

Comparative Analysis of Bamboo Species as an Alternative to Steel Reinforcement

^[1] Aniket Sahare, ^[2] Dr. Debarati Datta, ^[3] Pankaj Mali

^[1] PG Student (MTech. STR), VNIT Nagpur, ^[2] Assistant Professor, VNIT Nagpur,

^[3] Research Scholar (Ph.D.), VNIT Nagpur

Abstract:— With the world embracing the concept of sustainability, the importance of bamboo as a sustainable material is gradually increasing in the construction sector. Since there are many species of bamboo available across the globe, region specific studies are important to understand the bamboo harnessing potential of that region. This study is focused on Vidarbha region as it is very rich in bamboo (90% of total state production of bamboo) and involves comparative study between the two main bamboo species found in Vidarbha i.e. *Bambusa arundinacea* (Locally known as Katang) and *Dendrocalamus strictus* (Locally known as Manvel). In this paper, experimental investigation has been carried out to study the mechanical as well as physical properties of both the species, in order to check their suitability against conventional steel reinforcement. The bamboo species have been procured from Nagpur district. The samples were prepared and tested according to IS 6874:2008. To understand the physical nature of these species, tests were conducted to determine the physical properties that included Moisture content test, Density test and Shrinkage test. The tests carried out to determine mechanical properties were Bending strength test, Compressive test strength and Tensile strength test. The comparative test results are presented in the paper.

Index Terms - Bamboo reinforcement, Node, Sustainability, Wall thickness.

I. INTRODUCTION

In every construction project, the main objective is cost minimization and the prime materials influencing cost of reinforced concrete are cement and steel. The world is slowly starting to realize the importance of sustainability and is searching for a suitable and sustainable alternative to these materials. Sustainability means meeting our own needs without compromising the ability of future generations to meet their own needs. In our context, the basic principle is that the energy and resources consumption due to the construction and operation of a structure must be minimized. Sustainable building materials can be defined as sustainable during their whole life-cycle, readily available from many sources. Past research has shown that many alternatives have been used and their feasibility is shown to be good. For example: Replacement of steel by synthetic fibers, bamboo reinforcement. Also as steel production processes has three times more energy consumption than cement production, replacement of steel as a reinforcement has become a concerned area of research in recent years.

Some of the factors which favors bamboo as an alternative to steel is its relatively high tensile strength, cost effectiveness, eco friendly nature, availability and also its weight is almost a quarter to that of steel. Bamboo can also be used in construction of low cost houses in

addition to its use in trusses and scaffolding

II. CODAL PROVISIONS

At present, the application of bamboo as an engineering material is largely based on practical and engineering experience as the design guidelines are inadequate. Following are the few codal provisions available: Indian standards:

1. NBC : 2005 : National Building code of India
2. IS 6874 : 2008 : Method of test for round bamboo
3. IS 8242 : 1976 : Method of test for split bamboo
4. IS 9096 : 1979 : Code of practice for preservation of bamboo for structural purposes
5. IS 13958 : 1994 : Specification for bamboo mat board for general purposes

International Guidelines for Bamboo:

1. ISO 22156:2004: Bamboo – Structural design
2. ISO 22157-1:2005: Bamboo – Determination of Physical and Mechanical properties.

In this study, IS 6874(2008) and NBC (2005) have been used to carry out the experimental investigations.

III. OBJECTIVE

The overall objective of this research work includes checking the feasibility of bamboo as an alternative reinforcement for conventional steel. The research work includes determining the physical and mechanical properties of the two selected bamboo species and deciding the better specie among them. Different bamboo reinforced concrete elements are to be prepared using the bamboo specie selected based on their properties.

IV. SELECTION OF BAMBOO SPECIES

There are around 100 bamboo species available in India with huge variation amongst their characteristics. Even in a single shoot (full culm) of bamboo, the physical property may show a certain trend because of the fibrous structure of the bamboo, wall thickness and its node to node connections. As the focus of this study is to find a solution for low cost housing, locally available bamboo species were explored with the help of a field vendor and two of the most suitable species were selected with the help of literature and codal provisions.



