# BENDING PERFOMANCE ON BAMBOO TRUSS

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***ABSTRACT**: Bamboo, with its inherent flexibility and elasticity, emerges as a compelling material for structural applications, particularly in trusses. This abstract explores the advantages of bamboo's fibrous composition, emphasizing its elastic properties and potential in optimizing truss designs. Bamboo's natural elasticity allows it to be molded into various shapes, making it an ideal candidate for irregular truss configurations that conventional materials may struggle to accommodate. The structural performance of bamboo trusses can be significantly enhanced by leveraging their flexible characteristics. Through the integration of bamboo's elastic properties into truss designs, it is possible to develop structures that not only support significant loads but also adapt to varying architectural requirements. This approach promises both aesthetic and functional benefits, offering unique design opportunities and improved structural performance. To substantiate the efficacy of bamboo trusses, hydraulic tests were conducted in a laboratory setting. These tests evaluated the durability and strength of bamboo trusses under load-bearing conditions, simulating real-world scenarios. The results demonstrated that bamboo trusses, even with irregular shapes, can sustain substantial roof loads while maintaining structural integrity. The ability of bamboo to withstand these stresses validates its potential as a versatile and resilient material in construction. In summary, bamboo's elasticity and flexible nature present significant advantages for truss applications. By optimizing its elastic properties and incorporating irregular shapes, bamboo trusses offer a viable and innovative solution for structural support, as confirmed by rigorous hydraulic testing. This approach not only enhances the functionality and durability of the trusses but also opens new avenues for architectural design.*

***Keywords:** Bamboo, Bending, Truss*

## INTRODUCTION

Since the beginning of times bamboo has served as multifunctional plant, used for many purposes such as furniture, food, biofuel, fabrics, cloth, paper, pulp, charcoal, ornamental garden planting and many more. Bamboo is a grass plant with the family name graminae and is composed of segments along the stem.(Putri et al., 2016) In construction we often see bamboo are being used as flooring, roofing designing, and scaffolding. From many species of bamboo, we could find 159 types and 88 types of endemic bamboo species of the archipelago. Lucky for us our ancestor had passed us many heritage ways of processing bamboo, and yet still developing until today. There are many ways of preserving them and the most interesting fact is how their craftsmanship skills develops throughout the times. They use this various type of skills set to create weaving, ornamentation, and a lot more. Bending is one technique that are commonly used with bamboo, and it is making bamboo unique from any other materials due to its flexibility.Due to its fast growing, bamboo is one of the most sustainable materials, it is also fast to construct meaning it will be able to be disassembled and assembled anywhere. And due to its strength, flexibility and durability bamboo is a good material option for building trusses since it will withstand earthquake, it can be shaped/ bent into curve shape. Bamboo has a character that is flexible (easily formed), has the potential for curved shapes (a shape that is quite difficult to achieve with other construction materials).(Anastasia, 2014) The purpose of this research is to see how bamboo perfomanc when they are used as a curve member on a truss.

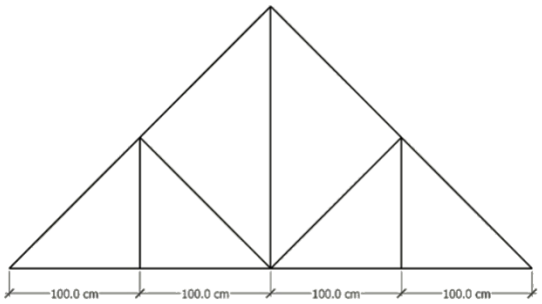



**Figure 1** Basic bamboo with 4m span
Source: Zaqy K.

## LITERATURE REVIEW

Bamboo trusses have gained significant attention in recent years due to their sustainable and eco-friendly nature. As a renewable resource, bamboo offers several advantages over traditional building materials such as steel or concrete. One crucial aspect of evaluating the performance of bamboo trusses is their bending behavior. This theoretical review aims to explore the bending performance of bamboo trusses, including their structural behavior, factors influencing bending strength, and potential applications.

Bamboo trusses are primarily subjected to bending loads when used in structural applications. Understanding their structural behavior under bending is essential for designing safe and efficient structures. Bamboo exhibits anisotropic properties, meaning its mechanical properties vary with direction. The culm (stem) of bamboo consists of a series of hollow cylindrical segments called internodes, which are connected by solid diaphragms known as nodes. The nodes play a crucial role in transferring loads between internodes and contribute to the overall strength and stiffness of the bamboo truss.

The design took into account both the weight of the bamboo itself and the fabric attached to it. Although the roof is largely inaccessible, provisions were made for a live load to facilitate inspections. Given the frequent occurrence of typhoons in Hong Kong, wind load was a crucial factor in designing the bamboo shell, impacting both individual components and overall structural stability with respect to uplift and sliding. Due to the bamboo structure's relatively short exhibition duration, it was classified as a temporary structure, allowing for reduced wind load considerations in the design. Wind loads were evaluated in both major directions (X and Y), along with downward and uplift forces. (Ho & Fong, 2020)

When subjected to bending loads, bamboo trusses undergo both compression and tension stresses. The top side experiences compression forces, while the bottom side experiences tension forces. The distribution of stresses within the bamboo truss depends on various factors such as the geometry of the truss, loading conditions, and material properties.

