BAMBOO REINFORCED CONCRETE BEAM – STEP TOWARD SUSTAINABLE DEVELOPMENT

Vijay R Wairagade[1], Ishwar P Sonar[2]

1. Savitribai Phule Pune University, Pune, India
2. College of Engineering, Pune, India

ABSTRACT. Most of the Indians (60%) live below the poverty line and since the population is on the rise the demand of basic needs increases. Engineer's role is to provide the best facilities at optimum cost. And as such Concrete is the most consumed construction material in the entire world because of its various advantages such as low cost, availability, easy to mould, good compressive strength, fire resistance etc. But it cannot be used alone because of its low tensile strength. And therefore it is usually reinforced with steel which is very strong in tension. Due to the increasing cost, unavailability and other drawbacks of the steel, it become necessary to use an alternative material as reinforcement for low cost housing.

Bamboo which is abundantly available renewable material is used as a construction material from the earlier times due to its eco-friendly, advantageous, economical and versatile properties. As it is good in tension and bending properties it has drawn the attention of researchers to use it as reinforcement in cement concrete for low cost constructions. The feasibility for usage of bamboo as reinforcement in concrete is evaluated through a series of experimental investigations in the present study. In this paper we have tried to explore the structural behaviour and the future applications of bamboo reinforced beam for a low cast housing preferably in rural areas where bamboo is available in abundant as a step towards sustainable development.

Keywords: Bamboo, Sustainability, mechanical and physical properties, concrete, reinforcement.

Vijay R Wairagade is an Associate Professor and HoD of Civil Engineering Department, Indira College of Engineering and Management, Savitribai Phule Pune University, Pune, India. His research interest includes planning & designing of low cost buildings for rural and tribal areas and in particular study of renewable material in reinforced concrete members.

Dr Ishwar P Sonar is an Assistant Professor at Civil Engineering Department, College of Engineering, Pune, India. His research interest includes concrete durability and performance, product development, low cost construction, reuse and recycling of materials in concrete construction and testing of materials. He has published extensively on the subject of eco-friendly material in concrete.

INTRODUCTION

Concrete is the mainly used material in building construction. It is used largely because it is economical, readily available and has suitable building properties, such as high compressive strength. It has low tensile strength due to this, it is often reinforced with steel bars. These bars provide the high tensile strength to concrete. But use of steel has some disadvantages, like higher cost and non-renewability of steels. Production of steel is responsible for a major source of greenhouse gas emission. Hence, many attempts are carried out by researchers to provide a low cost sustainable alternative of steel by using locally available material. Many researchers investigated the possibilities of using vegetables, fibers materials as reinforcement in concrete. Vegetables fibers materials which have been studied are 1) jute, 2) coconut, 3) coir, 4) sisal, 5) babadua, 6) date palm, 7) raffia palm, 8) bamboo and bamboo fibers, etc. although, most of these studied yielded good results still bamboo has a clear advantages over other natural reinforcing material.

There are several good reasons why bamboo is considered as reinforcement for concrete:

- It is of low cost compared with steel
- It is readily available
- Its strength to weight ratio compares favourably with steel.

Bamboo is one material which reaches its full growth in just a few months and reaches its maximum mechanical strength in just few years. It exits abundance in tropical and sub-tropical regions and makes it an economically advantageous a lightweight design, better flexibility, and toughness due to thin walls with discretely disturbed nodes and its great strength make it a good construction material. It is used as structural material for scaffolding at construction sites, building roads, furniture, rugs, diapers, clothes, promote fertility in cows, medical purposes and many more accessories.

Basic Characteristics of Bamboo

Bamboos are giant grass-like plants and not trees. Bamboo is seismically resisting material and for sustainable environment development without harming our global environment. Bamboo exhibits certain characteristics which limit its effectiveness as concrete reinforcement. But this can be overcome by adopting proper methods.

Durability of Bamboo as an Engineering Material

The durability of bamboo depends strongly on the preservative treatment methods in accordance with basic requirements. Its chemical composition should not have any effect on the bamboo fiber and once injected it must not be washed out by rain or humidity.

Bond

If seasoned (dry) bamboo is used as reinforcement, when the concrete is poured it will absorb water and swell. Later, as the concrete dries, the bamboo will shrink and the bond will be broken. If unseasoned (green) bamboo is used, it will lose water and shrink as the concrete dries and again the bond will be broken. The bond can be improved in a number of ways.

