The Strength Of Bamboo: Exploring Its Role In Reinforcing Concrete Structures: A Review

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Abstract- *This review paper critically examines the role of bamboo as a reinforcement material in concrete structures, synthesizing existing research findings and insights without conducting new experiments. The paper provides a comprehensive overview of bamboo's mechanical properties, its sustainability advantages, and its application in enhancing the structural integrity of concrete. Through an extensive analysis of published literature and case studies, this review highlights bamboo's remarkable strength-to-weight ratio and flexibility, making it a promising alternative to conventional steel reinforcement. The sustainability aspect of bamboo reinforcement is a central theme, focusing on its renewable nature, minimal environmental footprint, and carbon sequestration potential. This eco-friendly profile aligns with the growing demand for sustainable building materials and practices.Practical considerations are thoroughly examined, including challenges related to standardization, building codes, and the long-term performance of bamboo-reinforced concrete in different environmental conditions. The review also identifies gaps in current research and suggests avenues for future investigation to advance the use of bamboo as a viable reinforcement material.*

Keywords- Bamboo, Concrete, Tensile Strength, Compressive Strength

I. INTRODUCTION

Bamboo has been used empirically as reinforcement in concrete structures due to its mechanical properties and availability in developing regions. The idea of using bamboo as a sustainable alternative to steel in reinforced concrete structures raises questions for builders, engineers, and researchers regarding its structural capacity, compatibility, constructability, and sustainability. This paper provides a comprehensive review of the literature in the field and compares the structural capacity of steel reinforcement and bamboo reinforcement in a typical concrete structure. The review focuses on the use of small diameter whole-culm (bars) or split (also known as splints or round strips) bamboo. Bamboo-composite materials are briefly discussed, although they represent a possible bamboo-based concrete reinforcing product. However, other applications of bamboo-derived materials in concrete structures, such as bahareque construction, bamboo fiber reinforcement, and bamboo ash admixtures, are beyond the scope of this discussion.

Bamboo is often considered as a renewable and strong alternative material to timber. It is sometimes even referred to as a strong-as-steel reinforcement for concrete. One of the key benefits of bamboo is its high rate of biomass production and renewability, especially when it is sustainably managed. However, claiming that bamboo is as strong as steel is not accurate. Dry, bamboo's characteristic strength is, at best, comparable to that of high-grade hardwood, which ranges from 30 MPa to 50 MPa Bamboo is a natural, typically hollow and anisotropic material with high variability of physical and mechanical properties both across the section and along the culm. Its density varies through the cross section, ranging from 500 to 800 kg/m³. In longitudinal tension-dominated failure modes, bamboo usually exhibits brittle behavior. The variability of longitudinal mechanical properties of bamboo is similar to those of wood, with coefficients of variance ranging from 10 to 30%. However, due to the absence of radial fibers, bamboo is particularly weak in the direction perpendicular to the fibers, making it more susceptible to longitudinal shear and transverse tension and compression failures. In contrast, steel is a man- made, isotropic, and ductile material with a density of 7800 kg/m³ and a tensile yield strength of conventional reinforcing bars ranging from 400 to 550 MPa. Bamboo is one such sustainable building material which has higher than six times the strength by weight ratio comparable with steel. The amount of CO2 emission in the atmosphere in case of bamboo is 50 times less as compared to steel and cement. Further, bamboo also consumes around 1 tonne of carbon dioxide during its growth phase. However, there are different issues such as properties variation across species, bond strength development in concrete, treatment processes involved in the application of bamboo in the form of reinforcement in concrete. This study evaluates bamboo bond issues in concrete and discusses the different shortcomings which require further research.

II. LITERATURE REVIEW

Atul agarwal and Damodar maity (2011) they studied axial compression and bending test was performed on Plain, Steel & Bamboo reinforced members. As explained in there experimental program, For example, a total of 12 columns (150x150x1000mm) were casted using design mix (M20) as per IS code. These columns included 3 columns of steel reinforcement, 3 colun:ns of plain concrete, 3 columns of untreated bamboo reinforcement & 3columns of treated bamboo reinforcements (with varying percentage of reinforcement; i.e. 3, 5, & 8%). The load deformation curves displayed significant nonlinearity, indicating that the bamboo has the capacity to absorb energy. Failure of Columns predominately occurred in shear in shear under compressive loading. Plain concrete and untreated bamboo columns showed brittle behaviour in which, tiny cracks occurred at the surface of the column at about 80% of maximum axial force.