Fig.1. Dendrocalamus strictus (Manvel)



Fig.2. Bambusa arundinacea (Katang)

V. DETERMINATION OF PHYSICAL PROPERTIES

A bamboo species with good physical properties is more reliable and durable. The following physical properties are determined below as per the Indian

Standards:

5.1 Moisture content test

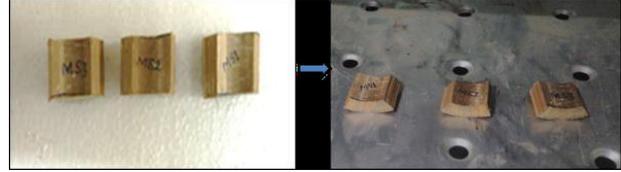


Fig. 3. Bambusa. arundinacea (Katang) samples

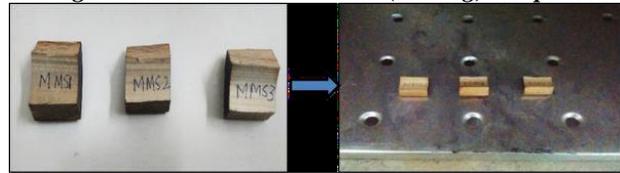


Fig.4. Dendrocalamus strictus (Manvel) samples

Table 1. Results of moisture content in Bambusa arundinacea

Sample ID	Initial mass (gm)	Oven dry mass (gm)	% Moisture content
MS-1	7	6	16.67
MS-2	6.5	5	30
MS-3	6.5	5	30
(%)Average moisture content			25.56

Table 2 .Results of moisture content in Dendrocalamus strictus

Sample ID	Initial mass (gm)	Oven dry mass (gm)	% Moisture content
MS-1	4	3.5	14.285
MS-2	4	3	33.33
MS-3	4	3	33.33
(%)Average moisture content			26.98

5.2 Shrinkage test



Fig. 5. *Bambusa. arundinacea* (Katang) samples



Fig. 6. *Dendrocalamus strictus* (Manvel) samples

Table 3. Results of shrinkage in *Bambusa. arundinacea*

Sample ID	Shrinkage along length	Shrinkage along diameter	Shrinkage along thickness
Sample-1	0.194	3.2055	2.974
Sample-2	0	3.483	2.89
Sample-3	0	3.154	3.91
%Average shrinkage	0.646	3.28	3.278

Table 4. Results of shrinkage in *Dendrocalamus strictus*

Sample ID	Shrinkage along length	Shrinkage along diameter	Shrinkage along thickness
Sample-1	0.2723	1.6077	3.2606
Sample-2	0.3	2.06	5.0913
Sample-3	1.258	3.018	2.05
%Average shrinkage	0.6101	2.228	3.4673

5.3 Density test

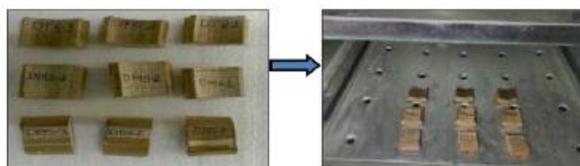


Fig. 7. *Bambusa. arundinacea* (Katang) samples

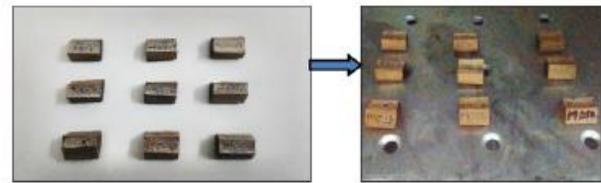


Fig. 8. *Dendrocalamus strictus* (Manvel) samples

Table 5. Results of density in *Bambusa arundinacea*

Sample ID	Density of top culm in kg/m ³	Density of middle culm in kg/m ³	Density of bottom culm in kg/m ³
Sample-1	1142.85	1125	888.8
Sample-2	1142.85	1125	888.8
Sample-3	1142.85	1125	888.8
Average Density	1142.85	1125	888.8

