

REVIEW OF BAMBOO AS REINFORCING MATERIAL IN CONCRETE

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Abstract - In recent years, we being more responsible towards global warming and sustainability issues, the society senses towards use of natural materials for construction. Bamboo is expected to contribute significantly to earthquake-resistant construction and seismic retrofit technology for developing countries as bamboo is found to be low cost, fast growing and broad distribution of growth in Maharashtra, India particularly. Bamboo is a unique group of gigantic grasses the culm of which originates in underground rhizomes. Plants and fibers are annually reproducible clean resources. Bamboo is also found good in tension and bending properties, so it can be used as reinforcement in cement concrete for low cost constructions. The outcome of review research will allow us to understand the advantages and disadvantages, Tensile, compression and flexural strength of a particular bamboo, analysis of bamboo types which can be suitable of construction and be used/replaced as reinforcement to some extent atleast. The local materials available gives a cultural experience in the development of the construction methods and techniques.

Key Words - Bamboo, natural material, Sustainability, mechanical properties, concrete, reinforcement.

1.INTRODUCTION

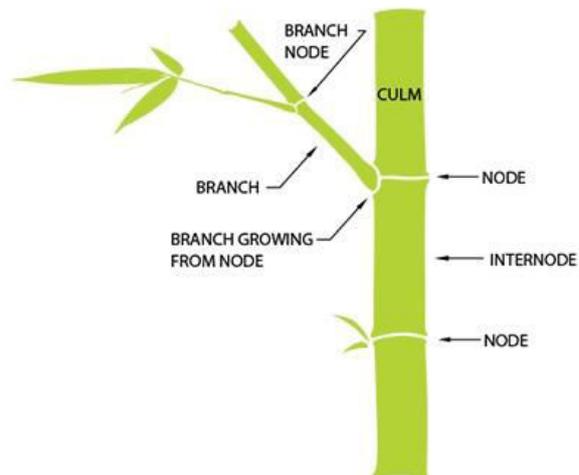
Constructing buildings is one of the important aspect which heavily depends on steel. As steel is difficult to obtain because of its expensive prices, usage of steel is limited heavily due to which the developing countries are affected to some extent. The production of steel has high consumption of fossil fuels, so, the steel discharge in the construction of structures has been presented, showing the possibility of drastic reduction by research institutes.

Pollution of air and water has been seen due to rapid development and production of materials like steel, iron, glass, cement and aluminium that use limited mineral resources which leads to environmental destruction. Meanwhile, for developing countries, it is important to make the development of buildings construction; low cost, no requirement of sophisticated technologies and reliable construction methods.

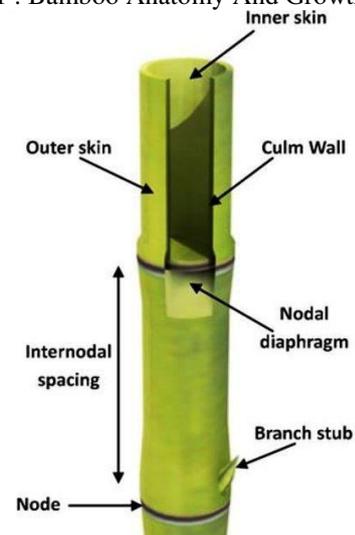
On the other hand, plants and fibers are annually reproducible clean resources. Bamboo being classified as a grass member of a larger grass family, it can be easily found in tropical and some temperate areas of the world.

Bamboo has over 1500 identified bamboo species in the world and is one of the fastest growing plants. It can reach full height ranging from 15-30 mm in a period of two to four months. All types of bamboo consists similar anatomy, which consists of nodes, internodes, and diaphragm. [1]

If the bamboo gains more height, the thickness decreases along the culm while the fibers density increases from the bamboo culm's inner wall to outer wall.



Img – 1 : Bamboo Anatomy And Growth Habits



Img – 2 : Bamboo culm anatomy

Bamboo **Plant Types** – Common Bamboo Varieties
Clumping & Running Bamboo.

