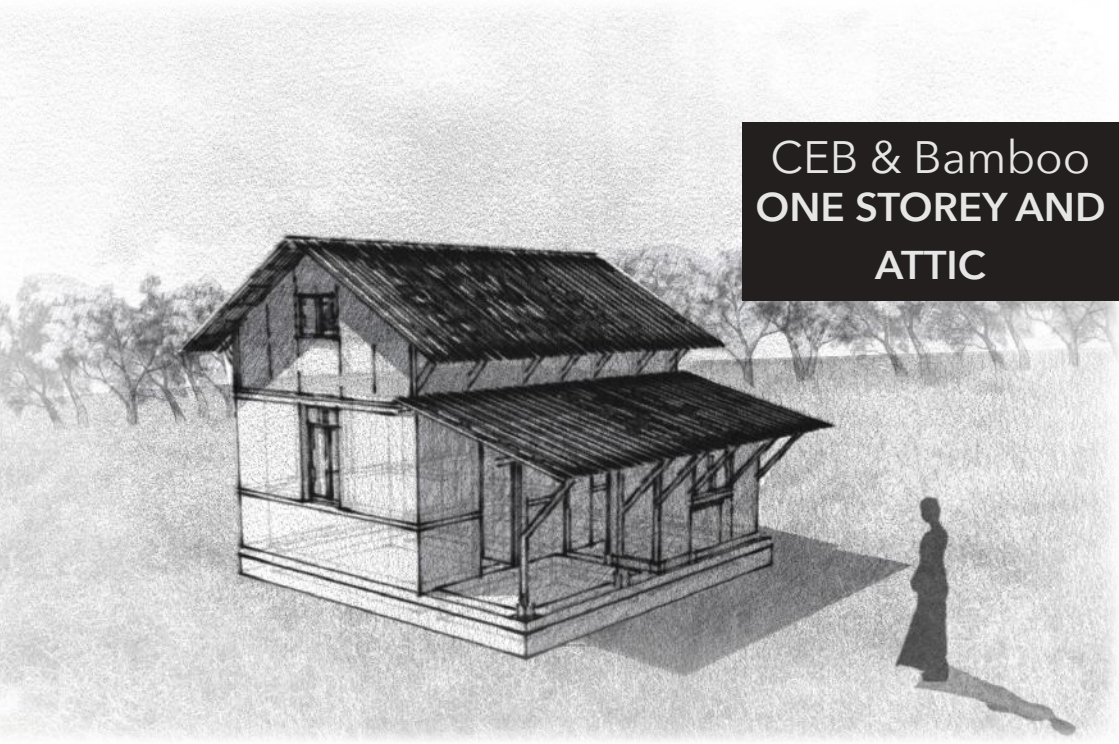
CONSTRUCTION MANUAL



CEB & Bamboo

ONE STOREY AND ATTIC

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.

For your Feedback please call our toll free number 16600133332

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Habitat for Humanity® Nepal

ABOUT THE MANUAL

This construction manual outlines the techniques and procedures adopted for the construction of the Compressed Earth Block (CEB) 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 CEB 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 CEB house construction.

Habitat for Humanity® Nepal

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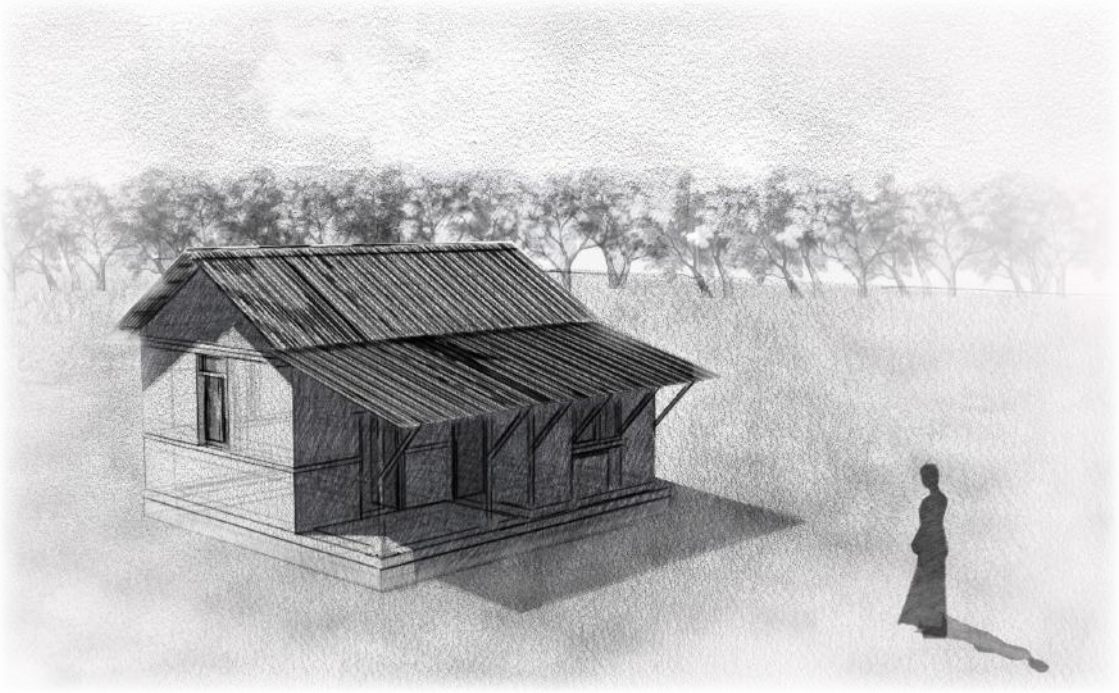
PART 2: ATTIC

