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Design And Analysis Of Hanger Irrigation System

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Abstract*: *The goal of the research is to evaluate the effectiveness of newly designed hanger irrigation system in providing consistent water supply for agriculture. Irrigation is a vital component of agriculture, and efforts have been made to increase the irrigated area through surface irrigation projects and groundwater resources. Agriculture has a significant impact on India's economic development, as around 70% of the population relies on it for their livelihoods and essential needs. However, the growing population has led to water scarcity, which poses a significant challenge to the farming sector. Therefore, there is a need to discover alternative irrigation systems that are durable and affordable. To minimize labor costs and ensure uniform water usage, the hanger irrigation system was designed using SolidWorks software, and Finite Element Analysis was employed to enhance vibrational sustainability and reduce deformation in the model. The structure was built using structural steel and bamboo fiber as materials, and vibration analysis was conducted with the ANSYS 19 software to ensure stability. Static analysis was also performed using different materials to improve the system's load-bearing capacity, and cost comparisons were made between bamboo and steel models. The results of the modal and static analyses of different materials were discussed to arrive at a conclusion.

Overall, the study highlights the importance of effective water management during irrigation to achieve maximum crop productivity and meet the country's food production goals. The hanger irrigation system has the potential to provide a consistent water supply while minimizing labor costs, making it a viable alternative irrigation system for agriculture.

***Keywords*: IRRIGATION, FEA, ANSYS, DESIGN**

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I. INTRODUCTION

Spray irrigation is a widely used modern system of irrigating that relies on machinery. It works by spraying water out in all directions, similar to how you might water your lawn at home. Large farms often use spray irrigation systems, which can take the form of long hoses with sprinklers along their length or a center-pivot system that moves in a circle around the fields. While the former can be less efficient due to water evaporation, the latter is more effective as it can cover up to 130 acres.[11] High-pressure spray irrigation systems are still commonly used today, but they can be inefficient, losing up to 35% of water to evaporation and wind. Low-pressure sprinkler systems, also known as drip irrigation, are a more efficient and modern alternative. Proper sprinkler irrigation design can help reduce soil sealing and maximize crop uniformity. The type of crops grown and their watering requirements determine the machine flow rate and the frequency of irrigating. Centre-pivot irrigation is a method of crop irrigation that rotates equipment around a pivot to water crops with sprinklers. These systems are highly effective on large land fields and can efficiently use water to optimize crop yield.[5] Valley Irrigation provides suitable irrigation water sources, sprinkler irrigation systems, and water flow rates for every type of crop. Centre-pivot irrigation systems were initially water-powered, but most now use electric motors. These systems can create circular patterns observed from above, in crops, which are sometimes known as crop circles. Center-pivot irrigation systems have the benefit of being particularly successful on big land fields due to its capacity to utilize water effectively and maximize crop output. By considering soil characteristics, water flow rates, and crop requirements, farmers can design efficient and effective irrigation systems that promote healthy plant growth and maximize crop yield.[6] Another benefit of using efficient irrigation systems is reducing water waste and minimizing environmental impacts. Excessive water use can result in soil erosion, dwindling groundwater supplies, and fertilizer and chemical pollution of water sources. Therefore, implementing efficient irrigation practices is crucial for sustainable agriculture and preserving the environment. In addition to spray and center-pivot irrigation systems, there are other types of irrigation systems, such as drip irrigation, subsurface irrigation, and overhead irrigation. The best method to use depends on a number of variables, including crop type, soil type, climate, and water availability. Each system has benefits and drawbacks. Overall, modern irrigation systems have significantly improved crop production and helped farmers meet the growing demand for food while reducing water waste and environmental impacts.[7]

Nasser Al Aqeeli, et al. [1]. In the present work focuses on designing and analyzing a center pivot irrigation system using SolidWorks and ANSYS Fluent software. The study is conducted in Saudi Arabia, and it evaluates the water distribution and the impact of wind on the irrigation system's performance.

