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A REVIEW ON INVESTIGATION STUDY ON BAMBOO AS REINFORCEMENT MATERIAL

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Abstract— In many developing nations, the use of steel as a construction reinforcement is steadily rising. However, due to cost and availability considerations, there's a growing need to find suitable replacements for steel. In cases where steel production falls short of meeting demand, having a viable alternative that rivals steel's qualities becomes imperative. Bamboo emerges as a promising alternative to steel in small-scale construction and affordable housing, especially in countries like India, due to its abundance and durability. It can effectively serve as a substitute for steel in reinforcement, offering commendable tensile resistance, a crucial requirement for such applications. The inherent strength of bamboo, stemming from its natural tubular structure that withstands wind forces well, makes it a viable option. Addressing bamboo's weaknesses and promoting its innovative use as a steel replacement presents a valuable opportunity. This research intends to perform a literature analysis to evaluate the practicality of utilizing bamboo as a reinforcing material in concrete constructions, while significant investigation has been carried out on the strength attributes of metal-reinforced concrete, comprehensive knowledge on bamboo-reinforced concrete is insufficient. Hence, this research seeks to offer preliminary understanding of the strength features and behavior of bamboo-reinforced concrete, particularly in addressing challenges related to affordable shelters.

Keywords— Strengthening Material, Bamboo, mechanical properties, strength

I. INTRODUCTION

Because of its good mechanical qualities and accessibility in developing nations, research has demonstrated that bamboo is employed in concrete structures.[1] Numerous research has investigated the feasibility of utilising bamboo in structural applications rather than more conventional steel reinforcement. All things considered, these studies suggest that bamboo has enough strength and material properties to be a viable substitute for steel reinforcement. One such experiment's goal was to determine how long bamboo would last as reinforcement for concrete structures [2]. This paper gives a comprehensive analysis of the literature on the Structural and material characteristics of bamboo, which is used as reinforcement in traditional concrete constructions, in order to address these difficulties.

II. OVERVIEW OF BAMBOO AS A REINFORCEMENT MATERIAL

Bamboo is an important construction material in many areas of the world, but because of its relatively low strength compared to metals, it is seldom used as a structural reinforcement. Recently, the use of bamboo as a reinforcement in composite materials has shown promise. The reason that construction materials fail is that stresses are exerted on them that exceed their strength. With respect to bamboo, regardless of whether it is a simple or complex material, tensile failure occurs at about 1.5% strain, and the tensile strength and modulus at this point are roughly 150 MPa and 3000 MPa. Success in using bamboo as a reinforcement material is more probable than attempting to increase the strength of bamboo itself with chemical or mechanical treatments because the losses in environmental friendliness and low cost of untreated bamboo would limit its acceptability. We discuss current advancements in bamboo-composite materials and their potential as a product for concrete reinforcement in brief in this study. It is important to bear in mind that other applications of materials sourced from bamboo in concrete buildings, such as bahareque building, bamboo fibre strengthening, and bamboo ash additives, are not mentioned in this piece. Bamboo is sometimes described as a reinforcement for concrete that is "as strong as steel," and it is frequently described as a highly renewable and robust substitute for wood. A 2007 study conducted by the Food and The Agriculture Organization of the United Nations (FAO) estimated that more than one billion individuals reside in traditional bamboo abodes worldwide. Moreover, nearly 2.5 billion people worldwide make their living from bamboo [3]. Some academics have expressed doubts regarding the longevity of bamboo when it comes to its use as reinforcing in concrete constructions [3].[2] Research on the durability of natural fibres utilised as reinforcement in Portland cement composites raised concerns regarding the lifespan of bamboo. To answer the global need for an economical, environmentally sustainable, and energy-efficient alternative, particularly in developing countries, a suitable substitute is being looked for. Because of its widespread availability, low cost, and abundant natural resources, bamboo is an excellent alternative to traditional concrete reinforcing bars in low-cost projects. But what matters most is that it is strong in both compression and tension [4] Bamboo presents a compelling substitute for steel in applications requiring tensile strength because of its exceptionally strong tensile properties. (370 MPa) [5]