Cold-hardy Climate types -

- **Running**
- Golden Groove, Black Bamboo, Kuma Bamboo
- **Clumping**
- Chinese Mountain, Umbrella Bamboo

Warm Climate types -

- **Running**
- Black Bamboo, Red Margin, Golden Groove, Giant Japanese Timber
- **Clumping**
- Chinese Goddess Hedge Bamboo, Fernleaf, Silverstripe [2]

Top 10 Types of Bamboo in India -

- Bambusa Polymorpha
- Bambusa Striata
- Bambusa Tulda
- Dendrocalamus Giganteus
- Dendrocalamus Hamiltonii
- **Dendrocalamus Strictus (Manvel)**
- Drepanostachyum Falcatum
- Gigantochloa Rostrata
- Indocalamus Wightianus
- Melocanna Baccifera [3]

In China, contractors have utilized bamboo as scaffoldings, while in Bali, bamboo is used to construct a Green School, where all structural components of the building is sourced from a local bamboo supplier. So recently, its seen that there is a growing interest in using bamboo as a construction material, in place of timber or steel.

The Important factors of bamboo are strength and moisture content, which determine both ability and capacity of full bamboo culm. In terms of durability, it varies according to species and age ranges. It is estimated that an untreated bamboo has a design life of approximately 10-15 years if it is stored appropriately, while a treated bamboo will have a much longer design life.

The aim of this research is to investigate on the different species of local bamboo's easily available and find out the possibility of utilizing bamboo as a reinforcing construction material. [4]

2. LITERATURE REVIEW

In this research paper titled “**Green Gold Manga Bamboo (*Dendrocalamus stocksii*) for Commandable Profit from Cultivable Wasteland**”, A. D. Rane, S. S. Narkhede, V. V. Dalvi, V. K. Patil, P. M.Haldankar, S. B. Dodake, A. A. K. Dosani and T. Bhattacharyya talks about DFI (Doubling

Farmers Income) through bamboo cultivation in konkan region of Maharashtra. Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli has provided several technological services for promoting cultivation of this species in the Konkan region. Konkan farmers have cultivated manga bamboo in their farmlands for commercial purpose. The university has standardized the culm cutting vegetative propagation, spacing along with harvesting, agro forestry system and has analyzed the diversity of this species along the western Ghats for manga bamboo. As the area under the manga bamboo is increasing because nurseries have been proactively installed in farmers fields.Hence its recommended for plantation as live fence, on bunds of Nagli and as block plantation. A biannual harvesting cycle for this species fetches 18-24 sticks per clump and each stick fetches ₹ 40 to 60. [5]

In this research paper titled “**Dendrocalamus stocksii (*Munro*): A potential multipurpose bamboo species for Peninsular India**”, S.Viswanath, Geeta Joshi, P.V.Somashekar, Ajay D. Rane, Sowmya. C and S.C.Joshi gives an overview of species that are naturally distributed in Central Western Ghats and locally also known as Manga Bamboo. It is the most preferred bamboo species after *Bambusa bambos* and *Dendrocalamus strictus* by the farmers for cultivation. A manageable species with great economic and ecological importance as well as large scale utilization potential. This species is a preferred one among bamboo users because of its non-thorny nature, loosely spaced culms which facilitates easy management. Besides its use as edible shoots and in handicrafts, it is a component of various agricultural implements, farm structures and as a live fence. It is also used for scaffolding, pulp and paper, crafts, construction, making baskets, umbrella handles, walking sticks, as navigation tool in country boats etc. [6]

In this research paper titled “**In Vitro Propagation of *Bambusa balcooa* as Alternative Material of Wood**”, Siti Nurhayani, Rita Megia and Ragapadmi Purnamaningsih state that one of the bamboo species that is *Bambusa balcooa* can be alternative materiel used for wood as resulted in the vitro propagation process by the authors and funded by ICABIOGRD (*Indonesian Center for Agricultural Biotechnology and Genetic Resource Research and Development*) .Use of wood as a raw material for instance in building, manufacture of paper need material from tree that take a long time to grow should be replaced. Combination of chemicals like BAP (*6-Benzylaminopurine*) and TDZ (*Thidiazuron*) was significantly affecting the growth of *B. balcooa* shoots. Vermicompost fertilizer was more suitable for *B. balcooa* growth under acclimatization compared to compost fertilizer. [7]