Caner Demir, Murat Kacira et al. [2] focuses on the both design and evaluation of an autonomous center pivot irrigation system. The study aims to optimize irrigation scheduling and system control for enhancing water usage effectiveness and crop productivity through site-specific and precision irrigation management.

N. P. Samarasinghe, R. P. Abeygunawardhana et al. [3] The research paper evaluates the mechanical performance of bamboo fiber-reinforced polymer (BFRP) composite as a sustainable alternative to steel in construction. Focus of the study is the compressive, flexural, and tensile strengths of the BFRP composite, and compares them to those of steel. The results show that the BFRP composite exhibits comparable or even superior mechanical properties to steel, indicating its potential as a sustainable alternative. The study suggests that BFRP composite can be used in various construction applications, particularly in non-load bearing components.

X. Liu, B. Song, X. Wang et al. [4] The study aims to explore the potential of BFRP pipes as a sustainable and eco-friendly alternative to steel pipes. The paper presents the fabrication process and testing results of the BFRP pipes, including mechanical properties, water tightness, and corrosion resistance. The study shows that BFRP pipes have good mechanical properties, with high strength and stiffness, and can effectively resist corrosion, making them a promising alternative to steel pipes in water transportation applications.

II. DESIGN OF THE SYSTEM

Fig. 1. Solid works of hanger irrigation system

A. Basic calculation

Water Pump Calculation:
For Hanger Irrigation System,
Force acting on wheel = 3000N
Radius of wheel = 450mm = 0.45 m
Required Torque is,
*T = Force * Radius*
T = 3000 * 0.45
T = 1350 N-m
Required energy – 0.75kW
Motor torque calculated -- 3000 rpm

On the basic of above calculation, energy required to move the system is 0.75 kW. Therefore, a 1 HP electric motor was selected to provide the necessary power for the system.

Pipe size – 12.25 inch
Water flow rate – 972222 mm^3 / s
The following formula is used to determine the power directly used for gearbox of pumped fluid energy:
$P_n = \rho \cdot g \cdot Q \cdot$
$= 1000 \times 9.81 \times 0.036 \times 5.5$
$P_n = 1942.38$ Watts

Where,
Pn – power,
Q – flow rate in m3/s,
H – overall head
g – acceleration due to gravity, m/s2,
ρ – pumped medium's density, in kg/m3

