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''USE OF BAMBOO FOR SUSTAINABLE CONSTRUCTION''

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Abstract - *Bamboo is also called as "Green Steel" for 21st century which is naturally available over the globe in tropical and non-tropical region like Asia, some part of America and Africa. Bamboo is contemplate as sustainable, adaptable, eco-friendly, rapid growing construction material. Given the high energy demand of current construction material and the scarcity of other naturally available resources such as a favorable alternative for construction purposes. After observation of this we have perceive bamboo is one of the key asset of building material. It has greater compressive strength than concrete, brick, or wood and its tensile strength is similar to that of steel. Using bamboo instead of traditional materials like concrete or steel in construction can help to make our environment healthier. When we choose bamboo, we are making a smart decision for the planet. It means we're using that grow quickly and doesn't harm the environment as much as other materials. This switch to bamboo can make a big difference in reducing the amount of pollution created by the construction industry. Not only does bamboo help the environment, but it also helps the economy and makes society fairer. This paper suggests that we should keep studying bamboo and finding new ways to use it in construction. By doing this, we can unlock even more benefits for the environment, the economy, and society as a whole. In short, using bamboo in construction can help us build a better, more sustainable future.*

Key Words: green steel, bamboo, favorable, traditional material, sustainable future, society fairer.

1.INTRODUCTION

The construction industry is a multifaceted sector involved in the planning, design, construction, and maintenance of infrastructure, including roads, bridges, dams, buildings, and tunnels. Key materials used are steel, cement, sand, and aggregates, significantly contributing to construction. Annually, around 1800-1900 million metric tons of steel are used globally, with 2023 seeing approximately 1814.5 million metric tons. Global cement consumption reaches about 4.4 to 4.5 billion metric tons annually, as per the U.S. Geological Survey and the Global Cement Report, with 2023 estimates at 4.4 billion metric tons. Aggregate usage, including sand, gravel, and crushed stone, is around 50 billion metric tons annually.

Using these materials impacts the environment in various ways. Steel production, involving resource-intensive processes like mining and smelting, contributes to deforestation, habitat destruction, soil erosion, and significant CO2 emissions—1.91 tons of CO2 per ton of crude steel cast in 2022, according to the World Steel Association. Cement production, responsible for about 7- 8% of global CO2 emissions, also exacerbates climate change and air pollution. Sand and aggregate extraction disrupts ecosystems, leading to habitat loss, erosion, and water pollution, impacting aquatic biodiversity and ecosystem health.

Historically, civilizations used bamboo for construction before steel was discovered. Bamboo's strength, flexibility, and abundance made it a versatile substitute. Ancient cultures in East Asia and South America used bamboo for beams, scaffolding, and even weaponry, showcasing its suitability for various climates and seismic activity. Structures like the bamboo bridges of ancient China and the frameworks of Mayan temples highlight its significance.

Bamboo, particularly Dendrocalamus Hamiltonii, is widely available in India's North-East states. This tall species, known locally as "Mol Bas," in my area reaches 15-18 meters with culm diameters of 5-15 cm. Bamboo has been used for tools, paper, textiles, food, soil stabilization, reforestation, and handicrafts for centuries. Recently, it has gained attention as a renewable, low-impact alternative to concrete and steel in construction. Its rapid growth rate ensures a sustainable supply, and its strength- to-weight ratio and flexibility make it suitable for structural applications, especially in earthquake-prone regions. Bamboo also offers environmental benefits by absorbing large amounts of CO2 and requiring minimal chemical inputs.

Studies on bamboo reinforcement focus on its performance under various loads, testing for its flexural strength. This tests evaluate how well bamboo can handle bending forces, which is essential for determining its suitability in applications where flexibility and resilience are required. These tests helps us to understand bamboo's potential as a construction material, ensuring it can support heavy loads without buckling or collapsing.

2. LITERATURE REVIEW

Researchers have been engaged in studying the use of bamboo in sustainable construction. Here are some of their accomplishments.

Sumeera Madhushan et al. (2023) "This review highlights the importance of understanding bamboo's physical, mechanical, and chemical properties for its effective use in construction, particularly emphasizing the need to explore preservation techniques due to bamboo's biodegradable nature. Previous studies on bamboo's material and mechanical properties across different regions are synthesized, underlying the variability in strength parameters influenced by factors like species, moisture content, and growth conditions. Furthermore, the review stresses the necessity of ensuring connection stability and long-term performance, with advanced high- performance bamboo connections showing promise in replacing traditional joints. Various preservative techniques, including oil-heated treatment and borax treatment, are discussed, each with its advantages and disadvantages. In terms of durability, borax preservation emerges as a viable option, through further research is needed to quantify its effects accurately. The review suggests future research avenues could focus on enhancing bamboo's durability through preservative techniques and exploring the potential of engineered bamboo products like cross-laminated bamboo, which offer improved mechanical properties.

