Comparative Study of hybrid bamboo beam with steel reinforced beam

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Abstract - The need has been brought to light by the rising demand for affordable housing and sustainable building methods for substitute materials in the building sector. Bamboo has long been used as a building material because of its high strength, low weight, and renewable nature. Its potential as a concrete reinforcement, however, has not been thoroughly investigated. Three M40- grade concrete beams were cast for this study: one with concrete and steel reinforcement, one with steel reinforcement, and one with bamboo reinforcement. To evaluate each beam's mechanical performance, flexural tests were performed. The findings show that bamboo can be just as strong as steel while also having major environmental advantages, such as sustainability and reduced carbon emissions. The potential of bamboo as an economical and environmentally friendly reinforcement option in concrete construction is demonstrated by this study. For broad use in the building sector, future studies should concentrate on refining bamboo processing methods and assessing its long-term durability. The hybrid beam provides good and balanced strength with significant cost savings. In low-cost construction scenarios and balanced strength, we can use hybrid beams.

Key words: Bamboo reinforcement, Cost analysis, flexural test, Strength hybrid beam.

I. INTRODUCTION

The construction industry is looking for alternatives as the demand for sustainable building practices rises globally materials that are economical and ecologically sustainable. When compared to conventional building materials, bamboo is a particularly promising material because of its strength, quick growth, and low environmental impact. Although bamboo has been utilized for centuries in many cultures, its potential as a concrete reinforcement material has not yet been fully investigated. In order to increase its tensile strength, concrete, a material that is frequently used in construction, usually needs reinforcement. Steel has long been the go-to reinforcement material, but it has high financial and environmental costs. As a lightweight and renewable material, bamboo presents a potentially sustainable substitute for concrete reinforcement. The purpose of this study is to determine whether using bamboo as reinforcement in concrete beams is feasible to evaluate its durability and strength in relation to steel reinforcement. Three M40 grade concrete beams—one with steel reinforcement and bamboo, one with steel reinforcement and bamboo—were cast and tested for this study. The beams were mechanically tested using a Universal Testing Machine (UTM) to assess their performance following a 28-day curing period. The main goal is to determine whether bamboo can be used as an environmentally responsible and efficient alternative to steel for concrete reinforcement, providing a long-term answer to the problems the building sector faces. Its quick growth rate makes it a highly renewable resource, and its flexural strength enables it to tolerate bending forces.

Bamboo also offers good thermal insulation, which increases its suitability for environmentally friendly construction methods.

The use of bamboo as reinforcement in concrete beams was investigated by Aryan et al (2024), who showed that bamboo can be a sustainable, affordable, and renewable substitute for steel due to its similar tensile strength. According to their research, bamboo can lessen mid-span deflection in concrete beams, which makes it a good choice for reinforcing. These results provide credence to the goal of the current study, which is to assess bamboo as an effective and environmentally friendly steel substitute for concrete applications.

This study explores the use of bamboo as reinforcement in concrete by Santosh Shivapuji, Malagonda Patil, and Rahul Sali's (2016). Their study looks at the issues of bamboo's strength and

durability in relation to concrete compatibility. According to the research, bamboo can be a cost-effective and environmentally friendly substitute for traditional building materials when used as reinforcement in low-rise structures. This study supports the goals of the ongoing project, which is to assess bamboo's potential as an economical and environmentally beneficial reinforcement material for concrete.

This study is investigated by Gavli et al. (2021). he study highlights bamboo's affordability in comparison to more conventional reinforcement materials, as well as its renewable and sustainable qualities. According to the research, bamboo may offer a workable way to lower building expenses while fostering environmental sustainability. This supports the current project's goal of assessing bamboo as a reinforcing material for concrete buildings.

This study is investigated by Rahman et al. (2022). Their experiments, which include bending and compression testing, demonstrate bamboo's potential as a useful reinforcement material. To increase the material's performance and durability in concrete applications, they advise more study, particularly the usage of bamboo poles rather than slats. This work advances the investigation of environmentally sustainable building substitutes.

This study is investigated by , Wadkar (2023) highlights the material's benefits over steel, such as its affordability, sustainability, and renewability. The study shows that bamboo can lower building costs without sacrificing structural performance by comparing the flexural and tensile behaviour of concrete reinforced with bamboo and conventional steel reinforcement. Despite the encouraging outcomes, problems like bamboo's inability to absorb moisture must be fixed before it can be used widely. This study adds to the continuous hunt for environmentally appropriate substitutes for concrete reinforcement.