PART ONE
ONE FLOOR



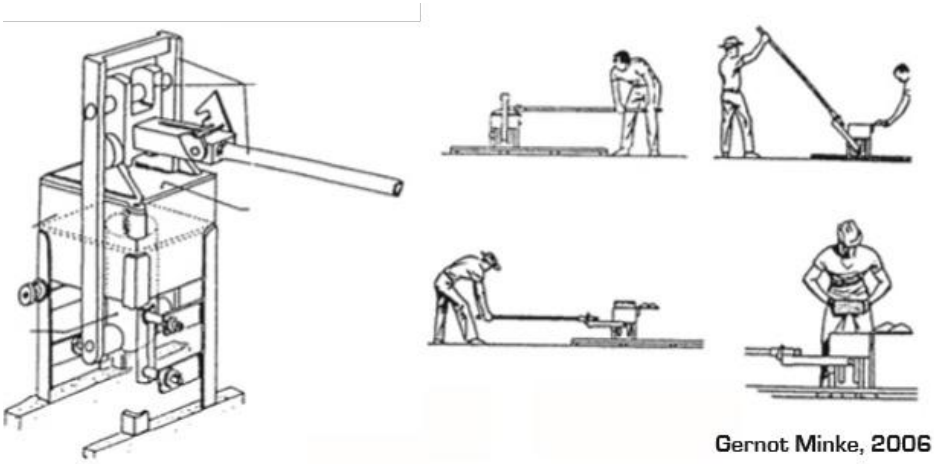
1 | COMPRESSED EARTH BLOCK

1.1 INTRODUCTION

The house in this manual is 21' x 21' (441 sq. ft.) It is a one storey house with two rooms of 12'4" X 8'9", a kitchen of 6'1" x 9'10" and a veranda of the same dimensions.The house can also have a bamboo attic as per the owners' requirements(Pg 68). It is composed by a core rectangular structure made out of compressed earth blocks and reinforced vertically with re-bars and horizontally through concrete banding at floor, sill and lintel levels. The kitchen and veranda have a light bamboo structure. The walls of the kitchen and gables are made out of woven bamboo and mud plaster (wattle and daub). The roofing structure is made out of bamboo, with bamboo mats for insulation and CGI sheets as roofing cover. Bamboo is a sustainable building material very suited for the construction of a house in different regions of Nepal.

1.2 WHAT IS COMPRESSED EARTH BLOCK?

Compressed earth blocks, also known as compressed soil blocks are a construction material made out of soil and a stabilizing material, such as lime, cement or clay, which is then compressed together through a mechanical press.



Gernot Minke, 2006

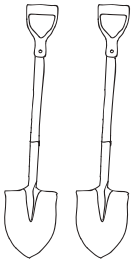
1.3 WHY BUILD WITH COMPRESSED EARTH BLOCKS?

• Use locally available material; soil, hence reducing the transportation cost and contributing to environmental effort.
• It contributes in keeping the local economy alive.
• Consistency in the quality of the material.
• It can be very easily assimilated.
• CEB structures are considered to be warm, solid and environmentally friendly.
• Since it uses sub soils of the earth leaving the exploitation of the top soil important for the agricultural purpose, it does not affect the ecological and occupational aspect.
• They are renewable resources that are found in abundance.
• CEB walls are sound proof, fire proof, bug proof and mold proof.
• Since the CEB blocks are made of natural material that do not emanate any toxic chemicals, it is a non-toxic building material.
• They are long lasting and durable.
• It can withstand seismic activities using steel reinforcements.

1 | COMPRESSED EARTH BLOCK

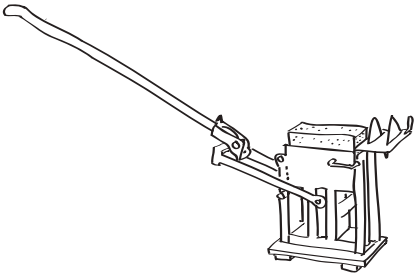
1.4 TOOLS NEEDED

① Shovels

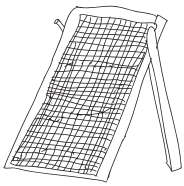


② Water Buckets

③ Machine



④ Screen



1.5 CONSTRUCTION PROCESS

1.5.1 The mix

The soil used for the fabrication of CEB consists of gravel, sand and clay mixed with water and occasionally with stabilizing materials such as lime or cement. The gravel and sand give strength to the material while the clay binds it together.