B. Drafting of hanger system

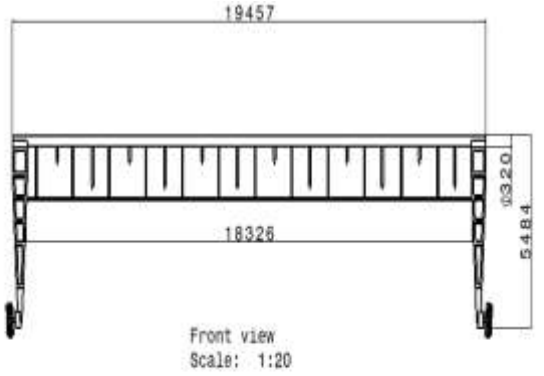

Fig. 2. Front view

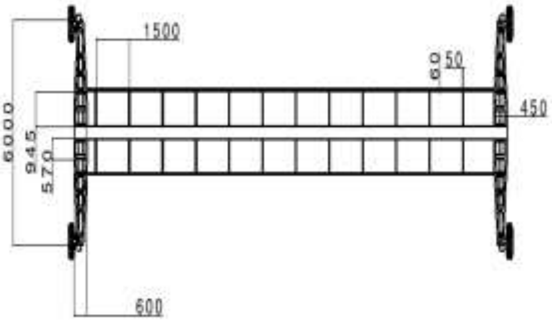

Fig. 3. Drafting

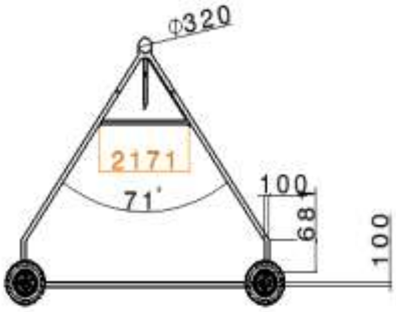

Fig .4 Drafting of hanger system

C. *Maintaining the Integrity of the Specifications*

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III. ANALYSIS

Using the limited component approach (FEM), mathematicians may address design and numerical physical science problems.[9] The underlying research, heat transfer, liquid flow, mass vehicle, and electromagnetic potential are examples of typical pain spots of interest. The solution to the limit esteem problems for incomplete differential circumstances is generally necessary for the logical structuring of these problems.

A. *Geometry of hanger system*

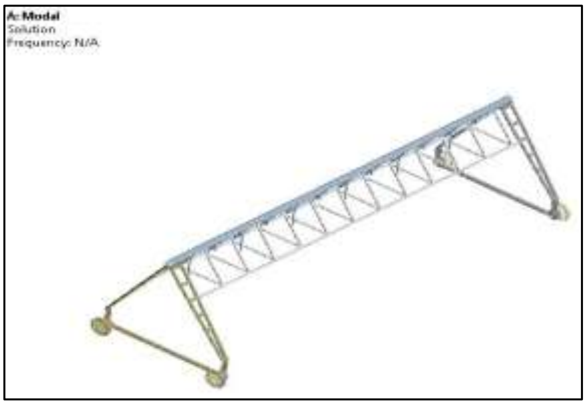

Fig.5. Geometry of hanger system

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B. *Mesh*

ANSYS A high-performance, adaptable, intelligent, automated product is coming together. In order to produce accurate, efficient multi-physics solutions, it produces the best mesh available. A mesh that is ideal for a certain study may be built for any portion of a model with only one mouse click. Full control over the settings used to create the mesh is offered to the skilled user who wants to adjust it. By utilizing the power of parallel computing, you can automatically reduce the time it takes to create a mesh.

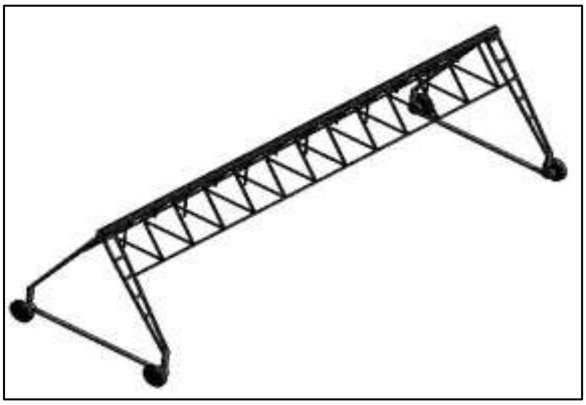

Fig.6 Meshing of Model

C. *Boundary condition*

A model's boundary condition is the determination of a known value for a displacement or a related load. You can only set the load or displacement, not both, for a given node.

