Analysis and Design of Truss in Dendrocalamus Bamboo

Prof. Aquib Zafar Ansari[1], John Bhondekar[2], Atharva Atkar[3], Gunsheel Bankar[4], Marghoob Alam[5], Arshi Parveen[6]

[1]Assistant Professor, [2]Student of Graduation, [3]Student of Graduation, [4]Student of Graduation, [5]Student of Graduation, [6]Student of Graduation

[123456]Department of Civil Engineering, Anjuman College of Engineering and Technology, Nagpur, India.

***Abstract*— Bamboo is a sustainable and eco-friendly material that has been used for construction for thousands of years. With the increasing focus on sustainable design and construction, bamboo is gaining popularity as a structural material. This study examines the analysis and design of truss structures made of Dendrocalamus bamboo, a species of bamboo commonly found in Southeast Asia, and compares them with steel trusses. The study involves the creation of a 3D model of the truss structures in STAAD Pro software and the application of appropriate loads and boundary conditions to simulate their behavior under various loading scenarios. The internal forces and stresses in the truss structures are calculated using the finite element analysis method, and their performance is evaluated and optimized based on design criteria and specifications outlined in relevant design codes and standards. The results of the analysis are presented and compared using statistical and comparative analysis methods, including the calculation of physical and mechanical properties of the materials used in the truss structures and the comparison of the performance of the bamboo and steel trusses in various load scenarios. The advantages and disadvantages of using bamboo and steel in truss design are discussed, including cost, weight, and sustainability considerations.**

***Keywords*— Bamboo truss, Dendrocalamus bamboo, structural analysis, design optimization, sustainable construction, finite element analysis (FEA), load-carrying capacity.**

I. INTRODUCTION

In this world of constantly increasing population and depleting resources there is urge to adopt cost effective and eco-friendly structure. Therefore, Bamboo is solution of this problem and use construction material. Bamboo is the substitute for building material like steel & wood. Bamboo is a giant grass with woody stem. It is the fastest growing woody plant produce fiber for Use within three years. Bamboo is a strong, versatile, renewable and eco-friendly material. Bamboo has been traditionally used as building material and in present times used in low-cost housing and building structure.

The main characteristics of the bamboo which is suitable for building material is its high tensile strength which is equivalent to the mild steel at the yield point and very good weight strength ratio making it high resilient against the force created by earthquake and hurricane. Bamboo is used in 70%replacing material of steel and wood reduce the cost 40%. Bamboo absorbs carbon dioxide and release 35% oxygen in. atmosphere. Thus bamboo is eco friendly, energy efficient and cost effective material. Bamboo is used in footing, trusses, scaffolding, tiles roofing, Bamboo walls and reinforcement. Bamboo is used in truss member for the spanning larger distances in public utility building like school building, storage areas, commercial.

Dendrocalamus is a genus of bamboo that includes over 150 species native to tropical and subtropical regions of Asia, Africa, and Australia. It is one of the largest and most widely distributed bamboo genera, with species ranging from small shrubs to towering giants that can grow over 30 meters tall. The Dendrocalamus bamboo is known for its fast growth rate and impressive size, making it a popular choice for use in construction, furniture, and other applications. Its culms (stems) can reach up to 30cm in diameter, making it one of the thickest bamboo species in the world. In addition to its commercial uses, Dendrocalamus bamboo is also important for ecological and environmental reasons. It plays a crucial role in stabilizing soil, preventing erosion, and providing habitats for a wide range of wildlife

II. PROPERTIES OF BAMBOO TRUSS

Bamboo truss is a type of truss made from bamboo, a renewable and sustainable material that has gained popularity in recent years due to its eco-friendliness and unique properties. Some of the properties of bamboo truss include:

1. High strength-to-weight ratio: Bamboo has a higher strength-to-weight ratio than many other building

materials, including steel and timber. This means that bamboo trusses can support heavy loads while still being lightweight and easy to handle.

