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European Journal of Advances in Engineering and Technology, 2022, 9(4s):35-39
International Conference on Tech Trends in Science & Engineering (ICTTSE) 2022
Suryodaya College of Engineering & Technology, Suryodaya Polytechnic, Nagpur, Maharashtra, India

Review Article ISSN: 2394 - 658X

Bamboo as a Structural Element: A Review

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ABSTRACT

The demand for building materials is increasing day by day, as the government is providing policies for housing in which a very limited amount is received to the user. In such situations, the use of conventional building materials affects the economy. This can be overcome by using eco-friendly and bio-degradable material. This review article describes the recent developments of bamboo as a structural material. Bamboo species are low-cost, recyclable, environmental-friendly and locally available. Due to eco-friendly and bio-degradability characteristics of these material, they are considered as strong material to replace the conventional steel as a reinforcement. The investigations have taken place in the context of enhancing properties of raw bamboo by appropriate chemical treatment. As per this literature investigation, all properties of raw bamboo having relevance to its utility as a raw material for structural member, such as yield strength in tension, yield strength in compression, yield strength in shear, resistance to water absorption, thermal resistance can be enhanced. In view of above, it is thought to what extent the properties of locally available bamboo species can be enhance so that it can be used as a raw material for structural members. This is the focused of the objective of present investigation.

Key words: Bamboo, Chemically treated, enhancing Properties

INTRODUCTION

To stay healthy, one need a proper place to reside for the entire life and that is home. This is one of the important components of one's life. But contrary to this, in India type and number of homes available is not adequate as per the estimation reported by the Ministry of Housing and Urban Poverty Alleviation, Government of India. With an annual population growth rate of 1.64% as compared to world population growth rate of 1.23% during the last decade, there would be a great demand to fulfill housing needs in coming years. In this context, the Pradhan Mantri Awas Yojana (Prime Minister Housing for All Mission, 2015), envisages to provide housing units to all. The mission seeks to build 20 million housing units for the poor and make Indian cities slum free by the slum rehabilitation projects and affordable housing projects for economically weaker section.

If officials fail to provide accommodation for all, it is estimated that 200 million Indian will be residing in slums by 2022. (UN Habitat estimates). This would result in an enormous demand of building materials like steel, cement and wood etc. To reduce this dependence on conventional building material there is a need to review alternate building materials and formulate guidelines for their application in construction industry.

However, with the traditional building technologies it is impossible to solve this menace as we cannot solely depend on the traditional construction materials such as concrete, bricks, wood to cover all housing needs, as they are produced from the natural resources. The continuous exploitation and depletion of natural resources is harming the environment. Moreover, different toxic substances such as carbon monoxide, sulfur oxides, nitrogen oxides and suspended particulate matter are invariably emitted in the atmosphere during manufacturing processes of traditional construction materials. Emission of toxic matter further contaminates the air, water, soil, and aquatic life which influence the human health and the standard of living. Thus there is a need for adoption of "Eco-Structures" that are in harmony with the surroundings and does not affect the environment neither through building materials or construction methods.

Bamboo has shown great future for making multiple materials and modules which are cost- effective and can be successfully utilized for structural and non-structural applications in construction. Bamboo can be developed in large quantity with low cost and this will be economical for construction purpose. Bamboo is a flexible material with its high strength, workability, and durability. Bamboo has high tensile property as well as compressive property. Bamboo is generally used as structural material but it is also used in the construction of bridges, scaffolding, and housing.

Moreover, in bamboo, the intermodal regions of the stem are usually hollow and the vascular bundles in the cross section are scattered throughout the stem instead of in a cylindrical arrangement. Bamboo includes some of the fastest growing plants in the world. Certain species of bamboo can grow 91cm within a 24 hour period. They are of notable economic and cultural significance being used for building materials and as a versatile raw product. Bamboo has a higher compressive strength than brick, wood, concrete and a specific tensile strength than steel. The world timber demand increasing at rapid rate but the supply is depleting. Industrially treated bamboo has shown greater strength as well as for manufacturing of composite materials and components which are economical and can be suitable for structural and non-structural application in construction. Developing countries have major demand of reinforced concrete steel but the production is less. Present investigations show that Bamboo has a great potential to replace with steel. Due to its light weight structure, harvesting and transportation is also done through simple process.

Due to its rapid growth cycle and varieties of area in which it is able to grow, bamboo is cheap. It requires the grass to absorb Co2. These factors can alone be incentive for investment in developing bamboo as reinforcement. With the advancement of science and technology new methods are needed for the processing of bamboo to make it more durable and more usable in terms of building material. Studies have been carried out on the basic characteristics and on processing of bamboo into various kinds of composite products. Bamboo has several unique features like ability to grow fast with high yield and also it matures quickly. Additionally, bamboo can grow abundantly that too at lower cost which make it more economical.

