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Sustainable Bamboo Structure in Modern Construction

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ABSTRACT: This project aims to study bamboo roof truss structures. Bamboo's strength and durability have been recognized by the Bureau of Indian Standards (BIS). It's increasingly used in construction due to its sustainability. Recent studies have looked at its mechanical properties like strength and flexibility. We used STAAD.pro software to simulate a warehouse design using bamboo. Comparing it with steel structures, bamboo showed variability due to growth conditions. Still, it has promising potential for sustainable construction. This research helps in creating design guidelines for bamboo construction, highlighting its strengths and areas for improvement.

KEYWORDS: Bamboo; Structural Performance; Treatment; Connections; STAAD.Pro;

I. INTRODUCTION

Bamboo has been used in traditional Asian houses for a long time because it's abundant in tropical forests. But with modernization, people started preferring materials like brick and steel, considering bamboo cheap and temporary. However, with concerns about global warming and sustainability, bamboo is making a comeback as a building material. It grows quickly and can be harvested in 3-5 years, unlike trees that take much longer. Bamboo also releases oxygen into the air and can be cultivated in plantations. It's a type of giant grass with sturdy stems called culms. A single bamboo plant can produce a lot of usable material in its lifetime. So, bamboo is now seen as a sustainable building option.



Fig 1. Various Types of bamboo

History of bamboo :

Bamboo, a member of the grass family, includes species that can grow up to 46 meters in height and weigh as much as 450 kilograms. Known for their hollow stems with scattered vascular bundles, bamboo plants are both strong and columnar. Remarkably, some species can grow up to 91 centimeters in a single day, or about 1 millimetre every 90 seconds. This rapid growth, along with bamboo's adaptability, makes it ideal for afforestation, carbon sequestration, and climate change mitigation. Bamboos occur native on 5 continents: Africa, Asia, South America, North America and Australia. In other words, all continents except for Antarctica and Europe have bamboo.

II. RELATED WORK

The following are the literature for the analytical and theoretical ideas as a part of reference and simplify the system modelling and performance analysis of the setup of industrial warehouse structure.[1] This study explores bamboo's historical importance and environmental benefits, highlighting its rapid growth and potential for sustainable building,

particularly in Eastern India.[2] The research emphasizes bamboo's strength, flexibility, and energy absorption qualities, advocating for standardized treatment and testing methods to enhance its reliability in construction.[3] This study promotes bamboo as a sustainable building material, demonstrating its strength and minimal environmental impact compared to traditional materials like concrete and steel.[4] The research evaluates bamboo's use in civil engineering, especially as reinforcement in RCC structures, and calls for standardized safety measures to address its mechanical variability and toughness.[5] This literature review highlights bamboo's potential as a structural material and the need for comprehensive standards and codes to facilitate its adoption in modern construction.[6] The study proposes bamboo reinforcement as a cost-effective alternative to steel for low-income housing in India, addressing the lack of awareness and scientific knowledge about bamboo's properties. [7] Researchers found that traditional Assam-type houses made of bamboo and ikra exhibit excellent earthquake resistance, attributed to their flexible connections and lightweight materials.[8] This paper analyzes a bamboo wall-framed structure using STAAD Pro software, demonstrating its structural potential under various loads and reinforcing bamboo's suitability for sustainable development.

Objectives:

- Emphasize bamboo's historical significance and sustainable attributes as a building material.
- Explore bamboo's viability for sustainable construction across various domains.
- Evaluate bamboo's versatility, strength, and energy-absorbing properties.
- Identify gaps in understanding bamboo properties and treatment techniques.
- Advocate for standardized procedures and codes tailored for bamboo in structural design.
- Address environmental concerns by promoting bamboo's use in construction.
- Test bamboo's structural performance against traditional materials like steel and concrete.
- Contribute to sustainable development goals through bamboo's use in construction.
- Demonstrate bamboo's structural integrity, durability, and cost-effectiveness compared to steel.

III. METHODOLOGY

Now, we're shifting our focus back to traditional bamboo structures but with a modern twist to make building with bamboo more convenient. Our study began by understanding the properties of bamboo and designing a bamboo warehouse. For this project, we're using bamboo with an outer diameter of 3 inches and 1.5 inches. We're analysing the structure using STAAD.Pro software from Bentley, which helps us simulate and understand how the bamboo elements will behave in the building. The rest of the detailed explanation of the method will be discussed in this methods part. We will further show the difference between the Steel Warehouse and Bamboo Warehouse. STAAD Pro is a software widely used in the field of Civil engineering. It has more flexible and advanced features than Auto CAD, being used in the construction industry. AutoCAD allows candidates to work on two-dimension models; however, STAAD Pro will let you work on three-dimensional models. Following is the plan of Warehouse on which we are going to calculate Dead Loads with Full Panel Point and Half Panel Point. Also, we will be calculating wind load and live load for the following structure. The loads calculated by us will be substituted in STAAD.Pro software to find how will the structure react. In this project we are using howe truss for Industrial warehouse of span 20meter.Below is the plan of warehouse

