

# **BAMBOO EMERGENCY SHELTER**

## **CONSTRUCTION MANUAL**



**International Network for Bamboo and Rattan**

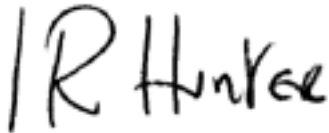
**Manual Prepared By**  
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## FOREWORD

More and more forests are being destroyed to make temporary emergency shelters for refugees. However bamboo is a perfect, yet largely unused, solution to this problem. It is straight, long, easy to handle, cheap and sufficiently durable for temporary shelters without needing chemical treatment. Most importantly, it is abundantly available and will prevent indiscriminate forest destruction. I think this manual has therefore been written at just the right time.

I would like to thank all those who were involved in designing and constructing the prototype shelter. I thank UNHCR, Ghana for collaborating with INBAR to find this solution. I hope the manual will be useful for those dealing with the demand for temporary refugee shelters in the bamboo-growing regions of the world.

A handwritten signature in black ink, reading "I R Hunter". The letters are cursive and slightly slanted to the right.

Dr. Ian R Hunter  
Director General  
INBAR

## **Acknowledgement**

I would like to mention few names who contributed significantly to this manual.

First of all, I would like to express gratitude to Mr. Peter Rasmussen, UNCHR, Ghana for his initiation of the project and the shelter design. Similarly, I would like to thank Ms. Annemarie de Ruiten, former representative of INBAR in Africa for her active coordination; Mr. Andrew Benton, INBAR, China; Mr. Daniel Ofori, BARNET, Ghana and Mr Charles Asare, INBAR volunteer, Ghana, for their contributions during the prototype shelter construction.

Last but not least, I would like to thank INBAR volunteer Miss Charity Teo, of Australia, for her great contribution in finalizing the drawings for the manual.

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## **1. Introduction**

Every year millions of people seek asylum across national boundaries due to political, social and environmental reasons. The United Nations High Commission for Refugees (UNHCR) is currently dealing with 20 million such refugees world-wide (UNHCR website, 2003). The initial requirement of these refugees is generally to find temporary shelter. The onus is then on the host country and International Agencies to provide them with temporary shelter until a permanent solution is found.

Such refugee forces create a lot of pressure on forests especially in developing countries. Clearing of forests for space, poles (to make shelter), food and firewood is a common practice. Forests are destroyed permanently to build temporary shelters. Environmental degradation is one of the main problems associated with refugees.

To provide quick and cheap shelters without deteriorating the forest area, UNHCR Ghana and INBAR developed a method of constructing a refugee shelter using bamboo. The structure is easy to construct, quick and cheap to assemble, and produced from sustainable resources.

## **2. Selection of Bamboo**

### **2.1. Species**

To produce the shelter bamboo culms between 60 and 100 mm diameter are required, which means that most of the large bamboo species of the world are suitable. Do not select culms with signs of deterioration or infection. Full details of the number and sizes of culms required are given on page 10.

### **2.2 Age**

Three-year-old non-flowered bamboo culms can be used. However, if the culms are to be re-used as in a mobile shelter, 3 to 6 years-old bamboos are recommended. The following paragraphs help you to determine the age of bamboo.

Determining the age of Bamboo: It is easier to estimate the age of planted bamboo once you know the year of planting. When the new shoots emerge mark them with the year of emergence. But determining the age of natural, non-managed bamboo is rather difficult. However, there are few rules of thumb that help to roughly estimate the age of bamboo.

- ◆ For non-managed sympodial bamboos the outermost bamboos are generally younger. The closer to the centre of the clump, the older the culm.
- ◆ When the color of the culm has changed from clear and shiny green to grayish green, and if the white bands at each node have almost disappeared and are replaced by almost imperceptible gray bands, then the bamboo shows clearly evidence of its maturity (Moran, 2003).
- ◆ If the bamboos are turning yellow they are too old.
- ◆ When you strike a bamboo with a metal implement, the sound of older bamboos is louder than that of younger ones.

## **2.3 Harvesting considerations**

### **When?**

- ◆ Harvest in the dry season. At this time the culm has a low moisture content and a reduced chance of attack by fungi.
- ◆ Never harvest in the rainy and moist seasons.

### **How?**

- ◆ Cut the culms 20 to 30 cm above the ground or just above the first node.
- ◆ Use a sharp tool or saw to avoid damage.
- ◆ After cutting stand the culms upright supported by a tree, stones or nearby bamboo culms for two to three weeks. This will reduce the starch content of the culm, which will reduce the chances of insect damage.

### **Transportation**

- ◆ Cut the bamboo into pieces of the required length to make transportation easier.
- ◆ Pack them in bundles of ten culms tied with rope or bamboo lashings.
- ◆ Carry by hand for short distance transport or a cart or truck for long distance transport.

**Drying:** Once the bamboo arrives at the construction site:

- ◆ Clear the ground (remove vegetation, large stones)
- ◆ If possible spray the ground with lime water.
- ◆ If possible, use overhead shade to protect the bamboo from rain.
- ◆ Keep the bamboo for 3-4 weeks in a standing position.

## **2.4 Other Considerations**

### **Morphology**

- ◆ Use bamboo without fissures, cracks or cuts on the surface.
- ◆ Use bamboo without signs of rotting, insect or fungal attack
- ◆ Straight bamboos with a minimal taper are preferred. Only 2/3 of their total natural length is useful for construction. The remainder could be used to make strips for weaving or for other purposes.

## **3 Preservation**

The natural durability of bamboo is 1-3 years where it is directly exposed to soil and atmosphere. When used under cover, the life expectancy of bamboo increases to 4 to 7 years but can be as high as 10-15 years in highly favorable circumstances.

The natural durability of bamboo is sufficient for one time use. However, if they are to be used repeatedly for refugee shelters, proper preservation is suggested.

There are two types of methods of preservation.

### **3.1 Non-Chemical Methods**

#### **A. Reducing starch content**

Starch makes bamboo vulnerable to attack by fungi and termites. Therefore, reducing starch content of bamboo is the best way to make it less vulnerable. You can reduce starch by:

- ◆ Keeping culms in a standing position for a week after harvesting and for two weeks after transportation.
- ◆ Harvesting only mature bamboos

#### **B. Soaking**

This should be done before drying the bamboo or immediately after harvesting.

- ◆ Harvest bamboo according to the method suggested in section 2.3
- ◆ Transport bamboo to a permanent water sources. Running water (a river or stream) is preferred
- ◆ Immerse the bamboo in water
- ◆ Use stones or other heavy materials to keep them submerged
- ◆ Leave for 3 to 6 weeks
- ◆ Take them out and keep in shade to dry them for at least one week

## **C. Smoking**

This is a simple and effective method. A temporary smoking chamber can be built to smoke bamboo until they have a slightly dark colour.

## **3.2 Chemical Methods**

Many kinds of chemicals are in use for the treatment of bamboo. Creosote oil, Borax and Boric Acid are some of them. Chemical preservation makes the shelter expensive and should only be used if the bamboos are used repeatedly for a long period of time. Two chemical preservation methods are described here which are easy to apply and commonly used.

### **A. Injecting Coal Tar Creosote Oil**

This preservative is poisonous and therefore is not recommended for exposed parts. However, it can be an effective preservative if used properly with appropriate methods.

#### **Procedures for Coal Tar Creosote Injection**

##### **Drilling the bamboo**

- ◆ Drill 6mm holes in all the bamboo internodes.
- ◆ Drill the holes close to nodes to avoid damage.