2. Flexibility: Bamboo is a flexible material that can bend without breaking, making it ideal for use in truss structures that are subject to wind and seismic forces. This flexibility also allows bamboo trusses to be designed with curved shapes and contours.
3. Durability: Bamboo is a durable material that is resistant to moisture, insects, and decay. Properly treated and maintained bamboo trusses can last for many years without showing signs of deterioration.
4. Sustainability: Bamboo is a renewable and sustainable material that grows quickly and can be harvested without damaging the environment. Using bamboo trusses in construction can help reduce the environmental impact of building projects.
5. Aesthetics: Bamboo has a unique and attractive appearance that can add a natural and organic feel to architectural designs. Bamboo trusses can be left exposed to showcase their natural beauty or finished with paints or stains to match the surrounding decor.

III. OBJECTIVE OF THE STUDY

The study's specific objectives are

1. Optimal design of bamboo as roof top (Rungmanch) in the building.
2. Comparative analysis of bamboo truss with steel truss.

IV. METHODOLOGY

A. Site Visit at Maharashtra Bamboo Development Board:

1) Conduct a site visit to the Maharashtra Bamboo Development Board to gather information about the availability, characteristics, and properties of Dendrocalamus bamboo.
2) Collect data on the different species of Dendrocalamus bamboo available and their growth patterns, dimensions, and mechanical properties.
3) Observe the existing structures or prototypes built using Dendrocalamus bamboo to understand their design, construction techniques, and any challenges encountered.

B. Review of Design Codes and Standards:

1) Refer to the relevant design codes and standards for bamboo structures, such as IS 9096:2006 (Code of Practice for Design of Bamboo Structures), IS 6874:2008 (Code of Practice for Construction of Bamboo Scaffoldings), and IS 1509:2017 (Code of Practice for Building with Bamboo).
2) Analyze these codes and standards to understand the recommended design methodologies, safety factors, load combinations, and other design considerations specific to bamboo structures.
3) Identify any limitations or gaps in the existing design codes and standards that need to be addressed in the analysis and design of the truss in Dendrocalamus bamboo.

C. Finite Element Analysis (FEA) Method:

1) Utilize the Finite Element Analysis (FEA) method to analyze the structural behavior of the truss in Dendrocalamus bamboo.
2) Create a 3D model of the truss using STAAD PRO software, considering the geometric dimensions, connections, and material properties of Dendrocalamus bamboo.
3) Apply appropriate boundary conditions, such as supports and loads, based on the intended use and structural requirements of the truss.
4) Perform static and dynamic analyses using FEA to determine the internal forces, displacements, and stresses in the truss under various loading conditions.
5) Validate the FEA results by comparing them with experimental data or analytical solutions available for similar bamboo truss structures.

D. Comparative Data Analysis Method:

1) The comparative analysis method involves comparing the results of the analysis of the Dendrocalamus bamboo and steel trusses in various load scenarios.
2) This analysis involves comparing the strength, stiffness, weight, and other performance factors of the bamboo and steel trusses.
3) The results of the comparative analysis help to identify the advantages and disadvantages of using bamboo and steel in truss design.
4) Comparative analysis, on the other hand, can involve comparing the results of the finite element analysis of the bamboo and steel trusses under various load scenarios.
5) This analysis can include comparing the internal forces and stresses, deflections, and other performance factors of the bamboo and steel trusses.

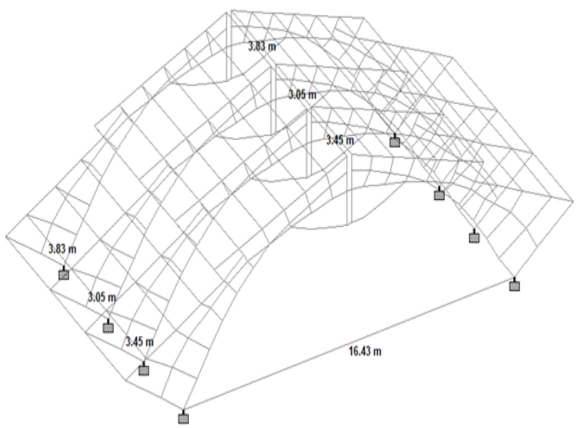
V. DESIGN AND CALCULATIONS

A. Calculation for Rangmanch Truss Diagram

Given: - Span = 16.43m

1.