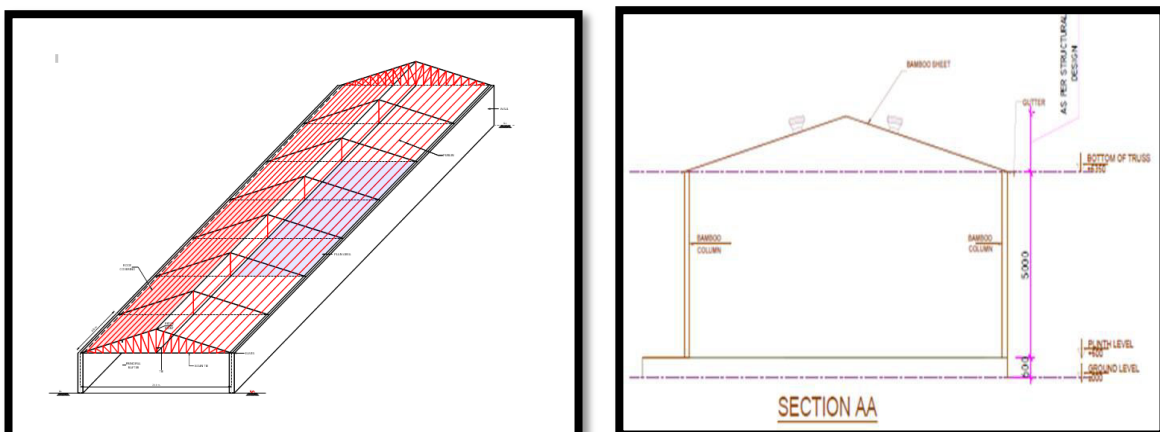


Fig 2. Plan of Warehouse

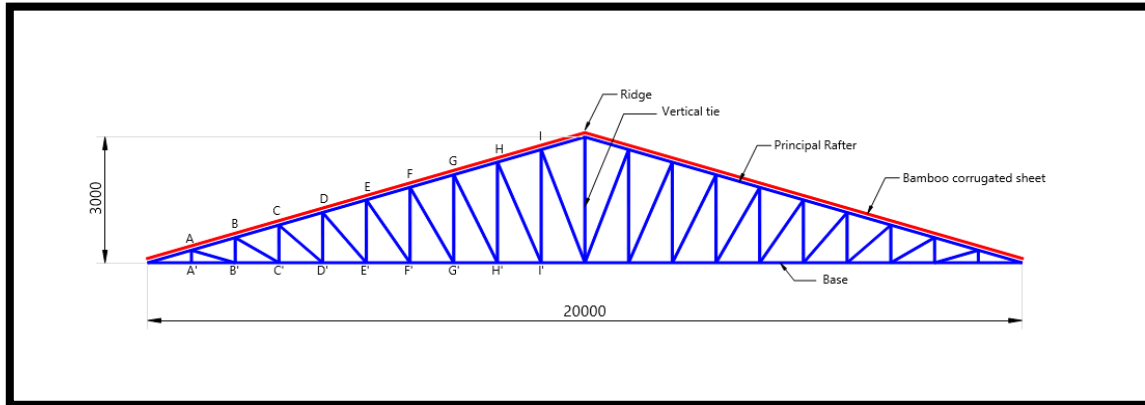


Fig 3. Plan of Truss

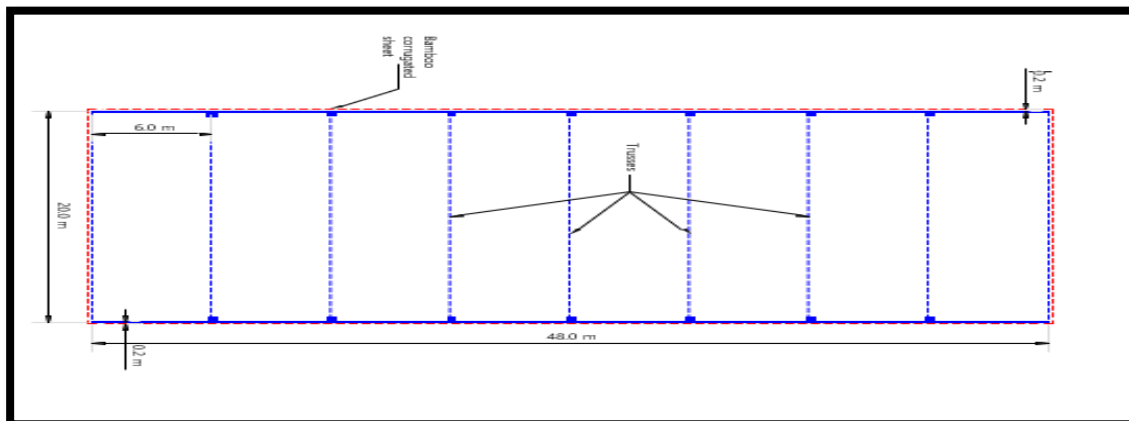


Fig 4. Top View of Warehouse

Both Bamboo Warehouse and Steel Warehouse structures are analyzed for following loads as per IS code: I. Dead Load II. Wind Load III. Live Load

As per the requirements, we initially calculated the height of the truss from IS: 15912-2018 (clause no. 7.9.4) as 3 meters. The spacing of the trusses is set at 6 meters, with a span of 20 meters. The length of the top chord (principal rafter) is 10.44 meters, and the number of panels is 20. The slope of the top chord is 17 degrees, which helped us calculate the number of trusses as 9. There are 8 purlins between two consecutive trusses. The half-plan area is 60 square meters, and the half-slope area is 62.64 square meters.

We calculated the wind load from IS: 875 (Part 3) for End Panel Points (EPP) and Full Panel Points (FPP), resulting in 2.73 kN for FPP and 1.365 kN for EPP. Next, we determined the dead load from IS: 876 (Part 1), first performing manual calculations to find the weight of the roofing material, weight of purlins, self-weight of the roof truss, and weight of wind bracing. These combined to give us the total dead load, which was then divided by the number of purlins on the whole truss, yielding loads of 1.786 kN for FPP and 0.893 kN for EPP for the bamboo warehouse truss, and 2.126 kN (FPP) and 1.063 kN (EPP) for the steel warehouse truss. Finally, the live load was calculated using IS: 876 (Part 2), resulting in 3 kN for FPP and 1.5 kN for EPP.