##### **Preparing the creosote**

- ◆ Pour the creosote oil to a small injecting pot.
- ◆ Check the quantity of creosote oil that can be injected in one squirt.
- ◆ Inject 50 ml of creosote into each internode. The number of squirts required will be dependent upon the quantity of creosote delivered in each squirt.
- ◆ Seal the holes with paraffin wax after injection.
- ◆ Shake the bamboo to distribute the creosote for better results.
- ◆ Rotate the pole three times a day for 4 days.

##### **Safety Precautions**

- ◆ Use gloves and masks while working with creosote.
- ◆ Keep children away.
- ◆ Keep away from fire. Creosote is highly inflammable.
- ◆ Wear safety glasses.

**Note:** Be sure to use pure creosote for better result.

## **B. Treatment with Borax and Boric Acid**

The chemicals borax and boric acid are tasteless and colourless. They are regarded as highly safe chemicals for preservation and recommended for use in most of cases. The procedures for cold immersion in borax and boric acid are given below.

### **Preparation of soaking drum**

- ◆ Cold immersion can be done in any kind of drum – old, clean, oil or fuel drums are ideal. Be sure there are no toxic remnants left in them.
- ◆ Cut two large drums longitudinally in half.
- ◆ Weld the ends together to make a long semi-circular soaking drum.
- ◆ Mount on a brick pedestal.
- ◆ Check the joints for leaks.
- ◆ Smooth all sharp edges for safety.

### **Preparation of the bamboo**

- ◆ Cut the bamboo to the required length
- ◆ Drill 6mm holes in all the bamboo internodes.
- ◆ Drill the holes close to nodes to avoid damage.

### **Preparing solution**

- ◆ Prepare a 2.5% solution of borax/boric acid (1.5% Borax, 1% Boric Acid)
- ◆ Stir the solution until the chemical fully dissolves in water.

### **Immersing bamboo (Cold Immersion)**

- ◆ Immerse the bundles of bamboo in the drum.
- ◆ Align them in such a way that more bamboos can be immersed at a time.
- ◆ Place loads on the top of bamboos to keep them immersed.
- ◆ Immerse culms at least for 24 hours.

### **Drying**

- ◆ Remove the bamboos and lean them against an upright support to dry them for at least 24 hours in the open air.

**Note:** There are other methods of preservation. The Bouchurie method is recommended if you have large numbers of bamboo to be treated.

## 4. Fabrication

The dimensions and size of the refugee shelter may vary according to the situation. In this case, the size of the shelter has been determined by the size of the roof cover (plastic sheeting). The standard UNHCR plastic cover size is 5m x 4m. Considering the 4-m dimension of the plastic cover along the length of shelter, an 8m long shelter can be built using two plastic covers.

The width and height of the shelter also depends upon the width of the plastic cover. However, one needs to consider the minimum width and height. This particular shelter has a top height of 1.8 m, which is enough for the movements in and out of the shelter. The total width of the tent is 3-m, though the usable width is only about 2m as the two corners of the shelter can't be utilised fully because of their low height.

The shelter can be separated into two compartments if necessary by putting a dividing curtain in the middle. This size of shelter is generally suitable for a family of up to 5 members.

### 4.1 Bamboo Pole Requirements

Table 1: Bamboo requirements

| SN | Particular                                            | Size (diameter) | Quantity  | Standard length (M) | Required length (M) | Total length (M) | Remark                                         |
|----|-------------------------------------------------------|-----------------|-----------|---------------------|---------------------|------------------|------------------------------------------------|
| 1  | Vertical Post                                         | 80-100 mm       | 6         | 3.5                 | 3.80                | 22.8             | 30cm extra for joints and 10 cm under ground   |
| 2  | Horizontal cross bars                                 | 80-100 mm       | 3         | 1.5                 | 1.8                 | 5.4              | 30cm extra for joints in two sides             |
| 3  | Diagonal bars                                         | 60-80mm         | 4         | 4.5                 | 4.7                 | 18.8             | 20cm extra in case needed for joint            |
| 4  | Longitudinal (horizontal) side bars (of 8.5 m length) | 60-80mm         | 5         | 8                   | 8.5                 | 42.5             | If 8.25 long bamboo are available. Recommended |
| Or | Or (do) (4.25 m length)                               | 60-80mm         | 10        | 4                   | 4.25                | 42.5             | If 8.25m long bamboo are not available         |
|    | <b>Total</b>                                          |                 | <b>23</b> |                     |                     | <b>89.5</b>      |                                                |

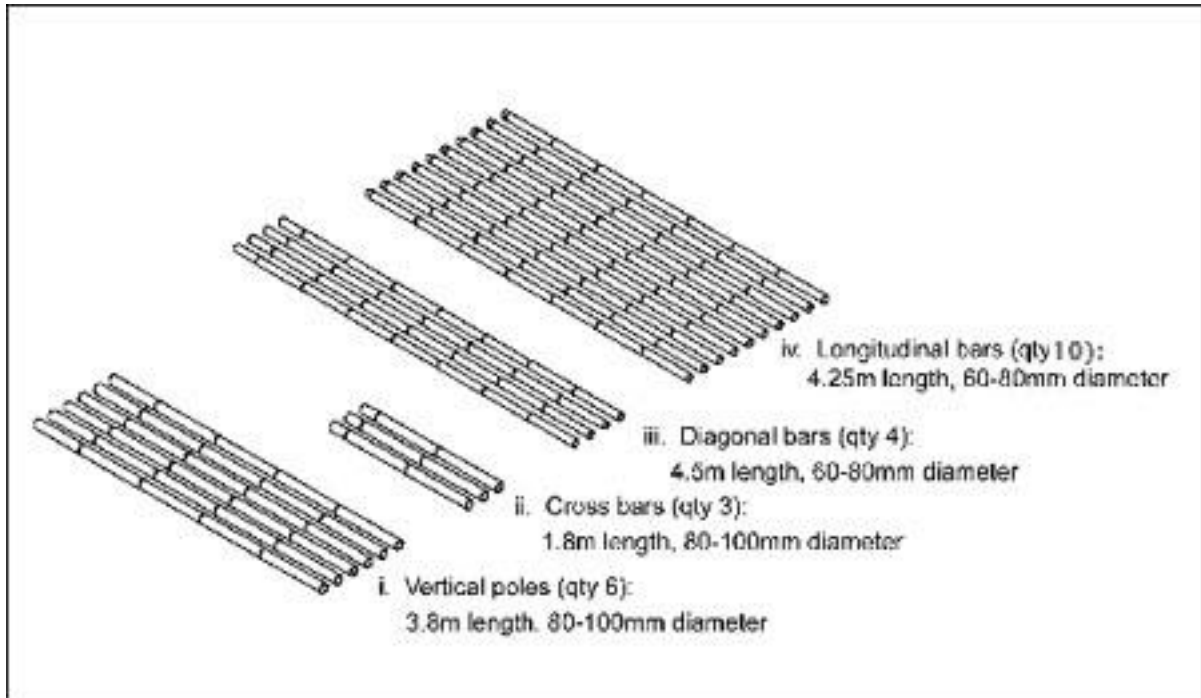


Figure 1: Bamboo poles

### Total length of bamboo required

60-80 mm diameter – 61.3m (Normal length of usable bamboo is 6 to 7m per pole hence the total number of bamboos required is 10).