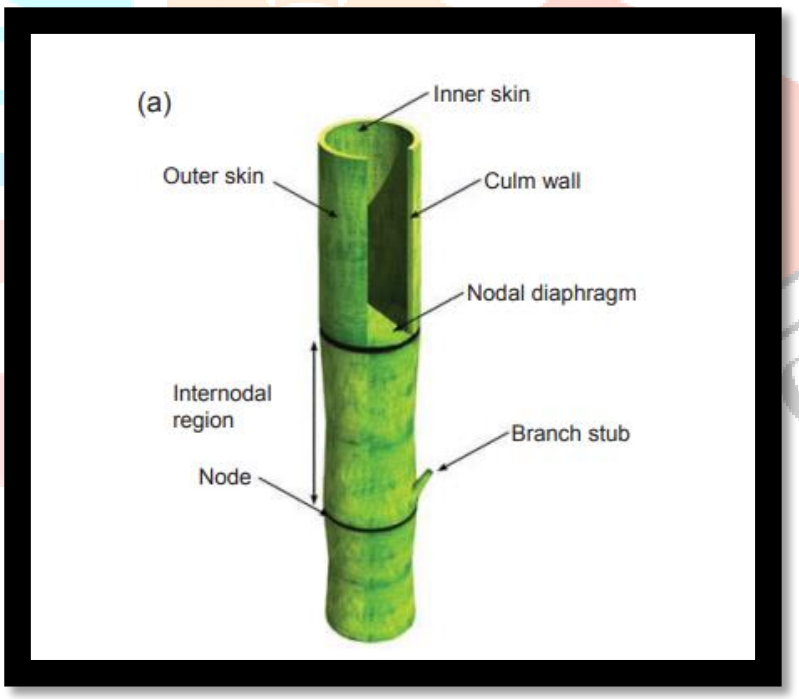
III. BACKGROUND OF THE STUDY

In the past century, as modern technology has advanced, has bamboo been utilised It is a challenging field of study to conduct research on a very robust and highly efficient building material that advances the science of civil engineering. Theoretically, such material ought to be practicable economically, readily accessible, and environmentally friendly. One excellent example of a natural building material is bamboo. It can withstand a sizable load relative to its weight, is resilient to abrasive wear, and is robust in tension and compression. For thousands of years, bamboo has been a primary building material in many parts of the world. Bamboo, for instance, grows on around 1.5 million hectares in Indonesia. Under the direction of architects and engineers, Costa Ricans have been building with Guadua bamboo for a number of years. subjected to a more thorough analysis of its mechanical and physical characteristics. Though most of it has been in the form of material that is not easily accessible to the global population, Asia and Japan have been the sites of the majority of the documented study on the mechanical properties of bamboo. Research on the effects of treating bamboo with some of the preservation techniques now in use and how they affect the mechanical characteristics and longevity of the bamboo culm is even harder to get. There is a great deal of room for further research in this area given the quick expansion of online information interchange, improved translation, and more transparent international collaboration. This ultimately resulted in the identification of structural components through factor analysis, the reaction of bamboo and its composite to environmental conditions, and the discovery of a novel preservation chemical that eliminates environmental hazards. This is an excellent illustration of a highly efficient and sustainable building material that, while initially labour intensive to use, can be customised at a lower cost. Additionally, it offers a great deal of possibilities for artisan production and site catch, maintaining sustainability in rural and third-world communities. Building

extremely basic constructions out of materials and with a methodical understanding might also be very beneficial to schooling. This comparison of old and new techniques is pertinent to design as well as the aftermath of man-made and natural structural failures. In this domain, novel insights have the potential to avert catastrophes concerning housing and infrastructure.

IV. BASIC CHARACTERISTICS OF BAMBOO

The structure of the stalk consists of segments and nodes, as outlined by [6], [7]. Essentially hollow tubes, internodes have cells that are aligned axially. As seen in Figure 1, an internal diaphragm forms at the nodes while the culm-sheath and branches develop on the outside. The stalk, or primary stem of the bamboo, is a cylindrical casing composed of connected sections known as nodes. These robust nodes with their solid diaphragms provide the bamboo with strength. and increase its resistance to buckling. The spaces known as internodes, which are usually hollow, add to bamboo's flexibility in withstanding wind stress [5], [6] investigated the mechanical characteristics of bamboo, emphasising its use in concrete. Their research showed that the maximal load of a concrete beam reinforced with bamboo increased by an astounding 400% when compared to unreinforced concrete. Bamboo stalks, illustrated in Figure 1, possess cylindrical exteriors segmented at nodes by strong horizontal partitions. They are characterized by their significant strength along the longitudinal fibers parallel orientation and their reduced strength in the perpendicular direction of the fibers.