LITERATURE REVIEW

During the past few years, several researches take place on Bamboo as a structural material. In present paper the investigations done by the researchers were categorized based on the chemical treatment, properties and testing methods applied on bamboo.

a) Based on Treatment on bamboo

Pradeep Kushwaha, Rakesh Kumar et al, Percentage concentration of NAOH for Bamboo treatment to enhance mechanical properties of bamboo composite has been studied. The mechanical properties of the alkali treated bamboo composites (tensile strength, elastic modulus, flexural strength, flexural modulus, toughness, and impact strength) were determined Optimum results have been obtained by bamboos treated with 5% NaOH solutions. However, the improvement was up to 5% concentration of NAOH treatment. Other method than alkali treatment and their behavior in mechanical properties need to investigate.

Dirk E. Hebel, Alireza Javadian et al (2013) suggested another method (hot pressed forming) to treat bamboo to microscopically enhance mechanical properties of bamboo composites. The relationship between tensile strength, pressure, temperature and pressing/holding time is being analyzed. It is observed that a maximum tensile strength (~ 180 MPa) can be obtained at a certain temperature/pressure combination. This is a very critical method to enhance mechanical property of bamboo composites. A certain temperature/pressure combination has been maintained to achieve max tensile strength.

Atul Agarwal, Bharadwaj Nanda, Damodar Maity et al (2014) The feasibility of usage of bamboo as a r/f in concrete has been evaluated through a series of experimental investigations on of various beams and column members. Varieties of adhesives have been used for the treatment on bamboo and their bond strength is investigated. From the comparative study the most suitable adhesive has been selected and used further to cast bamboo reinforced beams and columns. These

tests suggest that bamboo with proper treatment has potential to substitute steel as reinforcement. Experimental investigations were carried out only for beam and column member.

Nebihah Rahman, Leong Weng Shing et al (2017) The durability of bamboo composite material and effectiveness of protective epoxy coating were evaluated by subjecting samples to various corrosive environments. The epoxy can be an effective approach to simultaneously enhance the bamboo composite materials resistance towards acid attack and improve its bond strength with concrete for concrete r/f application. Introduction of sand particles on epoxy coating is suggested to improve the bond strength.

b) Based on properties of Bamboo

Sanjay K. Chattopadhyay, R. K. Khandal et. al. (2010) the physical, mechanical, and thermal behavior of the short BFRP composites at varying fiber volume percent has been studied. A certain configuration of bamboo fibre volume, length and diameter with a comptibliser is a recommended combination to improve thermal and mechanical properties of bamboo fibre. As all plant-based natural fibers have similarity in structure this study can provide some firsthand information for other possible natural fiber reinforced thermoplastic composites. Natural fibers other than bamboo with similar compositions are also expected to exhibit similar improvements in mechanical and thermal properties in their reinforced thermoplastic composites.

Shinji Ochi (2012) describes tensile properties of bamboo fiber reinforced biodegradable plastics. The unidirectional biodegradable composites were made from bamboo fiber bundles and a starch-based biodegradable resin. The tensile strengths of the composites increased with increasing fiber content up to 70%. The composites possessed extremely high tensile strengths of 265 MPa. The fabrication with emulsion-type biodegradable resin contributed to reduction in voids and fiber contacts in the composites. Moreover, heat resistance of bamboo fibers and bamboo fiber reinforced plastics was investigated. As results, tensile strength of both bamboo fiber and bamboo fiber reinforced plastics decreased at 160^{o}C.

c) Based on Test on bamboo

Khosrow Ghavami et. al. (2005), a concise summary regarding bamboo reinforced concrete beams, permanent shutter, concrete slabs and columns was discussed. The results of the investigations show that bamboo can substitute steel satisfactorily. Author suggests that there is a need to establish the characteristic strength of bamboo for design purpose based on a rigorous statistical analysis. Chemical treatment, shear behavior also need to investigate.

Mir Abdul Kuddus, Md. Naimul Islam Mohim (2016) comparatively evaluated the flexural performance and deformation characteristics of concrete beams reinforced with bamboo, cane and the twisted steel rebar. The yield strength (YS), ultimate tensile strength (UTS) and the elongation were determined. Steel rebars shows the better result. Chemical treatment of bamboo and cane need to investigate to get better result.