80-100 mm diameter – 28.2m (Total number of bamboos required is 5)

**Note:** If the smaller diameter bamboos are not available, then the larger diameter bamboo could also be used.

### 4.2 Tools and Equipment

- ◆ Bamboo – The quantity of bamboo required is given in table 1.
- ◆ Tent Cover – Two plastic sheets or other types of cover. Standard size is 5m x 4m.
- ◆ Wooden plates: 60 wooden (plywood) plates of 6–8mm thick and 50mm (L) x 50mm (W) – two for each bolt. Wooden plates are required only if bolts are to be used.
- ◆ Binding wire or 32 bolts each 25cm long.
- ◆ Pliers.
- ◆ Markers.
- ◆ Hand saws.
- ◆ Measuring Tape.
- ◆ Digging tools.

### 4.3 Jointing

The most important thing to decide is the method of jointing the bamboo. There are two ways to do so.

i) Use of binding wire

ii) Use of bolts

#### 4.3.1 Binding wire

Bamboo wire can be used for the bamboo jointing if the shelter is expected to be in use for less than about six months. If used for longer, the wire may rust and weaken the bindings, leading to failure of the structure.

- ◆ For each joint you require two pieces of 2.5m long and one piece of 1m long binding wire. A total of 6 meters is required.
- ◆ Take a piece of 2.5 m long wire and wrap it diagonally around the joint three times.
- ◆ Use pliers to twist together the two ends of the wire to tighten it around the joint.
- ◆ Repeat the process in the other diagonal direction (refer to figure 2)
- ◆ Use the 1-meter long binding wire to tighten the ties in place by wrapping it around the ties between the bamboos.

**Note:** Bamboos have to be sufficiently dry to use binding wire for jointing. The ties will loosen if freshly cut bamboos are used, as the diameter shrinks when bamboo dries.

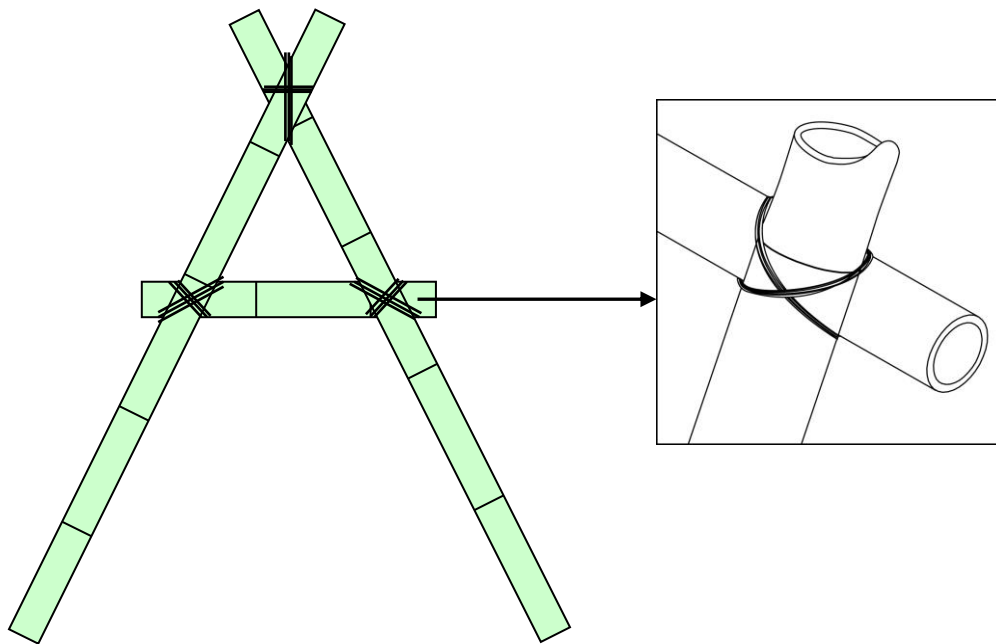


Figure 2: Jointing by binding wire

### 4.3.2 Bolts

Bolts are expensive and fabrication takes a little longer than with wire. However, this method is recommended if you wish to use the shelter for a long period of time or if you wish to use bamboo poles repeatedly to build shelters in other locations. The initial cost is higher but the cost will be recovered in the long run. It is also easy and less time consuming to disassemble and reassemble the structure.

- ◆ You need 32 bolts of 15-20 cm diameter
- ◆ You also require 50mm (L) x 50mm (W) wooden plates to support the bamboo from the sides.
- ◆ Drill the bamboo along with wooden plates.
- ◆ Use bolts as shown in the figure below.

**Note:** Electric power may be required for drilling.

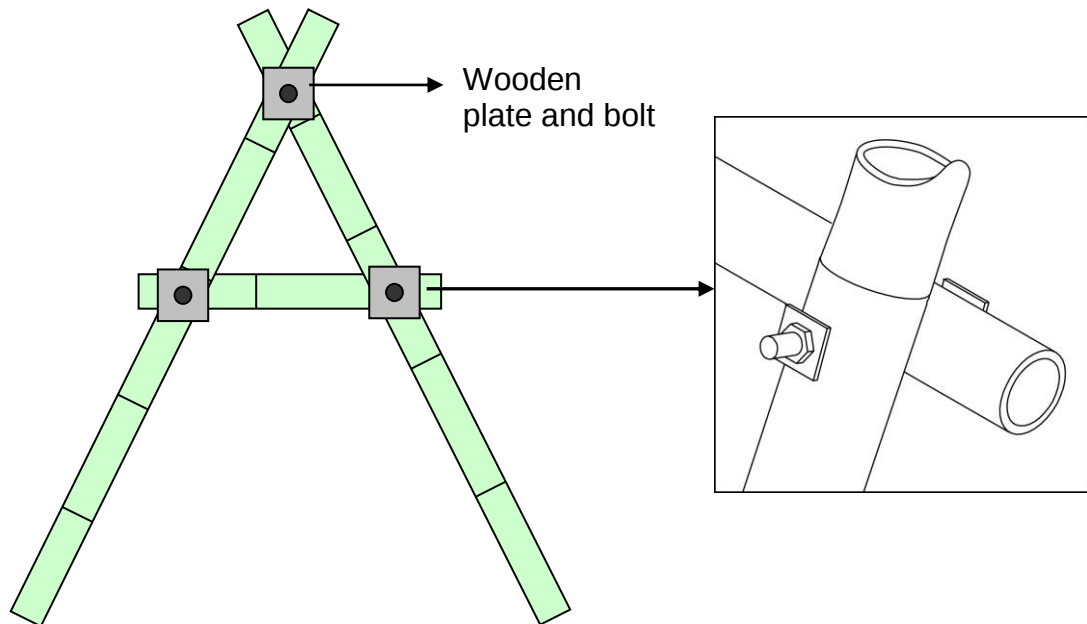


Figure 3: Jointing by Bolts

#### 4.4 Pre-fabrication of Vertical Posts

Firstly three vertical frames should be fabricated. 3.8 meter long bamboo poles are used for the purpose. To prepare an each frame, the following steps have to be followed.

- ◆ Take two 3.8 m long bamboo poles.
- ◆ Measure 3.5 m from the base and mark using a marker pen.
- ◆ If you are using bolts, drill a hole at the marked place.
- ◆ Measure 3 meters on the ground to set the distance of the pole bases.
- ◆ Locate one end of each vertical post on the marked points (3 meters apart).
- ◆ Join the top ends of the posts at the marked location, 3.5m high from base, using wire or bolts (refer section 4.3).
- ◆ Measure 2 meter up from the base of each culm and mark on both poles.
- ◆ Tie the cross bar (1.8m length) to both bamboo poles (refer section 4.4).
- ◆ Repeat the process to fabricate other two more frames (as total required is 3).