(b)

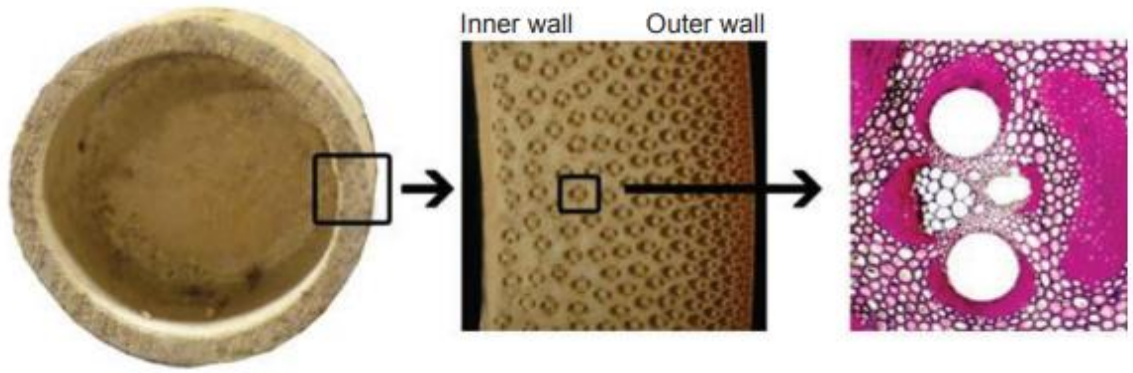


Figure 1 (a) culm bamboo segment with Node, Inter-nodal region and Nodal diaphragm [7], (b) section of culm wall showing grading of vascular bundles [6]

V. LITERATURE REVIEW

S. Bagchi et.al, In the present worldwide context, marked by population growth, innovation is crucial in all areas. The pressing demand for alternative approaches is underscored by the swift consumption of resources. An old-fashioned building material known for its affordability and durability is bamboo. Bamboo is a more environmentally friendly material than steel, whose manufacture produces different pollutants and carbon dioxide emissions. Furthermore, because bamboo is less expensive than steel due to increased demand, it is more accessible, which is especially advantageous for low-income populations. Its ability to be used in a variety of small-scale construction projects as a feasible substitute for steel highlights its worth as an environmentally friendly building material.[8]

M. M. Rashid et.al. Bamboo cellulose has become popularity as an environmentally acceptable substitute for synthetic polymers. It comes in the form of hydrogels and nanocrystals. It is a cheap and sustainable option because of its simple extraction from bamboo and wide range of uses in sectors like packaging and pharmaceuticals. Bamboo cellulose has antibacterial and UV protection qualities, which make it a valuable material to use less of in place of synthetic materials. [9]

Sanjeev Gill and Dr. Rajiv Kumar emphasized the potential of bamboo as a reinforcement material due to its rapid growth and renewability, typically ready for harvest within 5 to 6 years. The water absorption rate directly impacts bamboo's strength, which is notable for its favorable tensile strength, making it suitable for reinforcement purposes. The performance of bamboo as reinforcement mirrors that of plain steel bars.[10]

Ghavami. K studied the bonding and bending properties of bamboo in lightweight concrete is crucial, especially in developing countries facing housing challenges. The lack of research in low-cost housing projects highlights the need for training and education among scientists, engineers, and designers to develop efficient construction plans. Additionally, specialized educational systems, access to diverse information, and economic vitality are essential for progress. The compressive and shear test results vary based on the bamboo type, with higher tensile strength compared to compression strength ranging from 12 to 53 MPa. In tests involving Bambusa vulgaris schard and Dendrocalamus, treated bamboo Encased with 1.5mm steel wire at 40mm intervals and coated with Negrolin-sand exhibited superior performance, with a 90% improvement in bond stress (0.97 N/mm²) compared to untreated bamboo (0.52 N/mm²).[11]

Ari Wibowo et.al study explored the substitution of metal reinforcement using bamboo rods and the incorporation of recycled materials like Styrofoam as a lamination filler to create lighter and more cost-effective concrete structures. The flexural strength testing revealed a 15% decrease in flexural strength compared to a conventional RCC slab of the same size. However, the weight advantage was notable, with a 20% reduction in weight. This research provides valuable insights into bamboo's performance in practical design scenarios, especially considering that the Basic bending strength of reinforced concrete slabs with limited reinforcement often exceeds the necessary moment requirements.[12]

Ajinkya Kaware, Prof. U. R. Awari, Prof. M. R. WakchaureBamboo exhibits weakness at its nodes, with the highest likelihood of failure occurring at these points. Its bond stress is also relatively low, necessitating treatment with an epoxy coating to enhance bond strength. Due to its weakness in shear, bamboo is not suitable for use as shear reinforcement. However, its commendable tensile strength makes it a viable option for reinforcing R.C.C structures in low-cost housing projects. Bamboo's behavior is comparable to that of steel bars. The moisture content of bamboo varies depending on the topographical conditions.[13]