Low modulus of elasticity

The relatively low modulus of elasticity can cause problems in respect of the following:
Cracking and deflection: A bamboo reinforced element will crack and deflect perhaps 50% more than a steel reinforced element of equivalent section.

LABORATORY PROGRAM

Selection and preparation of bamboo strips

To check the feasibility and reliability as reinforcing material and to select appropriate kind of bamboo specimen, series of tests are conducted on the selected bamboo samples to find out physical and mechanical properties. Bamboo samples were collected from local market of Talegaon, Pune and Ahmednagar. The species of bamboo are Dendrocalmus Strictus which is predominantly found in India. The age of bamboo used is 3 to 4 years having brownish appearance and samples which are cut in winter. Diameters of bamboos are ranging from 30 mm to 50mm and thickness 6mm to 20mm. The bamboo splints of desired size are cut from these bamboo culms were prepared for testing. To improve the bond strength, bamboo splints are coated with oil paint (coating materials) & sprinkled with sand being economical.

For the reinforcement, the bamboo samples are treated in three stages. Firstly bamboo specimen are polished by sand paper. Then a coat of black color oil paint is applied on the specimen. Finally, a coat of fine aggregates (dry sand) is applied on the specimen to improve the bonding between the bamboo and concrete.

Testing of bamboo Samples

The various tests conducted on the selected Bamboo samples, where the outcome found to be very much competitive and satisfactory to use the material in concrete, we have decided to cast and test the bamboo reinforced concrete beams.

Figure 1 Collection of bamboo samples from local market and testing of bamboo splints

Casting and Testing of BRC Beams

The various tests conducted on the selected Bamboo samples, where the outcome found to be very much competitive and satisfactory to use the material in concrete, we have decided to cast and test the bamboo reinforced concrete beams. Thus BRC beams of 2.4 mtrs in length

are casted with different number of bamboo splints are used in cement concrete M30 grade and cured for 28 days. The strain gauges are also installed under the expert's supervision.

The BRC beams are then tested in UTM of 400KN capacity with the proper arrangement to support 2.4 meter length beam by fabricating a built up section. The BRC beam installed with strain gauges are also tested under the expert's supervision. Two point loading test is done on bamboo reinforced beams to study their failure load and failure pattern.

Figure 2 Casting and testing of BRC beams

Further from these observations we tried to find out some conclusion. In the first trial of RC & BRC beams. It is observed that the BRC beams are following the similar trend like RC beams. This build hopes and brings confidence to continue the work. The strength observed was 60% of RC beams with the average of 2.70 % of bamboo as a reinforcement. The stresses developed in bamboo at failure load observed were very less.

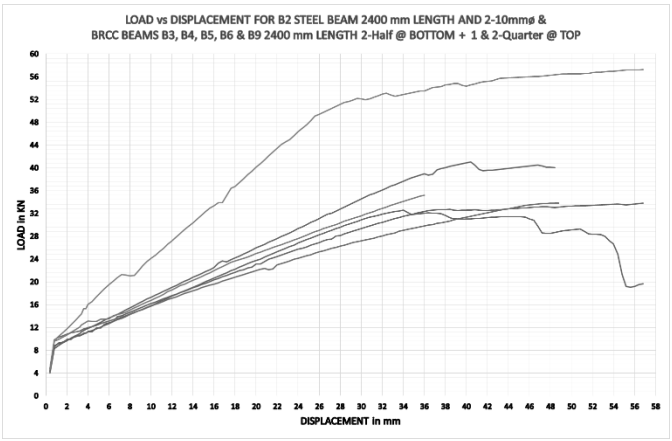

Figure 3 Comparison of RC & BRC Beams

Design Constants – Bamboo and Concrete

The outcome of the earlier test results of BRC beams leads to develop some constants so as to further design and test the beams and to verify the assumed standards. So with some assumptions and the values obtained from the test results of the bamboo specimens, I tried to

calculate constants. Since we have decided to use M30 grade of concrete for casting of final beams, I have plotted the variation of Mr with bamboo percentage only for M30. From the graph it is clearly reflected that it is better to have maximum 4.36 percentage of bamboo as a reinforcement.