Tanisha Rampal et al. (2023) "This literature review emphasizes bamboo's potential as a sustainable construction material, attributed to its rapid growth and environmental friendliness. Its adaptability across architectural and design domains underscores its historical and contemporary relevance. Despite its merits, challenges like water damage persist, although ongoing technological advancements offer remedies. Furthermore, the review identifies a gap in specific bamboo applications, suggesting an area ripe for further investigation. Ultimately, bamboo emerges as a crucial, versatile, and culturally significant resource for eco-conscious design initiatives both in India and globally.

Cleysson Marcio Guimaraes da Cunha el at. (2023) " This literature review explores the economic impact of Brazil's civil construction sector, noting its significant influence on the economy alongside concerns about resource depletion and waste generation. With a growing focus on sustainability, attention turns to bamboo as a promising alternative due to its durability and rapid growth. The review examines the feasibility of integrating bamboo into construction practices, emphasizing the importance of economic viability, sustainability, and regulatory considerations in achieving a balanced approach to development and environmental stewardship.

Maria Fe V. Adier el at. (2023) "The significance of bamboo as a traditional construction material persists owing to its adaptability and remarkable strength-to- weight ratio. However, ensuring its long-term durability necessitates meticulous treatment due to inherent variations in mechanical properties. Extensive research indicates that both natural and chemical treatments offer avenues for enhancing bamboo's properties, albeit challenges such as managing temperature and treatment duration persist. A comprehensive literature review encompassing 57 articles spanning the period from 2003 to 2023, supplemented by additional scholarly references, underscores gaps in comprehending bamboo's characteristics and treatment modalities. To address these gaps, the thesis recommends the formulation of centralized protocols for bamboo preparation, exploration into alternative reinforcement materials, and the refinement of testing methodologies. The standardization of treatment procedures and the critical evaluation of existing testing protocols emerges as imperative steps to bolster bamboo's reliability and facilitate its sustainable integration into construction practices.

Samjetsabam Chainey et al. (2022) "This literature review explores bamboo's role as a sustainable construction material. Bamboo, abundant in tropical regions worldwide, boasts remarkable versatility and eco- friendliness. With strengths exceeding those of traditional materials like concrete and wood, bamboo offers a compelling solution to concerns about resource depletion. Amidst challenges in providing affordable housing due to population growth, bamboo emerges as a promising alternative. Furthermore, its potential to replace steel reinforcement in construction is examined in this study, which investigates the performance of bamboo-reinforced concrete and housing systems featuring bamboo as a primary component.

Priyanka Shukla et al. (2020) "The literature review underscores bamboo's role as a highly sustainable resource, showcasing its diverse applications across industries such as construction and fabric production, and its significant economic contributions worldwide. Extensive research highlights bamboo's remarkable tensile strength, akin to that of steel, positioning it as a viable alternative to conventional timber. This assertion is further supported by various Life Cycle Assessment tests. While certain Asian nations have embraced bamboo, emerging as key global producers and innovators, others, including India, despite their substantial bamboo production, lack a robust bamboo industry infrastructure. Consequently, artisans and growers in these regions encounter obstacles stemming from inadequate legislative backing, limited resources, and infrastructure, elucidating a notable gap in the bamboo resource development continuum.

Madhukar Ramchandra Wakchaure (2016) "The literature review highlights the pivotal role of reinforcing cement matrices in modern construction, with steel being the predominant material due to its adaptability. However, global steel shortages and cost issues in developing nations have prompted a quest for economical alternatives, leading to the investigation of bamboo as a reinforcement material. This thesis delves into bamboo's potential for concrete reinforcement, emphasizing its physical and mechanical attributes. Through experimental research and treatment

methods aimed at enhancing bamboo's properties, an analytical and design framework for bamboo-reinforced concrete elements is developed. Validation is conducted via testing of beam and slab specimens, validating the reliability of the proposed framework. Additionally, the thesis presents design illustrations and an extensive reference list

Sri Murni Dewi el at. (2016) " Recent research at Brawijaya University in Indonesia has advanced bamboo-reinforced concrete through three key approaches: attaching pegs to reinforcement for enhanced structural integrity, using lightweight bricks to reduce beam weight, and incorporating lightweight aggregate in bamboo concrete composite frames. These methods address challenges such as durability and compatibility, making bamboo a more viable and sustainable construction material . The findings offer valuable insights and pave the way for further developments in bamboo-reinforced concrete.

3. GAP-AREA

This research explores the mechanical properties of Dendrocalamus Hemiltonii (locally known as Mol Bas) bamboo specimen under flexural strength, and understand its application area. Despite its promising mechanical characteristics, and availability understanding the performance of this bamboo is crucial for their widespread adaption in sustainable construction practices, specially in North-East region. Closing this research gap could facilitate the procedure acceptance and utilization of Mol Bas bamboo as a viable alternative to conventional construction materials, contributing to move environmentally friendly and resilient built environment.