In this research paper titled “**Physical properties of thorn less bamboos (*Bambusa balcooa* and *Bambusa vulgaris*)**”, N. Krishnakumar, S. Umesh Kanna, K.T. Parthiban and

P. Rajendran check on the physical properties such as moisture content and basic density of thorn less bamboo's available over bambusa bambos. This study was carried out due to concern of paper industries in India has been constrained due to high cost of production caused by inadequate raw material availability coupled with high cost of the available raw material. Hence the industries are looking for fast growing material to remain competitive and productive. Under such circumstances bamboo being considered as the fast growing tree suitable for pulp and paper industries.

Particularly thorn less bamboo easily available are *Bambusa balcooa* and *Bambusa vulgaris* which go through various schemes as a source of multifarious industrial wood raw material. As a result *Bambusa balcooa* performed consistently better over *Bambusa vulgaris* and *Bambusa bambos* and registered significantly higher values for moisture content, basic density. [8]

TABLE-I: Statistics of Bamboo Species Availability in India

Bamboo Species Availability in India		
Bamboo Species	Availability	Uses/Purpose
Dendrocalamus Stocksii (Manga)	Konkan Region, Maharashtra	Farm fencing, Commercial Purpose
Dendrocalamus Strictus	Western Ghats, Maharashtra	Scaffolding, Construction
Bambusa balcooa	Nagaland, Bihar, U.P	Furniture, Construction
Bambusa vulgaris	West Bengal, North East	Fencing, Temporary Shelters

Results from the above Literature review and Table-I state that the following bamboo species are easily available in India and are used in some or the other commercial purpose like farm fencing, furniture making, scaffolding, temporary structures etc which can be studied further in aspects like tensile, compressive and flexural strength to replace steel in reinforcement atleast some extent.

3. METHODOLOGY

The methodology adopted for this research includes reviewing the research papers and finding out the easily available bamboo nearby or in India and which are strong enough and are currently used for furniture, temporary structures and scaffolding in the construction industry. Further discussing the same with the guides and engineers through which a study on selected bamboo's to made with respect to their mechanical properties which will justify that the following bamboo specimen can be replaced with steel for reinforcement process.

4. MECHANICAL PROPERTIES of Bamboo

In this research paper titled “**Analysis of bamboo reinforced concrete column**”, Ajinkya Kaware¹, Prof. U.R.Awari, and Prof. M.R.Wakchaure represent that design and testing of Bamboo reinforced concrete column to be casted with bamboo reinforcement varying from 2.5 % to 4 % at an increment of 0.5 with 3 rectangular specimen of size 230 x 150 x 750 mm³, 3 specimen of square column 150 x 150 x 750 mm³ and 230 mm diameter and 750 mm length 3 circular specimens for each increment in reinforcement. Above mentioned column are compared with steel reinforced concrete column of similar dimension, numbers and shape with minimum steel reinforcement. [9]

In this research paper titled “**Bamboo reinforced concrete: a critical review**”, Hector Archila, Sebastian Kaminski , David Trujillo, Edwin Zea Escamilla and Kent A. Harries addresses such ‘bamboo-reinforced concrete’ and assesses its structural and environmental performance as an alternative to steel reinforced concrete. A prototype three bay portal frame, that would not be uncommon in regions of the world where bamboo reinforced concrete may be considered, is used to illustrate bamboo reinforced concrete design and as a basis for a life cycle assessment of the same. The authors conclude that, although bamboo is a material with extraordinary mechanical properties, its use in bamboo-reinforced concrete is an ill-considered concept, having significant durability, strength and stiffness issues, and does not meet the environmentally friendly credentials often attributed to it. [10]

