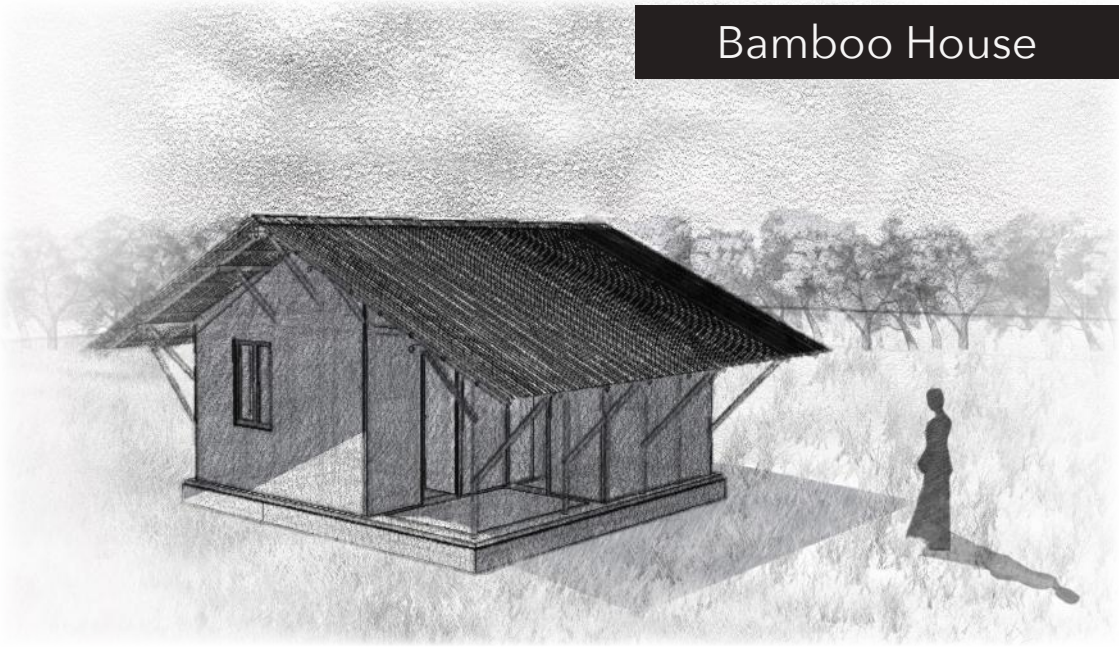
CONSTRUCTION MANUAL

Bamboo House



Habitat for Humanity® Nepal

Habitat
for Humanity®
Nepal

HABITAT FOR HUMANITY NEPAL

Habitat For Humanity Nepal is a non profit organization building simple, decent and affordable housing in partnership with people in need.

In 1997, Habitat for Humanity started operating in Nepal by working directly with the local communities in five districts. By 2005, more than 800 families were served through decent housing. To increase its impact, Habitat Nepal began to leverage on partnerships with non-government organizations, microfinance institutions, and village lending and saving groups. In July 2011, the "Meaningful Life through Housing" campaign was launched to provide sustainable housing through a people-driven approach and cost-effective construction technology. Operations focused on building decent homes incrementally with rural families in eastern and western Nepal. More than 54,000 families have had strength, stability and self-reliance with HFH Nepal until the devastating earthquakes struck in April and May 2015.

Habitat's vision: A world where everyone has a decent place to live.

Mission: Habitat for Humanity brings people together to build homes, communities and hope.

- Focus on shelter.
- Advocate for affordable housing.
- Promote dignity and hope.
- Support sustainable and transformational development.

Habitat Nepal is committed to building homes and hope in both disaster-affected and non-affected areas across the country.

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ABOUT THE MANUAL

This construction manual outlines the techniques and procedures adopted for the construction of the bamboo house designed and developed by Habitat for Humanity Nepal. It intends to serve as a guide and a reference source for the readers interested or involved in the construction of the house. Since the manual only provides the general and the most important parameters of the construction, the readers who are interested or planning on building with bamboo are strongly recommended to consult a trained mason or get technical advice before deciding and use trained masons while building.

On the same note, this manual is also not intended as a substitute for training on bamboo house construction.

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1 | BAMBOO

1.1 INTRODUCTION

The house in this manual is built entirely from treated bamboo on a stone/brick foundation with cement mortar. The house has a gable roof with bamboo structure covered from CGI sheet and mud plastered woven bamboo walls. Bamboo is a sustainable building material very suited for the construction of a house in different regions of Nepal.

1.2 WHAT IS BAMBOO?

- Bamboo is the fastest growing plant in the world.
- It is considered a grass species that grow faster than trees.
- Each piece takes 3 - 4 years to mature.

1.3 WHY BUILD WITH BAMBOO?

- It is the most readily available building material.
- It is relatively cheaper in cost to that of timber.
- It is light in weight making its transportation and construction work easy.
- Due to their flexible nature, they have a wide range of structural and non-structural applications.
- A bamboo structure constructed of well treated bamboos can last upto 50 years.

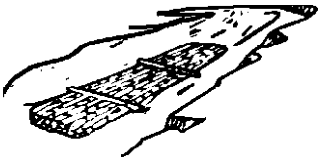
1.2 WHY TREAT BAMBOOS?

- Without correct treatment, bamboo can be destroyed by insects and fungi in a relatively short period of time.
- Untreated bamboo can only last upto 2.5 years.
- Treatment of bamboo extends its durability and useful life, thus delaying its degradation.
- Also treatment preserves the dimensional stability, retains strength and imparts properties such as fire resistance, luster, etc. and improves aesthetic quality.

1.3 TREATMENT

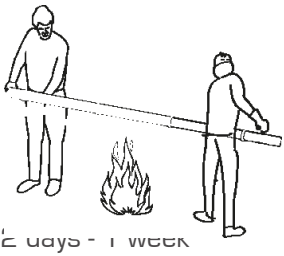
① MAIN TRADITIONAL TREATMENTS

Leaching



1-3 months

Smoking



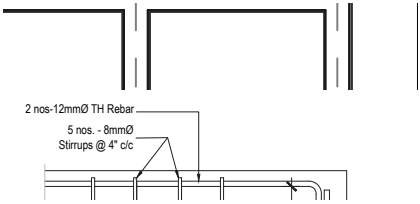
2 days - 1 week

Bamboo lasts

= Upto 10 Years

② MAIN CHEMICAL TREATMENTS

Soaking/Diffusion



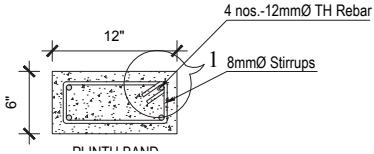
2 -3 Weeks

Bamboo lasts

= Upto 50 Years

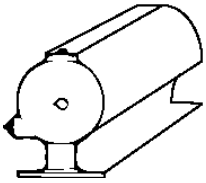
Freshly cut bamboo (max. 2 weeks old)
submerged in a tank filled with preservatives

Modified Boucherie



2 - 3 hours

Vacuum Pressure



Freshly cut bamboo
(max. 24 hours old)

Dry bamboo kept inside the vacuum

Excreting starch content by pressure injecting chemical mix

③ CHEMICAL: BORAX + BORIC ACID + WATER = 1:1:10

2 | SITE SELECTION

2.1 INTRODUCTION

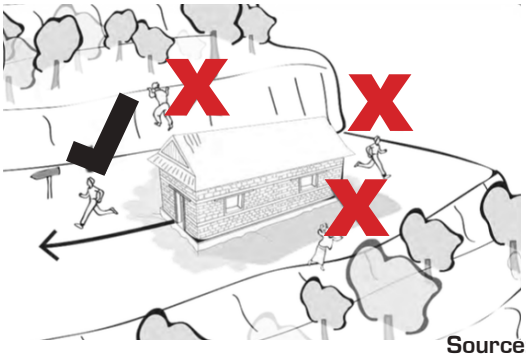
It is important that the house is built in a safe location.
“Choose a safe location for your house. Even if you can’t choose, there are still things you can do.” (Shelter CLuster. 10 Key Messages).

2.2 CHOOSE A SAFE SITE

Avoid flood prone areas, like the bottom of valleys or near river beds.
Avoid areas prone to landslides.