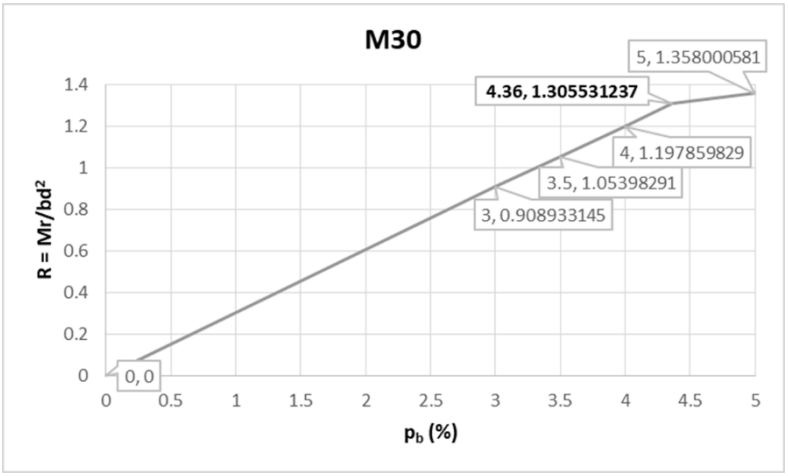

Figure 4 Variation of M_r with P_b

RESULTS AND DISCUSSION

So accordingly I have casted few more beams with 1.96%, 2.93% and maximum 3.91 percentage of bamboo splints as reinforcement. Out of these beams strain gauges are attached to bamboo splints and the concrete surface at different positions in two beams. Total 33 beams were casted out of which the shortlisted test results of 12 nos. of beams are considered. Two point loading test is done on bamboo reinforced beams of dimensions 1200 mm X 150 mm X 250 mm to study their failure load and failure pattern. For all the beams (RC & BRC) ultimate experimental load was more than calculated load. Also except 1.96% reinforced BRC beams, every other beams shows better load carrying capacity at allowable deflection of 3mm (span/350). If we could extend the allowable deflection for BRC upto 4.2mm (span/250), all beams exhibits much safer load compared to designed load.

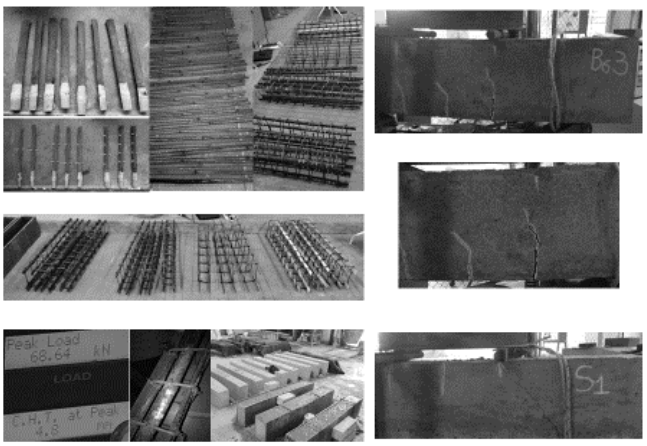

Figure 2 Casting and testing of BRC beams

Also very important outcome of these tests are the highly satisfactorily results by 3.91% of BRC beams compared to 0.48% RC beams. The results at 3.91% of bamboo reinforced beams are higher than the results of 0.48% RC beams. If we could consider the span/250 as allowable factor for deflection in case of BRC members, the results are much better than regular RC members.

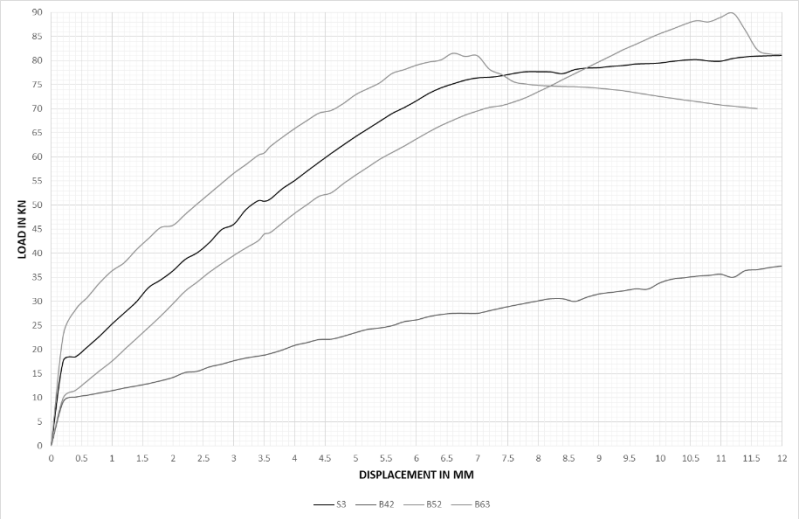

Figure 5 Comparison of RC & BRC Beams

CONCLUDING REMARKS

The behaviour of BRC members with 2.93% reinforcement and 3.91% reinforcement is very much similar to RC members with 0.48% reinforcement. If these outcomes are further verified with few more test then we may be conclude with some constants for the design of BRC members by WSM.