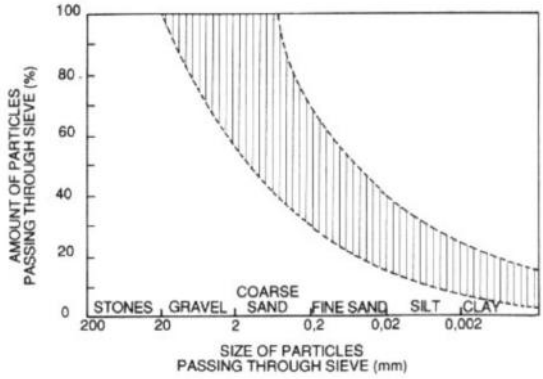
The proportions of the soil for adequate fabrication of CEB vary considerably, so it is always recommended to try different mixtures and test them.

We will first test the soil of our land. If it is not appropriate we will add sand, clay or gravel depending on what is missing.

To increase its strength we could add 5% of cement.

1 | COMPRESSED EARTH BLOCK

The Earth institute of France (CRA-Terre) recommends the soil to be inside the following proportions



PROPORTIONS OF VARIOUS KINDS OF MATERIAL

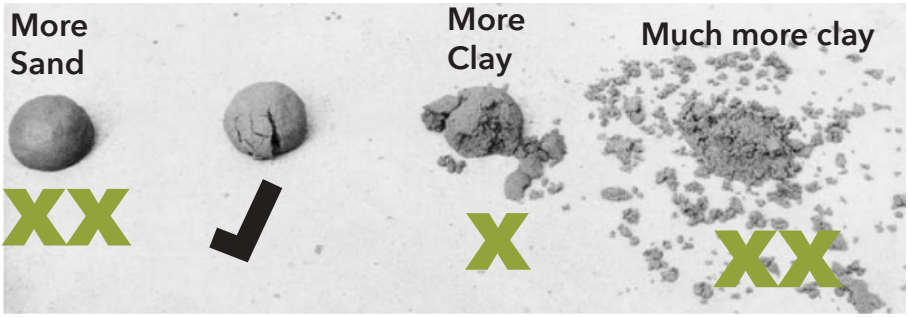
Gravels: 0 - 40%
Sands: 25 - 80%
Silts: 10 - 25%
Clays: 8 - 30%

On site tests

There are many on site tests we can do to get a right mix but probably the easiest is the ball dropping test.

Ball dropping test

Make a ball of 4cm of diameter of your soil as dry as possible, yet wet enough to be formed. Drop it to the floor from a height of around 1.5m.



Gernot Minke, 2006

1 | COMPRESSED EARTH BLOCK

1.5.2 Steps

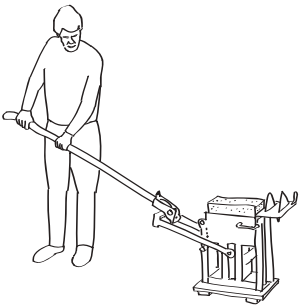
① Screening

The appropriate soil is sifted through 1/4´ to 3/8´ inch wire screen

② Mixing

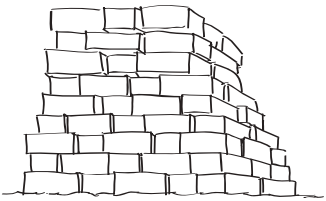
We then mix the soil adding a 10-12% moisture content

③ Making the bricks



The soil is then compressed and moulded forming bricks.

④ Drying



The bricks are then stacked and covered from the sun and left untouched for around 2-3 weeks to dry. If exposed to the sun, they will develop cracks.

2 | SITE SELECTION AND SHAPE

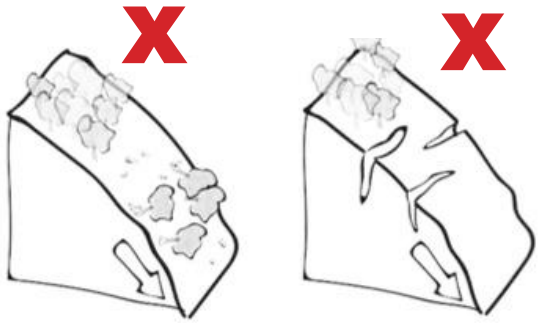
2.1 INTRODUCTION

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

Don’t build on steep slopes. Look for landslide signs (cracks, fallen trees).



2 | SITE SELECTION AND SHAPE

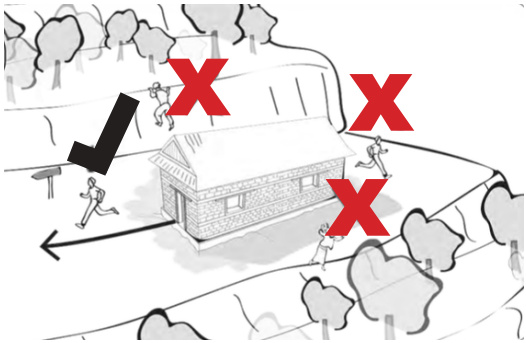
Remove Damaged buildings first

2.3 POSITION YOUR HOUSE SAFELY

Keep a safe distance between your house and slopes or cliffs.