The process on STAAD.Pro was initiated by first creating a Howe truss using the above parameters for height, span, etc. The truss was placed 10 meters above ground level, indicating that the supporting poles are 10 meters tall. Subsequently, the material properties for bamboo were defined with the following specifications. The general specifications of bamboo were input for trapezoidal tubes of 3" and 2" outer diameters. Similarly, the steel hollow pipes were specified with the same outer diameter. The properties were then assigned to the respective materials. After that, all the calculated loads were applied to the truss using the nodal member option at each panel point for both the steel and bamboo warehouses. Finally, the analysis of both structures was conducted.

IV. RESULTS

In this comparison of deflection, it was observed that the highlighted member of the Bamboo Warehouse Structure (BWS) exhibits a sagging moment, whereas the Steel Warehouse Structure (SWS) also demonstrates a sagging moment. However, upon comparison, it was noted that the hogging moment exhibited by the SWS is greater than that of the Bamboo Warehouse Structure (BWS).

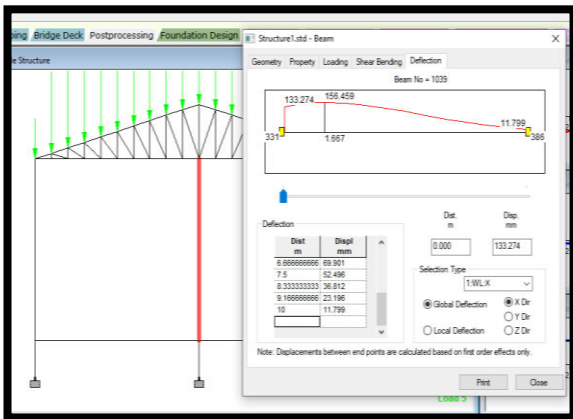


Fig 5. Deflection of BWS

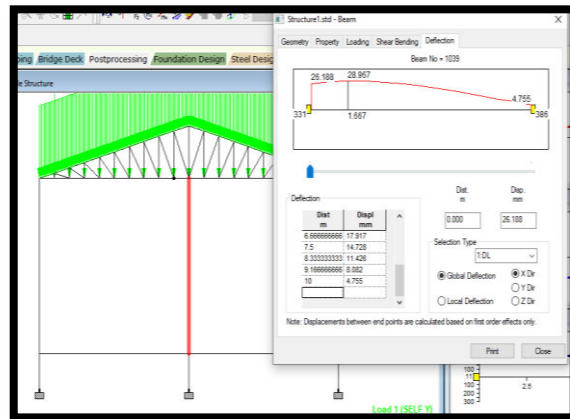


Fig 6. Deflection of SWS

Here, the displacement diagrams of both structures show no deflection, indicating that bamboo possesses comparable strength to steel. This conclusion suggests that bamboo can be effectively utilized as a structural material.

