Analysis of Bamboo Dome Subject to Point Load

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Abstract - The analysis of a bamboo dome subject to point load investigates the structural response of bamboo as a sustainable building material when subjected to localized point loads. Bamboo, with its unique properties such as high strength-to-weight ratio, flexibility, and environmental benefits, presents a promising alternative for lightweight, eco-friendly construction. This study employs both theoretical and computational approaches, utilizing finite element analysis (FEA) to simulate the deformation, stress distribution, and overall load-bearing capacity of a bamboo dome under varying point load conditions. The influence of bamboo's material properties, dome geometry, and load location are examined to evaluate the structural integrity and performance. The results provide a comprehensive understanding of bamboo dome behaviour, offering insights into its potential use in architectural and civil engineering projects that prioritize sustainability. This research contributes to the advancement of green building design, enhancing the adoption of bamboo as a viable construction material in modern architecture.

Key Words: Bamboo Dome, Point Load, Structural Analysis, Sustainability, Load-Bearing Capacity, n Material Properties, Eco-friendly Construction, Stress Distribution.

1.INTRODUCTION

without internal supports. From A dome is a closed, bowl-shaped vault often placed over a circular room, formed by rotating a curve around a central axis. Recognized as one of the oldest architectural structures, domes maximize space while minimizing material use, making them appealing to engineers and architects alike. The evolution of construction materials, from stone to contemporary options like bamboo and 3D-printed materials, has led to innovative interpretations of dome design. Advanced technologies, including rapid prototyping and parametric design, enhance the structural capabilities of domes, allowing them to span large areas a structural mechanic's perspective, steel domes are considered double-curved bar shells, necessitating complex computational models that account for geometric, material, and structural behaviors under various loads.

Traditional design approaches utilize first-order elastic analysis, treating structures as individual elements, but this does not fully leverage modern technological advancements. More sophisticated methods incorporate geometric and material non-linearity's, which reveal the interactions between structural components and allow for a more accurate distribution of forces. Euro code 3 emphasizes the importance of assessing second-order effects in structural designs, although it lacks specific guidelines for dome structures. This gap underscores the complexity of designing domes, which has prompted extensive research focused on computational modeling, node stiffness, shape optimization, and structural stability. Advanced analysis software, such as ANSYS and ABAQUS, is frequently used to explore various dome configurations, including ribbed and geodesic domes. Research highlights the impact of dimensions, connectivity, and imperfections on structural performance, especially under combined loads like dead weigh wind.

2. LITERATURE SURVEY

2.1 Regeneration, Cultivation, and Sustenance of Bamboo (Kwame Anane Fenin &Damenortey Richard Akwada) [2017]

The fundamental methods for regenerating seedlings for use on farms or in plantations are covered in this chapter. The three most significant techniques for raising young seedlings for plantations are thoroughly covered, along with the procedures involved in their cultivation. The chapter focuses on how rhizomes, culm cuttings, and seeds can all help seedlings regenerate. This chapter also examines the selection of land locations and the setup for the planting of young seedlings, including a discussion of land selection, pre-planting procedures, propagation techniques, post planting procedures, harvesting, and handling. The impacts of fungal diseases, insect attacks, and post-harvest treatment and preservation techniques are discussed in relation to bamboo, both before and after harvesting. The consequences of these infections.

2.2 Advances in Connection Techniques for Raw

Bamboo Structures (Mary Joanne C. Aniñon and Lessandro Estelito O. Garcian) [2024]

Bamboo can be used in structures because of its remarkable mechanical characteristics and sustainability, however connection system difficulties make it difficult to use. The anisotropic qualities, geometrical fluctuations, and hollow, thin-walled structure of bamboo make connection design more challenging. There is still no agreement on the best bamboo connections, despite a plethora of research and suggested connection options. For raw bamboo buildings, the connections should be strong, affordable, useful, straightforward, and simple to assemble. This work examines 62 scientific publications that were published between 2003 and 2024 that were found in the Scopus database, along with other pertinent references. It points out areas in which research is lacking and suggests doing more research on bamboo connections while taking species, harvest age, kind of treatment, and node position into account. To foresee and reduce the hazards connected with bamboo connections, an examination of failure modes and long-term behavior is necessary.

