

“Design of Long Span Bamboo Roof”

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Abstract — A number of cultures have used bamboo for roofing materials. The Chinese used bamboo for roofs with the ends covered with round tiles. A boric acid/borax solution is used to preclude fungus and insect infestation. Roofs can also be treated with lime to protect them. Long lasting tiles made with bamboo utilize a bamboo strip reinforced fiber-cement laminate where the bamboo strips are weaved into a web for additional strength. A variety of techniques have been developed to create roof support systems. These include a prefabricated triangular truss system comprising of units eight meters long. Bamboo, truss systems have been developed using flat bamboo strips which are connected with bolts. Due to its hollow form, bamboo is relatively strong and stiff and lends itself easily for roof trusses in the same manner as timber roof trusses.

I. INTRODUCTION

A bamboo truss is a frame made of bamboo poles. Poles connected to each other in a particular form typically it takes the shape of the roof. The only challenge is with connecting the poles together in a way that hold them firm for a long time. Over the years there have been many ways in which people connected these poles to make a bamboo truss. A number of cultures have used bamboo for roofing materials.

Due to its hollow form, bamboo is relatively strong and stiff and lends itself easily for roof trusses in the same manner as timber roof trusses. Bamboo as a local building material can increase the local content of a house construction is therefore an opportunity to increase the economic independence and self-reliance of local populations. However, bamboo must be treated in order to increase durability and it is also not completely straight which can cause problems for the achievement of an even roof surface. In addition, structurally sound joints are difficult to construct without the use of expensive materials such as steel bolts and plywood or metal sheets.

Bamboo roofing offers endless design potential, and with the right tools and materials, you can build a DIY bamboo roof for any exterior structure. The cross-section, self-weight and displacement values of bamboo structure to determine the truss shape design problem in the greenhouse. The truss shape has designed in eight different types: Double Howe, Modified Fan, Modified

Queen, Pratt, Fan, Double W, M shape and W shape. The displacement value in each truss shape is determined by using standard load (Dead Load, Live Load, and Wind Load) to calculate axial force in each truss shape member. The results of eight type displacement values show that the minimum displacement is Modified Fan truss shape and the minimum weight of the trusses structure in greenhouse is Double Howe truss shape.

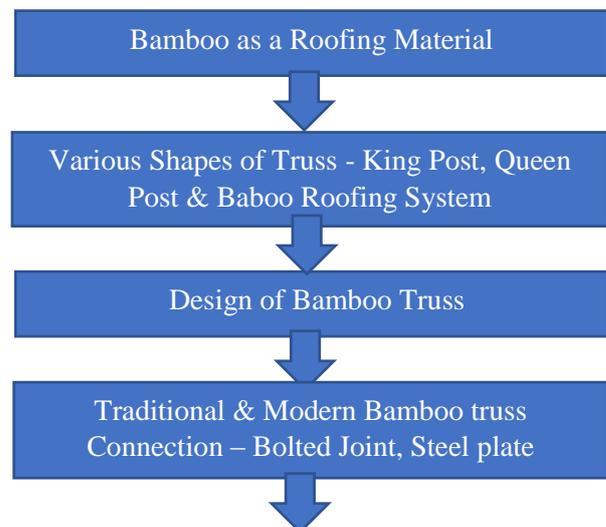
II. AIM OF THE WORK

The aim of the project is,

- To design a long span Bamboo Truss with low cost.
- To absorb carbon dioxide and produce oxygen by using Bamboo.
- Using bamboo roofing sheets that's are environmentally friendly and safe alternative to plastic, zinc or corrugated asbestos panels.
- Bamboo housing is very economical as well as necessary for poor man.

III. METHODOLOGY

METHODOLOGY





1. Bamboo as a Roofing Material

Bamboo has been widely known as a sustainable building material due to some reasons among others are bamboo can be easily cultivated and harvested in a relative short time and can be reused. Bamboo as building materials is easy to bend and lithe. Those characters are very suitable for organic shaped building construction. Bamboo is a low-cost building material available in wide parts of the world: it is lightweight, durable, flexible, and easily cultivated and processed.