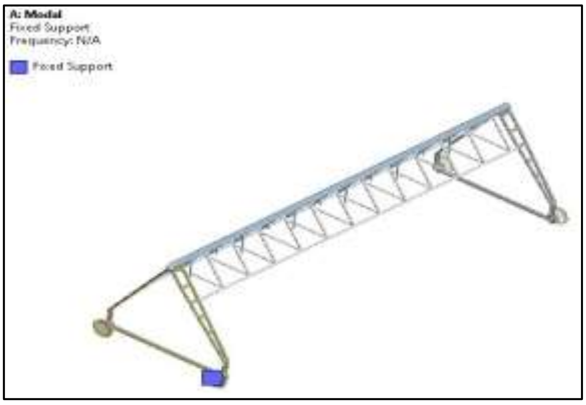

Fig.7 Boundary condition

IV. RESULTS AND DISCUSSIONS

A. *Modal analysis (mode shape result of structural steel)*

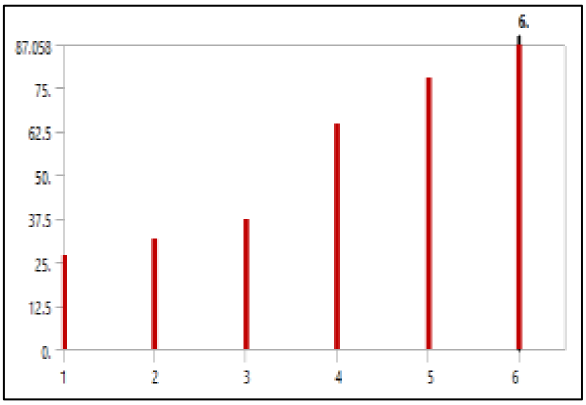

Fig.8 Fundamental frequency of the structure in graphical form

TABLE I

Sr.no	Mode	Frequency(Hz)
1	1.	26.855
2	2.	31.383
3	3.	37.048
4	4.	64.619
5	5.	77.648
6	6.	87.058