## RESEARCH METHODS

This research is using quantitative method, by building 1:10 scaled model for the design exploration, then building 1:2 scaled model to see if the design would work (joints, strength) before we build the final design which are 1:1 scale. Before designing the truss frame, the design is analyzed using the configuration formula (m=2j-r) then to find out the pull and press rods on the bamboo using the Cremona analysis. Last was testing the truss on a hydraulic press machine to determine the behavior of the truss we designed.

## RESULTS AND DISCUSSION

The main characteristics of most structures are elements that withstand tension and compression, such as rigid structures.(Apsari & Dewi, 2021) Truss is an assemblage of rods arranged in such a way forming a rigid framework. Looking into some truss design from many material (bamboo, concrete, steel, wood, etc..) we can compare, and most important

we could design bamboo truss that can only be built using bamboo material meaning it will be unique compared to other materials.

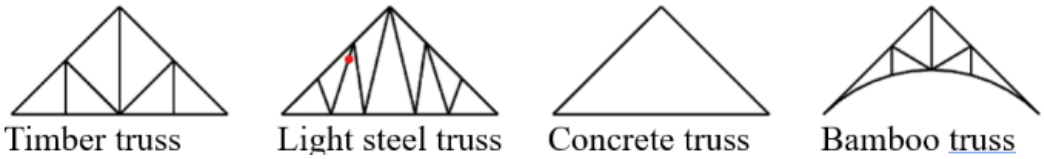



**Figure 2** Exploration truss design with different materials
Source: Zaqy K.

Bamboo as building material is not constantly use into organic shaped building. The reference shape of bamboo building mostly come from wooden building which is generally constructed using simple frame structure. Therefore the builders tend to construct bamboo into frame structure thus becoming a box, static and, considered as boring.(Nurdiah, 2016) From the picture above we can see each material has its own needs due to its characteristics. In this case we can determine that bamboo can be flex or bent, that is why making truss design with some curves will make the bamboo more stand out.



**Figure 3** Design exploration for 1:10 scale model
Source: Zaqy K.

Curve elements are very common in bamboo technology, this cant be achieved by other material. While designing the truss we first considered its functionality, sustainability, and minimizing the use of material then we also thought of its joint and many available techniques of bamboo. as seen in this drawing curve element was being used a lot in this design, the only way for it to work is to make the curve element only a s compression not as tension .

From all the design process of 1:1 0 scaled model is that we should be able to think BAMBOO meaning how we should maximize the many techniques of processing bamboo such a s bending, rank, and many others that can't be achieved by other material. (People will chose wood over bamboo if it can be done by wood/other material because of its cost).

- 1:2 Scaled Model

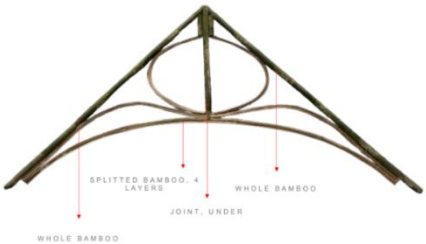



**Figure 4** Scaled model of 1:2
Source: Group 1 (Ni'mal, Zaqy K., Omar)

The steps of making bamboo trusses is very important, especially in this design. The first step of making this design was to make the main frame which are the triangular shape and the under, then we start making the curve starting from the middle, top then bottom. This order of step will make the joint at the bottom possible to be connected with the right order.The curve uses a technique called bamboo split and ranking/ stacking them together. Curve member in truss must be solid so it can be a compression member, the way to make

the curve solid is by bending them to the desired shape then bolting them in multiple place (number of bolt depends on the length and needs).

Since bamboo have eleasticity characteristic bamboo can easilly be curved. There are 2 method of bending bamboo which are cold and hot bending. The method that are being used in this design are cold bending.(Maurina et al., 2014)

- 1:1 Scaled Model

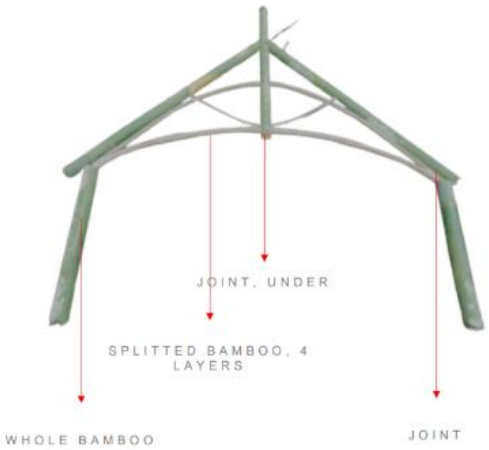



**Figure 5** Scaled model of 1:1
Source: Group 1 (Ni'mal, Zaqy K., Omar))

Building the 1:1 scaled design uses the same technique and steps, the only different is redesigned middle curve and top curve elements. This was necessary to prevent hurting the bamboo. (Too many connections at one joint will weaken the bamboo).