In this research paper titled “**Bamboo as reinforcement in structural concrete elements**”, Khosrow Ghavami states that the results of some of the recent studies of the microstructure of bamboo as a functionally gradient material. These studies led to the establishment of bamboo's composite behaviour through the rule of mix. A concise summary regarding bamboo reinforced concrete beams, permanent shutter concrete slabs and columns is discussed. Finally, some recommendations for future studies are proposed with the hope that the newly developed material could contribute, on a large scale, to sustainable development without harming our globe. [11]

In this research paper titled “**Flexural behaviour of concrete with bamboo and steel reinforcement**”,

Prof. V Giridhar Emphasizes on flexural behavior of concrete with or without reinforcement.To reduce the cost of construction, bamboo prefers to use as reinforcement in structural elements and studied its flexural behavior with bamboo and steel reinforcement and evaluate the strength parameters with steel reinforced beam and PCC specimens. Flexural strength of the concrete with bamboo reinforcement with respect to PCC is increased to 15.8% for 7 days and 30.34% for 28 days. Similar trends were observed in flexural

strength of the concrete with steel reinforcement with respect to PCC is increased to 28.6% for 7 days and 77.7% for days. [12]

In this research paper titled “**Corrugated bamboo as reinforcement in concrete**”, Abdullah Khatib and Ghassan Nounu investigated the use of mechanical interlock to solve a fundamental problem in using bamboo as reinforcement in concrete – the bamboo–concrete bond. It was found that corrugating bamboo is effective in improving the bond between bamboo and concrete. This contributes to a higher bending capacity of bamboo-reinforced concrete beams and limits the deflection of bamboo-reinforced concrete beams. It was found that a 2 mm projection in the corrugation was more effective than a 1 mm projection. [13]

In this research paper titled “**Properties and Classifications of Bamboo for Construction of Buildings**”, Aisha Haladu Bornoma, Muhamed Faruq, and Moveh Samuel state the various properties and characteristics of bamboo and how they could be used for possible construction of some domestic and some of their possible advantages over conventional wood used in building constructions. From one perspective bamboo is more impervious to water harm than the normal hardwood. Be that as it may it is as yet a characteristic material made of natural components, and thusly extreme dampness will make it twist or will enable shape to develop. One of the principle focal points of working with bamboo is that it is a magnificent, common and sustainable asset, equipped for fast development that can maintain a strategic distance from future deforestation of our valuable tropical rainforests. [14]

In this research paper titled “**State of The Art: Bamboo as a Structural Material**”, M. B. Varma finds suitability of bamboo as a structural member. Many research workers have studied different properties of bamboo. They have presented properties which attract attention of structural engineer to try and use bamboo, bamboo strips in structural elements. Bamboo is light in weight, easily available and available in ample and also unskilled workers can handle very easily, with vary less cost, so may fulfill requirements of good building material. [15]

In this research paper titled “**Bamboo reinforced concrete beam – step toward sustainable development**”, Vijay R Wairagade, Ishwar P Sonar state that 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. Authors 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. [16]

In this research paper titled “**Fracture Behavior and Mechanical Properties of Bamboo Reinforced Concrete Members**”, Masakazu TERAJ AND Koichi MINAMI state that the seismic retrofit of the masonry structures in the design and construction of bamboo reinforced concrete. A study of the feasibility of using bamboo and non-steel as the reinforcing material in concrete members was conducted in our laboratory. Six beam specimens were constructed and a total of 11 beam tests were performed to examine the flexural cracking and the shear cracking strength. Additionally, monotonic compression tests were carried out on 16 column specimens, which has 200mm in diameter and 500mm in height with confining steel bars or PP-band spirals, in order to study fracture behavior and mechanical property of bamboo confined concrete. [17]

In this research paper titled “**Experimental Analysis of Bending Stresses in Bamboo Reinforced Concrete Beam**”, Dinesh Bhondea, Dr P. B. Nagarnaik, Dr D. K. Parbat, Dr U. P. Waghe say that Bamboo has been a very fascinating natural material useful in almost all aspects of life. Bamboo is a light weight, tensile, flexible, sustainable, eco friendly, green material and its use shall be advocated in building construction for sustainable development.