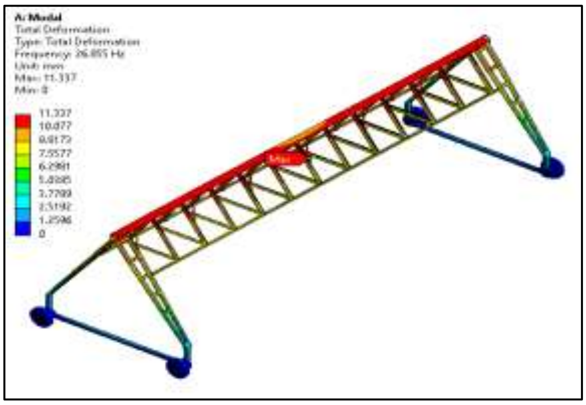

Fig.9 Fundamental Frequency of mode shape 1 is 26.855 Hz

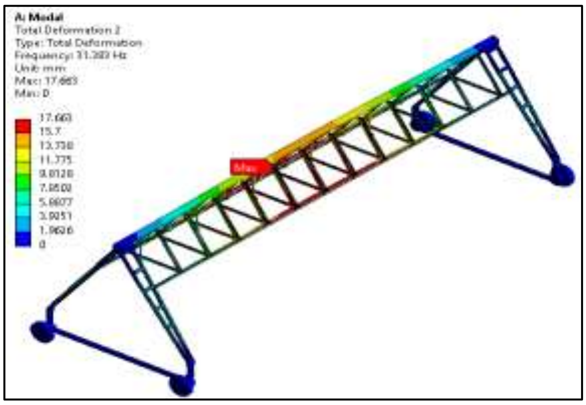

Fig.10 Fundamental frequency of mode shape 2 is 31.383 Hz

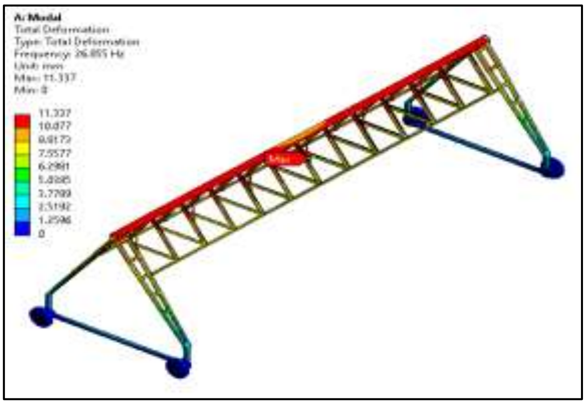

Fig.11 Fundamental frequency of mode shape 3 is 37.048 Hz

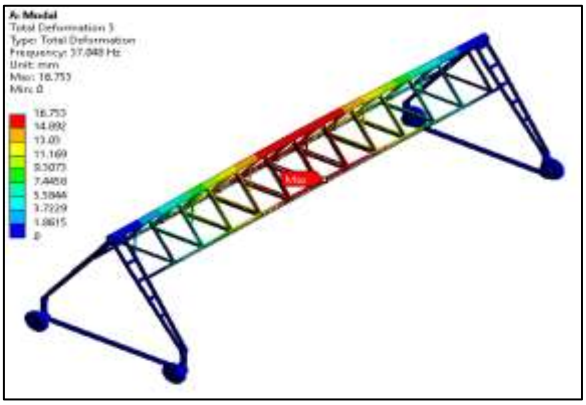

Fig.12 Fundamental frequency of mode shape 4 is 64.619 Hz

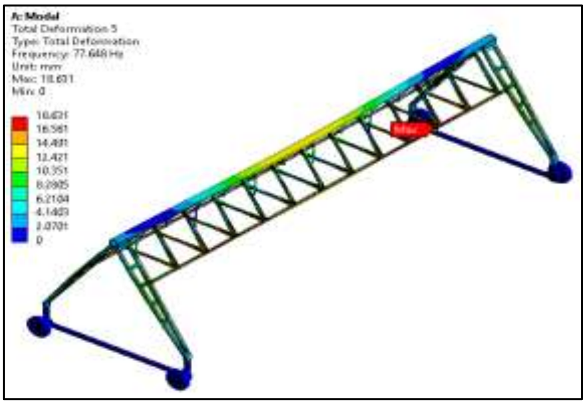