REFERENCES

1. ATUL AGARWAL, BHARADWAJ NANDA, DAMODAR MAITY, Experimental investigation on chemically treated bamboo reinforced concrete beams and columns, Construction and Building Materials, ELSEVIER, 71, 2014, pp. 610–617.
2. DINESH BHONDE, P. B. NAGARNAIK, D. K. PARBAT AND U. P. WAGHE, Experimental Analysis of Bending Stresses in Bamboo Reinforced Concrete Beam, ELSEVIER - Proceedings of 3rd International Conference on Recent Trends in Engineering & Technology 2014.
3. DIRK E. HEBEL, FELIX HEISEL AND ALIREZA JAVADIAN, Engineering Bamboo, The new composite reinforcement, Chair of Architecture and Construction, Future Cities Laboratory, Singapore ETH Centre, Singapore.

4. FRANCIS E. BRINK AND PAUL J. RUSH, Bamboo Reinforced Concrete Construction, U. S. NAVAL CIVIL ENGINEERING LABAORATORY, Port Hueneme, California, February 1966.
5. GHAVAMI K., 2005, Application of Bamboo as a Low-cost Construction Material, Proceedings of the bamboo workshop, Nov. 14-18, 1988, pp. 270-279.
6. JULES J.A. JANSSEN, Designing and Building with Bamboo, Technical report no.20, International Network for Bamboo and Rattan 2000.
7. KENT A. HARRIES, BHAVNA SHARMA, MICHAEL RICHARD, Structural Use of Full Culm Bamboo: The Path to Standardization, International Journal of Architecture, Engineering and Construction Vol.1, No. 2, June 2012.
8. LEENA KHARE, Performance Evaluation of Bamboo Reinforced Concrete Beams, The University of Texas at Arlington, December 2005, pp. 1-100.
9. LIMAYE D., 1952, Strength of Bamboo (Dendrocalmus Strictus), Indian Forester, Timber Mechanics Branch, Forest Research Institute, Nov. 1952, pp. 558-575.
10. TIMOTHY CLANCY FERGUSSON-CALWELL, Viability of Bamboo reinforced concrete for residential housing in Indonesia, School of Engineering and Information technology, Charles Darwin University, 2015.
11. WAKCHAURE M. R., KUTE S. Y., MEHETRE P. R., Bamboo Reinforced Concrete For Sustainable Development, UKIERI Concrete Congress - Concrete Research Driving Profit and Sustainability, 2016, p.p. 1576-1585.
12. DR. I. P. SONAR, Performance of Bamboo reinforced Concrete Composite Structural Elements, International Conference on Sustainable Technologies for Concrete Constructions, ACI, Mumbai, Sep. 3-4, 2010.
13. VIJAY WAIRAGADE, Study of Bamboo as Reinforcing Material in Concrete, National Conference on Innovations in Engineering and Management, NCIEM-2013, Pune, Jan.31–Feb. 01, 2013.
14. VIJAY WAIRAGADE, DR. ISHWAR SONAR, Review of Bamboo as Potential Reinforcement in Concrete, International Conference on Advancement in Engineering and Technology, ICAET-2014, Pune, Sep. 1-3, 2014.
15. VIJAY WAIRAGADE, DR. I. P. SONAR, Bamboo as Potential Reinforcement in Concrete Panels, Ancient Science and Technology: Retrospection and Aspirations, ASTRA-2015, Pune, Jan. 10-11, 2015.
16. VIJAY WAIRAGADE, Experimental Study of Bamboo Reinforced Concrete Beam, Regional Research Conference, INNOVATION-2017, Pune, Nov. 15, 2017.
17. PRAYUSH PAREKH, SAIPRASAD PATIL, PRANJALI SALUNKHE, VIJAY WAIRAGADE, Study of Structural Behaviour of Bamboo Reinforced Lintel Beams, International Civil Engineering Symposium, IIT Bombay , ICES, March-2018, p.p. 68-71.
18. PRAYUSH PAREKH, SAIPRASAD PATIL, VIJAY WAIRAGADE, Bamboo Reinforced for Sustainable Construction for Rural Areas, International Journal of Innovative Research & Studies, Volume 8, Issue IV, April-2018, p.p. 284-287.