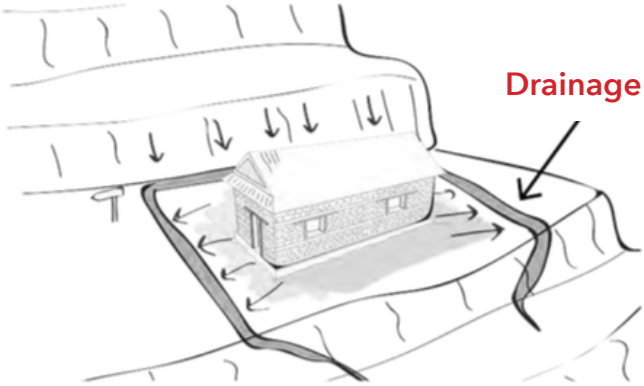
2.4 HAVE AN ESCAPE PLAN

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

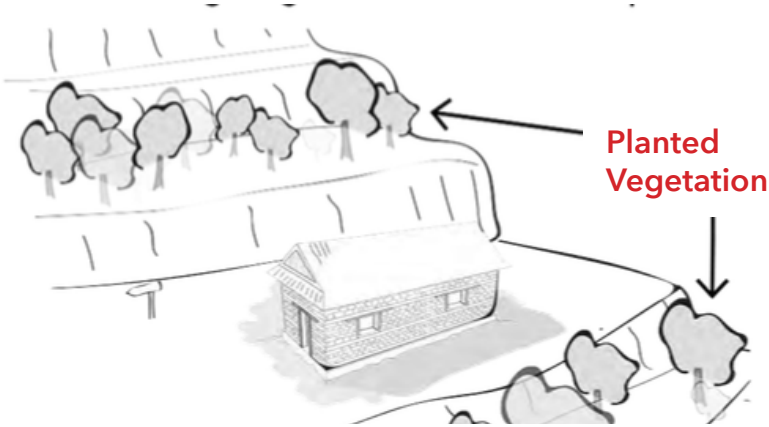


2.5 MAKE YOUR SITE SAFER

Ensure proper water drainage of the site.



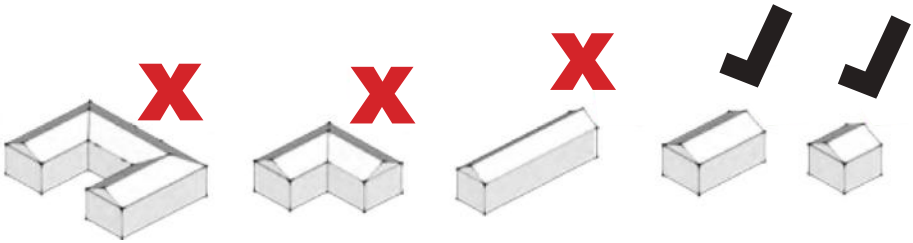
Plant retaining vegetation on the surrounding slope.



2 | SITE SELECTION AND SHAPE

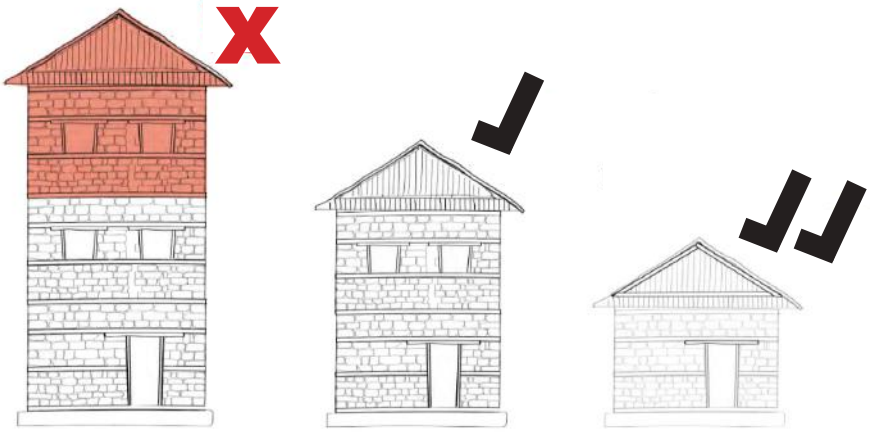
2.6 SHAPE

Use a regular shape that is not too narrow. U and L shapes will twist during earthquakes.



