Experimental and Theoretical Study on Axial Compression Behavior of Cold-Formed Thin-Walled Steel-Bamboo Scrimber Composite Column. A Literature Review

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Abstract- ***This literature review provides an overview of studies on the use of cold-formed steel (CFS) and bamboo as potential structural materials. CFS is widely used in construction due to its high strength-to-weight ratio, while bamboo is gaining attention as a sustainable alternative because of its renewability and excellent tensile strength. The review focuses on literature that examines these materials both individually and in hybrid systems, as well as their mechanical, durability, and structural performance in different regional contexts. Additionally, it identifies potential opportunities, challenges, and limitations that may arise from combining high-strength CFS with bamboo in structural applications. While significant progress has been made in understanding the performance of these materials, unresolved issues remain, such as material compatibility and the long-term sustainability of hybrid structures. This review aims to contribute to a deeper understanding of this emerging research area and support the development of greener, more sustainable construction practices.***

I. INTRODUCTION

Issues related to the depletion of resources and the environment, in which climate change and pollution are prominent today, have intensified the search and offered alternative ways to construction materials [1]. Steel, concrete, and brick masonry are the most common building materials used today, which has led to environmental pollution, excessive energy use, and non-renewable issues [2]. Promoting sustainable building materials is essential in order to replace highly polluting and non-sustainable ones.

The integration of cold-formed steel and bamboo as composite materials in structural applications has gained significant interest due to their complementary mechanical properties and sustainability potential [1]. CFS sections have low density and are uncomplicated to manufacture which makes them ideal for use in both industrial and domestic construction [3]. Cold-formed steel (CFS) is structural-quality sheet steel that has been molded into various shapes without the use of heat, and it has significant advantages as a construction material. It can withstand shrinkage, splitting, moisture absorption, warping, termites, and fire. CFS's consistent quality lowers waste and expenses, making it appropriate for a variety of situations [1].

In addition to being extremely sustainable, cold-formed steel also greatly aligns with global objectives to reduce the environmental effects of building. There is less need for virgin raw materials and waste production because steel is a recyclable material that can be used repeatedly without losing its mechanical qualities [3]. CFS has a lower carbon footprint, as no hot working operations are needed [4].

One of the direction to finding solution is to explore for new material applications, such as recycling and reuse, sustainable product production, or use of renewable resources, bamboo is thought to be more affordable alternative with high tensile strength and is an organic substitute for metal that thrives in tropical regions, which are often associated with developing

nations that have the fastest rates of urbanization and papulation expansion, since using bamboo in construction could be economically beneficial for the majority of developing countries, bamboo is becoming more and more popular as a steel substitute, by satisfying local value chains, promote trade and employment opportunities, and reduce reliance on foreign market [5]. Structural analysis of bamboo as a modern engineering building material showed how bamboo could be viable material for modern built construction, for Engineers, Researcher, and Builders, the idea of using bamboo extensively as a sustainable substitute for steel in reinforced concrete structures presents significant challenges related to constructability, sustainability, and structural capability and compatibility [6]. This is because bamboo grows in underdeveloped countries and has certain mechanical qualities [7][8]. Because of its sturdy structure, bamboo is a great building material, it is twice as strong as concrete and in terms of compressive strength and possesses tensile strength similar to a steel, compared to wood, bamboo fiber experiences more shear stress, bamboo is more widely distributed that wood, it also be bent without breaking and considered an incredible material, especially when compared to steel, which has tensile strength of [9].

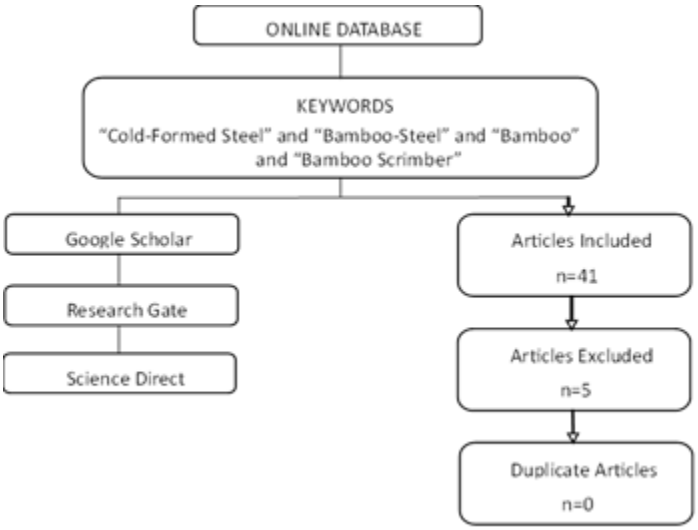
The use of both these materials, bamboo and steel in construction systems can help in reducing the consumption of non-renewable sources while ensuring a strong construction framework [10]. The focus of this literature review is to highlight the existing progress, issues and the prospects in the field of bamboo-steel composites. This review attempts to address the gap by detailing the combination between the natural characteristics of bamboo and the finishing effects of steel in providing further solutions on sustainable construction norms.