The need for better infrastructure is rising in demand as well. Schools, Hospitals, bridges etc. So much infrastructure demands a lot of brick and mortar which is short in supply. An effective and eco-friendly alternative could be bamboo. Although an entire structure can be built using bamboo, let's look at the roofing solution today. Bamboo is a grass that is extremely hard and durable all the right attributes required for a roof. Bamboo also grows quickly which means that there will be adequate supply. A bamboo roof needs support. Just like a concrete roof is supported by iron rods. A bamboo roof is supported by Bamboo Truss.

1.1 Specification of Bamboo

1. Mannaga
2. Kanak
3. Bambusa
4. Black Bamboo
5. Bambusa vulgaris
6. Guadua Bamboo
7. Moso Bamboo

8. Timber bamboo

1.2 Bamboo Truss

Due to its hollow form, bamboo is relatively strong and stiff and lends itself easily for roof trusses in the same manner as timber roof trusses. Bamboo as a local building material can increase the local content of a house construction is therefore an opportunity to increase the economic independence and self-reliance of local populations. However, bamboo must be treated in order to increase durability and it is also not completely straight which can cause problems for the achievement of an even roof surface. In addition, structurally sound joints are difficult to construct without the use of expensive materials such as steel bolts and plywood or metal sheets. These materials also reduce the attractiveness of the truss as a truly natural element for aesthetic reasons.

2. Common Truss Types

- King Post :
The king post trusses are used for simple roof trusses and short span Bridge. It is the simplest form of truss is used when there is a need to support the weight of an expensive roof. It is used when length of a span is about in the range of 5 to 8 m.
- Queen Post :
It is suitable for roofs of span varying from 8m to 12m or 9m to 14m.
- Howe Truss :
It can be used for span from 6 – 30m
- Fan Truss:
It can be used for span from 10-15m
- Pratt Truss:
It can be used for span from 6-10m

2.1 Components Parts of Trusses

- 1) Rafter: One of a series of diagonal members of the truss that meet at the apex in order to support the roof deck and its loads.
- 2) Under purlin: Horizontal beams supported by posts and used to support the mid-span of rafters to cover longer spans.
- 3) Strut: A diagonal member of the truss that has a compressive force acting on it and used to maintain rigidity and add strength to the structure.
- 4) Ridge Beam: It is the horizontal beam that supports the ends of the rafters at the ridge.

5) **Strutting Beam:** The horizontal beam that supports roof loads and transfers them directly to load-bearing walls.

6) **Top Plate:** The horizontal beam that supports the roof by supporting the rafters to the wall.

3. Design of Bamboo Truss

➤ **Howe Truss:**

A truss having vertical and diagonal members between the upper and lower horizontal members. Span up to 6m to 30m.

▪ **Components Parts of Truss:**

1. **Upper chord:**

An inclined or horizontal member that establishes the upper edge of a truss.

2. **Lower chord:**

The horizontal member defining the lower edge of a truss.

3. **Diagonal**

4. **Vertical**

5. **Span:**

The span of the truss refers to the length of the bottom chord covering the width of the room or structure that the truss is covering.

6. **Rise:**

The rise of the truss is the vertical distance between the apex and the line joining the supports.

☐ **Howe Truss**

I. Span: 1.8m

II. Rise: 0.5m

III. Panels: 3 Nos.

IV. Spacing: 0.3m

☐ **End Connections of two Bamboo – Use Bolted Connection**

☐ **Use treated Bamboo**

4. Bamboo Truss Connection

1) **Traditional connections**

1. Friction tight rope connection

2. Wedge connection

3. Plug-in bolt connection

4. Positive Fitting

2) **Modern connections**

1. Bamboo-Tec

2. Transportation Armature

3. Induo-Anchor Technique

4. Pan knot space truss

1) **Traditional Bamboo truss connection**

In the past bamboo truss was made by putting the bamboo poles together and strapping a rope around them. If you notice today's scaffolding at the construction sites it looks similar. The issues with this type of bamboo truss connectors is that the load of the roof was not equally distributed. There is friction which may compromise the strength of the roof.