Wei Feng Zhao, Jing Zhou, Guo Bin Bu, introduced various applications of bamboo-reinforced concrete elements in construction, including columns, beams, slabs, and walls. Experiment results demonstrated a remarkable increase in ultimate load capacity, up to 400%, compared to unreinforced concrete beams. For bamboo-reinforced lightweight concrete beams, the construction of rectangular bamboo-reinforced columns should be approximately 2.25 times thicker than steel-reinforced ones for safety. When substituting bamboo

for steel in slab designs, there's no need to adjust thickness. Bamboo mesh panels used in walls provide structural integrity, shock absorption, and eco-friendliness. These findings support bamboo's effective substitution for steel, making bamboo-reinforced concrete elements viable in various construction projects.[14]

The research conducted by **Pratish Kumar Singh, Aashish Jodhani, and Abhay Pratap Singh** indicates that bamboo exhibits greater durability when positioned vertically compared to a horizontal orientation. Furthermore, bamboo can be permanently bent using heat, either through dry heat or applied pressure. The choice of coating for bamboo treatment depends on the type of seasoning material used. Applying a brush coat or dip coat of emulsion proves effective in treating bamboo. The design of bamboo-reinforced concrete beams follows a similar approach to designing steel reinforcements.[15]

VI. MECHANICAL PROPERTIES OF BAMBOO

Bamboo is a naturally occurring composite that resembles grass and grows to be one of the fastest-growing woody plants in the world.[16] For load bearing, steel structures and reinforced concrete (RCC) are used together. However, the fact that steel is expensive and non-renewable presents a serious problem.[17] The cellulose fibres in bamboo, a member of the Bambusoideae grass family, are encased in lignin. Because of its remarkable strength-to-weight ratio, it is frequently used in construction for wall structures and scaffolding. Bamboo has been shown in numerous studies to be both versatile and effective in building applications. For example, to demonstrate the robustness of Parallel Strand Bamboo (PSB), it was bonded with adhesives under significant pressure in the research.[18] found that PSB was a transversely isotropic bio composite with good strength. Bamboo fibres' potential as a component in bio composites and its suitability for inclusion in cement concrete were discovered through an analysis of its use.[19] Alternative building materials have been thoroughly investigated; one such material is bamboo strips, which can be used to reinforce concrete. This required mixing cementitious ingredients, replacing some of the river sand with synthetic sand (m-sand), and replacing 25% of the cement with fly ash and ground granulated blast furnace slag (GGBS). Bamboo tensile strength tests and microscopic examinations were conducted on concrete samples. In contrast to BRC with alternative components, conventional bamboo-reinforced concrete (BRC) demonstrated a 6.5% higher level of flexural resistance, even if the alternative materials improved compressive and split tensile strengths. While highlighting the performance disparities between traditional and alternative material mixtures, these findings also emphasise the potential of bamboo.[20] did a detailed review concentrating on bamboo's role in beam strengthening, examining both its benefits and limitations.

Advantages and Disadvantages of Bamboo:

Advantages:

1. Bamboo has lightweight nature and eco-friendliness are notable benefits.
2. Its affordability and widespread availability are advantageous.
3. The ease of cultivation and farming production add to its appeal.
4. Its strength and versatility make it a desirable material.
5. Its accessibility to economically disadvantaged populations is a key advantage.
6. Its rapid growth rate contributes to its usefulness.
7. Its high productivity levels are beneficial for various applications.

Disadvantages:

1. Bamboo requires preservation to maintain its strength over time.
2. Its natural shape can limit design options.
3. Coating is necessary to protect against fungi, insects, and other threats.
4. Despite its overall strength, bamboo joints can be weak.
5. Proper guidance and adherence to detailed codes are essential for effective use.
6. Bamboo is not inherently fire-resistant, requiring additional precautions.

VII. CONCLUSION

- Bamboo can be used effectively in low-cost housing and temporary structures due to its affordability and availability.
- Bamboo can attain tensile strengths between 120 N/mm² to 370 N/mm², making it suitable for reinforcement.
- Its water absorption capacity, while good, can reduce mechanical properties, highlighting the need for proper treatment.
- Seasoning treatments, such as bituminous paint, epoxy, and coal tar, can reduce water absorption and enhance durability.
- Bamboo has a low bond stress with concrete, requiring epoxy coatings to improve bonding and reduce stress.
- Bamboo reinforcement design mirrors that of R.C.C. steel beams, but it cannot be used for shear reinforcement due to its weak shear strength.
- Compression strength varies based on bamboo species, with values between 47.9 to 69.9 MPa.
- Bamboo's eco-friendly nature and the projected reduction in steel production over the next 60 years suggest a shift towards sustainable materials like bamboo.
- Bamboo's weaknesses, such as weak bond stress and shear strength, require treatments like epoxy coatings to improve its suitability for structural use.
- Major failures in bamboo often occur at nodes, highlighting the need for careful design and reinforcement strategies.

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