Author evaluates bamboo reinforced concrete beam with four point loading. The load elongation curve was plotted and load at first crack, ultimate bending moment at failure was studied. The values of maximum bending stresses at extreme concrete fibre and the concrete surrounding reinforcement were found. Ultimate experimental stresses, design stresses were compared. [18]

In this research paper titled “**Experimental investigation on behavior of bamboo reinforced concrete member**”, Arpit Sethia and Vijay Baradiya explain that tensile strength of bamboo is quite high and can reach up to 125 MPa. This makes bamboo an pretty alternative to steel in tensile loading applications. The bamboo concrete composite elements can be used as alternate for concrete, steel and wood used in housing and other products required in the day to day applications. In this study it has been attempted to develop engineered bamboo structural elements for use in low cost housing. The results obtained accrue the advantage obtained by the composite members when compared to standard reinforced concrete and plain concrete. [19]

In this research paper titled “**The Recent Research on Bamboo Reinforced Concrete**”, Sri Murni Dewi and Devi Nuralinah say that three kinds of structures studied in recent year, the mounting of pegs on reinforcement, the use of lightweight brick to reduce the weight of the beams, and the use the light weight aggregate for bamboo concrete composite

frame. All that experiments overcome some problems exist in using bamboo as environmental acceptance structures. [20]

In this research paper titled “Assessing the structural response of a mortar infilled steel eyebolt bamboo connection under bending and cyclic loads”, Gian Karlo Cabanas define bamboo connection displayed some desirable mechanical characteristics that would make it a useful addition to future bamboo building codes. It exhibited ductile deformation and maintained its moment capacity despite undergoing significant rotations, showing that serviceability limit states would govern in design.

This connection design successfully incorporated guidelines from bamboo building codes and has potential for widespread usage. It had a relatively simple design that used commonly available materials and behaved in a desirable ductile way. Mortar infilling successfully prevented local bamboo failure but the infilling process required significant effort and more than doubled the weight of the connection. [21]

Results from above papers w.r.t to mechanical properties

From the above review of papers, thesis and dissertation bamboo definitely has the strength compared to that as steel which are proofed through various research and tests performed by various authors with precise treatment on bamboo required for reinforcement.

TABLE-II: Mechanical Properties

No	Bamboo Specimen	Ref	In Comparison with Steel,				
			> or <				
			Tensile	Compression	Flexural	Durability	Bond
1	Dendrocalamus Stocksii	5,6	>	>	>	>	>
2	Dendrocalamus Strictus	3,9	>	>	>	>	>
3	Dendrocalamus brandisii		<	>	<	-	-
4	Dendrocalamus asper		<	<	<	-	-
5	Bambusa nutans		<	>	<	-	-

6	Bambusa balcooa	7,8	>	>	>	>	>
7	Bambusa vulgaris	8	<	>	<	-	-
8	Bambusa tulda		<	<	<	-	-

Note- Green colour indicates where all mechanical properties of a particular specimen show more or same amount of strength as compared to steel.

5. CONCLUSION

Bamboo specimens which are available in India like Dendrocalamus strictus (*Manvel Bamboo*), Dendrocalamus stocksii (*Manga Bamboo*) & Bambusa Balcooa (*Dagdi Bamboo*) can also be used for construction if the specimen undergo following tests of tensile, Compression, Flexural, Durability and Bond strength. The above three specimen of bamboo's can surely replace steel for replacement atleast to some extent i.e for G+1 structures or low cost G+1 housing projects.

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REFERENCES

[1] Masakazu TERAJ & Koichi MINAMI, *Fukuyama University, Japan*. Research and Development on Bamboo Reinforced Concrete Structure, 15 WCEE, LISBOA 2012.