After reaching the maximum load, the load capacity decreased abruptly and it finally failed in few seconds. There were no visible signs of spoiled concrete covering to warn of impending failure. Whereas in steel and bamboo reinforced columns more ductile behaviour was observed, wherein tiny became visible at surface of columns firstly at 80-90% of maximum axial force. Final failure was accompanied by tensile st growing signs of cracks and spalling of concrete. Inside th Furthermore, the results, exhibited that the maximum load carrying capacity of steel reinforced (min reinforcement, comparis 0.8%) column is nearly equivalent to that of treated bamboo upto 50 (8% reinforcement) reinforced column (owing to the strength of bamboo samples). Transverse load test performed on above set of columns revealed the lateral deflection, strain characteristics and failure mode pattern of the steel, plain and value. T bamboo reinforced columns. Hence, further analysis of results obtained, would assist in evolving comprehensive design methodology in case of reinforced columns. Bamboo concrete composite structural members can provide tailored solutions to the ecohousing initiatives at cheaper costs. The results obtained accrue the advantage obtained by the bamboo composite members. compared to standard reinforced concrete and plain concrete. However, further studies to achieve higher mechanical properties and understanding their behaviours in details would make this a reality.

Anurag Nayak, Arehant S Bajaj, Abhishek Jain, Apoorv Khandelwal, Hirdesh Tiwari [2013], bamboo can replace the timber and other material in construction work. When seasoned bamboo is used as reinforcing material it should receive a waterproofing coating to reduce swelling when in contact with concrete. Without some type of coating bamboo will swell before the concrete has developed sufficient strength. Bamboo reinforcement technique is cheaper than steel reinforcement.

I. K. Khan (2014), has conducted the experimental investigation of bamboo reinforced concrete beams. In this study we are going to compare the beams reinforced with steel and bamboo sticks of square, triangular and circular cross section. Based on the experimental results obtained load carrying capacity, deflection, flexural and shear strength of bamboo reinforced beam with square cross section is higher when compared to bamboo reinforced beam with triangular and rectangular cross section. Hence, the tensile strength and modulus of elasticity of bamboo is one half and one third of steel respectively.

Dr. Ashok Kumar Gupta, Dr. Rajiv Ganguly, Ankit Singh Mehra [2015], the density of bamboo is very low which makes it very light material. Water absorption capacity is increase as increase in node. Tensile stress increase as increases in number node**.**

Sanjeev Gill, Dr. Rajiv Kumar[2016], bamboo can use as reinforcement. Bamboo is cheap substitute for steel because bamboo grows much faster and is renewable source after 5-6 years. Water absorption in bamboo is directly affect the strength of bamboo. Tensile strength of bamboo is good so it can be use as a reinforcement. The behavior of bamboo as a reinforcement is same as plain steel bar.

Pritesh Kumar Singh, Aashish Jodhani, Abhay Pratap Singh[2016] , it is been found that bamboo in the vertical position is more durable than in horizontal. Bending of bamboo can be permanently bent if heat, either dry or applied the pressure. The type of coating will depend on the seasoning material is used. A brush coat or dip coat of emulsion is useful for treatment of bamboo. Bamboo reinforced concrete beam design is similar to steel reinforcing design.

Ajinkya Kaware, Prof. U. R. Awari, Prof. M. R. Wakchaure[2018], bamboo weak at node, maximum failure occur at node of the bamboo. Bamboo is weak in bond stress hence it should be treat with epoxy coating to get bond stress. Bamboo is weak in shear so it cannot used as a shear reinforcement. Tensile strength of bamboo is good so it can be used as a reinforcement in R.C.C structure for low cost housing. The behaviour of bamboo is same as the steel bar. Moisture of content of bamboo is varies according to topography.

