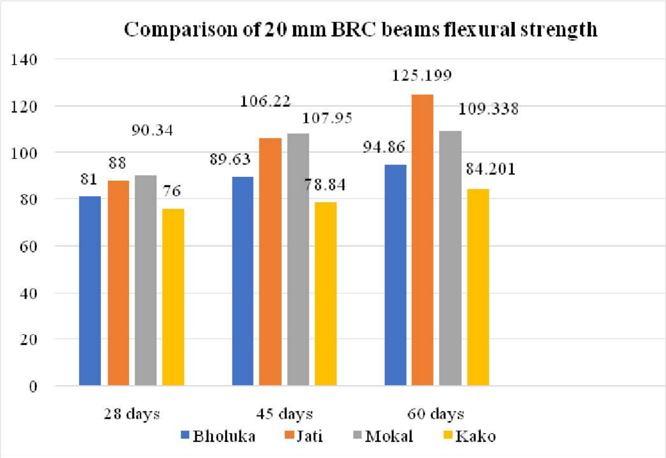
From the results, it can be concluded that BRC beams strength depends on the species, curing period and also on the average diameter of bamboo splints used. In this study beams with Jati and Bhokula as reinforcements showed better results. Also beams with longer curing period and greater diameter size perform better as compared to beams with smaller diameter and shorter curing period. Thus, it can be said that as the width of the bamboo splints increases the load carrying capacity of BRC beams also increases. Hence, dimension of the bamboo splints also plays a vital role in the performance of BRC beams. However, optimized size reinforcements are to be selected in order to avoid uncertainty in the design. Comparative plots of load vs curing period and load displacement characteristics are shown above in order to justify the test results of Table 1

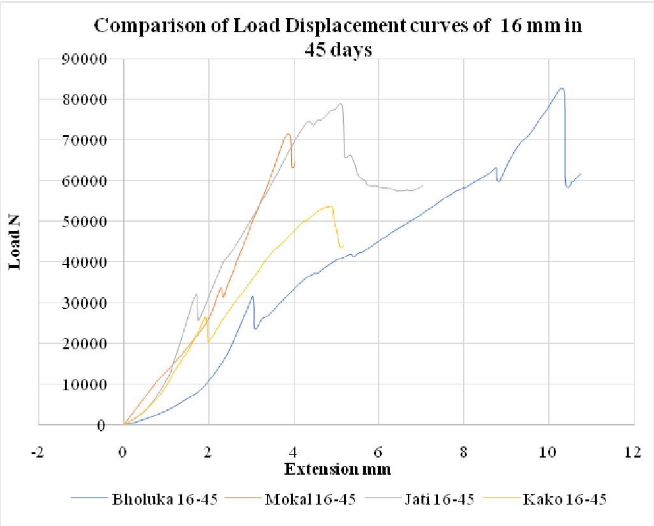












5. CONCLUSION

From the experimental work, it can be concluded that flexural strength of bamboo actually depends on the area of cultivation, type of species and cross-sectional area. An improved flexural performance of BRC beam has been observed with the increase in number of days of curing period and increase in the size of bamboo rebar. The aim of the study is to compare the flexural strength between different bamboo species. It has been found that the strength in flexure varies from species to species. In our case of study, the Jati Bamboo (*Bambusa tulda*) and Bholuka Bamboo (*Bambusa balcooa*) gave the best results, while Mokal bamboo (*Bambusa nutans*) showed moderate strength. The Kako Bamboo *(Dendrocalamus hamiltonii)* exhibited the lowest strength. To conclude the use of bamboo has the potential and can act as a substitute material for construction in India which will be a bold step toward building a sustainable environment. With the abundance of bamboo in our region, further research should be conducted to find out detailed characteristic and properties of the species and their various attributes. Due to the great advantages bamboo yield to the environment bamboo can be a substituted material for both wood and steel in construction. With adequate government input into policy measure, bamboo can be a very resourceful material, thereby contributing highly to mitigate the negative impacts of environmental degradation due to use of natural resources, militate against climate change, protect the biodiversity and promote sustainable construction development. Also, the government should encourage the use of bamboo in construction such as low-income housing scheme and also partner with governing bodies and also building industries.

6. ACKNOWLEDGEMENTS

This work was supported in part by a grant from the NEQIP-JEC. I am also grateful to **Mr R.K Kalita**, Scientist of Rain Forest Research Institute for his guidance, advice and help in treatment of bamboo splints.

I would also like to express my gratitude to **Mr Jayanta Jyoti Bora**, Principal Scientist, CSIR- NEIST, Jorhat for his guidance and help and also allowing me to avail the lab facilities of General Engineering Department of NEIST-Jorhat. I am very much thankful for his support and advice.

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