Karthik A, P. Ram Mohan Rao A, P.O. Awoyera et.al (2017), Bamboo strips were used as reinforcement in a concrete that was made with supplementary cementious materials and partial replacement of river sand with manufactured sand. (m-sand) Result show that BRC with conventional materials shows more strength as compared to BRC with alternative material. Bamboo r/f bond strength with alternative materials need to investigate.

Pankaj R. Mali, D. Datta (2018) Total 15 concrete slab panels were fabricated and tested as per Eurocode EN-1448-5 (2006). The effect of total replacement of main steel reinforcement by bamboo(Plain Bamboo and Chemically Treated bamboo) on the flexural behavior of slabs in terms of load-deformation characteristics, energy absorption capacity, crack patterns and failure modes have been studied. Test results show that there is improvement in the load carrying and deformation capacity when proposed bamboo strip is used as reinforcement in concrete slab panels as compared to that of PCC (Plain Cement Concrete) and RCC (Reinforced Cement Concrete) slabs. Interestingly the structural behavior of slabs using newly developed bamboo reinforcement has shown significant improvement in flexural performance and it was marginally better than the RC slabs having M.S. bars as main reinforcement.

Abhijeet Dey, Nayanmoni Chetia (2018) the frictional properties of bamboo reinforced concrete beams have been achieved by rolling the bamboo reinforcements with sand, G.I wire and coir. Bond Strength, flexural strength, tensile strength has been taken into consideration for comparison purpose. Result shows that GI wire is more efficient as compared to others. 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**.** With the increase in span of the beam the mid span deflection increases which is also an important criterion when serviceability limit state is considered, thus reduction of mid span deflection is another major area of research.

Gisleiva C. S. Ferreira, Antonio L. Beraldo (2016) the feasibility of bamboo strips application as flexure and shear reinforcement in concrete beams has been evaluated. Experimental analysis of six simply supported BRC beams subjected to two point loads was carried out up to collapse. The ultimate test loads for the different beams were compared to the loads predicted according to ACI 318. It was concluded that bamboo can potentially be employed as substitute of the steel reinforcement. Behavior of shear by using different stirrups material needs further investigation.

DISCUSSION

Bamboo has excellent engineering properties and can be utilized for low cost housing project. It can mainly be used as reinforcement to the structure. According to study by researchers in world, in next 60 years steel production will be reduce hence a utilization of natural and eco friendly options like bamboo should be used. It is definitely benefitted to the society as it is economical, less energy consumption.

CONCLUSION

1. Properties of bamboo can be enhanced by proper treatment applied on bamboo.
2. Tensile strength of bamboo is much higher than steel.
3. Bamboo is weak in shear; it cannot be used as sher reinforcement in RCC structure.
4. As low cost housing and ecofriendly material is concern, bamboo can be best suitable alternative, but the chosen treatments should be cheaper, with locally available material and should not demand high skilled labour.

ACKNOWLEDGMENT

The author would like to thank Maharashtra Bamboo Development Board, Nagpur.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

REFERENCES

[1]. G Khosrow Ghavami (2005) “Bamboo as reinforcement in structural concrete elements” Cement & Concrete Composites 27 (2005) 637–649.

[2]. Pradeep Kushwaha, Rakesh Kumar (2009) “Enhanced Mechanical Strength of BFRP Composite Using Modified Bamboos” Journal of Reinforced Plastics and Composites, Vol. 28, No. 23/2009.

[3]. Sanjay Chattopadhyay1, R. K. Khandal1et.al. (2010) “Bamboo Fiber Reinforced Polypropylene Composites and their Mechanical, Thermal, and Morphological Properties"Journal of Applied Polymer Science DOI 10.1002/app32826.

[4]. Shinji Ochi (2012) “Tensile Properties of Bamboo Fiber Reinforced Biodegradable Plastics"International Journal of Composite Materials 2012, 2(1): 1-4

[5]. Dirk E. Hebel, Alireza Javadian et al (2013) “Process-Controlled Tensile Properties of Newly Developed Bamboo Composite Materials” Leuven and Texcomp-11 Conference. 16-20 September 2013, Leuven

[6]. Atul Agarwal1, Bharadwaj Nanda, Damodar Maity (2014) “Experimental investigation on chemically treated bamboo reinforced concrete beams and columns” Construction and Building Materials 71 (2014) 610–617.