Table 6. Results of density in *Dendrocalamus strictus*

Sample ID	Density of top culm in kg/m ³	Density of middle culm in kg/m ³	Density of bottom culm in kg/m ³
Sample-1	1333.33	750	1333.33
Sample-2	1200	1333.33	1000
Sample-3	1600	1600	1000
Average Density	1377.77	1227.77	1111.11

VII. DETERMINATION OF MECHANICAL PROPERTIES

6.1 Compression Test

Three samples of each species were prepared and arranged concentric with the machine. The load applied on the specimen at a rate of 0.01mm/sec.



Fig. 9. Testing of Bamboo samples

The average compressive strength calculated were 77.23 MPa & 89.03 MPa for *Dendrocalamus strictus* (Manvel) and *Bambusa arundinacea* (Katang) respectively.

6.2 Bending Test

The static bending test as per IS 6874:2008 was conducted and a load deflection curve obtained for the two species.



Fig.10 Static bending test on bamboo sample

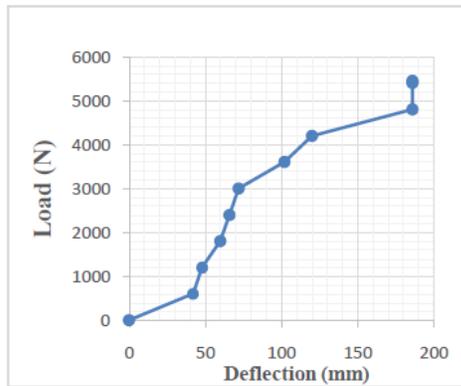


Fig. 11 Load deflection curve for Dendrocalamus strictus (Manvel)

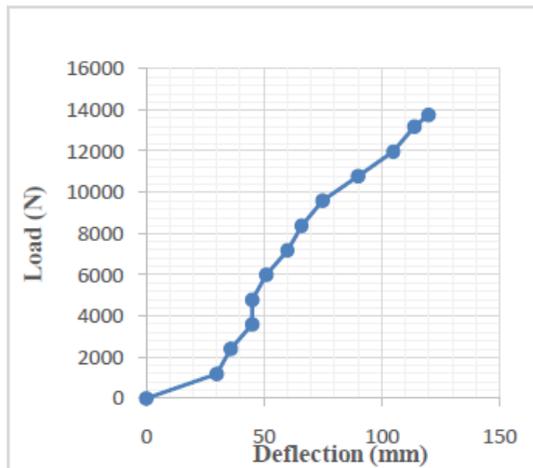


Fig.12. Load deflection curve for Bambusa arundinacea (Katang)

The average flexural strength calculated were 84.7

MPa & 90.42 MPa for *Dendrocalamus strictus* (Manvel) and *Bambusa arundinacea* (Katang) respectively.

6.3 Tensile Test

As the bamboo is weaker at the nodes, each of the two species was checked for their normal as well as nodal strength. The samples were tested according to IS 6874 in digital universal testing machine.



Fig 13. Tensile test specimens
Table 7. Results of Tensile strength

Sr.no	Dendrocalamus strictus (Manvel) MPa		Bambusa arundinacea (Katang) MPa	
	(with node)	(without node)	(with node)	(without node)
1.	115.35	228	132.1	232
2.	200	146.5	78	152
3.	97	209	70	250
Average	138	194.5	93.36	211.33

VII. CONCLUSION

From the tests performed, considering an overall weightage factor, *Bambusa arundinacea* (Katang) clearly emerges out as a better species compared to *Dendrocalamus strictus* (Manvel). It will be tested with a series of sealant materials to select the most suitable combination using pull out test. Further research on bamboo concrete elements can be carried out using *Bambusa arundinacea* as an alternative replacement to steel.

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