2.3 HAVE AN ESCAPE PLAN

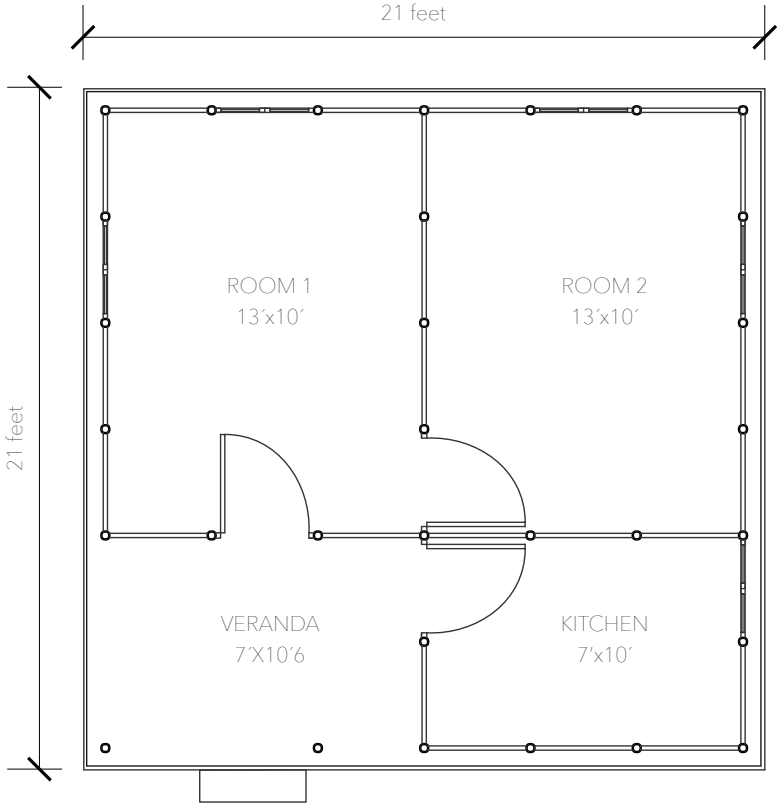
Ensure safe escape for everybody from the site. Have a preparedness plan, which includes all occupants and family members.



Source: Shelter Cluster, 10 Key Messages

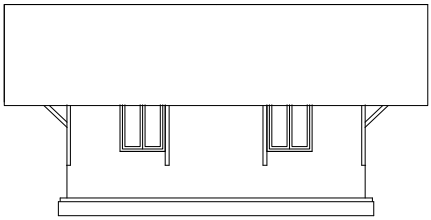
3.1 FLOOR PLAN

The house has two rooms, one kitchen and one veranda.
As the house is flexible and modular, the placements of the rooms can be interchanged as per the owners requirements. However, column locations should not be changed. The placement of door/ window openings can also be altered as per the owners requirements.

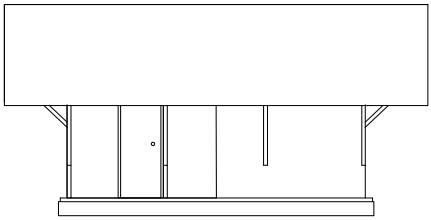


3| HOUSE PLANS

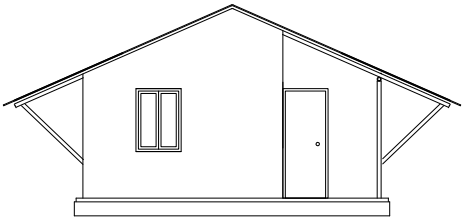
3.2 ELEVATIONS



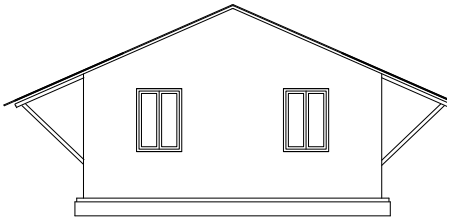
BACK ELEVATION



FRONT ELEVATION



SIDE ELEVATION



SIDE ELEVATION

4 | BILL OF QUANTITIES

4.1 CONSTRUCTION MATERIALS AND MANPOWER

Below is the list of materials and labours required to build the bamboo house. Re-use of materials already in the owner's possession is recommended to reduce the cost of the house.
Make sure to get an estimated cost of the materials and labours to ensure that there is enough funding to complete the construction.

S.N	Description	Quantity	Unit
	Manpower		
1	Skilled Labour	101	Nos
2	UnSkilled Labour	222	Nos
	Materials		
3	Cement	25	Bags
4	Sand	2	Tractor @3 m3/ Tractor
5	Aggregrates	2	Tractor @3 m3/ Tractor
6	Stone	3,0	Tractor @3 m3/ Tractor
7	mud	4	Tractor @3 m3/ Tractor
8	Local wood	0,208	m3
9	19mm plywood	4,0	m2
10	Nail	2	Kg
11	10mm Reinforcement(kg)	116	Kg
12	7mm Reinforcement(kg)	51	Kg
13	Binding wire(kg)	4	Kg
14	Bitumein washer	350	nos.
15	24 gauge CGI sheets	6	bundle
16	3mm commercial plywood	3	m2
17	Handle	16	nos.

4 | BILL OF QUANTITES

S.N	Description	Quantity	Unit
	Materials		
18	Hinge	26	nos.
19	Cheskin	20	nos.
20	lockset	6	nos.
21	Door lock	3	nos.
22	2.5" bamboo	30	nos.
23	2" bamboo	50	nos.
24	3" bamboo	125	nos.
25	1.5" bambo	30	nos.
26	J-hook	95	nos.
27	Ridge sheet	10	nos.
28	U-Shaped Strap (5 mm thk)	40	nos.
29	Straight Strap (5 mm thk)	15	nos.
30	Varnish	7	ltr.

List of Nut bolts used

S.N	Diameter (mm)	Length (inch)	Quantity (nos.)
1	6	3	200
2	6	9	100
3	8	4	156
4	10	5	100
5	10	6	50
6	10	7	40
7	12	10	4

5.1 INTRODUCTION

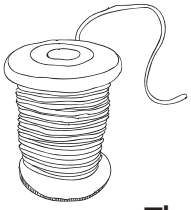
Once the site is selected, dimensions of the house (Chapter 3) and the foundation (Chapter 6) are known, start cleaning the site and doing the layout. The layout will guide the placement of the house. It is recommended to be done by 2-3 persons.

5.2 TOOLS NEEDED

1

Measuring tape

2

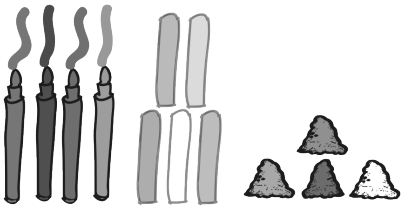


Thread

3

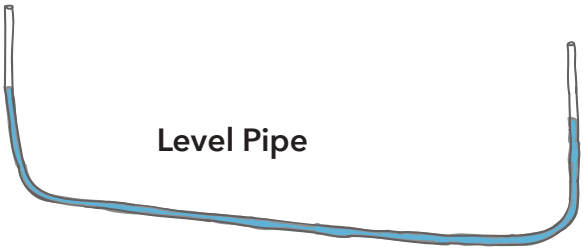
Stakes

4



Colour to mark on the stakes and ground

5

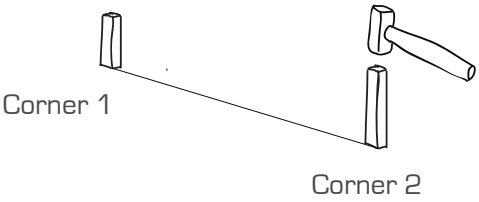


Level Pipe

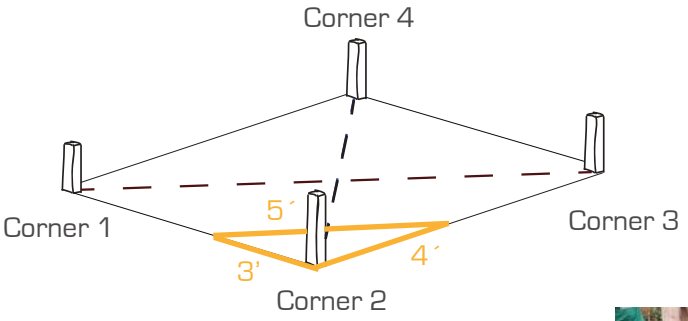
5 | LAYOUT

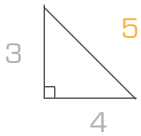
5.3 STEPS

1. Measure out one side: Place stakes at each side (corners 1 and 2). Use a hammer or a similar tool to bang in the stakes.

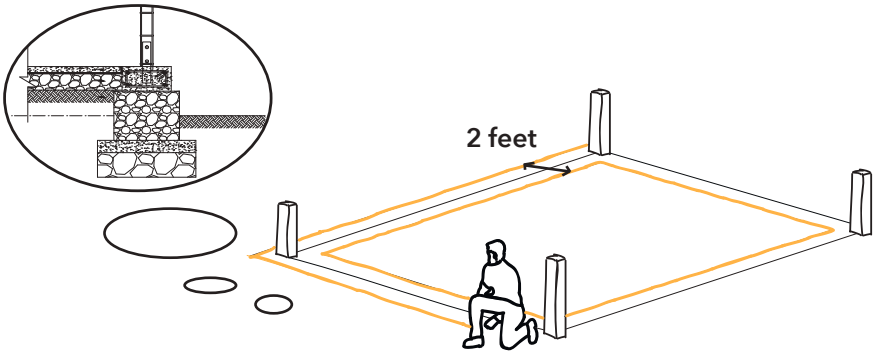


2. Use the 3-4-5 method to get the right angles: To find the right angle, measure 3 feet , 4 feet on the other and the diagonal joining them has to be 5 feet. Once the angle of 90º is obtained, measure corner 3 and place another steak.
Repeat the same process in corners 3 and 4.