II. METHODOLOGY

This section described the concept and hypotheses when selecting search terms for electronic databases such as Google Scholar, Science Direct, and Research Gate. The researcher sorted every article published between 2010 and 2024 to choose the most reliable source that could be used for the study. Articles that were included in this literature review were related to the main purpose of this study that answers the following research questions:

Research Questions:

1. What are the physical and mechanical properties of bamboo?
2. What treatment methods guarantee bamboo's resilience when combined with steel?
3. What are the techniques to connect or combine bamboo and steel together in the construction application?



III. DISCUSSION

3.1 Mechanical Properties and Physical Properties of Bamboo

To effectively employ bamboo, especially as a building or engineering material, it is important to know its physical and mechanical properties. Such properties give an understanding of the use of the material within the structure for selected functions such as strengthening and bearing elements of the structure. For instance, one of the applications of bamboo is when high tensile strength is a requirement since it can substitute for steel in some cases. It is important to know these properties accurately in order to ensure safety and reliability of structures, as their miscalculation can result the failure of such structures, particularly under wind or heavy loading circumstances. Table 1. emphasizes the various compositional uses of bamboo, including its physical and mechanical features that make it a worthwhile material. The use of bamboo in different

types of structures does demonstrate its light weight, high tensile strength and renewability. However, the discussion reveals some set of important problems which must be dealt with in order to make it structurally better when used in combination with steel or other materials. Table 1 shows the properties of bamboo structure.

Table 1. Properties of Bamboo

Type of Structure	Physical Properties	Mechanical Properties	Key Results /Challenges	Citation
Bamboo Scrimber	Composite material in processed form Density: 0.8 to 1.15 g/cm^3	Compressive strength: 60 to 80 MPA Tensile strength: 120 to 250 MPA Elastic Modulus: 15 to 25 GPA	Increased uniformity and strengthening other than plain bamboo Uses adhesive which is cause of the problem to the environment	[11], [12], [13]
Bamboo as reinforcement	Natural Elasticity Uneven texture, and the distribution of strength differs from from one node to another.	Tensile Strength increased: 1.34 MPA Modulus elasticity: 2 to 3 MPA	Increases ductile behavior in concrete, good tensile strength and compressive strength Progressively weakens without a coat	[7], [8], [14], [15], [16], [17]
Bamboo-Steel	Steel and bamboo plywood internal dimension of the Steel that is 2 mm thick is 120 mm by 60 mm.	Modulus Elasticity: 117 GPA and 260 MPa respectively	Mild increase of compressive and tensile strength, Issues connecting the materials together and there is high possibility of bamboo getting damaged by moisture and caught in flames	[1], [18], [19], [20]

At the application of bamboo for columns, beams, slab other application, its performance can be even more effective due to its geometry shape and high ratio of strength against the weight of a single tube [14], [17], [21]. However, the variation in species, age, and the environment in which it is grown limits the performance. With the aspect of variability limitations to some degree, bamboo scrimber as a composite material resolves some of these concerns but has poorer environmental and cost effectiveness since it makes use of glues, shells, and other materials [12], [22]. Among the many concerns regarding the use of bamboo, its composite materials have to deal with endurance. When compared to traditional materials, bamboo has a short shelf-life because it is prone to moisture, insect attacks, and fire [5].

3.2 Bonding Techniques for Bamboo-Steel Composite

Bonding techniques involving bamboo and steel should be within reach because these materials have already started to gain traction when it comes to use in green construction, and when combined, they can help increase structural efficiency. On the upside,

bamboo being a green product emits less carbon onto the atmosphere, and with steel the structure will need less maintenance throughout its service life. Understanding the most effective means of bonding dissimilar materials ensures that efficient mate. Table 2 shows the Bonding techniques for bamboo-steel composite. Bamboo and steel brings certain potential and difficulty owing to the physical characteristics of the two materials. It is possible to achieve good resistance, flexibility and durability by applying epoxy resin bonding or polyurethane adhesives but sensitive curing times and environmental conditions are problems [25]. Bolts and clamps are also good joints because they are easy to assemble and maintain but the joints have corrosion as well as esthetic limitations [24]. However, all these methods have certain drawbacks where uniformity in the bond, corrosion, or degradation of material are some of the issues that need to be addressed. Higher development in adhesive and fastening technology along with advancement in surface treatment remains important in achieving better and stronger performance of bamboo-steel hybrid structures in building construction [11].