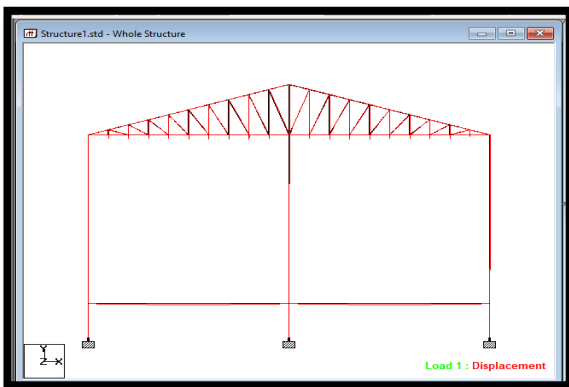


Fig7. Displacement of BWS Whole Structure

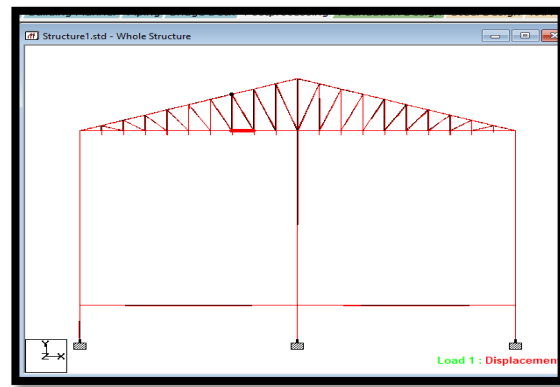


Fig 8. Displacement of SWS Whole Structure

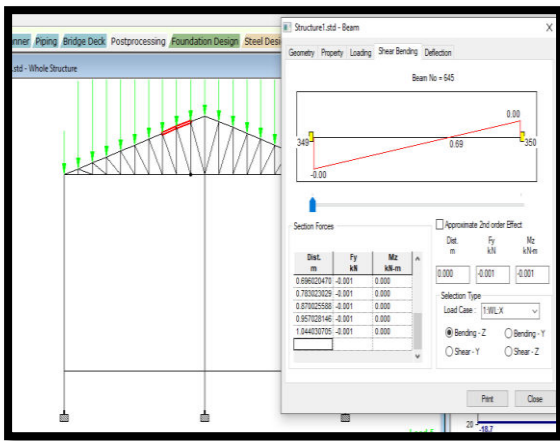


Fig 9. Shear Bending of BWS member

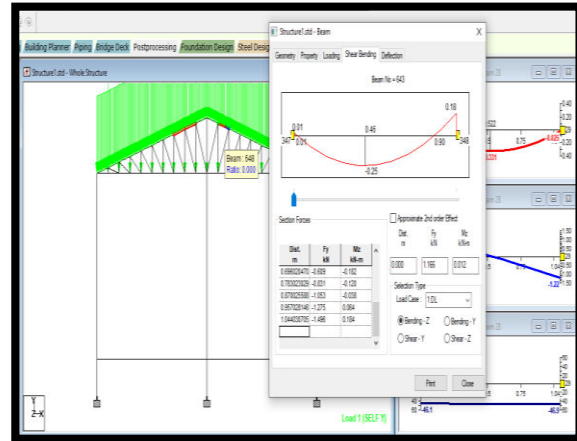


Fig.10. Shear Bending of SWS member

V. CONCLUSION

Warehouse Structures (SWS) in terms of various load calculations and their applications. Using STAAD.Pro software, the analysis results for stress, bending, moment, and forces (fx, fy) were obtained and compared for both structures.

The comparison of deflection, a key feature in STAAD.Pro, revealed that BWS exhibits a hogging moment, while SWS shows a greater sagging moment. The displacement diagrams indicated no deflection for both structures, demonstrating that bamboo has strength comparable to steel. These findings highlight bamboo's potential as an effective structural material, offering sustainable and cost-effective construction possibilities, especially in bamboo-abundant regions.

Furthermore, the lower cost of bamboo structures compared to steel structures suggests that bamboo could be a viable industrial option. This study provides a strong foundation for further research into bamboo construction, promoting more sustainable and environmentally friendly building practices. It also underscores the importance of software tools like STAAD.Pro in advancing our understanding of different construction materials.

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