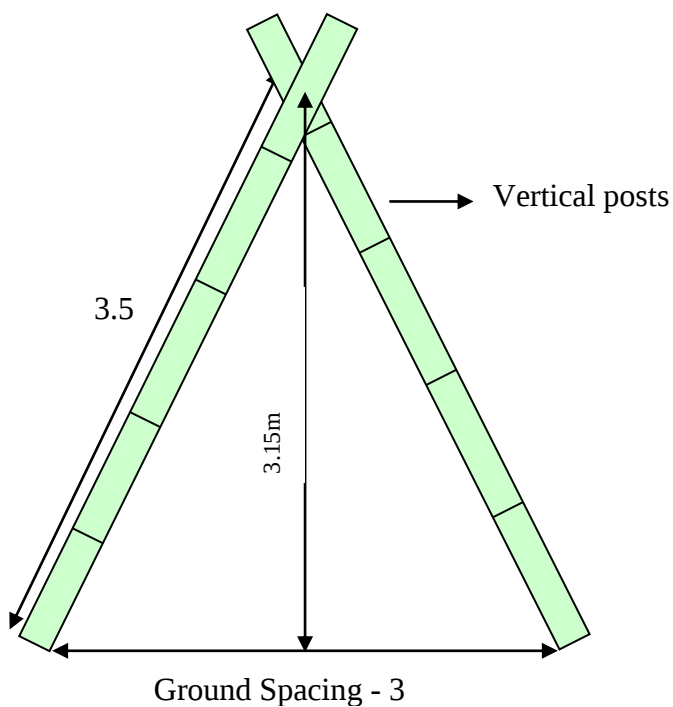


Figure 4: Shelter façade

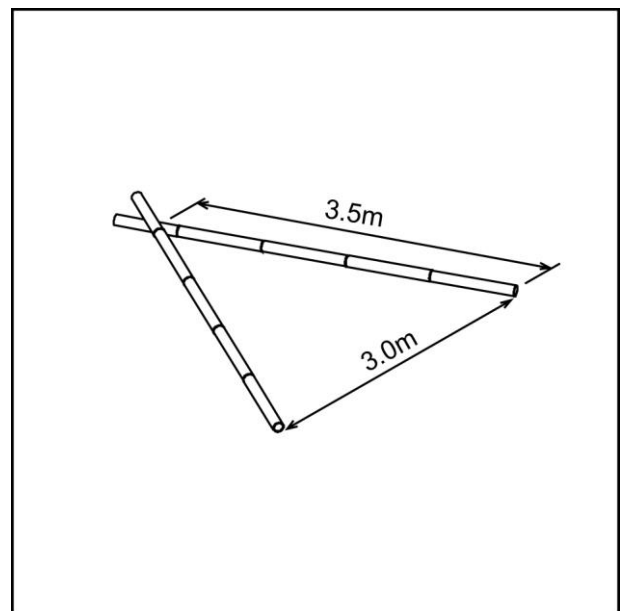


Figure 5: Assembling Posts

#### 4.4.1 Cross Horizontal Bars

Cross bars are 1.8 meter long bamboo poles which are used to support the longitudinal (horizontal) bars in the later stage. They are tied with vertical posts two meters from the base of the vertical pole (1.8-meter vertical distance from the ground). Please see the following figures for the details.

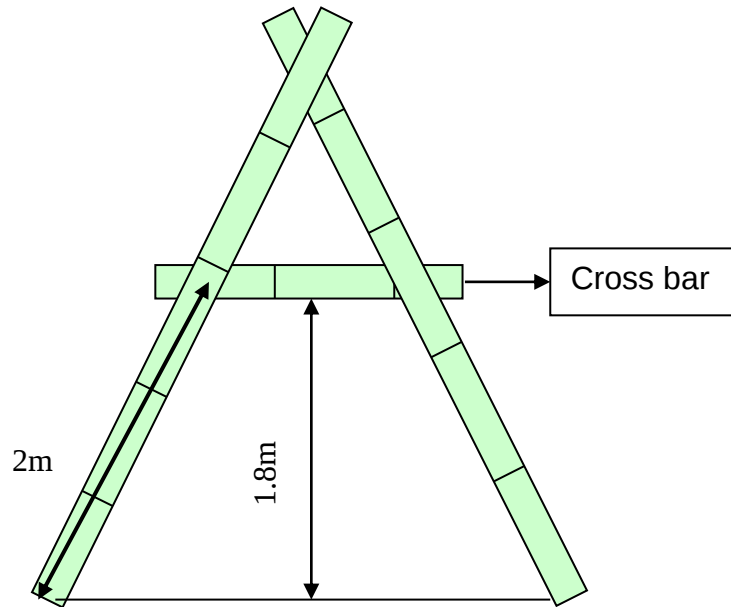


Figure 6: Cross bar

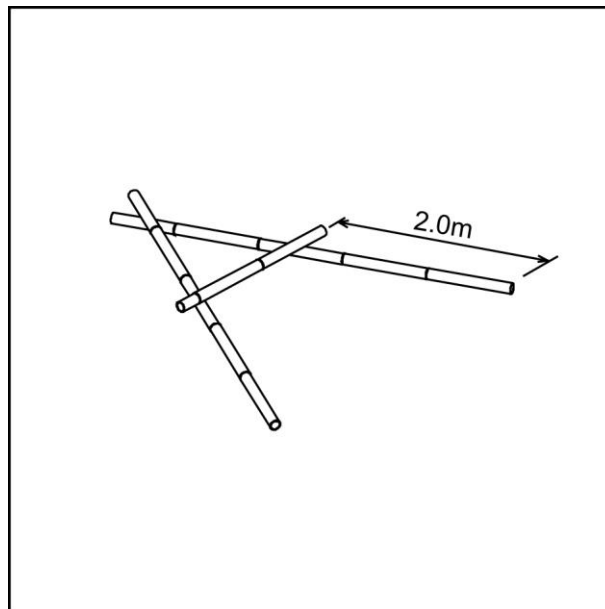


Figure 7: Assembling the cross bar

## 4.5 Fabrication - Assembling the Shelter Frame

### 4.5.1 Assembling two vertical posts

Three vertical prefabricated frames are required to fabricate an eight-meter long refugee shelter. The frames are placed 4m apart.

- ◆ Insert the basal ends of each pole of the first frame 10 cm into the ground to anchor the frame firmly and give the frame more stability.
- ◆ Ensure the post is vertically orientated using a line bob.
- ◆ Measure four meters from the first post and measure another 4m from the second post. Make a mark at each place on the ground.
- ◆ Use rope to align three posts in one line.
- ◆ Ensure the first two frames are upright (for convenience the third post will be placed later).