[2]<https://www.gardeningknowhow.com/ornamental/foilage/bamboo/common-bamboo-varieties.htm>

[3]<http://www.biologydiscussion.com/economic-botany/top-15-types-of-bamboo-found-in-india-botany/52815>

[4] M.R. Wakchare and S.Y. Kute, Department of Civil Engineering, K.K. Wagh Institute of Engineering Education and Research, Nashik, India. Effect of moisture content on physical and mechanical properties of bamboo, Asian journal of civil engineering (building and housing) vol. 13, no. 6 (2012) pages 753-763

[5] A. D. Rane, S. S. Narkhede, V. V. Dalvi, V. K. Patil, P. M.Haldankar, S. B. Dodake, A. A. K. Dosani and T.

Bhattacharyya, Green Gold Manga Bamboo (*Dendrocalamus stocksii*) for Commandable Profit from Cultivable Wasteland. Jul 18

[6] S.Viswanath, Geeta Joshi, P.V.Somashekar, Ajay D. Rane, Sowmya. C and S.C.Joshi, *Dendrocalamus stocksii (Munro): A potential multipurpose bamboo species for Peninsular India.*Jan 13. A Publication of Institute of Wood Science & Technology, Bangalore.

[7] Siti Nurhayani, Rita Megia and Ragapadmi Purnamaningsih, In Vitro Propagation of *Bambusa balcooa* as Alternative Material of Wood. April 18

[8] N. Krishnakumar, S. Umesh Kanna, K.T. Parthiban And P. Rajendran, Physical properties of thorn less bamboos (*Bambusa balcooa* and *Bambusa vulgaris*) July 17.

[9] Ajinkya Kaware¹, Prof. U.R.Awari, and Prof. M.R.Wakchaure, Analysis of bamboo reinforced concrete column, International Journal of Innovative Research in Science, Engineering and Technology. Vol. 2, Issue 6, June 2013

[10] Hector Archila, Sebastian Kaminski , David Trujillo, Edwin Zea Escamilla and Kent A. Harries, Bamboo reinforced concrete: a critical review, Materials and Structures (2018) 51:102

[11] Khosrow Ghavami, Bamboo as reinforcement in structural concrete elements, Cement & Concrete Composites 27 (2005) 637–649

[12] Prof. V Giridhar, Flexural behaviour of concrete with bamboo and steel reinforcement, ISSN 2249-6149, Issue 7, Vol.6 (October-November 2017)

[13] Abdullah Khatib and Ghassan Nounu, Corrugated bamboo as reinforcement in concrete, Structures and Buildings, Volume 170 Issue SB4

[14] Aisha Haladu Bornoma, Muhamed Faruq, and Moveh Samuel, Properties and Classifications of Bamboo for Construction of Buildings, *Journal of Applied Sciences & Environmental Sustainability* 2 (4) 105 - 114, 2016

[15] M. B. Varma, State of The Art: Bamboo as a Structural Material, ISSN:2319-6890(online),2347-5013(print) Volume No.5, Issue Special 1 pp : 300-303 8 & 9 Jan 2016

[16] Vijay R Wairagade, Ishwar P Sonar, Bamboo reinforced concrete beam – step toward sustainable development, UCC-2019-164

[17] Masakazu TERAJ AND Koichi MINAMI, Fracture Behavior and Mechanical Properties of Bamboo Reinforced Concrete Members, ICM11

[18] Dinesh Bhondea, Dr P. B. Nagarnaik, Dr D. K. Parbat, Dr U. P. Waghe, Experimental Analysis of Bending Stresses in Bamboo Reinforced Concrete Beam, ICRTET 2014

[19] Arpit Sethia and Vijay Baradiya, Experimental investigation on behavior of bamboo reinforced concrete member, eISSN: 2319-1163 | pISSN: 2321-7308

[20] Sri Murni Dewi and Devi Nuralinah, The Recent Research on Bamboo Reinforced Concrete, *ISCEE 2016*

[21] Gian Karlo Cabanas, Assessing the structural response of a mortar infilled steel eyebolt bamboo connection under bending and cyclic loads, Thesis · May 2018.

[22]<http://www.bamboobotanicals.ca/html/aboutbamboo/bamboo-growth-habits.html>

[23]<http://keralabamboomission.org/mob/English/product/bambusa-balcooa/>

[24] <http://mahabamboo.com/index.php>