III. METHODOLOGY

Bamboo reinforced concrete construction follows same design, mix proportions and construction techniques as used for steel reinforced. Just steel reinforcement is replaced with bamboo reinforcement. Nature's material, bamboo has been widely used for many purposes. Mainly as a strength bearing material. It is used for building shelters from an earlier time. Bamboo has used for scaffolding works, formwork supporting stands and many in building construction works. These are limited to medium-large projects Even though existence of bamboo has been found from centuries, bamboo as reinforcement material is an innovation in the civil engineering construction field. This innovation was based on Clemson's study that has been conducted in the Clemson Agricultural College. Bamboo is a biodegradable and renewable in nature. It is energy efficient as it is of natural origin and environmentally sustainable in nature. These properties have forced to use this in the construction field for centuries. The steel as a reinforcing material is a demand that isincreasing day by day in most of the developing countries. There is situations when the production is not found enough toface the demand for steel. Hence is essential to have an alternative that is compared to steel. Bamboo is found in abundant, they are resilient and hence these can face the demandas a reinforcing material and become an ideal replacement for steel. The tensile strength property which is the main requirement of a reinforcing material is seen appreciable for bamboo, compared with other materials including steel. The structure of bamboo. from its origin gives this property. The hollow tubular structure has high resistance against wind forces when it is in natural habitat. Working on the weak points of bamboo and bringing up an innovation of bamboo as a structural steel replacement, would be a great alternative.

Exploring the strength of bamboo in reinforcing concrete structures involves a systematic methodology that considers various aspects. Here's a general outline:

1) Literature Review:

- Begin by conducting a comprehensive literature review to understand the existing research on bamboo as a reinforcement material in concrete structures.
- Identify the properties, advantages, and limitations of bamboo in this context.

2) Material Selection:

- Choose the type of bamboo: species, age, and treatment (if any).
- Determine the size and shape of bamboo elements (rods, mats, etc.) for reinforcement.

3) Testing Bamboo Properties:

- Conduct tests to determine bamboo's mechanical properties, including tensile strength, compressive strength, modulus of elasticity, and moisture content.
- The durability of bamboo under different environmental conditions.

4) Concrete Mix Design:

- Develop concrete mix designs suitable for the intended application.
- Consider the addition of various admixtures to improve bond strength with bamboo.

5) **Bamboo Preprocessing**:

- If required, treat bamboo to improve its durability, such as by boron or borax treatment.
- Properly dry and cure bamboo to prevent decay..

6) Structural Testing:

- Construct concrete test specimens with bamboo reinforcement and control specimens without bamboo.
- Subject the specimens to load tests to evaluate the structural performance, load-carrying capacity, and deformation behavior.

7) Economic and Environmental Assessment:

- Evaluate the cost-effectiveness of using bamboo as reinforcement.
- Assess the environmental benefits of using a renewable material like bamboo.

IV. CHARACTERISTICS OF BAMBOO

Rapid Growth: Bamboo is known for its rapid growth,withsome species capable of growing several feet in a single day under ideal conditions**.**

Strength and Flexibility: Bamboo is strong and flexible, making it a valuable construction material. It has a higher tensile strength than steel and is often used in scaffolding and building.

Lightness: Bamboo is relatively lightweight, making it easy to transport and work with.

Sustainability: Bamboo is considered an eco-friendly material because of its rapid growth and renewability. It requires minimal pesticides and fertilizers.

Versatility: Bamboo has a wide range of uses, from construction and furniture to textiles and even as a food source in some cultures.

Hollow Internodes: Bamboo typically has hollow segments called internodes, which contribute to its lightweight and strong structure.

Aesthetic Variety: Bamboo comes in various colors and patterns, allowing for creative and aesthetically pleasing designs in products.

Water Purification: Some bamboo species can filter and purify water due to their unique root structure, which makes them valuable for water treatment.

V. PROPERTIES OF BAMBOO

Tensile Strength:

Bamboo is able to resist more tension than compression. The fibres of bamboo run axial. In the outer zone are highly elastic vascular bundle, that have a high tensile strenght. The tensile strenght of these fibres is higher than that of steel, but it's not possible to construct connections that can transfer this tensile strength. Slimmer tubes are superior in this aspect too. Inside the silicated outer skin, axial parallel elastical fibers with a tensile strength upto 400 MPa can be found. As a comparison, extremely strong wood fibers can resist a tension upto 50 MPa.