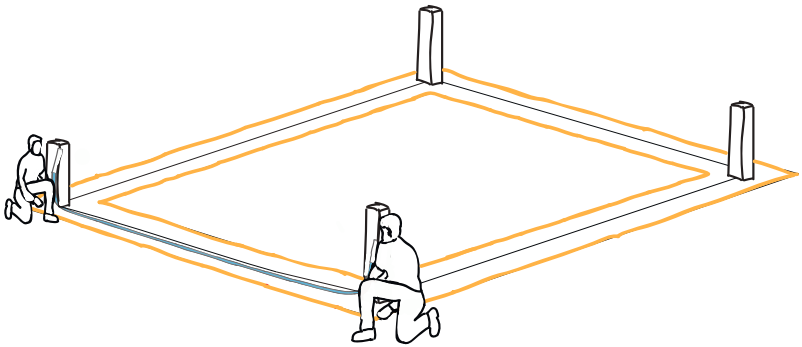




3 Measure the thickness of the foundation: With a thread from stake to stake measure the thickness of the foundation and mark it with colour.



4 Level the land: It is very important to make sure the house and therefore the ground is leveled. Use a level pipe and fill it with water. With that, mark the heights on the stakes.



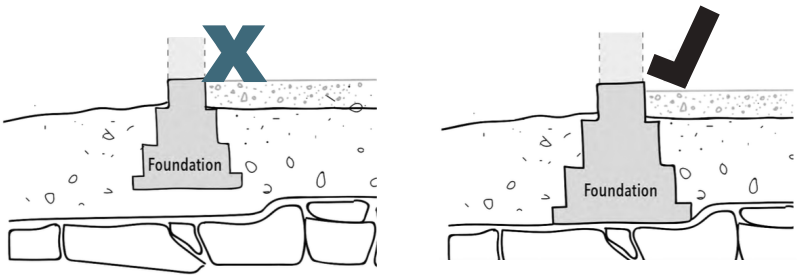
6 | FOUNDATION

6.1 INTRODUCTION

The foundation of the house is made up of stone with cement mortar. “A house is stronger if it´s built on strong foundations” (Key Messages).

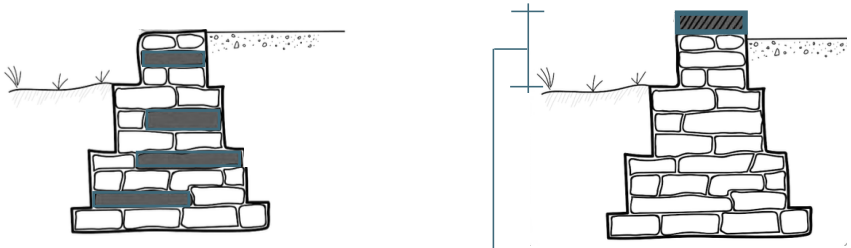
6.2 PRINCIPLES

1. Make sure the foundation lays on firm ground.
   Don’t build on soft ground. If there is soft ground, dig deeper to reach the firm ground.



2. Tie stones are esential to provide stability to the foundation.

3. Add a plinth band to your foundation to increase its strength.

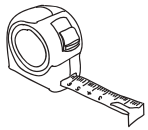


Plinth level should be at least 1’ above external ground level and higher than past flood water level to stop water going inside the house

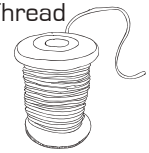
Source: Shelter Cluster, 10 Key Messages

6.3 TOOLS NEEDED

1. Measuring tape



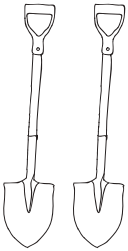
2. Thread



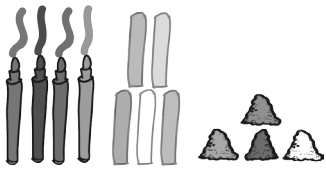
3. Float

4. Water buckets

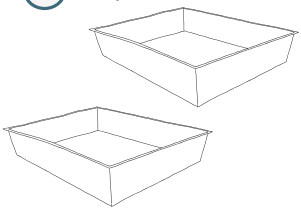
5. Shovels



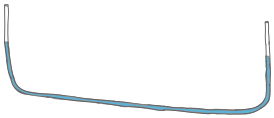
6. Color to mark on the stakes and ground



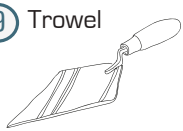
7. Trays



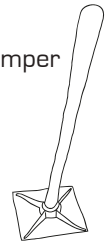
8. Level Hose



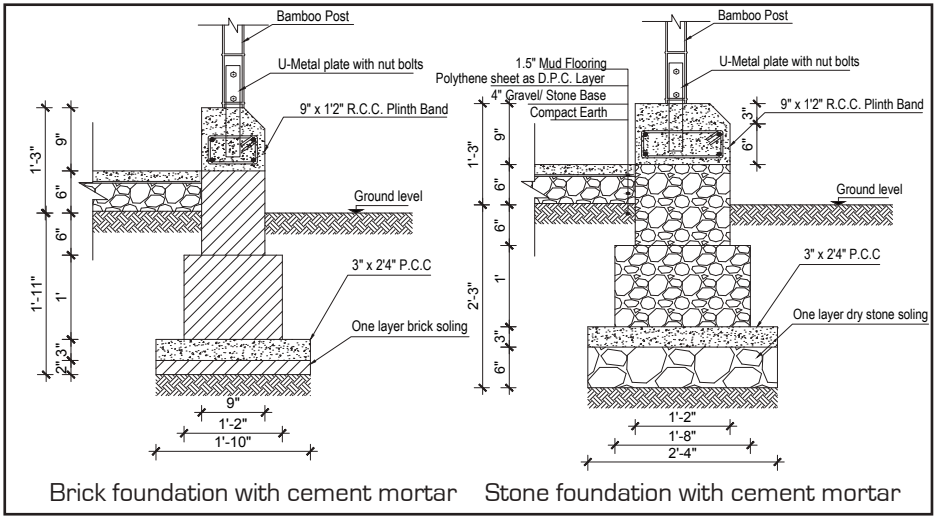
9. Trowel



10. Wooden Tamper



SECTION DETAILS

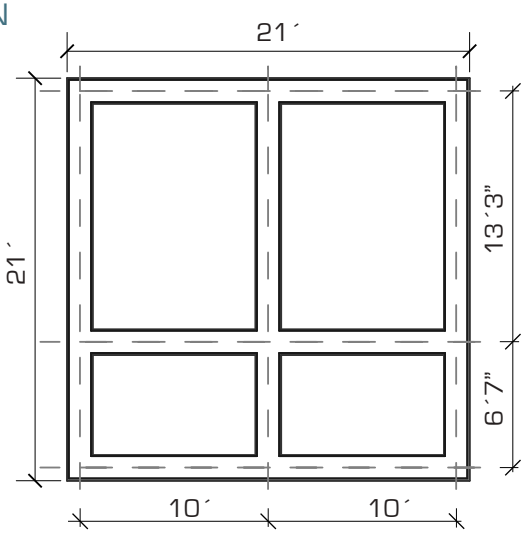


Brick foundation with cement mortar

Stone foundation with cement mortar

6| FOUNDATION

TRENCH PLAN



6.4 STEPS

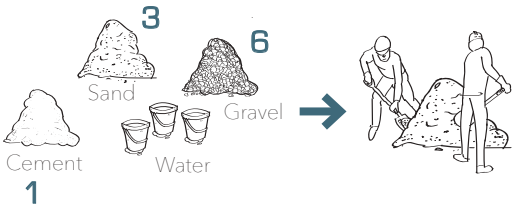
(1) First, dig a trench down to the firm ground (minimum 1'6" or as required). Then, place a layer of dry stone soiling.

② Fill the gaps with gravel

③ Once the gaps are filled, pour PCC (Plain Cement Concrete).

NOTE: Ensure the foundation is leveled at each step. Once the PCC is layed the work should stop for 18-24 hours and the PCC should be kept damp so it cures properly.