3.3 Treatment Method for Bamboo

It is crucial to know bamboo treatment methods as they greatly improve bamboo's performance and its usefulness in various applications, especially in construction. Even if bamboo is renewable and environmentally friendly, it has a disadvantage of being prone to insects, fungus, moisture, and many other forms of destruction. Treatment techniques help in increasing its validity for structural purposes because they enhance its average life, strength, and resistance to those factors. Besides, increasing awareness and technical capacities to use eco-friendly building methods treating bamboo properly will also reduce its cost and therefore can be a long-term replacement for the commonly used materials such as wood and steel. These treatments also help solve issues related to fire resistance and size precision which allows to use bamboo in more types of construction and design. Table 3 shows the different kins of treatment for bamboo.

Table 2. Bonding Techniques

Bonding Techniques	Methodology	Key Results/ Challenges	Citation
Mechanical Fasteners: Screws Rivets Bolts	Bamboo was drilled and mechanical fasteners used to attach to steel components.	Average yield strength is about 910 MPa Bamboo splitting at attachment points. Challenge of Making sure that the fasteners do not harm the bamboo during the installation and fasteners perform in composite applications, over the life span as well.	[20], [23], [24]
Bonding Adhesives Epoxy Polyester Polyurethane	Before the bonding process the surfaces of bamboo and steel were cleaned and pre-treated with a chemical agent to enhance adhesion.	High tensile strength achieved in bond. Average bond strength: 3.36 MPA to 3:40 MPA Need to improve bond strength	[23], [25], [26]
Hybrid Bonding use of adhesive bonding and fastener in combination	Bamboo and steel layers were bonded together by high strength	Maximum bonding shear stress: 1.64 MPA	[12], [23], [27]

	adhesives.	Challenge on Making sure there is a balance between the mechanical bonding and the adhesive bonding so as to maintain strength, and not to over-complicate or cost	

Table 3. Different kinds of Bamboo Treatment

Bamboo Treatment	Methodology	Key results/ Challenges	Citation
Chemical Treatment	Bamboo immersed in sodium hydroxide (NaOH) solution to remove lignin and hemicellulose. Bamboo treated with borate solution to prevent fungal decay and insect infestation	Effective in preventing fungal growth and damage from insects. Limited effectiveness in high humidity places for an extended duration	[6], [14], [28], [29]
Fire Treatment	Bamboo soaked in flame retardant chemicals or coated with fire resistant solutions	Can improves fire sociability, thus using bamboo for building structures is made safer. affect mechanical properties and change its aesthetics.	[30], [31], [32]
Heat Treatment	Bamboo subjected to high temperatures (160–220 °C) in controlled environments. Treatment duration varied (1–6 hours)	Increased dimensional stability and resistance to pests. Increased dimensional stability and resistance to pests.	[28], [33], [34]

IV. RESEARCH GAPS

After careful assessment on the literature reviews found, the articles' gaps are here in table 4

NO.	CHALLENGES	CITATION
1	Absence of well-defined standard procedure for treating bamboo	[35], [36], [37]
2	Limited research on the effects of binding chemicals for bamboo-steel	[20], [22], [25]
3	Long term performance and durability	,[19], [22], [38]
4	Process impact of cold-forming	[39], [40], [41]
5	Bamboo-steel comparability with traditional materials in terms of cost and performance	[5], [18], [38]

In order to optimize the possibilities presented by bamboo-steel composites in the construction sector, it is important to address some of the treaty issues which were raised. In particular, the absence of a clear and agreed upon methodology for the treatment of bamboo results in low quality products, which affects its market acceptance. Also, insufficient investigation of binding compounds and the long-term performance of composite steel-bamboo products limits their efficiency and their introduction in the market. It is also important to know the effect of the processes such as cold forming and their compatibility with conventional materials to minimize costs and improve performance. Addressing these aspects will improve the strength, environmental acceptance and economic potential of bamboo-steel composites making them a more excellent option for use in contemporary buildings.

CONCLUSION

Utilizing bamboo scrimber in combination with cold-formed steel is beneficial in the construction of lightweight, eco-friendly, and strong structural systems. Several publications highlight the existence of certain crucial factors that govern axial compression, while the reinforcement of the composite structure's core is reported to be the fabrication method that controls the column's performance and load-bearing ability. However, there are still many unanswered questions in this review, such as improving the bonding of components, reducing usage wear and tear, as well as addressing protection issues against fires. By combining both the experimental aspects and modeling, this research puts forward the view that the development of hybrid material systems is critical for the efficient, safe and robust use of structures materials for applications.

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