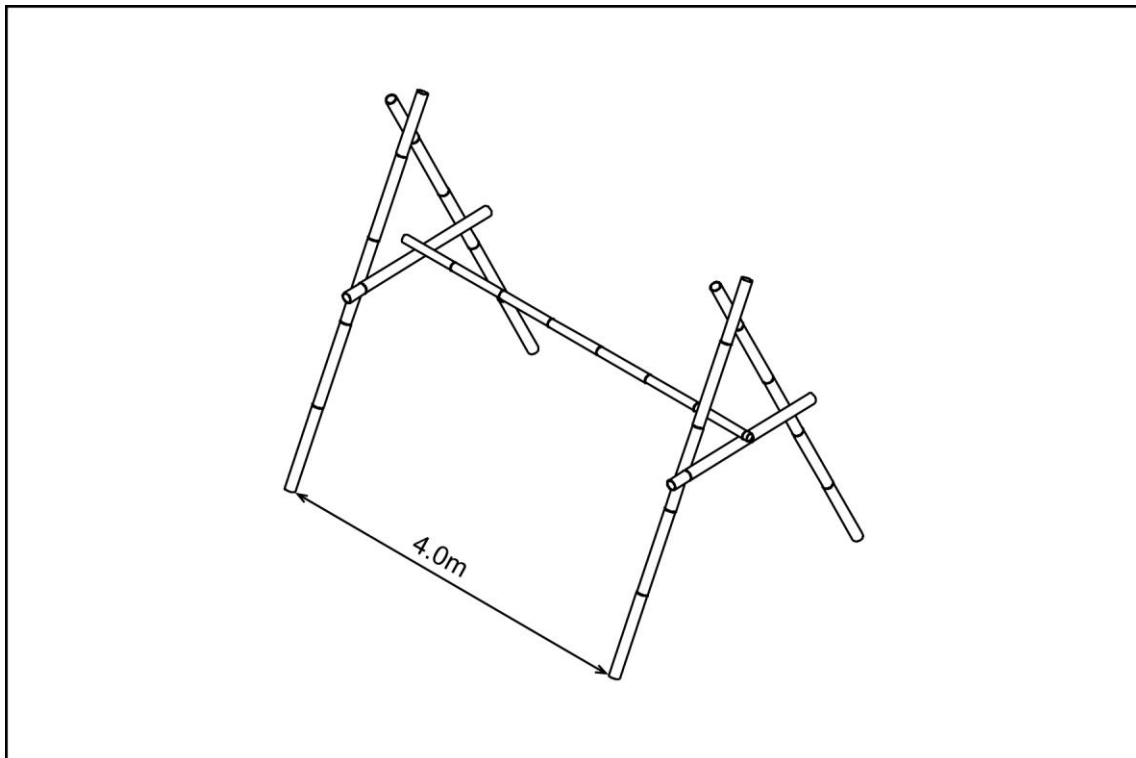


Figure 8: Standing the first 2 posts and middle longitudinal (horizontal) bar (I)

#### 4.5.2 Central longitudinal (horizontal) bar and third post

- ◆ Hold the two vertical frames vertical (refer section 4.5.1).
- ◆ Place the central horizontal bar at the mid point of the cross bar of each frame (figure 8).
- ◆ Fix it to the cross bar using binding wire or bolts.
- ◆ Place the third vertical frame in position (4 meter apart)
- ◆ Insert the second central horizontal bar and fix it to the cross bar of the second and third vertical frames (figure 9).

The central bar gives stability to the structure. Now all three frames stand without any external supports.

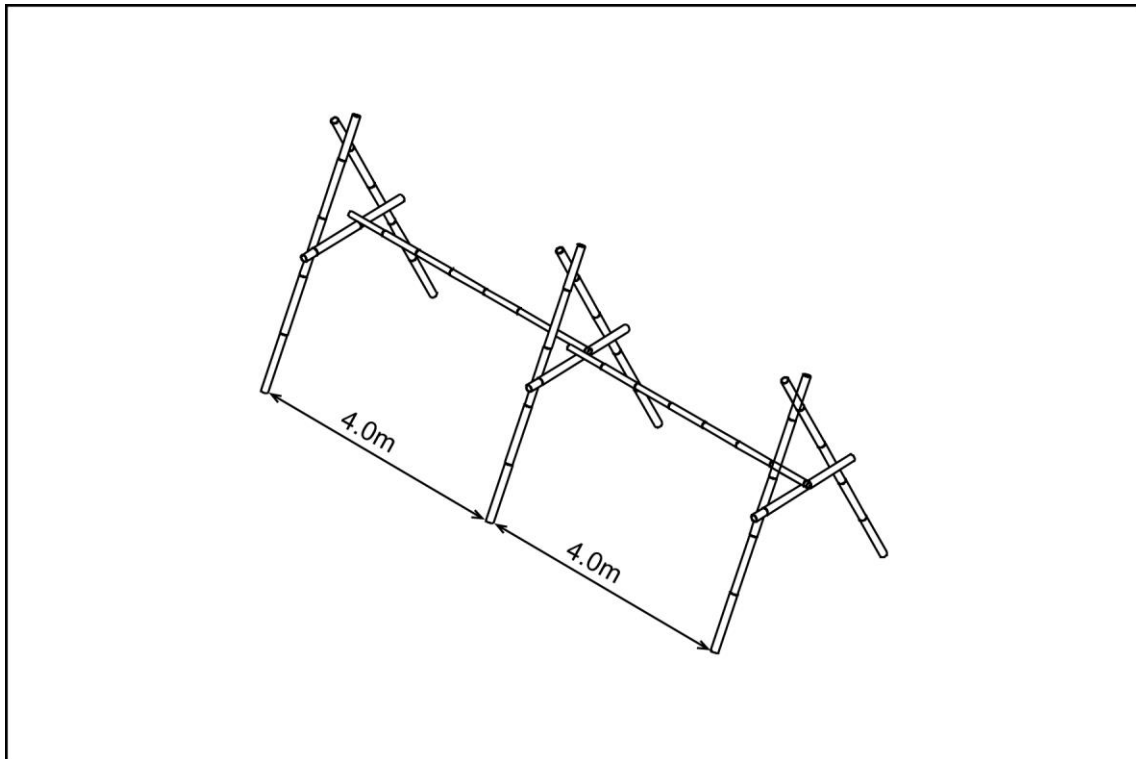


Figure 9: Standing third frame and central longitudinal (horizontal) bar (II)