PCC RATIO: 1:3:6



To ensure a good mix keep in mind the following tips:

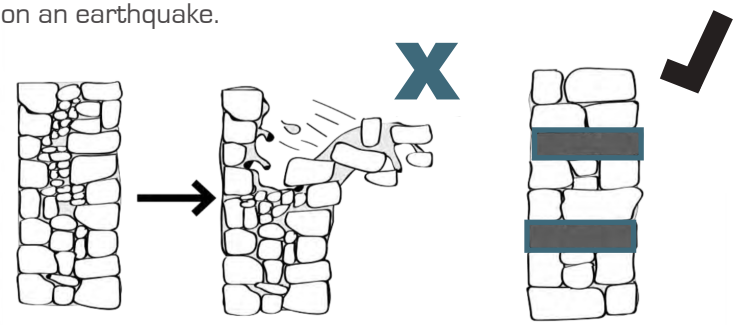
- Use clean water.
- Do not mix directly on ground but rather use an impervious surface (tin/plastic)
- Mix it dry for 2 times and wet for 1 time.

6| FOUNDATION

④ After pouring the layer of PCC, lay the stone foundation with cement mortar. For a strong foundation, ensure the wall is built following the stone wall principles shown below

STONE WALL PRINCIPLES

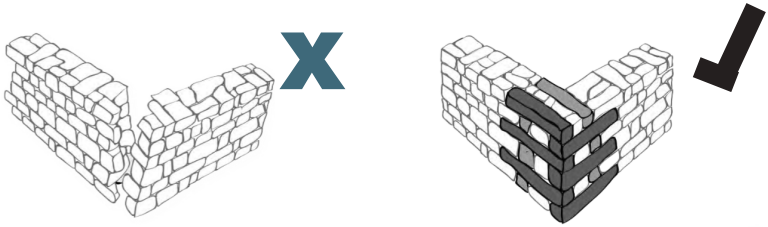
① Use tie stones, as small stones can push the wall apart on an earthquake.



Source: Shelter Cluster, 10 Key Messages

② Use good materials. It is important to have big stones touching as much as possible.

③ Corner stones strengthen the wall and help reduce the risk of corner collapse



10 Key Messages

CEMENT MORTAR RATIO: 1:5 for Stone
1:4 for Brick

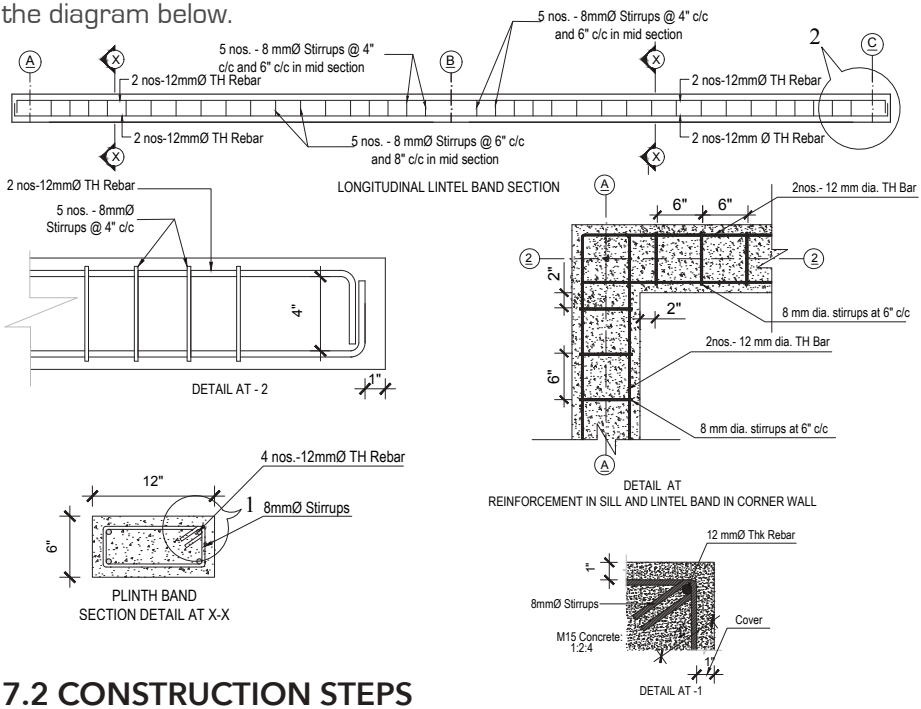
1 PART OF CEMENT

5 PARTS OF SAND

7 | PLINTH BAND

7.1 INTRODUCTION

The plinth band of cement and steel bars gives strength and stability to the foundation and ties it together. The steel in the band are arranged as per the diagram below.



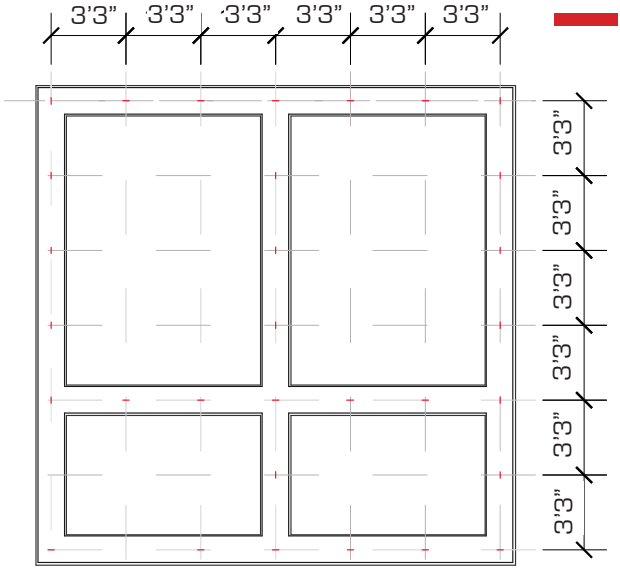
7.2 CONSTRUCTION STEPS

1. At the same time the foundation is being built, prepare the reinforcing steel for the banding. Begin bending the stirrups and then the main bars.

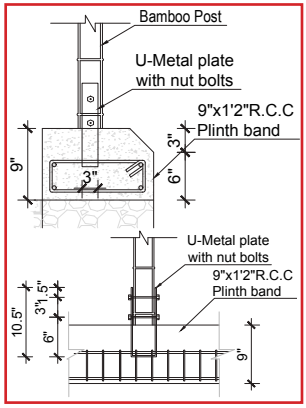
7 | PLINTH BAND

2 Fix rebars and stirrups in place on the foundation.
Ensure that the main bars bend around corners and have overlapping length (minimum 50 times the diameter of the re-bars being used).
Ensure that atleast 1" gap is maintained between the edge and the rebars.
Use small stones as spacers.

3 Place U-Straps for connecting the bamboos to the foundation. The U-straps should be attached to the reinforcing steel.



Placement of U-straps

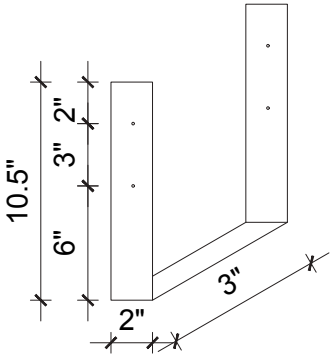


It's important to have a slope on the banding to protect the bamboo from rain

7 | PLINTH BAND

④ Proceed to place the formwork. The formwork should fit tightly to the foundation so that the concrete mix when poured does not leak out. Also, level the height of the concrete on formwork.

5 Mix and pour the concrete.



U-Metal strap thickness = 2.5 mm
Hole diameter = 8 mm

RCC RATIO: 1:1.5:3

1 PART OF CEMENT

1.5 PARTS OF SAND

3 PARTS OF GRAVEL

NOTE: After 2 hours of laying of the concrete, when it has begun to harden it should be kept damp for around 24h. No work should be done on top for at least 24 hours to allow for concrete to fully set.

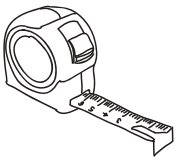
8 | BAMBOO STRUCTURE

8.1 INTRODUCTION

Once the foundation is ready, start placing the bamboo structure. To save time, the bamboo pieces can be cut and varnished while the foundation is being built.