2.3 Flexural behavior of the untreated plain bamboo reinforced concrete beam under four point loading (Alan Augustin, Rejitha Ratheesh,C.S. Belarmin Xavier)(2023)

Housing, shelter, and other infrastructure for utilities and safety are needed as the population grows. The cost of common commodities like cement, steel, and so on is rising. Because of the climate, cost, and depletion of natural resources, engineers must employ more widely available and sustainable building materials. Steel has a strength-to-weight ratio of six times that of bamboo, which grows quickly and is lightweight. Bamboo's asymmetrical shape can be handled with grace and creativity. The Dendrocalamus Strict us bamboo is utilized in this experimental study to examine the reinforcing properties of the species and examine how it reacts to various loading scenarios. The study contrasted steel-reinforced concrete beams with beams strengthened with Dendrocalamus Strictus bamboo. Steel wires are wrapped around untreated bamboo to create friction. Concrete, steel reinforcements, and bamboo are all included in this paper.

2.4 Multi-culm bamboo composites as sustainable materials for green constructions: section properties and column behavior (Asep Denih c, Gustian Rama Putra c) (2023)

Round bamboo culms offer good sustainable materials for a greenhouse construction. To withstand the greater weight, a multi-culm composite element made of round bamboo culms is secured or tied together. A portion of a multi-culm bamboo composite can be accurately modeled by circles that touch one another externally. The purpose of this work was to derive formulas for section parameters of a multi-culm bamboo composite, which could subsequently be embedded into a spreadsheet and graphing calculator. Up to nine full-sized, single- and multi-culm bamboo composite columns were put through testing in a lab setting to see how long they could withstand buckling loads before failing. The column that represented the total capacity of a few individual culms was taken into account. Furthermore, as a composite, the multi-culm column functioning as one was studied by the imbedded equations.

III. METHODOLOGY

3.1 Selection of bamboo

3.2 Study of different preservation techniques

3.3 Selection of proper preservation techniques

3.4 Model of a dome using bamboo

3.5 Study of the behavior of the dome under static

3.6 Preparation of model in FEM-based software Comparison of results

3.1 Selection of bamboo

When selecting a substrate for growing bamboo, it’s essential to choose a medium that provides the right balance of nutrients, drainage, and support. Bamboo is a versatile plant, but to thrive, it needs a good substrate. Here's what to consider when selecting a bamboo substrate Bamboo prefers well-draining, slightly acidic to neutral soil (pH 6-6.5), but different species might have slightly varying requirements. You can choose from a variety of substrates based on your growing environment. This is the ideal substrate for most bamboo species. It’s a balanced mix of sand, silt, and clay that holds moisture while draining well. Loamy soil provides good aeration for bamboo roots. For container bamboo, a standard well-draining potting mix with added perlite or coarse sand is ideal. This helps ensure the roots are not sitting in waterlogged soil.

3.2 Study of different preservation techniques

Bamboo is a fast-growing, eco-friendly material that is used in construction, furniture, crafts, and even as a food source. However, due to its high moisture content, bamboo is susceptible to decay, insect infestation, and other forms of deterioration if not properly preserved. Preserving bamboo is essential for extending its lifespan and maintaining its durability for use in various applications. Below is a study of different bamboo preservation techniques

Chemical Treatment (Preservative Soaking)

Chemical treatment involves soaking bamboo in various preservative solutions to protect it from insects, fungi, and bacteria. Common preservatives used for bamboo include copper-based compounds, borax/boric acid solutions, and chromated copper arsenate.