II. METHODOLOGY

A. Properties Of Bamboo –

The physical and mechanical properties of bamboo are given below .

Bamboo is a strong, lightweight material with a number of physical characteristics that make it appropriate for use in building. It is strong and manageable due to its density, which ranges from 600 to 900 kg/m³. Bamboo is extremely elastic, meaning it can bend without breaking, and it has a high tensile strength that is frequently on par with steel. It is a dependable material for structural applications due to its compressive strength. Bamboo has good moisture-absorbing qualities, is naturally resilient to fungi and pests, and is long-lasting. However, excessive moisture exposure can cause untreated bamboo to deteriorate. It is a highly renewable resource due to its quick growth rate and high flexural strength, which enable it to tolerate bending forces. Bamboo also offers good thermal insulation, which increases its suitability for environmentally friendly construction.

The table 1 below displays the mechanical properties of bamboo. For structural and material analysis, this table provides a reference for the general mechanical properties of bamboo.

Table 1: Mechanical Properties of Bamboo

Property	Value of range
Density	600-900
Compressive strength	40-80
Tensile strength	100-300
Shear strength	8-20
Modulus of elasticity	10000-30000
Modulus of rupture	50-150
Moisture content	8-20

B. Experimental work on bamboo reinforced concrete

a. Sizing

In reinforcement applications in this study, we can use whole bamboo culms with a diameter of 16mm.

b. Seasoning

Before using bamboo as reinforcement, it is best to harvest it and let it air dry or season for three to four weeks. The bamboo culms need to be appropriately supported periodically to avoid deformation and preserve their form and reduce warping while being seasoned.

c. Waterproof coatings

Bamboo, whether split or whole, needs to be waterproofed before being used as reinforcement. In order to stop the bamboo from absorbing moisture from the concrete, this coating is, necessary and might result in swelling. If the bamboo is not treated, the bamboo might swell before the concrete is strong enough, which could lead to damage and cracks. There are multiple waterproofing products on the market for this use.

d. Concrete Mix Design

IS mix design method for steel-reinforced concrete can be applied to bamboo-reinforced specimens.

However, modifications are essential to account for bamboo's water absorption and swelling tendencies. To minimize excess moisture, the concrete slump is kept as low as possible while maintaining workability. This prevents bamboo from absorbing too much water, which could affect its dimensional stability.

For M40-grade concrete, certain adjustments are necessary. Surface treatment like bitumen coating helps reduce moisture absorption. A lower water-cement ratio enhances durability while limiting swelling issues. Higher cement content improves bonding between bamboo and concrete.

Additionally, superplasticizers may be used to enhance workability without increasing water content. Careful curing methods are essential to prevent prolonged exposure to excessive moisture.

e. Tensile test on Bamboo strip

To check the feasibility of bamboo usage in the beam, a tensile test on a bamboo strip has been conducted. The result shows in Table 2 that when the load of 16000 N is applied, we get 0.033 strain and 6.48864 stress.

Fig.1 shows the Tensile test perform on Bamboo strip

Table 2 : Result of tensile test on bamboo by Bamboo as Reinforcement in Concrete for Low Cost Housing Santosh Shivapuji, Malagonda Patil, Rahul Sali(2016).

Load P (N)	Elongation (mm)	Strain	Stress (N/mm2)
10000	0.10	0.0003	54.0540
12000	0.50	0.0017	64.8648
14000	0.50	0.0017	75.6756
16000	1.00	0.0033	86.4864

III. RESULTS AND DISCUSSION

In the present study the usage of bamboo as a partial replacement of steel has been checked. Three different cases are studied three M40 grade concrete beams were cast.

In this study, the first beam of regular M40 concrete with bamboo as the reinforcement. The second beam of regular M40 concrete with bamboo and steel as the reinforcement and the third beam of regular M40 concrete with steel as the reinforcement. Flexural tests were conducted after the specimen was fixed in the Universal Testing Machine [UTM]. Two-Point loading was applied to the specimens in accordance with IS516.

Fig.2 Setup in UTM with specimen

A. Flexural test on a bamboo-reinforced concrete beam.

The first crack in the bamboo-reinforced beam widened after appearing vertically at the load application point suggesting a crack in the flexure. The concrete at the load point then began to crumble. The abrupt failure of the plain concrete beam revealed brittle cement concrete failure. The flexural strength is given into the table 3.