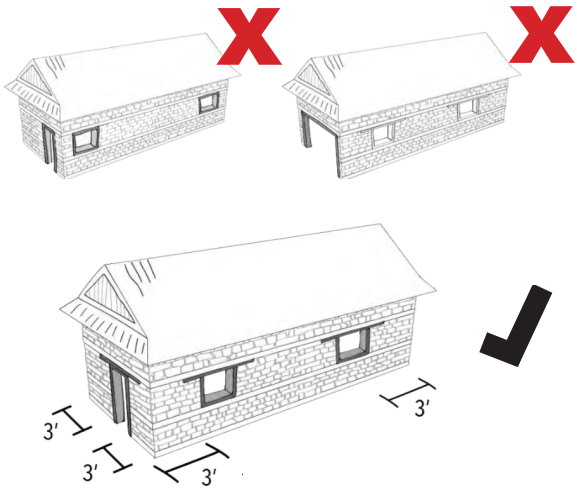
2.7 HEIGHT

Don't build more than 2 storeys and an attic. One storey buildings are safer in an earthquake than taller buildings.



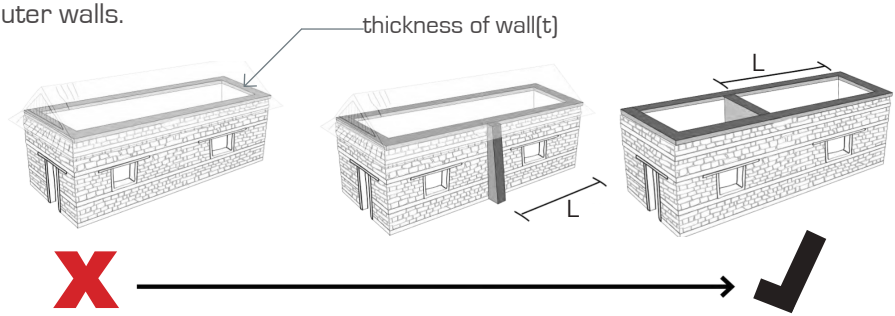
2.8 DOOR AND WINDOW OPENINGS

Large openings weaken a wall. Place openings away from corners and leave at least 3ft gap from corners and between openings.



2.9 LONG WALLS NEED SUPPORT

For a longer house, use regular wall supports or buttresses. It is important to build any internal walls from the same strong material and thickness as your outer walls.



L= Maximum length of unsupported wall

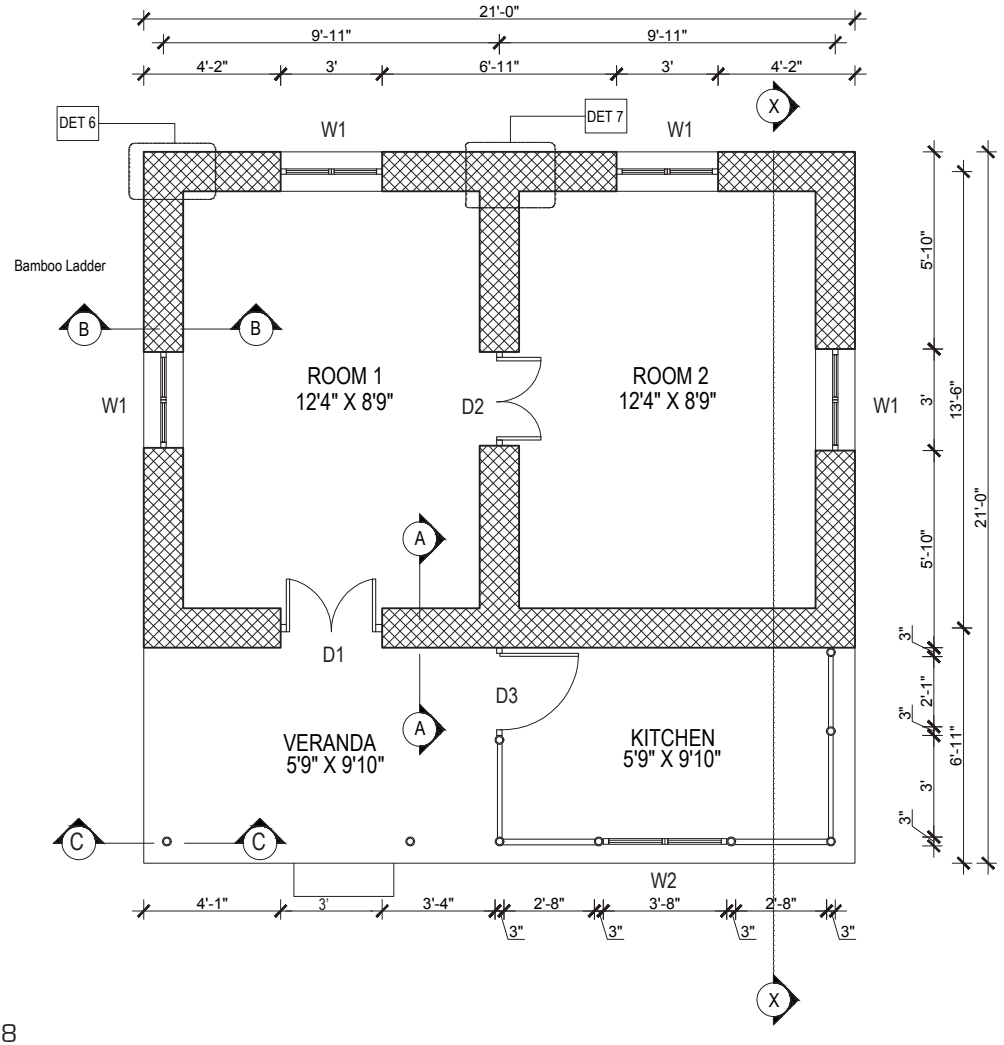
$L \leq 12 * t$

Source: Shelter Cluster, 10 Key Messages

3 | HOUSE PLANS

3.1 FLOOR PLANS

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.