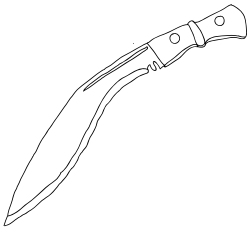
8.2 TOOLS NEEDED

1. Measuring tape

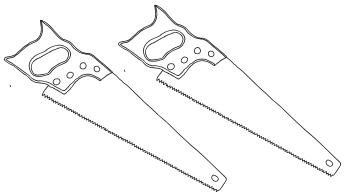


2. Markers

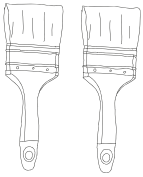
3. Gurkha Knife



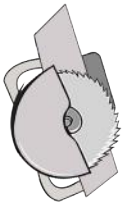
4. Saws



5. Brushes



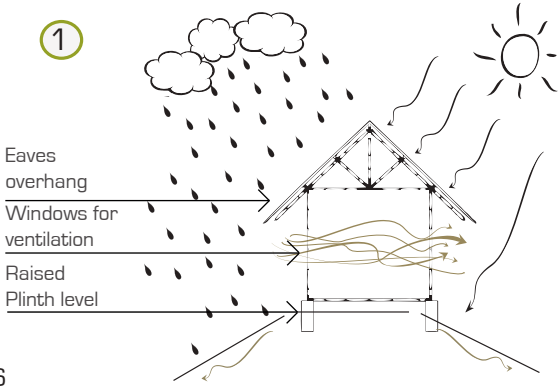
6. Electric cutter



8.3 BAMBOO DESIGN PRINCIPLES

If the bamboo house is built using these principles, it will last longer; upto 50 years.

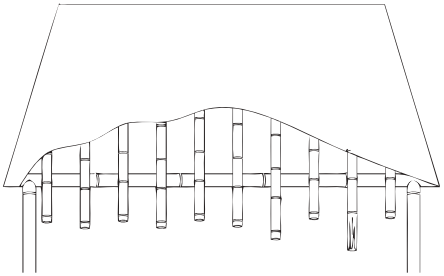
1



Bamboo should always be well protected from rain and sun. Moreover bamboo should be treated with a boron compound to be protected from fungi and insects and increase its durability.

2 The nodes are the strongest part of the bamboo and therefore it is very important to place them properly when building. Bamboo should be selected and cut so that the node is as close as possible to the connections.

3 It is crucial also that each bamboo of the structure finishes as close as possible to a node as this will protect the bamboo from cracks, moisture and degradation.



Source: Humanitarian Bamboo Guidelines

8.4 CONSTRUCTION STEPS

8.4.1 BAMBOO STRUCTURE. PART ONE

1 Cut the bamboo elements, mark them and apply 2 coats of varnish to protect the bamboo further and to give a nice finishing (Picture 1).

8 | BAMBOO STRUCTURE

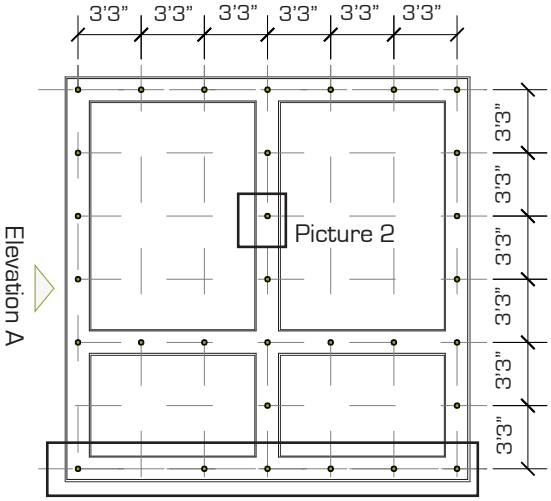
Picture 1

2 Bolt the columns to the metal straps.

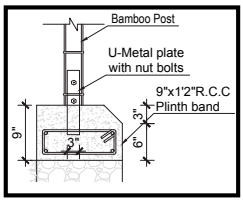
Ensure that there is a small gap (2-4 mm) between the bamboo base and the plinth to stop the column from rotting.

Columns

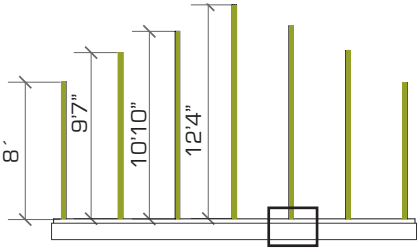
Sn.	Diameter	Length	Quantity
1	3”	12’4”	3
2	3”	10’10”	10
3	3”	9’7”	5
4	3”	8’0”	13



Picture 2



Detail 1



Elevation A

Detail 1

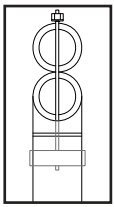
Picture 2

Picture 3

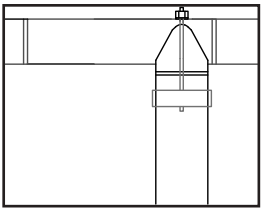
Picture 4

8 | BAMBOO STRUCTURE

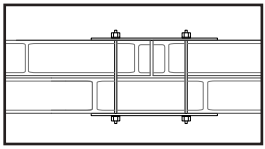
3 Bolt the beams to the columns with T-bolts as shown in the details. The middle beam will be composed of 2 members. To join them together, use metal straps and bolts as shown in the figure below (Detail 2 and 4).



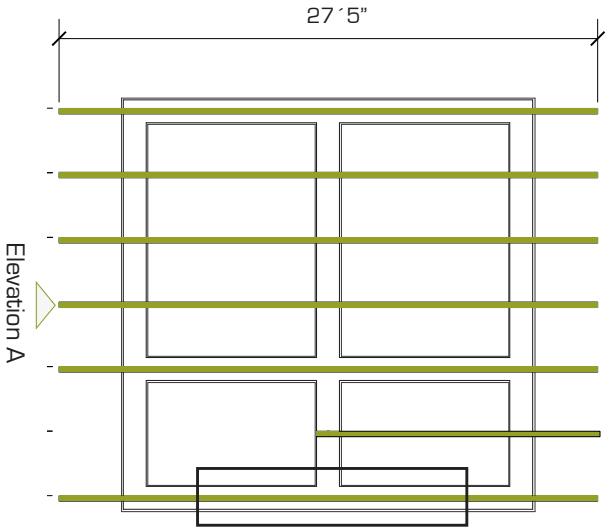
Detail 2



Detail 3



Detail 4



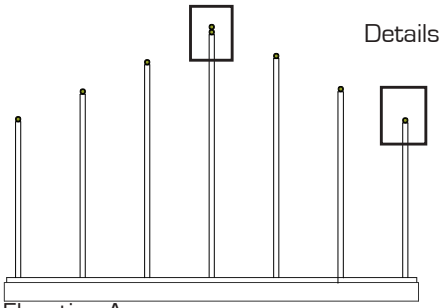
Picture 5

Beams

Sn.	Diameter	Length	Quantity
1	3”	27'5”	7
2	3”	13'9”	1

Detail 2 and 4

Details 3

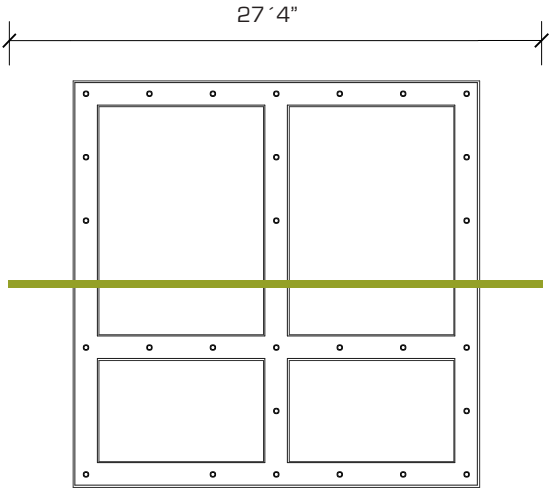


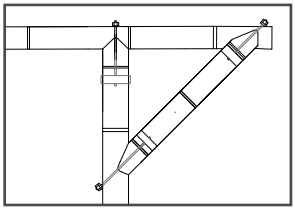
Elevation A

Picture 5

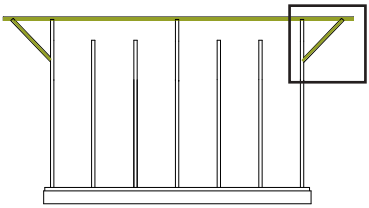
8 | BAMBOO STRUCTURE

NOTE: Before placing the second middle beam, diagonal bracing needs to be placed in order to be able to bolt it, as shown below.

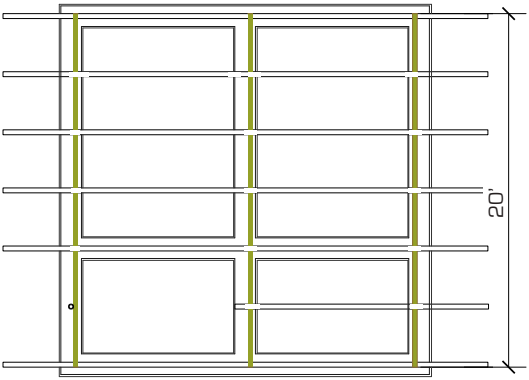


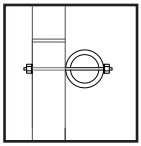


Detail 5



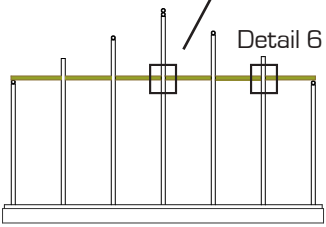
4 Continue to place the beams in the perpendicular direction, bolting them into the sides of the columns.