- Cremona

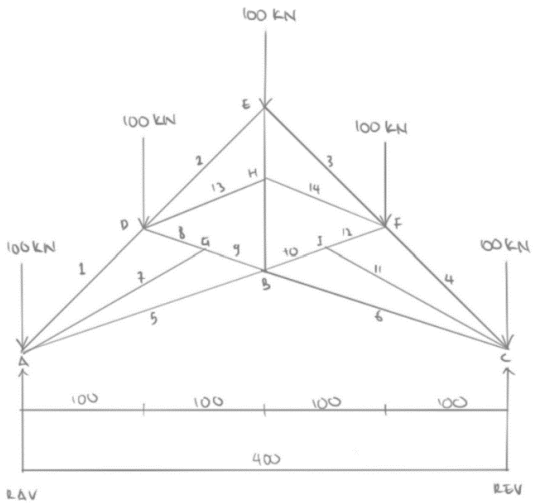



**Figure 6** Cremona Calculation
Source: Group 1 (Ni'mal, Zaqy K., Omar)

Calculation of curve members needs to be converted into straight element first then we can calculate the Cremona.

**Compression Test On Bamboo Truss**

- Test Preparation

Preparing for the test came into several steps.

3. Mounting the truss into the machine.
4. Aligning the top pressure point.

5. Aligning left/right point.
6. Setting up the roll joint and fixed joint on each side.
7. Placing side clamp to prevent side flex of the truss.
8. Setting up cameras for documentation.

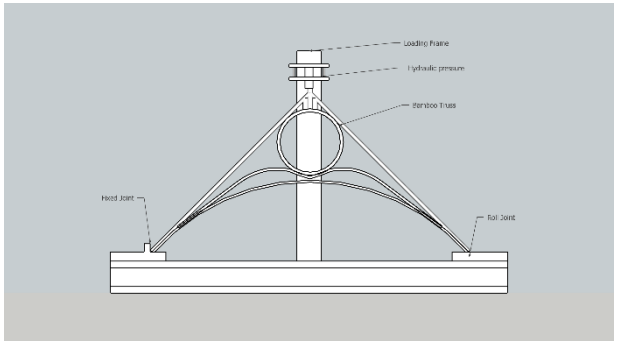



**Figure 7** Test setup
Source: Zaqy K.

The test began, the truss stars to fight back at the force that was given by the hydraulic press. our truss starts to deform quickly resulting in the peak point of 2,04kN at 6,751cm. The main problem of our truss is the under joint was not bolted to the lower member, this is causing most of the deformation. The under acts as a pull member (one of the ends was not secured) causing it to not function as it supposed to be. From the test we learned that when building a truss, we should consider which member is tension/ compression so we could understand which connection type to use and how to secure it.



**Figure 8** Roll joint movement
Source: Group 1 (Ni'mal, Zaqy K., Omar)

We could see 12 cm of movement in the roll joint. Which means the truss is reacting to the pressure by widening its shape, it is not very good because it is not holding its original form

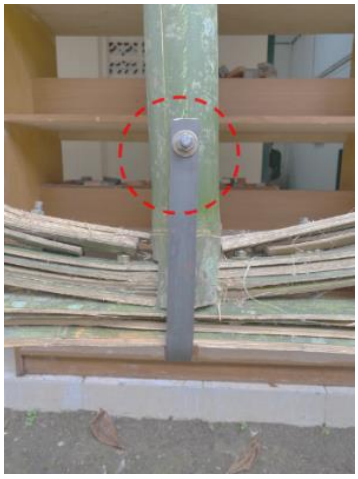


**Figure 9** Separation of under member and curve member.
Source: Group 1 (Ni'mal, Zaqy K., Omar)

From picture above we could see separation of the member, this was caused by when the truss being pressed there was some widening movement, and this joint were not secured by any connection.

- Test 2 Result



**Figure 10** Revised under joint with lower curve member
Source: Group 1 (Ni'mal, Zaqy K., Omar)

The revised model have only one difference which are its under joint, it is secured by using u clamp, preventing the old problem which the member got separated. This difference improved the test result a lot. First, we could see the roll joint stays in place, meaning there are less widening deformation. The under joint stays in place, it withstands higher peak point even with some of the member already cracked from the test before.

**CONCLUSION**

In conclusion, after conducting a hydraulic lab test on the curved bamboo structure, it can be determined that bamboo material performs optimally due to its irregular shape. Moreover, bamboo is already recognized as a strong material for structural components like trusses. Both of these aspects must be supported by the appropriate joint methods between the curved shape and the outer frame. Curved bamboo structures will reach optimal performance with adequate joints to counteract the tensile forces inherent in bamboo. Therefore, selecting the right connection method between bamboo components is crucial in

balancing the irregular shape's optimization with its function as a structural element in trusses.

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