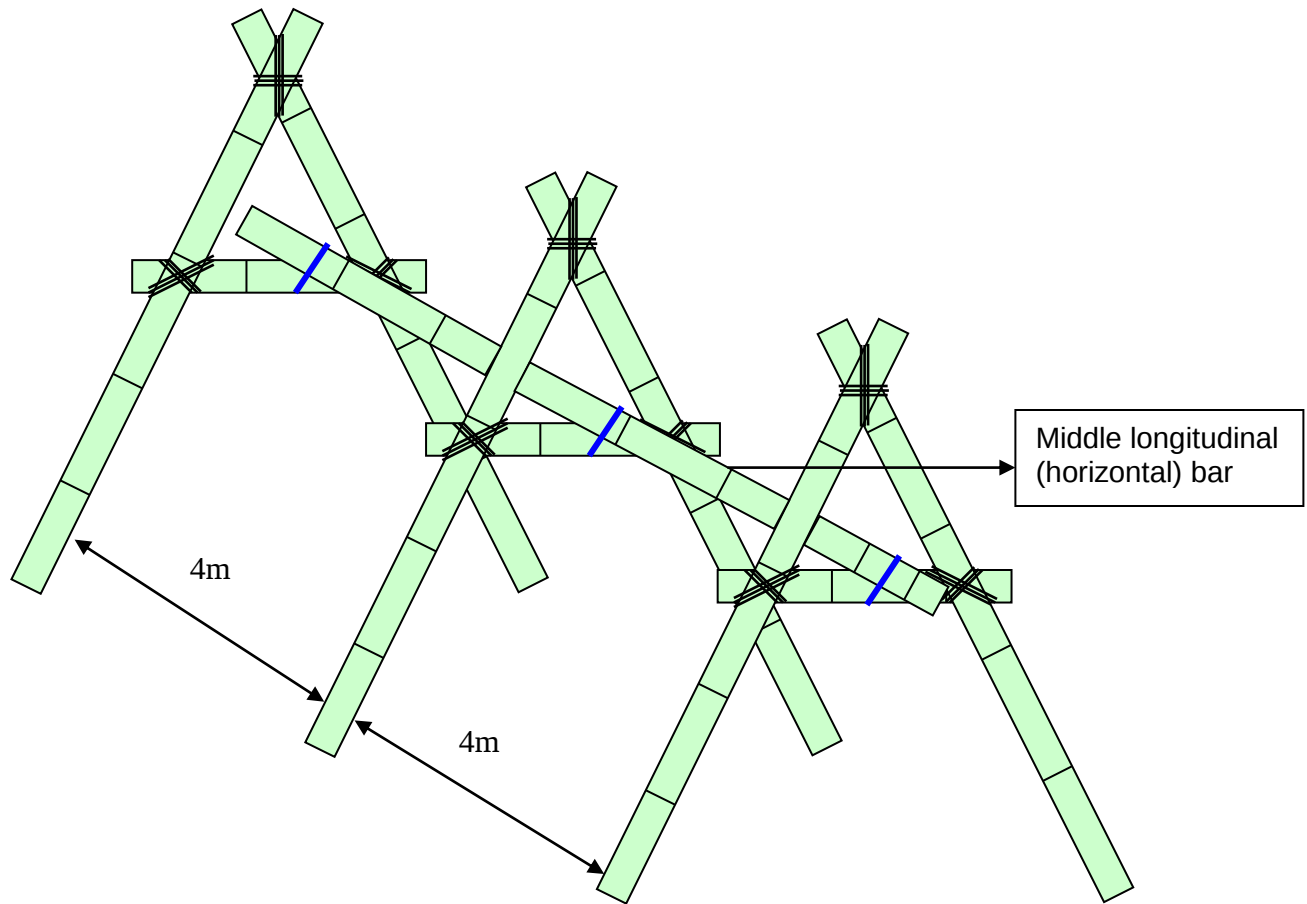
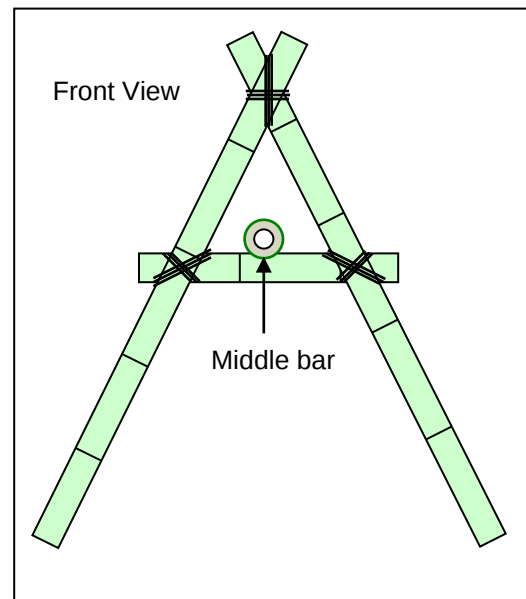


Figure 10: Aligning vertical frames and the middle bar



#### 4. 5.3 Ground level longitudinal (horizontal) bars (I)

After fixing the central horizontal bars, fix ground level longitudinal (horizontal) bars to the both sides of the framework.

- ◆ Take two 8.5m long bars (or four 4.25 m long bars).
- ◆ Place them inside the frame on the ground along the length of the shelter.
- ◆ Fix them to the vertical frames.
- ◆ See figure 11 for details.

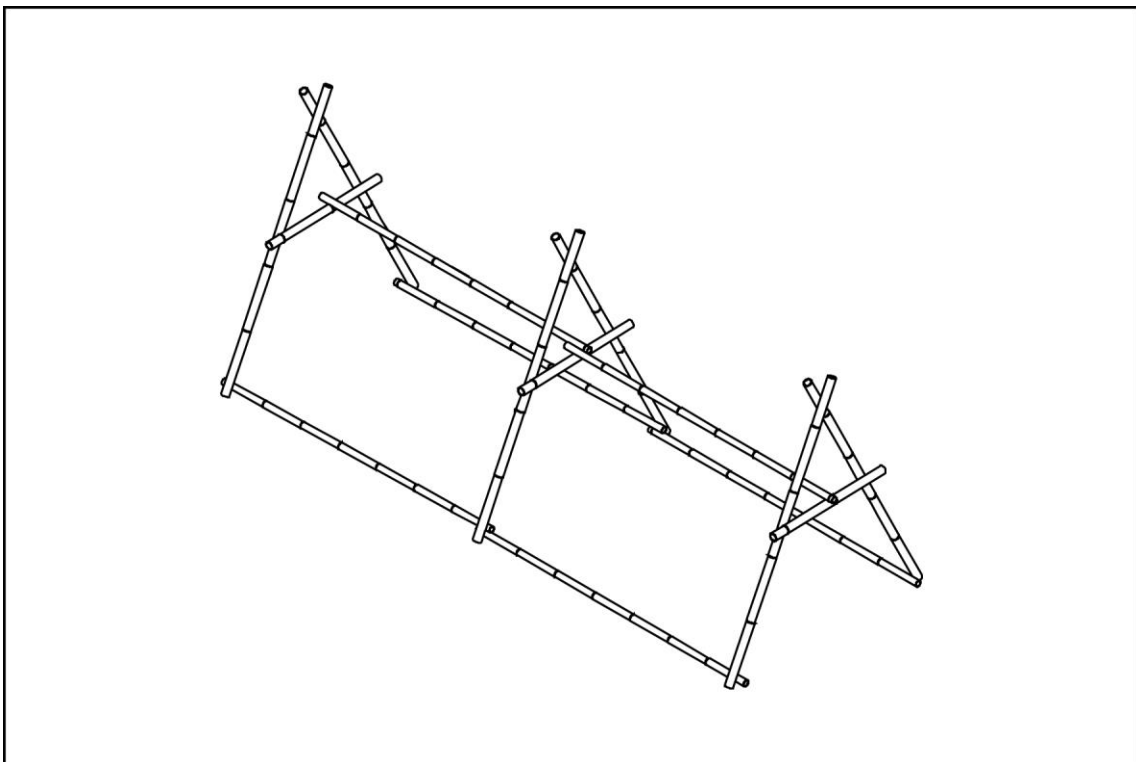
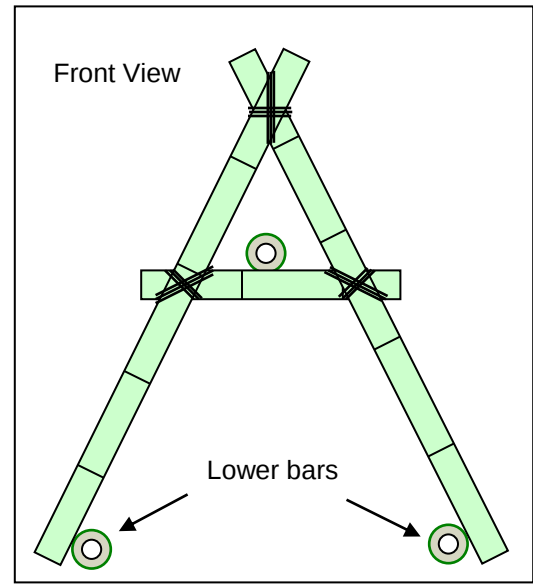
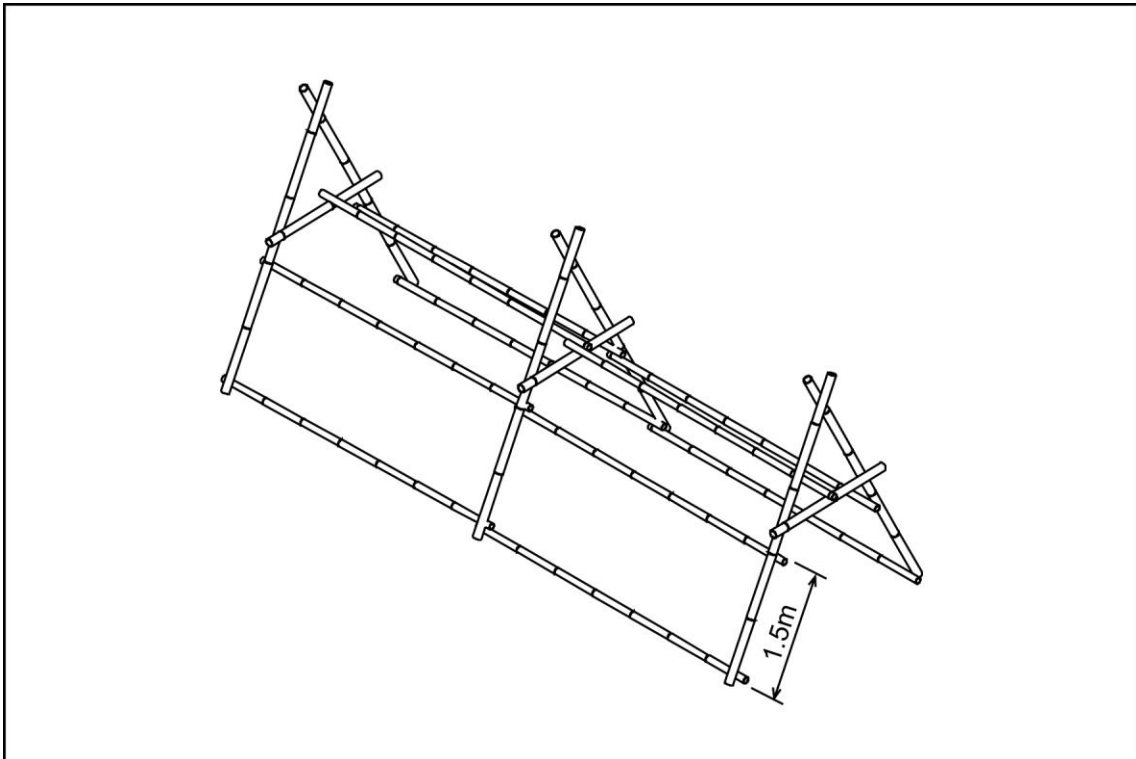
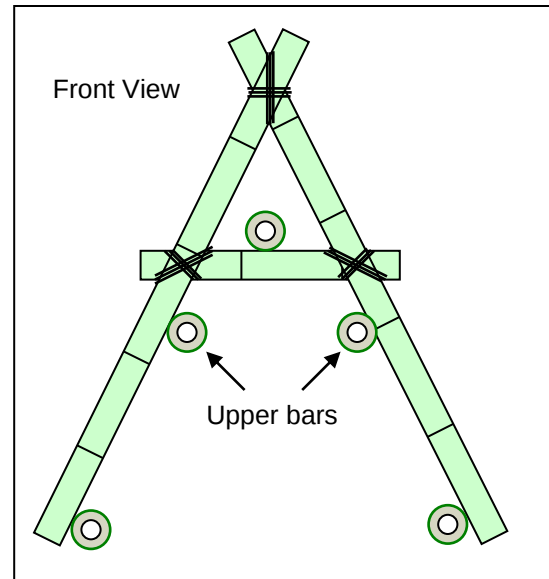