Detail 6

Picture 6

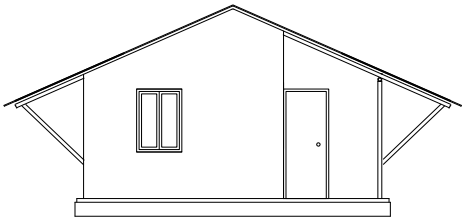


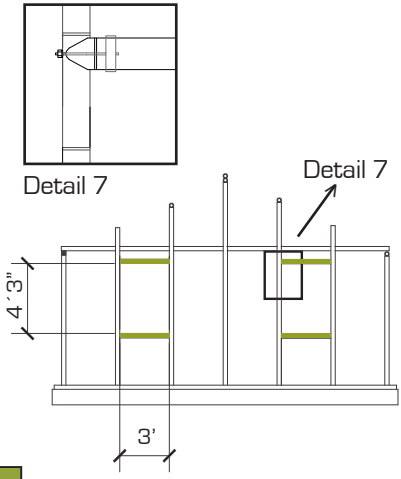
Sn.	Item	Diameter	Length	Quantity
1	Bracing	2.5”	3’2”	6
2	Beam	3”	20’	3

8 | BAMBOO STRUCTURE

Picture 6

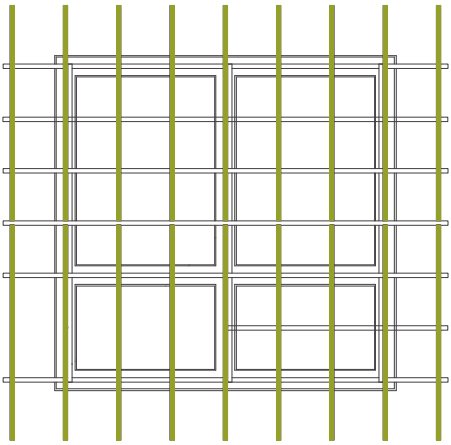
5 Lastly, place the window and door beams where the window and door frames will be attached as per the owners requirements.

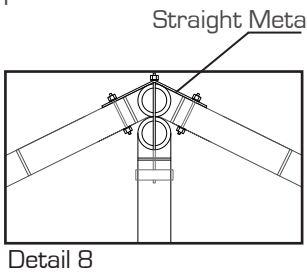


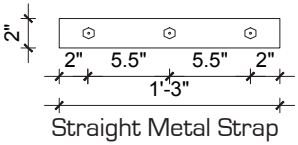


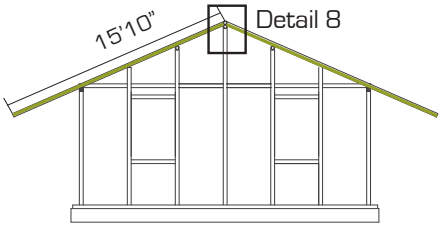
Sn.	Item	Diameter	Length	Quantity
1	Window beam	2"	3'	8
2	Door beam	2"	3'	3

6 The next step is placing the rafters. The rafters will be joined to the beams and columns through metal straps and bolts as shown below.







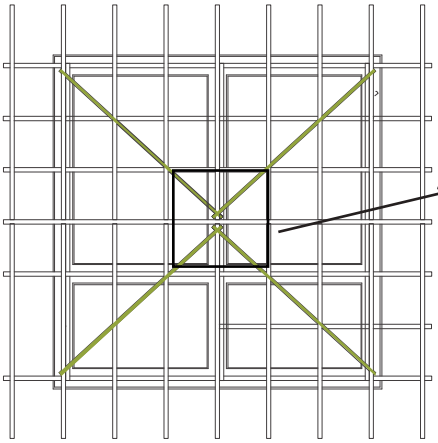


Sn.	Item	Diameter	Length	Quantity
1	Rafters	2"	15'10"	18
2	Bracing	2.5"	13'	4

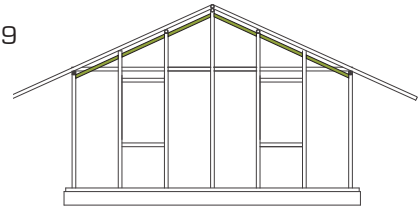
Picture 7

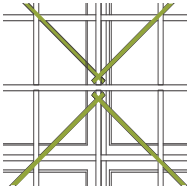
8 | BAMBOO STRUCTURE

7 We then place the diagonal bracing. The diagonal bracing is crucial when building particularly in earthquake prone areas and during high winds as it will hold the structure together and stiffens it.



The length of these poles is 13'. The poles will connect to the beams through bolts as shown in the picture below.



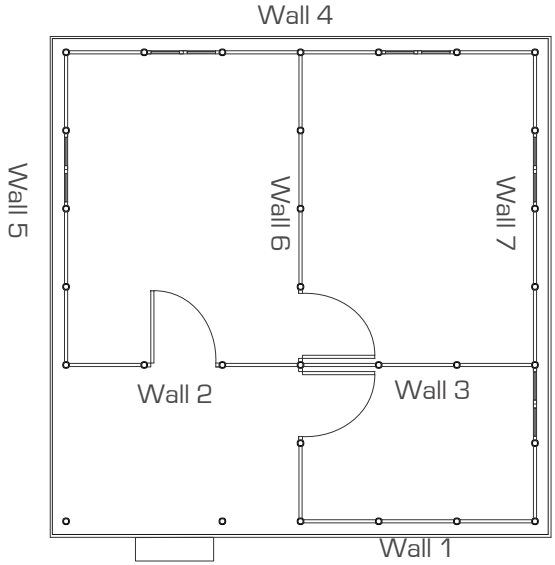


Detail 9

Picture 8

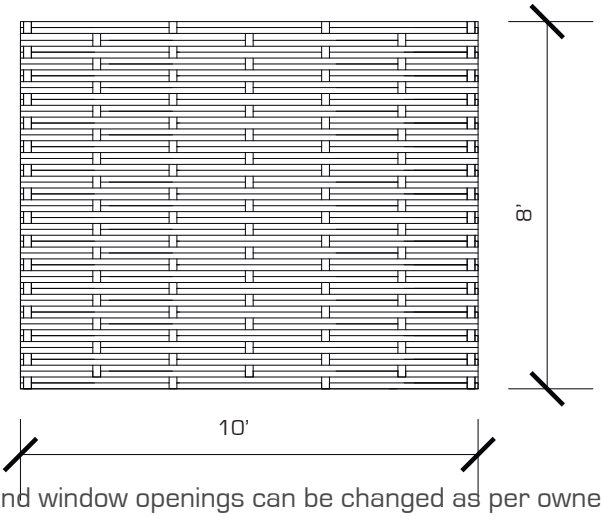
8.4.2 WALLS

The walls are made from woven and mud plaster and can be build aside while the construction is going on to save time. The walls should be attached to the outside of the bamboo structure with wire or self tapping screws.



The dimensions of the wall panels are as follows:

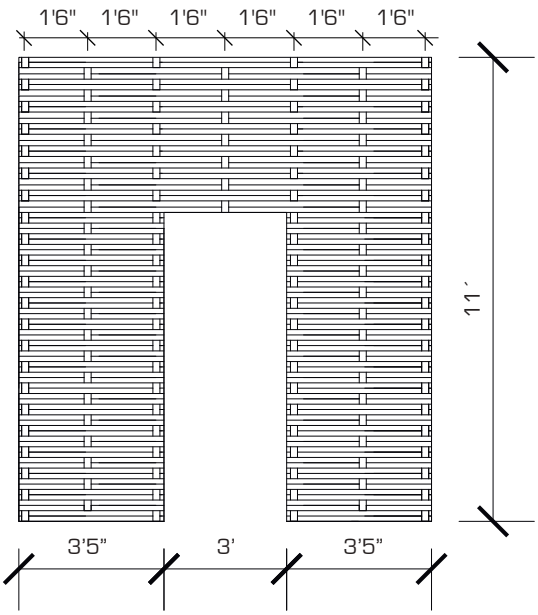
1 Wall 1



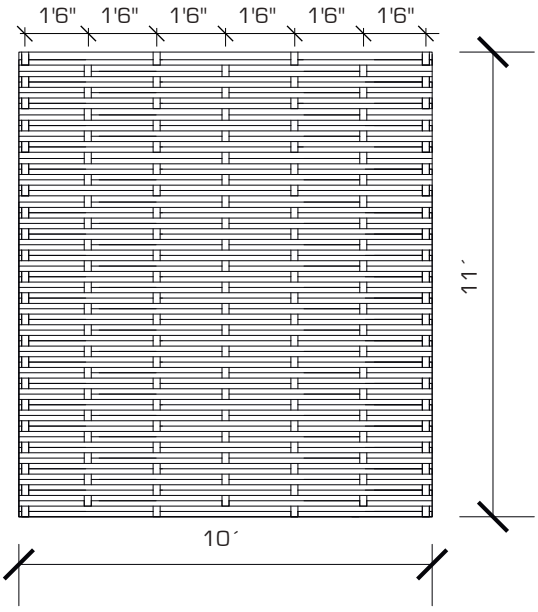
Note: Doors and window openings can be changed as per owner's requirements.