1. Self-weight of the roof truss = (span/3+5)×10
   = (16.43/3+5)×10
   = 105 N/m^2
2. Weight of bracing = self-weight × span × truss to truss distance
   =105 × 16.43 × 3.83
   = 6607.32
   = 6607.32/ (1000)
   = 6.607 KN
3. Nodes = weight of bracing/no of nodes
   = 6.607/22 = 0.3 KN



2. Dead Load Calculation: IS- 875-1 (1987):

ISMC = 150 = 0.192 KN/m^2(From IS 875-1, page 18)

1. Unit Weight of GI sheet = 0.92 KN/m^2
2. Weight of overall G.I sheet of truss = weight of G.I sheet x span x truss to truss distance/22
   = (0.92×16.43×3.83)/22
   = 2.631 KN
3. Purlins = ISMC x truss to truss distance / 22
   = (0.192×3.83)/22
   = 0.0334 KN
4. Total dead load = Node + weight of GI sheet + purlin
   = 0.3 + 2.631 + 0.0334
   Total Dead load = 2.9644 KN
5. Load on each point is half of the load = 2.9644/2
   = 1.482 KN

3. Live Load Calculation: IS -875 -2 (1987):

1. Live load = (uniformly distributed imposed load × span × truss to truss distance)
   = 0.75 × 16.43 ×3.83
   L.L = 47.195 KN
2. Load on each point = live load /node
   = 47.195/22
   = 2.145 KN
3. Live load on each end of support nodes = 2.145/2 = 1.072 KN

4. Wind Load Calculation: IS 875-3 (2015):

Basic wind speed at 10m height for Nagpur is 44 m/s - (from IS 875 clause - 6.2 Pg 51)

$P_d = 0.6 (V_z^2)$

$V_z = 44$ (for Nagpur)

1. $P_d = 0.6 \times (44)^2$
   = 1161.6 m/s
   = 1161/1000 = 1.161 KN
2. Wind load = P_d × span × truss to truss distance
   = 1.161 × 16.43 × 3.83
   = 72.995 KN
3. Wind load on each point = 72.995/22
   = 3.318 KN
4. Wind load at end supports = 3.318/2
   = 1.659 KN
5. Components of wind load-
   Let's assume that Ø =10^o for truss
   $F_y = F \sin Ø$, $F_x = F \cos Ø$
   3.318 × sin 10º = 0.576 KN
   × cos 10º = 3.267 KN
6. Slope of truss = tan θ =(R/8.215)
   tan θ = (4/8.215)
   θ = 25.96°concrete.

Table 1. Design force table

Member	Member force (KN) due to			Design force (KN)		
	DL	LL	WL	1.5 (DL+LL)	1.5 (DL+WL)	1.2 (DL+LL+WL)
FL0U1	-26.27	-44.77	-69.675	-106.56	-143.917	-168.858
FL0L1	23.620	39.560	62.644	94.77	129.396	150.98
FL1U1	0.00	0.00	0.00	0.00	0.00	0.00
FL1L2	23.620	39.560	62.644	94.77	129.396	150.988

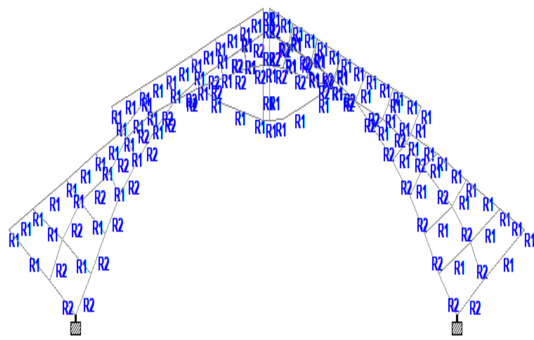
B. Various parameters of the model consider as follows