Figure 11: Longitudinal (horizontal) side bars at ground level

#### 4.5.4 Upper longitudinal (horizontal) bars (ii)

Fix two more bars 1.5 m above the ground level.

- ◆ Measure and mark the point 1.5-meter from the ground level along the frame poles.
- ◆ Use bamboo poles of 8.5 m long (or two pieces 4.5 m long per side).
- ◆ Fix them to the frame poles.
- ◆ Repeat the process on the other side.



Picture 12: Fixing the upper bars 1.5 above from the lower ones

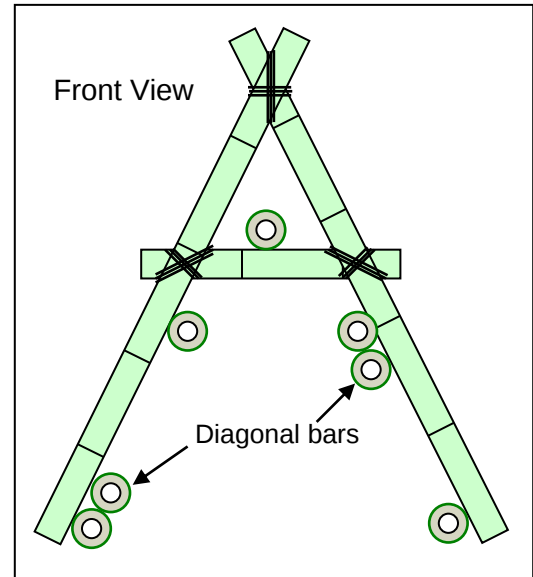
#### 4.5.5 Diagonal Bars

##### Side A

- ◆ Fix diagonal bars as shown in figures 13 and 14. You should fix bars on both sides but in opposite directions.
- ◆ You need two bamboos of 4.5m long for each side.
- ◆ On one side, one end of both diagonal bars meet at the middle frame, like an *inverted "V"*. See figure 13.

##### Side B

- ◆ On the other side, one end of both diagonal bars meet at the base of middle vertical post, like a "V" (Figure 14).
- ◆ Fix them to the frames and longitudinal bars wherever appropriate.