8 | BAMBOO STRUCTURE

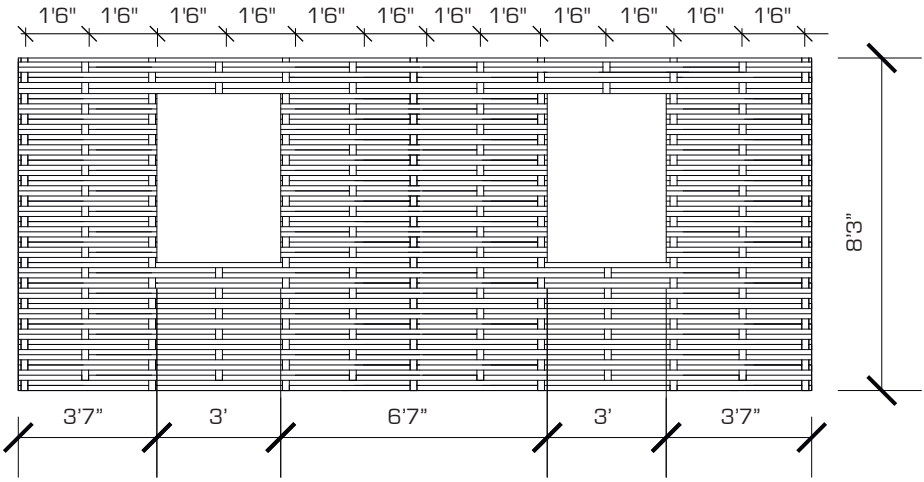
2 Wall 2



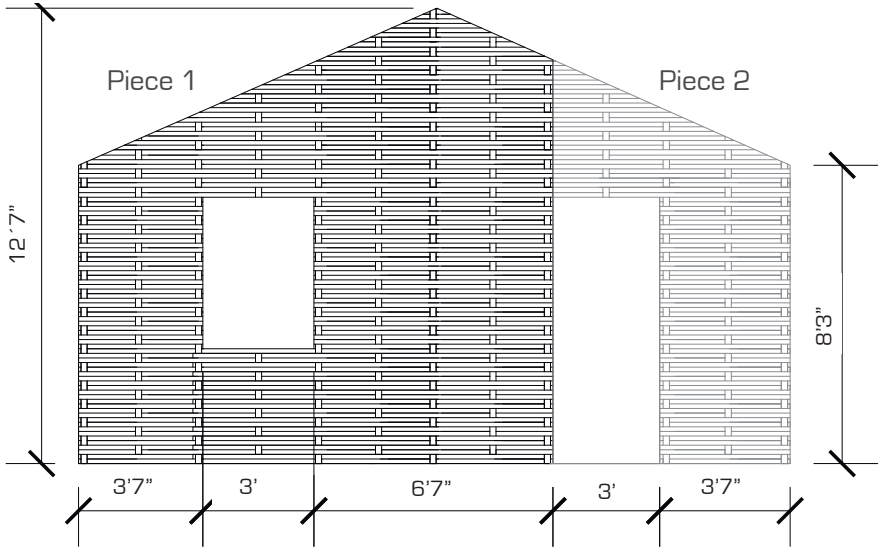
3 Wall 3



4 Wall 4

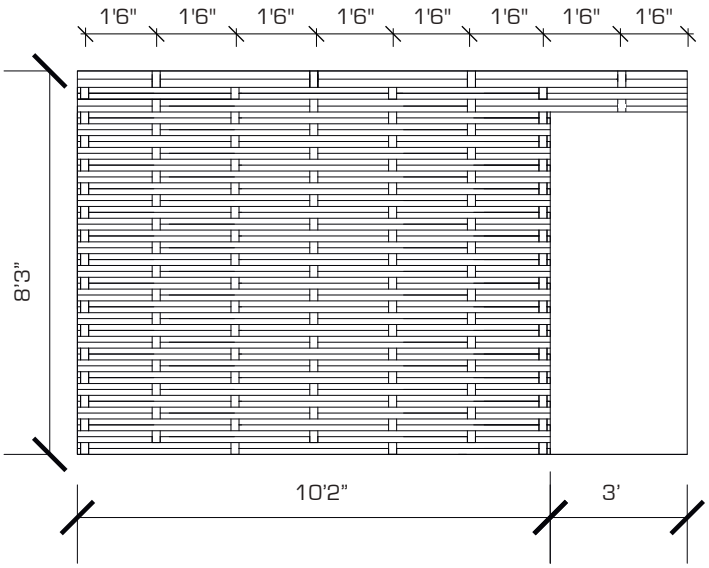


5 Wall 5

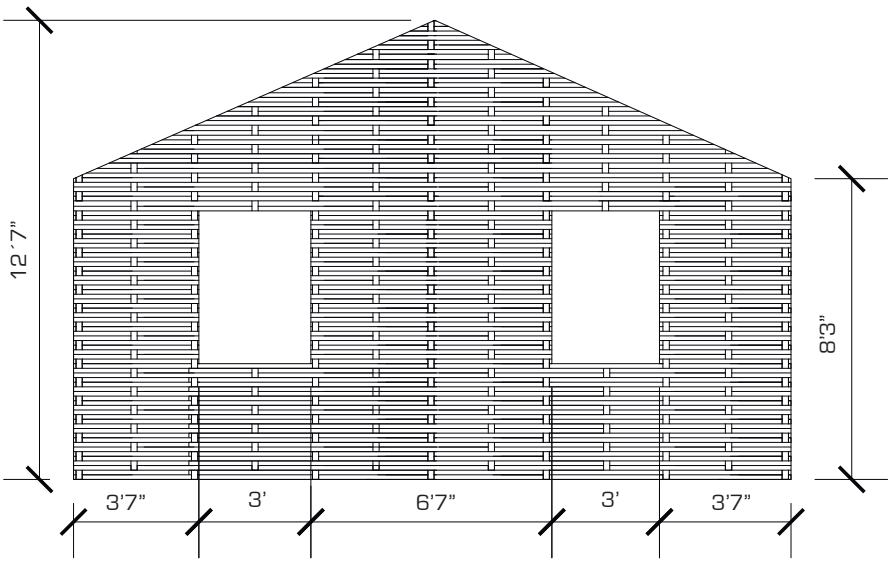


8 | BAMBOO STRUCTURE

6 Wall 6

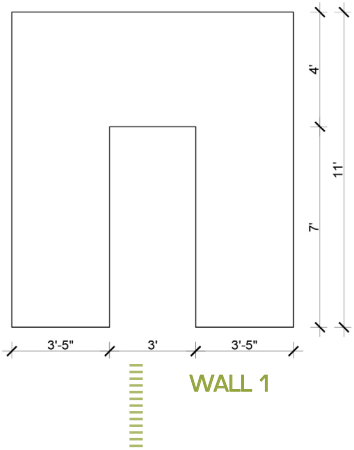


7 Wall 7

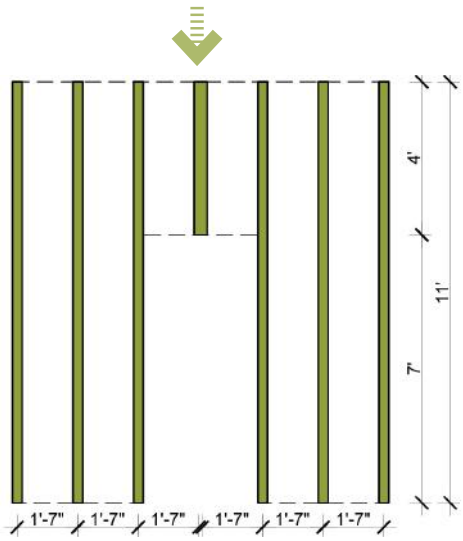


Process of making bamboo walls:

1. Measure the length and height of the wall.



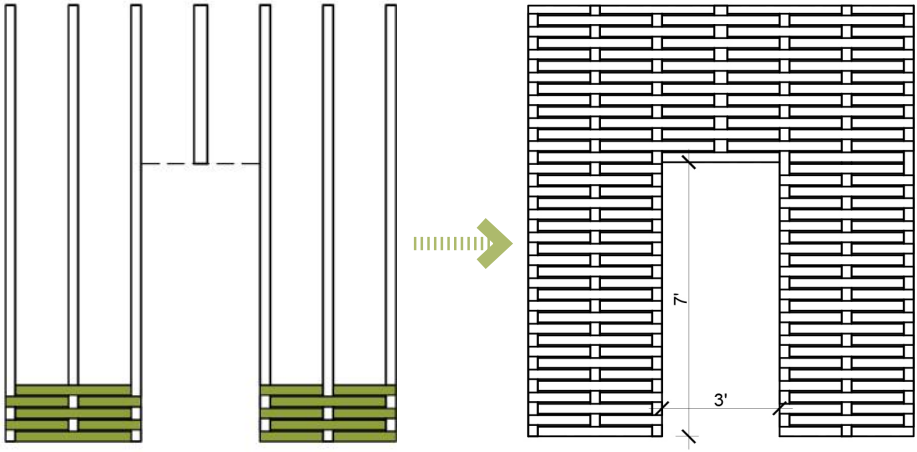
2. Cut the bamboo strips as per the dimensions and lay them on the ground. Lay the vertical members first at equal spacing or as per given dimensions. (Picture 9)



Picture 9

8 | BAMBOO STRUCTURE

4. Start weaving the wall with bamboo strips horizontally one at a time. (Picture 10, 11 & 12)



Picture 10

Picture 11

Picture 12

8 | BAMBOO STRUCTURE

Picture 13

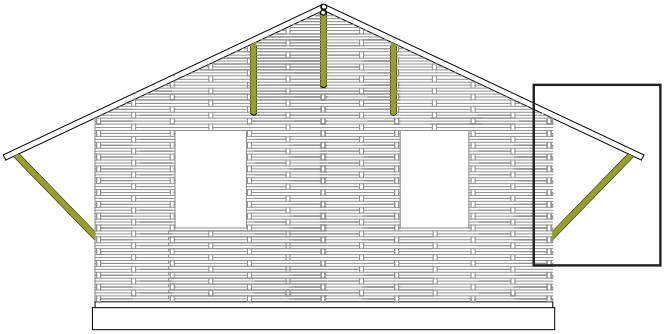
Picture 14

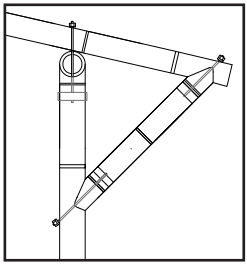
Picture 15

8 | BAMBOO STRUCTURE

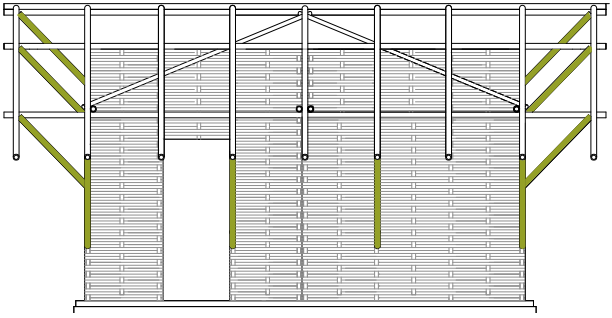
8.4.3. BAMBOO STRUCTURE PART TWO.

1 Once the walls are placed, proceed to attach the vertical bracing on the four facades. This bracing will strengthen the structure and allow longer eaves to protect the walls and bamboo from rain and sun.





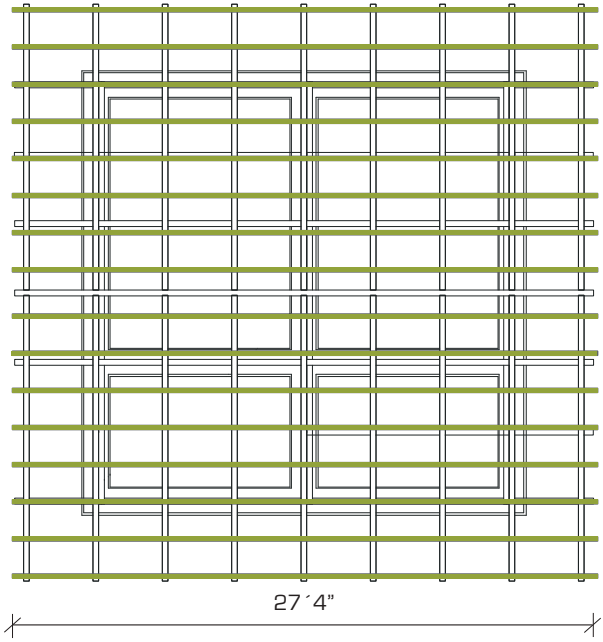
Detail 10

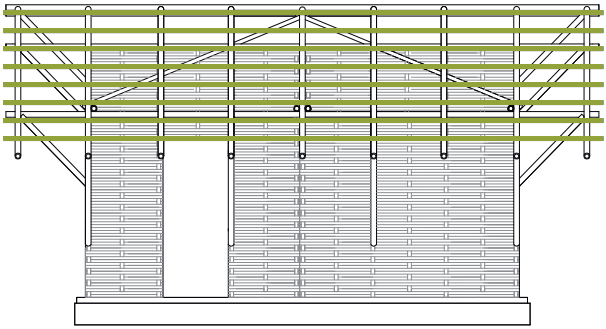


Picture 12

Sn.	Item	Diameter	Length	Quantity
1	Bracing	2.5"	4'	16

② Lastly, place the purlins, which will be attached to the rafters using bolts.





Sn.	Item	Diameter	Length	Quantity
1	Purlin	2”	27’4”	16

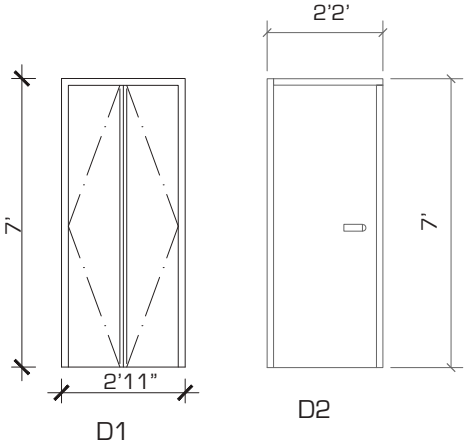
9| FINISHING

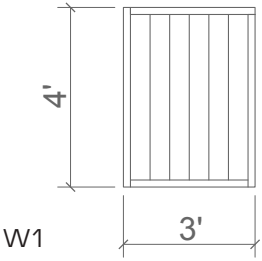
9.1 INTRODUCTION

After the bamboo structure and woven walls are erected, proceed to work on the finishing elements, which are roofing cover, plaster, flooring and doors and windows. These elements can be placed simultaneously by different workers, saving time.

9.2 DOORS AND WINDOWS

Doors and windows will be done preferably with timber. If not available or too expensive, the alternative would be aluminium.





As the house is flexible, the amount of doors and windows and their placement can be decided by the owner of the house but always considering they have to be placed at the centre of the walls.

Sn.	Description	Length	Height	Nos.
1	D1	3'	7'	3
2	W1	3'	4'	5

9.3 ROOFING

For the roofing we will use CGI sheets which will be attached to the bamboo through J-hooks. Ensure overhangs to protect rafters and purlins. Ideally a bamboo mat or similar would be placed underneath to improve thermal comfort and increase sound insulation.

9| FINISHING

9.4 MUD PLASTER

The walls of the house are made from woven bamboo matt and mud plaster

9.4.1 Determining the mix

The Mix:

Each soil is different and therefore it is difficult to propose the perfect mix. It is recommended to gather local knowledge about the loam mix used in the area.

- To prevent cracks don't use too much clay.

- Too little clay will result in a powdery weak plaster.

- Run all the earth through a sieve to get the stones out.

- The mix should contain enough coarse sand.

- Manure is normally added to increase adhesion, strength and smoothness.

- To reduce shrinkage cracks while drying, the mortar should contain sufficient quantities of coarse sand as well as fibers or hair.

- To improve surface hardness, cow dung, lime, casein or other additives should be added to the top layer.

HOW TO APPLY THE MIX:

- To make the clay work properly, use a good quantity of water and spread the plaster with big movements with your hands.

- The plaster should be thrown with strong impact (slapped on) to achieve a higher binding force.

- If the plaster has to be more than 10 to 15 mm thick, it should be applied in two or even three layers in order to avoid shrinkage cracks.

9.5 MUD FLOORING

Level the surface and trim any extra mud.

10 | SAFETY KIT

Safety First. Always wear the below listed tools to ensure safety while working.

Wear a mask in dusty areas & when painting; especially when working with cement

Helmets must be worn at all times to protect the heads

Wear hard soled, closed toe shoes or boots

Wear gloves when working; especially when working with cement

Wear safety goggles when cutting or plastering

Keep the site tidy to help prevent accidents

11 | REFERENCES

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