Fig.13 Fundamental frequency of mode shape 5 is 77.648 Hz

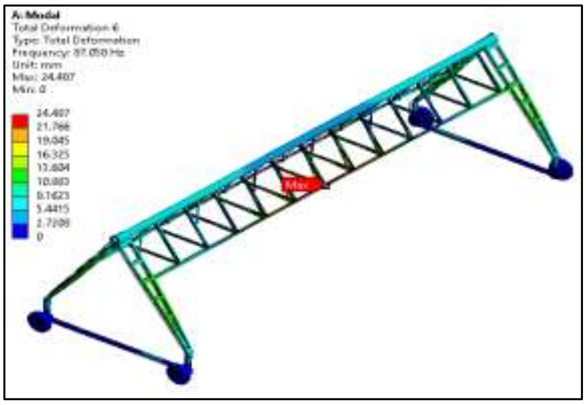

Fig.14 Fundamental frequency of mode shape 6 is 87.058 Hz

B. *Modal analysis (mode shape result of bamboo fiber)*

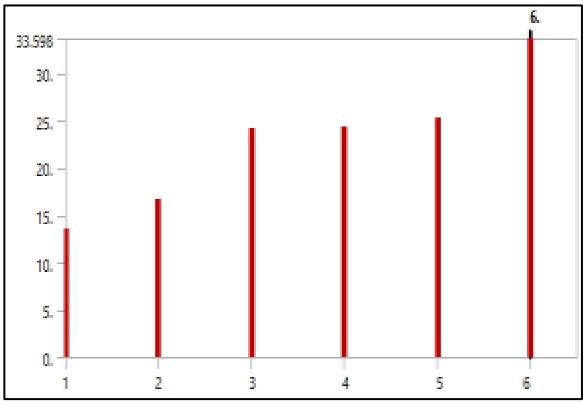

Fig.15 Fundamental frequency of the structure in graphical form

TABLE II

Sr.no	Mode	Frequency(Hz)
1	1.	13.564
2	2.	16.712
3	3.	24.183
4	4.	24.362
5	5.	25.26
6	6.	33.598