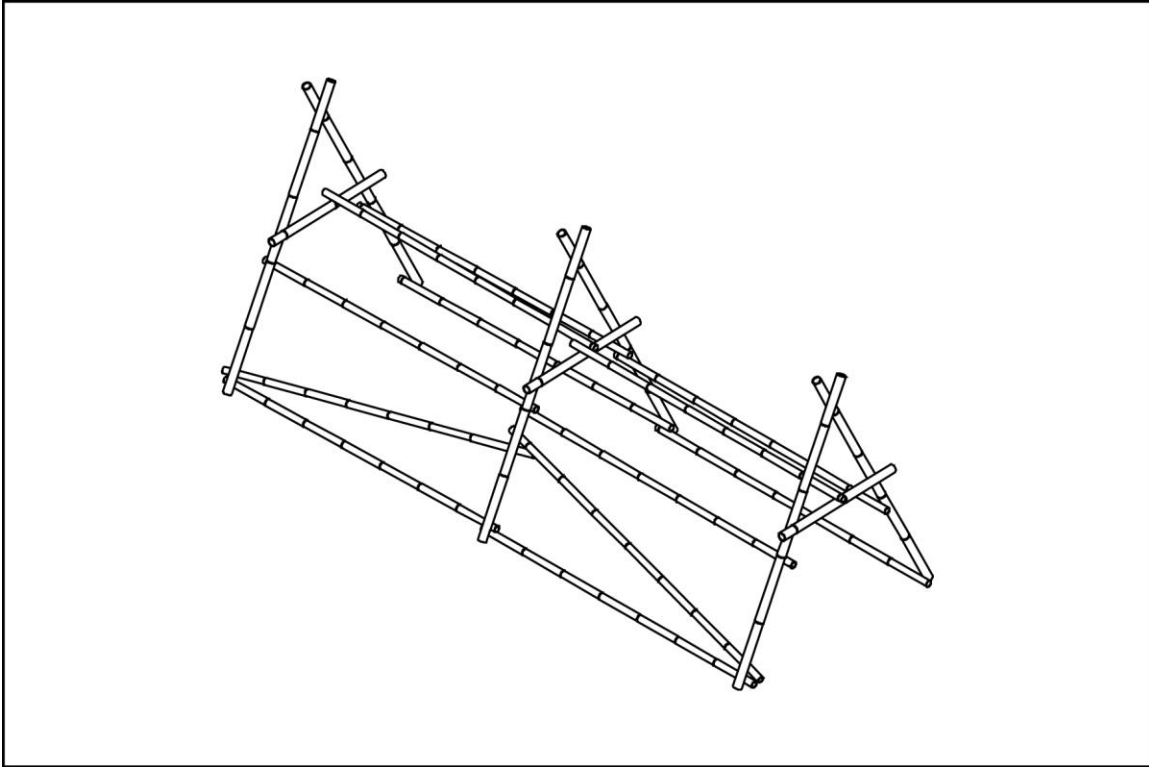


Figure 13: Diagonal bar side A

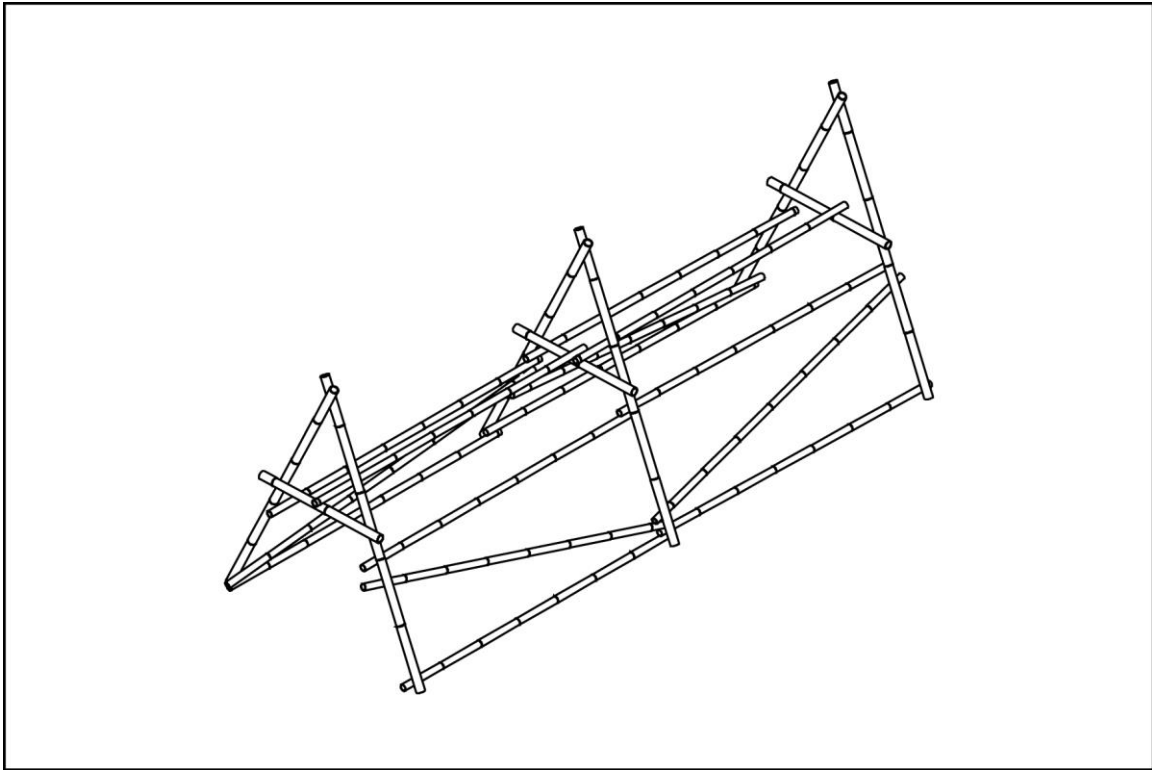


Figure 14: Diagonal bar side B

#### 4.5.7 Shelter Cover

When the bamboo shelter frame is completed, the final task is to put on the roof cover.

You need two covers 4m x 5m. This is a standard size used by UNHCR for refugee shelters. You can fix the plastic (or other) covers using rope and nails to the base longitudinal bars and vertical posts. To give strength to the cover, the distance between each tie should not be more than 0.5 m.

You can also make windows and doors on either ends of the shelter as required.

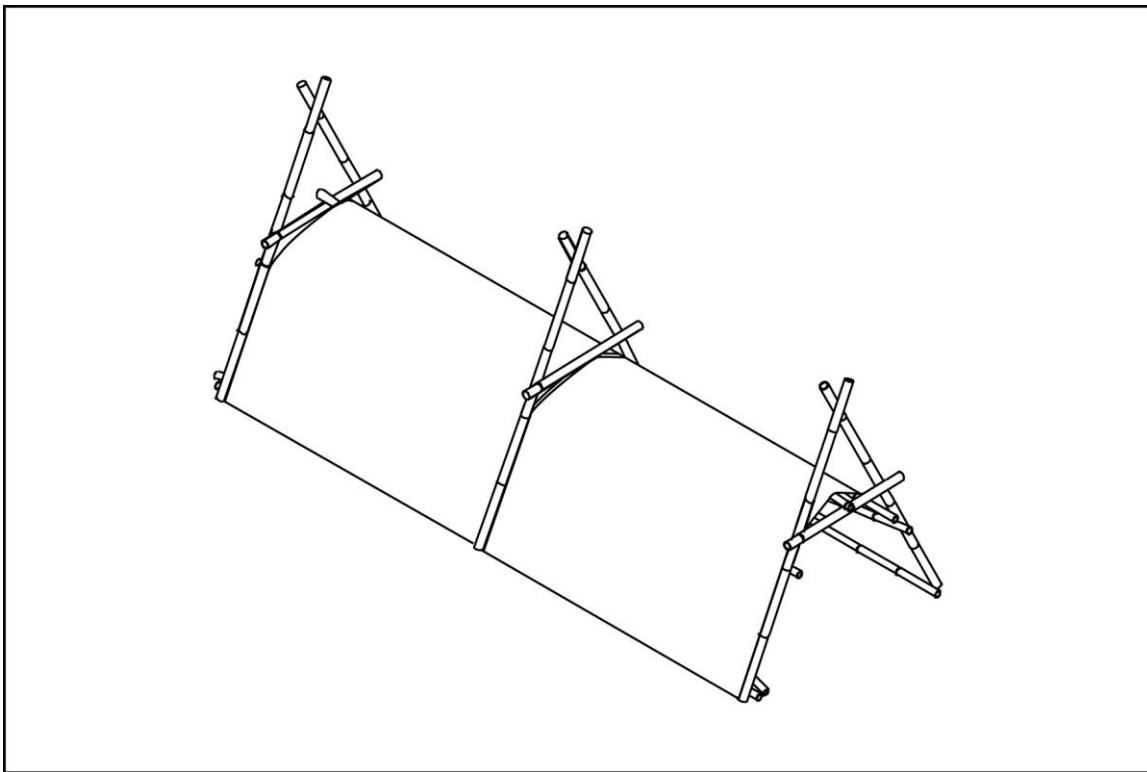


Figure 15: The covered shelter

## Annexes: Photographs



Picture 1: First two frames in place



Picture 2: Third frame showing central and side bars



Picture 3: Side view



Picture 4: Completed shelter frame



Picture 5: First roof cover in place



Picture 6: Second roof cover in place