Heat Treatment (Kiln Drying)

Kiln drying is a process in which bamboo poles are heated in a controlled kiln to reduce moisture content. This process also kills any insects and fungi present inside the bamboo

3.3 Selection of proper preservation techniques

Study of Different Preservation Techniques in Indrudation

When we talk about preservation techniques, the term indrudation seems unusual, and it's likely that there's a typo or misunderstanding of the term. You might be referring to inundation, which generally refers to the process of flooding or being submerged in water. In the context of preservation, inundation could relate to preserving natural resources, historical sites, or certain materials through flooding or submersion.

3.4 Model of a dome using bamboo

Building a bamboo dome is an exciting and sustainable architectural project. Bamboo is an excellent material for constructing domes due to its strength, flexibility, and environmental friendliness. It can be used to create both small, decorative models as well as large, functional structures. Below is a detailed guide and conceptual approach to constructing a bamboo dome, whether it's for a model or a full-scale structure. Cross-bracing involves adding diagonal bamboo pieces between the main structural elements to prevent wobbling and ensure the stability of the structure. For both geodesic and hemispherical domes, cross-bracing is especially important for larger models. In both types of domes, especially the hemispherical model, diagonal supports between arcs can help distribute the weight more evenly.

3.5 Study of the behavior of the dome under static

Bamboo is an excellent material for construction due to its sustainability, lightweight, and strength-to-weight ratio. However, when constructing a dome structure using bamboo, it is crucial to study how the dome will behave under static load. Static load refers to forces that do not change over time, such as the weight of the structure, furniture, people, or environmental loads like snow or wind. Understanding the behavior of a bamboo dome under these conditions ensures the safety, stability, and longevity of the structure.

In this study, we will explore the behavior of a bamboo dome under static loads by looking at various factors like material properties, load distribution, structural design, and the influence of reinforcement.

Before analyzing the static behavior of a bamboo dome, it's important to understand the material properties of bamboo, which significantly affect the structural behavior of the dome.

Key Material Properties:

Modulus of Elasticity (E): Bamboo has a relatively high modulus of elasticity, which means it ca