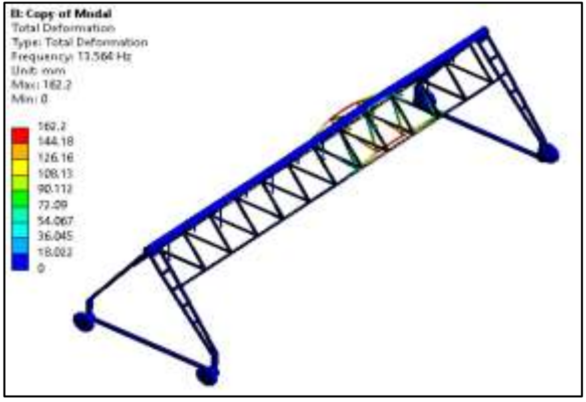

Fig.16 Fundamental Frequency of mode shape 1 is 13.564 Hz

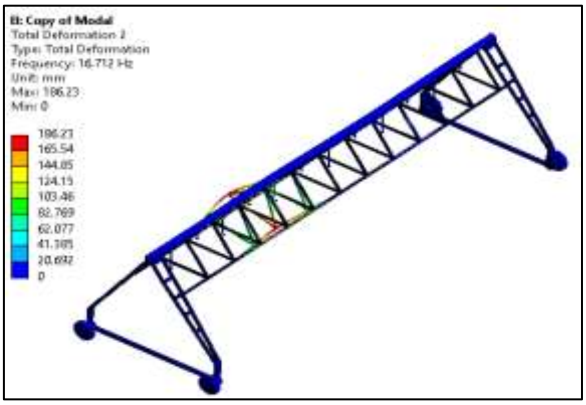

Fig.17 Fundamental frequency of mode shape 2 is 16.712 Hz

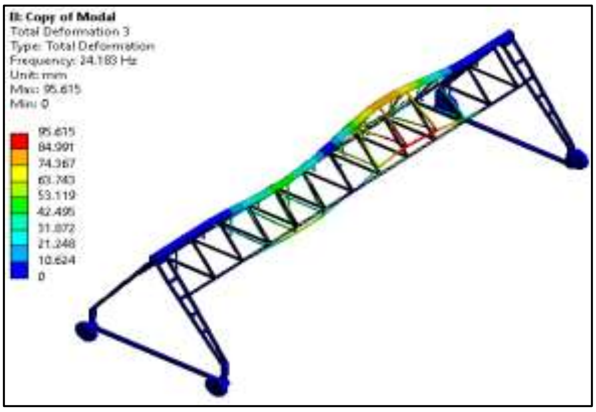

Fig.18 Fundamental frequency of mode shape 3 is 24.183 Hz

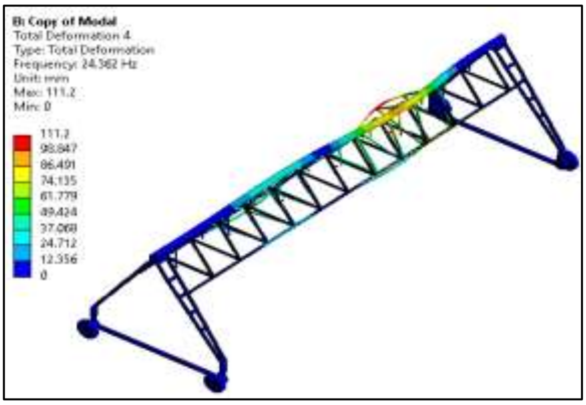

Fig.19 Fundamental frequency of mode shape 4 is 24.362 Hz

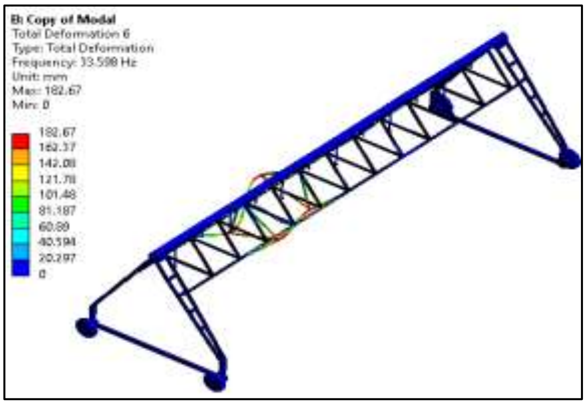

Fig.20 Fundamental frequency of mode shape 5 is 25.26 Hz

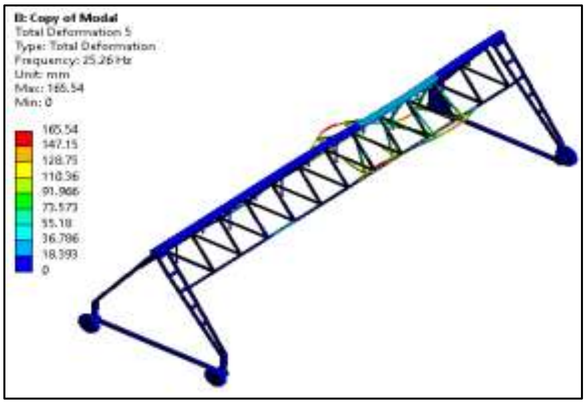

Fig.21 Fundamental frequency of mode shape 6 is 33.598 Hz

- ➢ When comparing the natural frequency of steel and bamboo, there is not a significant difference. Also bamboo fiber has high strength, high tensile strength and high stiffness due to this properties the structure will not deform early and will absorb the impact energy. Based on the modal analysis it can be concluded that bamboo fiber can be used as an alternative for the steel material if cost and lower weight factors are considered.