Fig. 3 shows the development of cracks and the failure.

B. Flexural test on a hybrid reinforced concrete beam.

In a hybrid concrete beam with steel strips, two irregular cracks appeared slowly. The bottom bamboo broke at the nodes, and the upper bamboo also failed at the nodes, causing a node split failure. Adding bamboo fibre improved the beam's flexural strength. The beam failed because the bamboo didn't bond well with the concrete. The flexural strength is given into the table

C. Flexural test on a concrete beam reinforced with steel stirrups.

In steel Reinforced beam with steel stirps, The cracks started appeared vertically at down side of beam and opposite side to point load applied. Gradually, vertical cracks formed on the beam in the direction opposite to where the load was applied. The flexural strength is given into the table.

D Comparative analysis of flexural performance in bamboo, hybrid and steel beams.

Table 3 : Result of Flexural test on Beams

Sr no	Grade of concrete	Size of specimen [beam] in cm	Beam ID mark	Span length In cm	Position of Fracture [values in cm]	Max load in [KN]	Flexural strength [N/Sq/mm]	Average Flexural strength [N/Sq/mm]
1	M40	75x20x22	Bamboo beam	75	22.9	110.6	19.39	
	M40	75x20x22	Bamboo beam	75	24.5	108.4	20.88	20.6
	M40	75x20x22	Bamboo beam	75	26.3	106.9	21.53	
2	M40	75x20x22	Hybrid beam	75	20.9	113.9	21.22	
	M40	75x20x22	Hybrid beam	75	23.5	115.6	22.26	22.37
	M40	75x20x22	Hybrid beam	75	25.6	117.3	23.64	
3	M40	75x20x22	Steel beam	75	20.3	122.3	22.81	
	M40	75x20x22	Steel beam	75	23.4	120.2	23.15	23.76
	M40	75x20x22	Steel beam	75	27.6	119.4	25.32	

As per the results,

1st: Steel beam (Average Flexural Strength: 23.76 N/mm²) 2nd: Hybrid beam (Average Flexural Strength: 22.37 N/mm²) 3rd: Bamboo beam (Average Flexural Strength: 20.6 N/mm²).Accordingly,among the three types examined, the steel beams had the highest average flexural strength, followed by the hybrid beams, and the bamboo beams had the lowest average flexural strength. An eco-friendly, economical, and sustainable substitute for conventional steel reinforcement is provided by hybrid bamboo beams. They are a well-rounded option for green building, even though their mechanical performance slightly lags behind that of steel but far surpasses that of bamboo-only beams.

IV. Cost analysis :-

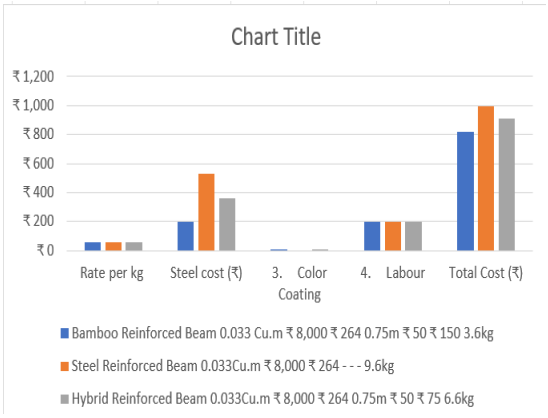

Fig 4 shows cost analysis of beams

A cost comparison of steel, bamboo, and hybrid reinforced concrete beams is shown in this chart. The bamboo beam is cheapest cost because bamboo is less expensive. The hybrid beam which uses both bamboo and steel has a moderate cost. The steel beam which uses high steel is the most expensive. Among the three beams hybrid beam is best choice as it gives both strength and cost savings.

V.CONCLUSION

From the experimental work the following conclusions are drawn.

This study assessed the strength and adaptability of steel-reinforced, bamboo-reinforced, and hybrid bamboo-steel concrete beams for low-cost construction. Steel's superior tensile strength and rigidity allowed the steel-reinforced beam to exhibit the highest load-carrying capability. The hybrid beam made of steel and bamboo had a strong strength-to-cost ratio, making it a viable choice for projects with tight budgets. Although not as strong, the bamboo-only beam demonstrated sufficient strength for non-critical structures or small buildings. Bamboo can be a sustainable substitute because it is inexpensive, lightweight, and environmentally benign. Thickness determines its strength, yet bamboo has great potential for low-cost building with the right choice and care.

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