4. OBJECTIVES

1. Performance of different Mol bamboo sections: This objective focuses on conducting flexural tests on different bamboo specimens to assess their load-bearing capacity. By analyzing the mechanical properties of halved bamboo sections, the study aims to determine their suitability for use in sustainable construction applications, such as modular or composite structures.

2. Investigate the influence of specimen configuration on flexural strength: Comparing the mechanical properties of different specimen configurations, including variations in the number of halved and full bamboo sections used in compression and tension zone for flexural strength. By systematically varying the specimen configurations, the study aims to identify how deflection varies with different specimen arrangements and to optimize specimen preparation protocols for future research and practical applications.

3. Comparing performance of Halved and full solid Mol bamboo specimens: To conduct comparative analysis between halved bamboo, one third of original half bamboo, and full solid bamboo specimen under two point loading system. By examining the difference in load bearing capacity, deformation characteristics, and load failure modes between halved, one third of original half bamboo, and full solid bamboo specimens. Aim of study is to provide insights into the structural integrity and potential applications of halved section bamboo sections in sustainable construction.

5. METHODOLOGY

Before you begin to format your paper, first write and save the content as a separate text file. Keep your text and graphic files separate until after the text has been formatted and styled. Do not use hard tabs, and limit use of hard returns to only one return at the end of a paragraph. Do not add any kind of pagination

5.1 Sample collection

The bamboo specimen are collected from Pamphok, Namthang south Sikkim, near Pamphok Government Junior High school, with specific coordinate (27.1427484, 88.4849345). The bamboo sample was carried to the CCCT college laboratory.

5.2 Specimen Details

Mol bamboo specimens of varying dimensions, ranging from 4 cm to 6 cm in diameter, were selected for this study. These specimens were divided into three categories, and three samples for each category was prepared.

1. Specimen 1 (H2B): Two half bamboo strand in the compression and tension zone. (Fig. 1.)
2. Specimen 2 (H3B) : Two 1/3 bamboo strand in the compression zone and three 1/3 bamboo strand in the tension zone. (Fig 2.)
3. Specimen 3 (HB) : Two half bamboo strand in the compression zone and two full solid bamboo in the tension zone. (Fig. 3.)

All specimens were standardized to the following dimensions: 700 mm in length, 150 mm in width, and 150 mm in height. To achieve concrete grade of M20 materials such as cement, fine aggregate, and coarse aggregate were used to assemble and fix the bamboo sections. Normal river sand was used, and the aggregate size for the specimens was 10 mm (approximately 60% of the total coarse aggregate) and 20 mm (approximately 40% of the total coarse aggregate).

Fig-1: Two half bamboo strand

Fig-2: Two 1/3 bamboo strand

Fig-3: Two half bamboo strand in the compression zone and two full solid bamboo in the tension zone

5.3 Test Setup

The test setup involved a flexure testing machine over which the beam specimens were placed, and the load was applied simultaneously at two points equidistant from the supports. This configuration subjected the specimen to bending moments and shear forces. Also findings based on the first crack load and failure load was recorded, which is provided in Table 1.

6. RESULT AND DISCUSSION

Table -1: Sample Table format

Sl. No	Specimen Type	First Crack Load (KN)	Failure Crack Load (KN)
1.	Half Bamboo Specimens	7	27
2.	One-third of the Original Half Bamboo Specimens	6	22
3.	Combined Half and Full Solid Bamboo Specimens	8.5	19

1. The findings demonstrate that the arrangement of bamboo reinforcement considerably influences the flexural strength and crack initiation load of the concrete sections. The Half Bamboo strand specimen exhibited the highest flexural strength, followed by the One-Third of the Original Half Bamboo Specimens and the Combined Half and Full Solid Bamboo Specimens.

2. The Half Bamboo Specimens had a larger effective area of reinforcement in both the compression and tension zones, leading to higher load-carrying capacity and delayed crack initiation.

3. The first crack load can be used to assess the initial stiffness of the bamboo-reinforced concrete. Specimen 1 (H2B) demonstrated the highest first crack load of 7 kN, indicating better resistance to initial cracking, while Specimen 2 (H3B) and Specimen 3 (HB) exhibited first crack loads of 6 kN and 8.5 kN, respectively. The variation in first crack loads shows the impact of bamboo configuration on the early-stage performance of the composite.

4. The halved bamboo configuration provided better load-carrying capacity, which could be attributed to the distribution of stresses and better bonding between the bamboo and the concrete matrix.

CONCLUSIONS

The study demonstrates that bamboo-reinforced concrete has significant potential as an alternative to conventional steel reinforcement, particularly in regions where bamboo is readily available and cost-effective. The results highlight that the configuration of bamboo strands (halved, one- third, and full solid) plays a crucial role in determining the flexural strength and overall performance of the composite. Halved

bamboo strands, in particular, exhibited superior load-carrying capacity, better distribution of stresses, and enhanced bonding with concrete. This makes halved bamboo sections an attractive option for reinforcing concrete in structural applications.

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BIOGRAPHIES

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