3D Render of the Model house

3 | HOUSE PLANS

3.2 ELEVATIONS

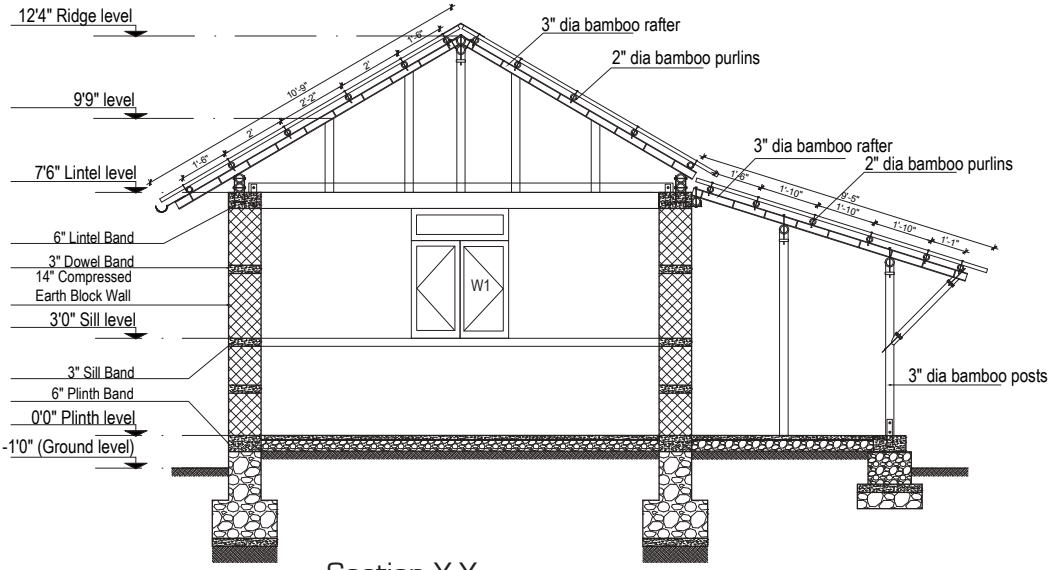
Front Elevation

Side Elevation 1

Side Elevation 2

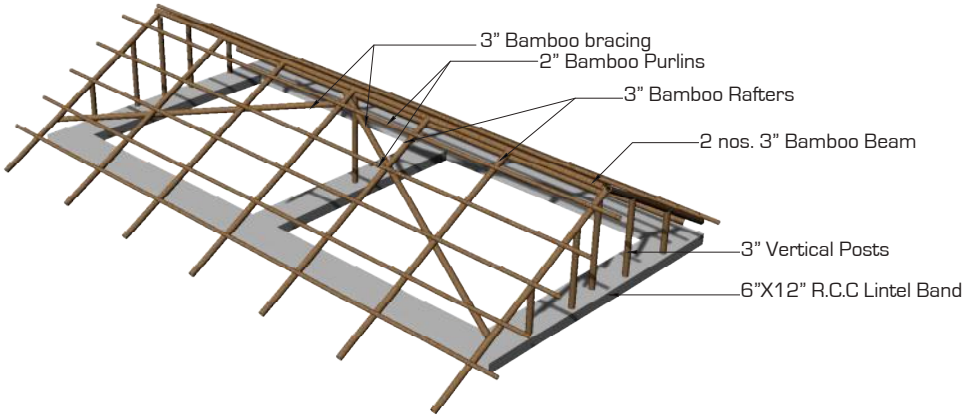
Back Elevation

3.3 SECTION



Section X-X

3.4 ROOF



4.1 CONSTRUCTION MATERIALS AND MANPOWER

Below is the list of materials and labours required to build the CEB and 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.