1. **Friction tight rope connection**

The 'friction tight rope' connection is widely used in traditional construction. These connections use natural materials like rattan, coconut fibre to join the bamboo culms together. Lashings, wraps, fraps, and clove-hitch are some knots used in these connections. To get tighter connections, we use green bamboo strips. These strips are watered before use and shrink while drying, resulting in a stronger connection.



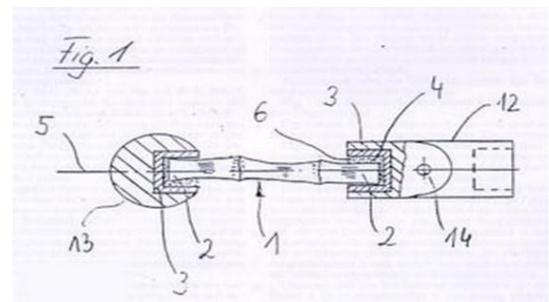
2) Modern Bamboo Truss connection

New joiners and connectors have been designed in recent times. Thanks to advancement in technology, skilled engineers and architects, The metal joiners and connectors. These joiners and connectors can be made in various shapes and sizes. This depends on the number of poles to be connected and the design of the roof. With the modern joiners there is rarely any friction between the poles. The weight is equally distributed. Incorporation of little steel helps in overcoming the problems faced in traditional system.

Bamboo connection by using nut and bolts, Steel Plates, and also used Bamboo pegs

1. Bamboo-Tec

Bamboo is a natural material and is thus subject to the irregularities of diameter within a single culm. The 'Bamboo-Tec' connection is a modern technique developed by Bruno Huber to counteract these irregularities. This connection uses bamboo culms that are cut to the desired length and are capped with artificial resin. The end caps are made of steel or aluminium and have circular grooves on the inner side. These grooves facilitate a stronger connection between the cap and the bamboo.

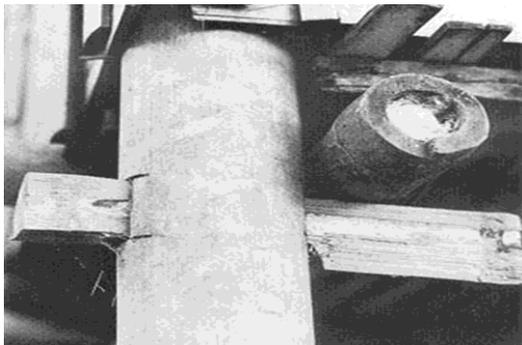


2. Transportation Armature

This method involves the threading of hollow bamboo culms with a metal armature. We fill the residual cavity with concrete. This connection increases the speed

2. Wedge connection

In a wedge connection, a wedge-shaped wooden piece is driven at the joint of two bamboo members. However, this connection requires additional reinforcement through the use of lashing or bolts.



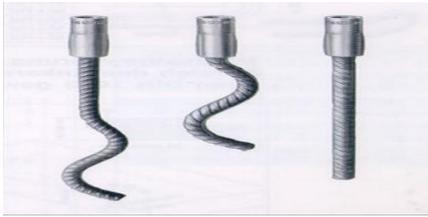
3. Plug-in bolt connection

The Plug-in bolt connection is not widely used and works on the similar principle of the tenon and mortise joint in wooden joineries. We must take care to avoid using the plug-in bolt connection close to the edge of the culm to prevent the splitting of the bamboo.

4. Positive Fitting

Positive fitting connections are widely used in traditional bamboo construction. These connections involve carving a hole in a bamboo culm and inserting a bamboo of a slightly smaller diameter. The joint is further strengthened using bolts or dowels. The disadvantage of this jointing technique is the reduction of the strength of the bamboo because of the cutting of the hole.

of construction by eliminating the time required for the fabrication of dowels.