1) Section Properties assigned in STAAD Pro

Table 2. Section Properties assigned in STAAD Pro

R1 = IS
Steel Pipe Section
bf = 0.25,
Depth = 0.25,
Thickness = 0.005

R2 = IS steel
Pipe section
bf = 0.30,
Depth = 0.30,
Thickness = 0.010



2) Support is assigned as fixed based
3) Load calculation

For analysis purposes following loads are calculated and the values are as follows

a) Dead load = 1.15 kN/m at internal nodes
b) Dead load = 0.575 kN/m at support nodes
c) Live load = 1.96 kN/m at internal nodes
d) Live load = 0.98kN/m at support nodes
e) Wind load = 3 kN/m at internal nodes
f) Wind load = 1.5 kN/m at support nodes

The following load combinations are considered as per IS 800-2007, IS 875-Part-3 and IS-456-2000

a) 1.5 D.L + 1.5 L.L
b) 1.5 D.L + 1.2 L.L + 1.2 W.L
c) 1.5 D.L + 1.5 W.L
d) 0.9 D.L + 1.5 W.L

VI. RESULT

A. Results of Critical axial force for steel (FROM STAAD PRO)

	Beam	L/C	Node	Fx kN	Fy kN	Fz kN	Mx kNm	My kNm	Mz kNm
Max Fx	220	4 1.5DL+1.5LL	1	48.887	0.678	0.027	0.081	-0.092	-0.024
Min Fx	320	7 0.9DL+1.5WL	126	-37.547	-0.21	0.012	-0.054	0.019	0.304
Max Fy	658	4 1.5DL+1.5LL	345	4.282	7.054	0.008	0.007	-0.009	1.765
Min Fy	660	4 1.5DL+1.5LL	346	4.181	-7.196	-0.003	0.003	0	-1.769
Max Fz	476	7 0.9DL+1.5WL	260	-3.412	-1.19	0.604	-0.028	-0.086	-0.407
Min Fz	143	4 1.5DL+1.5LL	30	4.746	1.758	-0.853	0.038	0.118	0.605
Max Mx	325	4 1.5DL+1.5LL	194	47.184	-0.051	-0.06	0.132	-0.022	0.197
Min Mx	48	4 1.5DL+1.5LL	30	45.189	0.347	0.016	-0.158	0.113	0.778
Max My	94	4 1.5DL+1.5LL	64	3.833	0.73	0.532	-0.079	0.571	-0.369
Min My	143	4 1.5DL+1.5LL	64	4.746	1.758	-0.853	0.038	-0.491	-0.651
Max Mz	343	4 1.5DL+1.5LL	191	9.565	6.02	-0.008	0	0.019	4.56
Min Mz	243	4 1.5DL+1.5LL	149	9.58	6.021	-0.014	-0.005	0.004	-3.671

Table 3. Results of Critical Axial Force for steel

B. Results of Critical axial force for bamboo

Table 4. Results of Critical Axial Force for bamboo

	Beam	L/C	Node	FxkN	FykN	FzkN	MxkNm	My kNm	MzkNm
Max Fx	220	4 1.5DL+1.5LL	1	48.887	0.678	0.027	0.081	-0.092	-0.024
Min Fx	512	7 0.9DL+1.5WL	255	-37.454	-1.983	-0.009	0.005	0.01	-1.333
Max Fy	656	4 1.5DL+1.5LL	344	4.296	0.307	0.002	0.002	0.004	0.137
Min Fy	660	4 1.5DL+1.5LL	346	4.182	-7.196	-0.003	0.003	0	-1.769
Max Fz	476	7 0.9DL+1.5WL	283	-4.716	-1.803	0.817	-0.036	0.471	0.664

Min Fz	143	4 1.5DL+1.5LL	64	3.476	1.288	-0.582	0.028	-0.336	-0.474
Max Mx	325	4 1.5DL+1.5LL	194	47.184	-0.051	-0.06	0.132	-0.022	0.197
Min Mx	62	4 1.5DL+1.5LL	31	45.727	-0.522	0.003	0.001	-0.003	-0.255
Max My	294	4 1.5DL+1.5LL	167	4.984	-0.413	0.039	-0.024	-0.003	-0.329
Min My	143	4 1.5DL+1.5LL	64	-4.746	-1.758	0.853	-0.038	0.491	0.651
Max Mz	343	4 1.5DL+1.5LL	191	9.565	6.02	-0.008	0	0.019	4.56
Min Mz	243	4 1.5DL+1.5LL	127	-6.675	-4.382	-0.009	-0.004	0.016	-3.427