	Up to plinth	Super Structure	Finishing work	TOTAL
MANPOWER				
Skilled Labour (Md)	36	86	13	134
Unskilled Labour(Md)	131	190	15	336
MATERIALS				
Cement (Bags)	77	63	6	146
Sand (Cu.m)	9	7	1	17
Aggregate (Cu.m)	3	3	-	6
Soil blocks (No.)	-	6042	-	6042
Wood (Cu.m)	0.043	0.221	-	0.264
Reinforcement (Kg)	289	385	-	674
3" dia Bamboo(Nos)	-	68	-	68
2.5" dia Bamboo(Nos)	-	45	-	45
2" dia Bamboo(Nos)	-	25	-	25
1.5" dia Bamboo(Nos)	-	32	-	32

4 | BILL OF QUANTITIES

4.1 CONSTRUCTION MATERIALS AND MANPOWER

	Up to plinth	Super Structure	Finishing work	TOTAL
MATERIALS				
8mm bolts(Nos)	-	213	-	213
J Hooks(Nos)	-	177	-	177
CGI Sheets (Sq.m)	-	85	-	85
Hinge(Nos)	-	30	-	30
Cheskin(Nos)	-	15	-	15
Lockset(Nos)	-	4	-	4
Handle(Nos)	-	7	-	7

5 | LAYOUT

5.1 INTRODUCTION

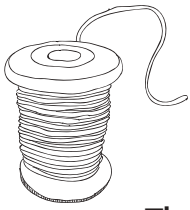
Once the site is selected and the dimensions of our house are known (Chapter 3)and our foundation (Chapter 6), start cleaning the site and doing the layout. The layout will guide the placement of our house. It is recommended to be done by 2-3 persons.

5.2 TOOLS NEEDED

1

Measuring tape

2

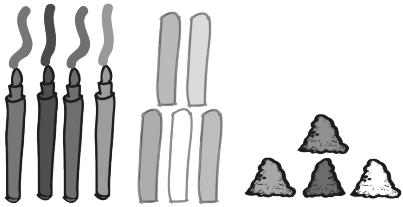


Thread

3

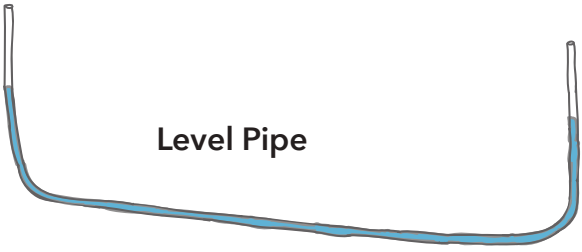
Stakes

4



Colour to mark on the stakes and ground

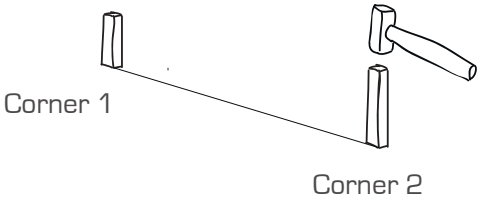
5



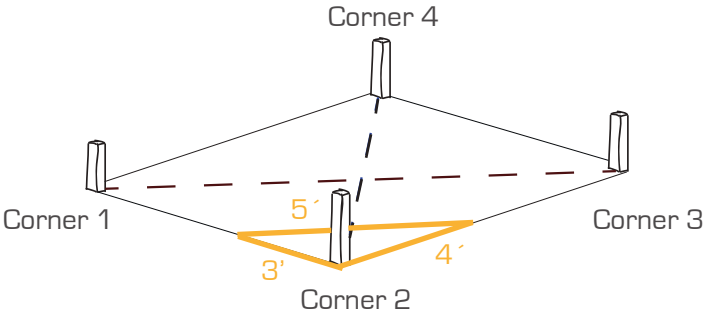
Level Pipe

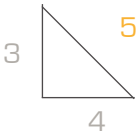
5.3 STEPS

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.



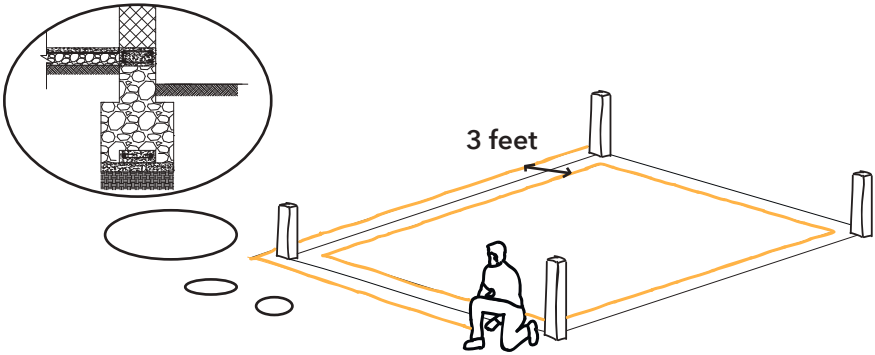
2 **Use 3-4-5 method to get the right angles:** To find the right angle measure 3 feet on one side, 4 feet on the other and the diagonal joining them has to be 5 feet. Once the angle of 90º is obtained measure corner 3 and place another stake.
Repeat the same process in corners 3 and 4.