3. Induo-Anchor Technique

The Induo-Anchor technique is used for bamboos with larger diameters. The joint comprises an anchor, which is a spherical node usually made of cast-iron. The node is drilled and tapped at varying angles to create desired connections. We thread the bamboo culms into the nodes using conical end bolts.

4. Pan knot space truss

A pan knot space truss comprises two components: a ball knot and thread rods which form the intermediate connection between the central knot and the bamboo culm. The advantage of this connection is the provision for dismantling. We use this connection for canes with a smaller diameter.

5. Comparisons Cost

Cost Comparisons Between Bamboo, Steel & RCC Slab of Hall Size 10m x 10m

Type of Structure	Size of Structure	Costing (Materials + Labours)
Steel Roof	10 × 10 m	₹ 2,92,478 /-
RCC Slab	10 × 10 m	₹ 2,10,208 /-
Bamboo Roof	10 × 10 m	₹ 1,95,000 /-

6. Bamboo Treatment & Preservation

Bamboo has very little natural toxicity and therefore, is easily prone to fungi and insect attack. The objective of treatment is to remove the starch and other carbohydrates (soluble sugars) that attract fungi and insects and replace it with chemicals in the cells of the bamboo thereby increasing the life of the bamboo. Well treated bamboo has a life expectancy of 50 years without losing its structural properties. The efficiency of the chemical treatment is influenced by anatomical structure of the bamboo culm. There are no radial pathways in the culm tissue, like the ray cells in wood, and lateral cell-to-cell movement of preservative depends on a slow

diffusion process. Freshly cut culms are easier to treat due to the water-filled cells providing a continuous transportation channel. Both ends of the culms should be cut up to the next node in order to remove the blockage of vessels. Whereas there are several indigenous treatment systems like limewash and smoking of bamboo, chemical treatments are known to have longer effect against fungi and insects.

➤ Various Treatment & Preservation Methods:

1) CCB (Copper Chrome Boron) Treatment:

CCB is very effective against wood bores, fungi, decay, and termites and protect bamboo for a long time. It has been found to provide protection for 50 years or more.

1. The first Bamboo is kept for 20 to 30 days.
2. Then drill the holes notch to notch on Bamboo
3. Then they are placed in a Bamboo treatment tank.
4. That tank contains CCB chemical.
5. This process completed in 7 hours.
6. Then this chemical treated bamboo are kept for 8 days.
7. Then they are thrown in washing tank to wash the Bamboo
8. After that Bamboo are straitening by heating and use water for cooling.
9. Then polishing the Bamboo.
10. Then Bamboo is used.



CCB (Copper Chrome Boron) Chemical Process Tank



Bamboo after Treatment

2) Boric Borax Acid Method:

Curing bamboo with borax and boric acid is popular bamboo preservation method around the world because it is effective and more environmentally friendly than other wood preservation.

- The combination of boric and borax in a ratio of 1:1.5 is an alkaline salt called: Disodium octaborate tetrahydrate and is available in pre-mixed powder form.

7. Details of Bamboo Roof

7.1 Bamboo Roof

Bamboo roofs make a beautiful addition to any exterior space and give tropical flair to your backyard. When you build your own bamboo roof, you can choose your dream design and select a thatch that best suits the style of your backyard. You can also save money by building the exact size and shape of roof you need instead of ordering a custom roof.

Bamboo roofing helps to minimize temperature effect. Bamboo roofing maintain cool environment during summer days also. It shows temperature variation in bamboo housing and outside temperature. Pollution problem does not arise due to bamboo utilization. Nowadays, bamboo is one of the advanced materials which gives maximum advantages in construction.