[7]. Mir Abdul Kuddus1, Md. Naimul Islam Mohim2(2016) “Performance of Beam Incorporating with Locally Available Reinforcement” Journal of Architecture and Civil Engineering Volume 3 ~ Issue 3 (2016) pp: 18-23 ISSN (Online): 2321-8193

[8]. S. Karthik, P. Ram Mohan Rao, P.O. Awoyer (2017) “Strength properties of bamboo and steel reinforced concrete containing manufactured sand and mineral admixtures” Journal of King Saud University – Engineering Sciences 29 (2017) 400–406

[9]. Nebihah Rahman, Leong Weng Shing et al (2017) “Enhanced bamboo composite with protective coating for structural concrete application"World Engineers Summit – Applied Energy Symposium & Forum: Low Carbon Cities & Urban Energy Joint Conference, WES-CUE 2017, 19–21 July 2017, Singapore.

[10]. Pankaj R. Mali, D. Datta (2018) “Experimental evaluation of bamboo reinforced concrete slab panels.” Construction and Building Materials 188 (2018) 1092–1100

[11]. Abhijeet Dey, Nayanmoni Chetia (2018) “Experimental study of Bamboo Reinforced Concrete beams having various frictional properties” Materials Today: Proceedings 5 (2018) 436–444

[12]. Manjesh Srivastava, Vikas Kumar (2018), "The Various Methods Using Low Cost Housing Techniques in India" Journal of Building Engineering, 15(2018) page no. 102-108.

[13]. Rao B. Srinivasa, Aziz Z. Sahid, (2018), "Low Cost Housing Techniques by Replacing Conventional Materials" International Journal of Scientific Engineering and Technology, Volume: 7, Issue: 1.

[14]. Yan Yu, Zehui Jiang et al (2010) "An improved microtensile technique for mechanical characterization of short plant fibers: a case studyon bamboo fibers "J Mater Sci (2011) 46:739–746

[15]. Amada, S., Ichikawa, Y., Munekata, T., Nagase, Y. and Shimizu, H. (1997), "Fiber Texture and Mechanical Graded Structure of Bamboo", Composites Part B, Vol. 28B, pp 13-20.

[16]. ISO (1999), "Determination of Physical and Mechanical Properties of Bamboo".

[17]. Malkapuram R., Kumar V., and Negi Y. S., "Recent Development in Natural Fiber Reinforced Polypropylene Composites," Journal of Reinforced Plastics and Composites (November 20, 2008).

[18]. Rao K. M. M. and Prasad A. V. R., "Fabrication and Testing of Natural Fiber Composites: Vakka, Sisal, Bamboo and Banana," Materials & Design 31, No. 1 (2010): 508–513.

[19]. Ardle J., Bamboos & grasses (London: Harper Collins, 2005); Hebel D. E., "Bamboo: The Future of Avernacular Building Material," BFT International, Concrete Plant + Precase Technology 79/2013, No. 03 (2013): 30–35.

[20]. Jiang, ZH; Hse, CY; Shupe, TF 2008. "Selected Physical and Mechanical Properties of Moso Bamboo (Phyllostachys Pubescens)". Journal of Tropical Forest Science (2008), http://www.treesearch.fs.fed.us/pubs/31456.

[21]. Yu Y. et al., "Mechanical Characterization of Single Bamboo Fibers with Nanoindentation and Microtensile Technique," Holzforschung 65, no. 1 (2011): 113–119.

[22]. Li Y. et al., "Bamboo and High Density Polyethylene Composite with Heat-Treated Bamboo Fiber: Thermal Decomposition Properties," BioResources8, no. 1 (January 8, 2013): 900–912;

[23]. Ochi S. (2012) "Tensile Properties of Bamboo Fiber Reinforced Biodegradable Plastics," International Journal of Composite Materials 2, no. 1(February 1, 2012): 1–4.

[24]. Gisleiva C.S. Ferreira et al, (2016) "Flexural and shear behaviour of concrete beamsreinforced with bamboo" Int. J. Sustainable Materials and Structural Systems, Vol. 2, Nos. 3/4, 2016.

[25]. Dinesh Bhonde, Dr P. B. Nagarnaik (2014), "Experimental Analysis of Bending Stresses in Bamboo Reinforced Concrete Beam" Proceedings of 3rd International Conference on Recent Trends in Engineering & Technology (ICRTET'2014).

[26]. Adom Asamoah Mark, et al (2011) "A comparative study of Bamboo reinforced concrete beams using different stirrup materials for rural construction" International Journal of Civil and Structural Engineering Volume 2, No 1, 2011ISSN 0976 – 4399.

[27]. S. Srimathi et al (2016) "A Review of Bamboo as a Reinforcement Material in Modern Construction" IJSTE - International Journal of Science Technology & Engineering | Volume 3 | Issue 05 | November 2016 ISSN (online): 2349-784X.