C. Analysis of the Truss (Rangmanch) for the following geometrical details

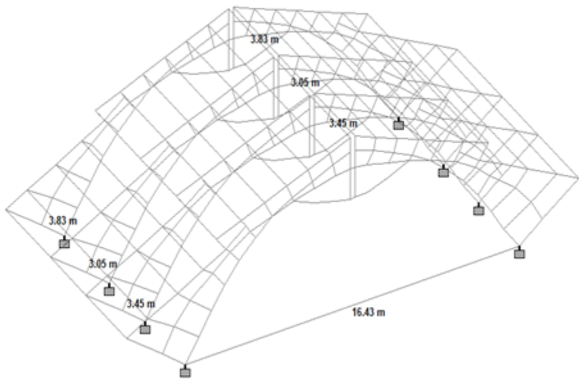


Fig.1 3-D Dimension of truss geometry

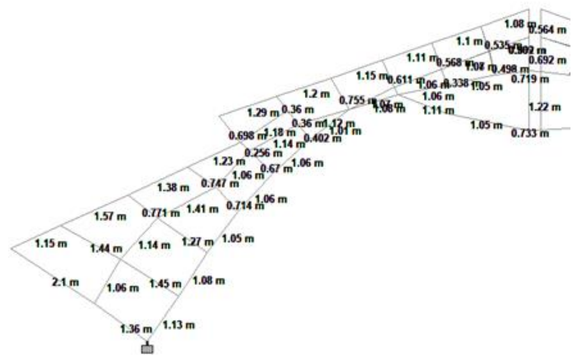


Fig.2 Standard dimension of each segment of the beams

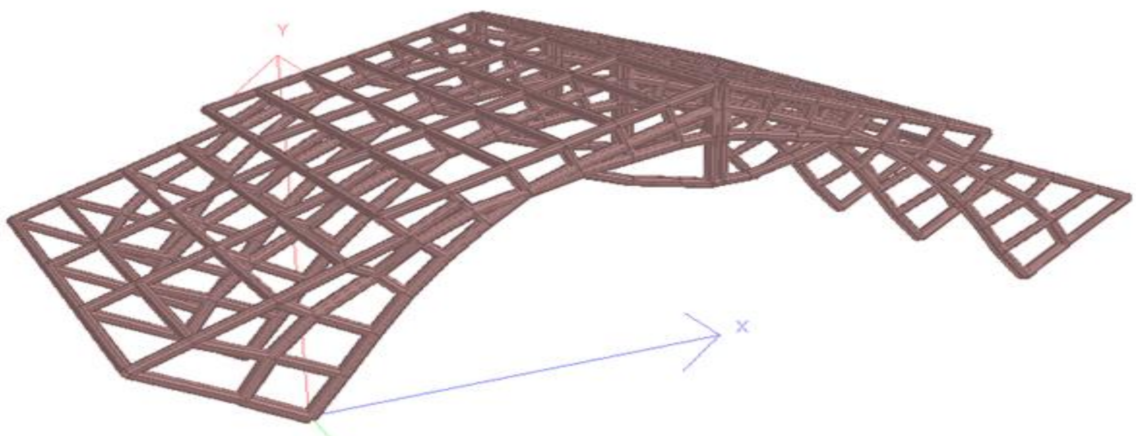


Fig.3 3-D Rendered model

VII. CONCLUSIONS

In conclusion, this thesis has explored the analysis and design of a bamboo truss using Dendrocalamus bamboo and STAAD Pro software.

The site visit provided valuable data on the physical properties of the bamboo, while STAAD Pro allowed for accurate modeling and analysis of the truss.

The results of the analysis showed that it is possible to design and analyze bamboo trusses using STAAD Pro to meet the required design criteria and design codes. The study has identified potential design considerations and limitations, such as the need for specialized connection details and the difficulty in predicting the behavior of bamboo under loading conditions.

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