7.2 Roofing Systems for Bamboo Buildings

1. Thatch
2. Halved bamboo
3. Terracotta tiles
4. Flattened bamboo shingles
5. Copper shingles

7.3 Bamboo Roofing Sheets:

- i. Treated Bamboo first flattened by machine.
- ii. Then apply Bitumen coat on flattened sheets.
- iii. Bitumen sheet is used for stick the Bamboo sheets.
- iv. First heat the Bitumen Sheet then stick the Bamboo sheet over it.
- v. Bamboo roofing sheet are made by sticking flattened sheet on bitumen sheet.



Bamboo Sheets



Bitumen Sheet to stick Bamboo sheet



Stick Bamboo sheet on Bitumen sheet



Bamboo Roofing Sheet

7.4 Corrugated Bamboo Roofing Sheets



Corrugated bamboo roofing sheets (CBRS) are an excellent alternative to corrugated metal, plastic or asbestos roofing sheets. They are produced from a natural and sustainable resource and can be used to cover homes, storage facilities, animal pens and many other temporary or permanent structures. CBRS is made from several layers of woven bamboo mats. These woven mats are impregnated with an adhesive resin and pressed together between two specially designed corrugated pressing plates. The sheets can be produced in a range of sizes to suit particular requirements and can easily be trimmed for special applications.

❑ The process of producing corrugated bamboo roofing sheets involves 6 steps:

1. Bamboos are split into thin slivers.
2. Slivers are woven into mats.
3. Mats are soaked in adhesive resin.
4. Mats are allowed to drain and dry.
5. Mats are glued together under high temperature and pressure.
6. Sheets are trimmed to shape.

8. Waterproofing Bamboo Roofs



Waterproofing the roofs is something that is taken seriously here especially when organic materials are used for construction. There are 3 key elements that ensure the roofs are waterproof:

1. Pitch of the Roof

Generally, roofs in tropical climates need to be sloped or pitched at a certain angle

2. 6 Layers of Bamboo

The bamboo trusses are first coated with 2 – 3 layers of rubber tree oil. The oil helps to protect the bamboo from moisture.

3. Drainage System

The large overhang of the roofs helps direct the rain water away from the earthen walls into the school's water drainage system.

9. Model Making

❑ Type of Truss: Howe Truss

❖ Span: 1.8m

❖ Rise: 0.5m

❖ Panels: 3 Nos.

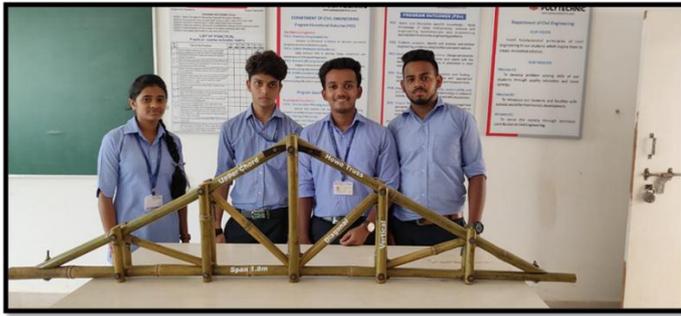
❖ Spacing: 0.3m

❑ End Connections of two Bamboo –

Use Bolted Connection

❑ Use treated Bamboo





Conclusion

- For a long time, bamboo has been known as “poor man’s timber”, so it is being used for cost effective housing or low-cost housing. Now a day, due to its various applications and properties of bamboo, it can be used as an alternative building material in construction industry. Bamboo is lighter in weight and stronger than steel. Bamboo has good tensile strength and hence also can be used as a building material in organic shaped buildings. Using proper preservative treatment methods bamboo can be used as a building material.
- Bamboo houses are eco-friendly. Locally available resources were effectively used for the house construction to bring down the cost of house construction. When treated Bamboos are used it makes the house structure more durable and the Bamboo house may be maintained for even 50 years.
- Bamboo is favoured not only by its natural features and its use but also by the fact that bamboo is a sustainable material. When using bamboo products, we are contributing to the protection of our habitat and our descendants: “Use bamboo instead of wood to retain the blue of the earth for a friendly and sustainable life”.

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