C. *Static analysis (maximum principal stress of structural steel)*

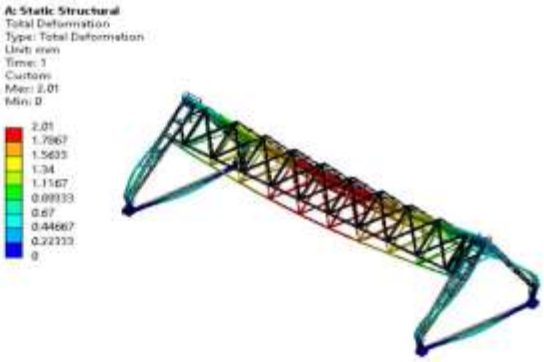

Fig. 22 The total deformation is observed to be 2.01 mm

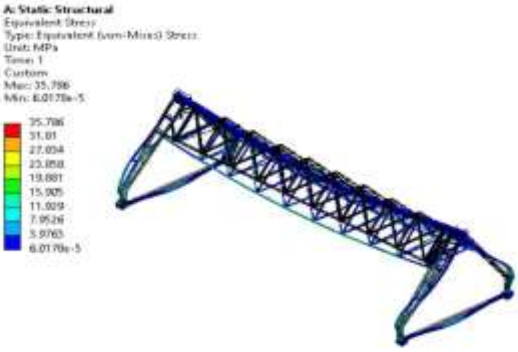

Fig. 23 The equivalent stress is observed to be 35.786 M Pa

D. *Static analysis (maximum principal stress of bamboo fiber)*

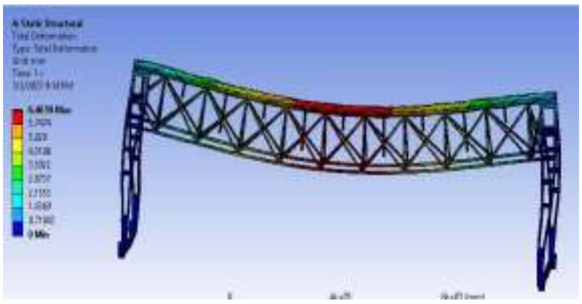

Fig. 24 The total deformation is observed to be 6.4659 mm

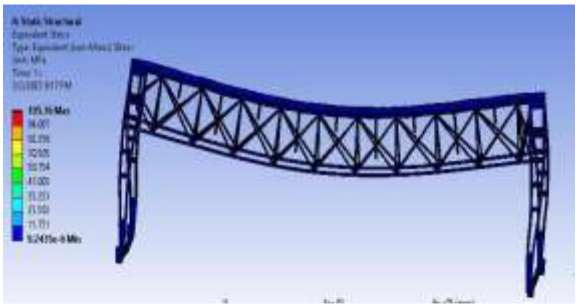

Fig. 25 The equivalent stress is observed to be 105.76 M Pa

- ➢ When comparing the static analysis of bamboo fiber material and steel material, it can be observed that total deformation values of the structural steel and bamboo fiber hanger systems are generally higher when the distance between the trusses is larger. This indicates that the systems are less rigid and more flexible when they are designed with wider distances between trusses. The hanger system performs better for longer spans and shorter distances between trusses. However, the bamboo fiber system still has relatively low total deformation and equivalent stress values compared to the steel so it may be a viable alternative for the steel.

E. Modal analysis result

TABLE III

MODE	Structural Steel Frequency(HZ)	Bamboo Fiber Frequency(HZ)
Mode shape 1	26.855	13.564
Mode shape 2	31.383	16.712
Mode shape 3	37.048	24.183
Mode shape 4	64.619	24.362
Mode shape 5	77.648	25.26
Mode shape 6	87.058	33.598

- Modal analysis have been performed on different materials, to obtain the desired frequency to improve the vibration sustainability.

F. Static analysis results

TABLE IV

Result	Total Deformation (mm)	Equivalent Stress(M PA)
Static analysis of Hanger system with 150 feet of span and 5 feet distance between trusses(Structural Steel)	2.01	35.786
Static analysis of Hanger system with 150 feet of span and 5 feet distance between trusses(Bamboo Fiber)	6.4659	105.76

- Static analysis, total deformation, equivalent stress have been carried out for different materials to find out the better load bearing capacity. It is observed that bamboo fiber still has relatively low total deformation and equivalent stress value. So the bamboo fiber hanger system has higher elongation properties than the steel which allows it to distribute the load more evenly and reduce stress concentration in certain area. It indicates that it may be able to withstand the same load with a lower risk of failure.

V. CONCLUSION

As different iterations of different materials have been performed for both modal and static analysis so from the modal analysis has led to the conclusion that the model with 150 span and 5 feet distance between trusses is better to use. Because it has high stiffness and high load bearing capacity. Also it has high vibrational sustainability and will not fail earlier as per analysis. The bamboo fiber hanger system has lower equivalent stress value than the structural steel hanger system, indicating that it may be able to withstand the same load with a lower risk of failure. There is not such a huge difference between the natural frequency of bamboo and steel. Also bamboo fiber has high strength, high tensile strength and high stiffness due to this properties the structure will not deform early and will absorb the impact energy. The cost comparison shows that bamboo fiber is significantly less expensive than structural steel. After conduction a market analysis, a cost comparison was made between steel and bamboo fiber. The results showed that bamboo fiber was significantly less expensive than structural steel, with a cost of Rs.4.34 per kg compared to Rs.87.1 per kg for steel. The cost per kg of steel was approximately 20 times higher than that of bamboo fiber. This indicated that using bamboo fiber could be a more cost-effective option than using structural steel. The cost to make a hanger irrigation system was estimated to be around Rs.5,37,755 when using steel material and Rs.69,908 when using bamboo material, based on the marker research. The cost of steel is approximately 7.7 times higher than the bamboo material. The bamboo fiber hanger system may be a viable alternative in some applications where lower weight and cost-effectiveness are important factors. If cost is the primary factor, then bamboo fiber is the better choice.

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