Compressive Strength:

Compared to the bigger tubes, slimmer ones have got, in relation to their cross-section, a higher compressive strength value. The slimmer tubes possess better material properties due to the fact that bigger tubes have got a minor part of the outer skin, which isvery resistant in tension. The portion of lignin inside the culms affects compressive strength, whereas the high portion of cellulose influences the buckling and the tensile strength as it represents the building substance of the bamboo fibers. Generally, the compressive strength of bamboo falls within the range of 40 MPa (megapascals) to 200 MPa.

Elastic Modulus:

The accumulation of highly strong fibers in the outer parts of thetube wall also work positive in connection with the elastic modulus like it does for the tension, shear and bending strength. The higher the elastic modulus, the higher is the quality of the bamboo. Enormous elasticity makes it a very useful building material in areas with very high risks of earthquakes. The elastic modulus of bamboo can vary depending on factors such as the species of bamboo, its age, and how it's processed. Generally, the elastic modulus of bamboo falls within the range of 5 GPa (gigapascals) to 20 GPa. Some bamboo species may have even higher or lower elastic moduli, but this is a typical range. It's important to note that bamboo's mechanical properties can be quite impressive, making it a strong and lightweight material.

Anisotropic:

Bamboo is an anisotropic material. Properties in the longitudinaldirection are completely different from those in the transversal direction. There are cellulose fibers in the longitudinal direction, which is strong and stiff and in the transverse direction there is lignin, which is soft and brittle

Shrinkage:

Bamboo shrinks more than wood when it loses water. The canescan tear apart at the nodes. Bamboo shrinks in a cross section of10-16 % and a wall thickness of 15-17 %. Therefore it is necessaryto take necessary measures to prevent water loss whenused as a building material.

VI. ADVANTAGE OF BAMBOO

- Engineers and architects appreciate bamboo's impressive strength-to-weight ratio. It's used in structural applications, providing a sustainable alternative to traditional building materials like steel and concrete.
- Professionals in sustainable architecture, interior design, and construction can promote eco-friendly practices by using bamboo. Its rapid growth and renewability make it apreferred choice for green building projects.
- Bamboo is often more affordable than traditional building materials like steel, concrete, or hardwood, making it a cost- effective choice in construction and design projects.
- Bamboo's lightweight nature reduces transportation costs, especially for long-distance shipping. This is beneficial for architects, builders, and manufacturers sourcing materials from different regions.
- Bamboo's flexibility allows professionals to design and build structures with curved or innovative shapes, adding strength and aesthetic appeal to projects.
- Bamboo's natural resilience can provide shock-absorbing properties in applications where impact resistance is essential, such as in sporting equipment and architectural features.

VII. DISADVANTAGE OF BAMBOO

- Bamboo's properties can vary significantly depending on the species, age, and growing conditions, making it challenging to predict its performance in professional applications.
- Joining bamboo can be more complex and labor-intensive compared to working with traditional materials. Skilled craftsmanship is often required for creating strong joints.
- Bamboo is not highly fire-resistant, which can be be a drawback in professional applications where fire safety isa concern.
- The lack of standardized testing and grading for bamboo products can make it difficult for professionals to ensure consistent quality and performance in their projects
- Bamboo's durability can be a concern in outdoor applications, as it may require additional treatment or maintenance to withstand weather and environmental conditions.

VIII. CONCLUSION

In conclusion, the use of bamboo as a reinforcement material in concrete structures presents a compelling combination of strength, sustainability, and cost-effectiveness. Bamboo's natural properties, such as high tensile strength and flexibility, make it an excellent choice for reinforcing concrete. Its advantages extend to sustainability, as bamboo is a rapidly renewable resource that aligns with eco-friendly construction practices. Moreover, bamboo often proves to be more cost-efficient than traditional reinforcement materials like steel, particularly in regions where it is abundant. Properly treated bamboo can exhibit resilience to pests, decay, and moisture, enhancing the longevity of concrete structures.

However, successful integration requires adherence to engineering standards and codes, as well as proper treatment and maintenance. Bamboo's role in reinforcing concrete structures represents an innovative and environmentally conscious approach to construction, which is increasingly relevant in our quest for sustainable and resilient building practices.

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