3.6. Preparation of model in FEM-based software Comparison of results

Fig -1: **BMD**

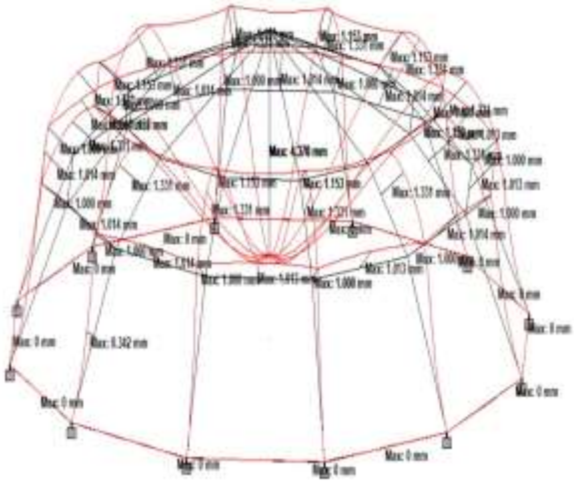


Fig -3: **DEFLECATION**

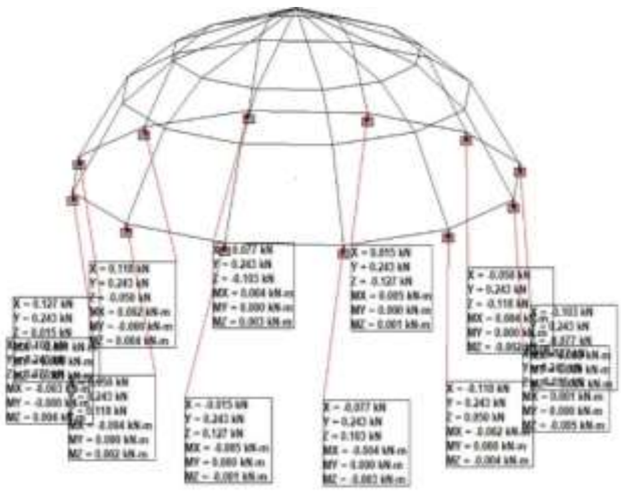


Fig -2: **REACTION**

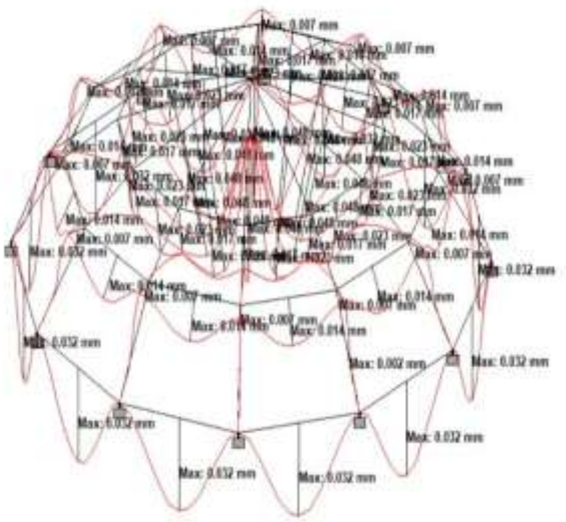


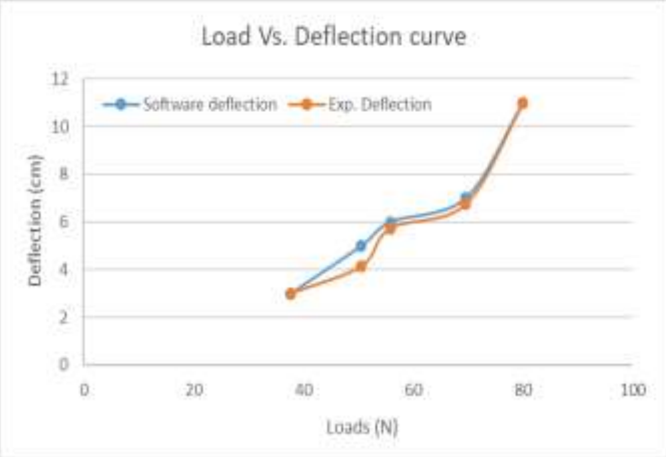
Fig -4: DSPLACEMENT

Table -1 Comparison of Results:

Here is a summary of the expected results and analysis for both methods:

Parameter	Manual Calculation	STAAD Pro (Software)
Load (P)	80 kg (converted to 784.8 N)	80 kg (converted to 784.8 N)
Deflection (δ)	Calculated using formulas (depends on I, E, L)	Calculated using FEA (local deformation analysis)
Bending Stress (σ)	Calculated based on M and S	Calculated using FEA and local bending moments
Shear Stress	Approximate (neglected in some cases)	Calculated using shear force distribution
Material Properties (E)	Assumed average value for bamboo (15 GPa)	Inputted precisely for bamboo (15 GPa or specified)
Geometry	Assumed simplified cross-section	Full 3D model with geometry and connections

Charts



3. CONCLUSIONS

The study successfully explored the structural and preservation aspects of bamboo as a sustainable building material. Various physical preservation techniques were evaluated, revealing that proper treatment significantly enhances bamboo's resistance to decay and increases its service life. A scale model of a bamboo dome was designed and constructed, demonstrating the feasibility of using bamboo in geodesic and curved structural applications.

Static load testing of the dome provided valuable insights into its load-bearing capacity and failure modes. When compared with Finite Element Method (FEM) simulations, the physical test results showed good correlation, validating the accuracy of the computational model. This comparison confirms that FEM software can be a reliable tool for predicting the structural behavior of bamboo structures.

Overall, the research highlights bamboo's potential as a lightweight, eco-friendly, and structurally viable alternative for small to medium-span architectural applications,

particularly when supported by effective preservation and design strategies.

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