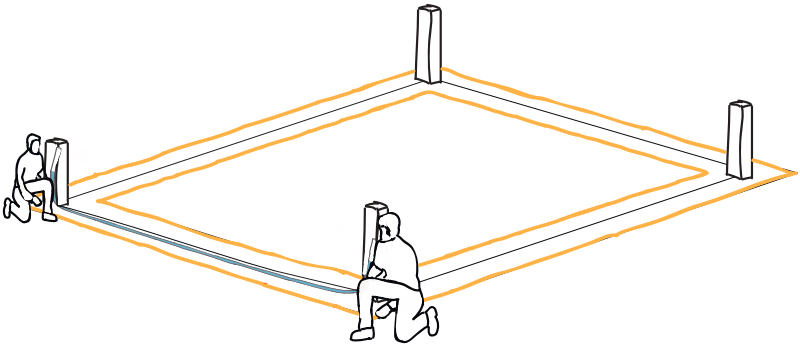


5 | LAYOUT

3 **Mark the thickness of the foundation:** With a thread from stake to stake fix the centre line of grids, 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 levelled.Use a level pipe filled with water. With that level pipe mark the heights on the stakes. Make sure to eliminate the presence of air bubbles in the pipe while marking the levels.

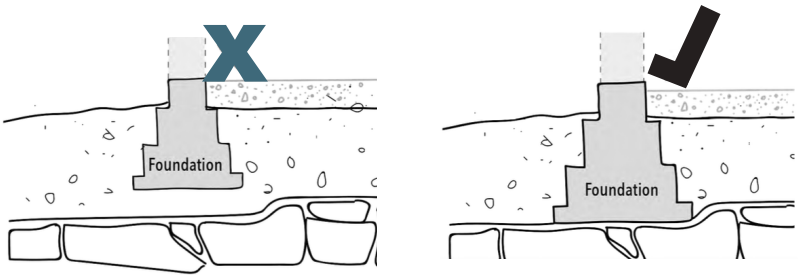


6.1 INTRODUCTION

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).

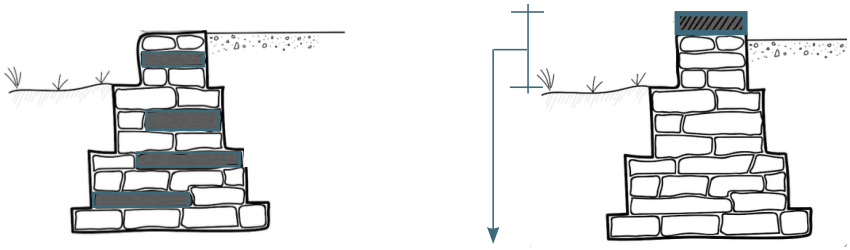
6.2 PRINCIPLES

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 from going inside the house

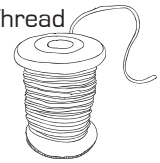
Source: Shelter Cluster, 10 Key Messages

6 | FOUNDATION

6.3 TOOLS NEEDED

1. Measuring tape

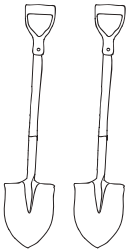
2. Thread



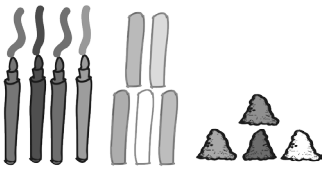
3. Float

4. Water buckets

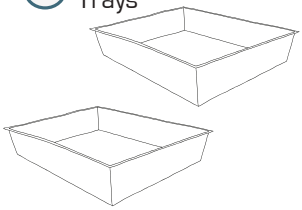
5. Shovels



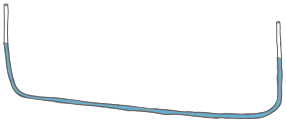
6. Colour to mark on the stakes and ground



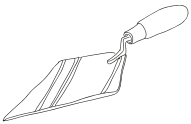
7. Trays



8. Level Pipe

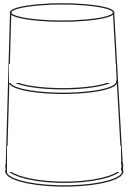


9. Trowel

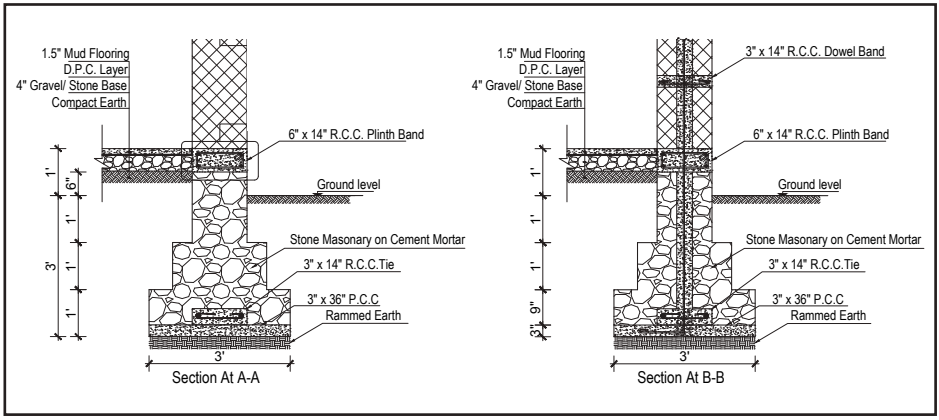


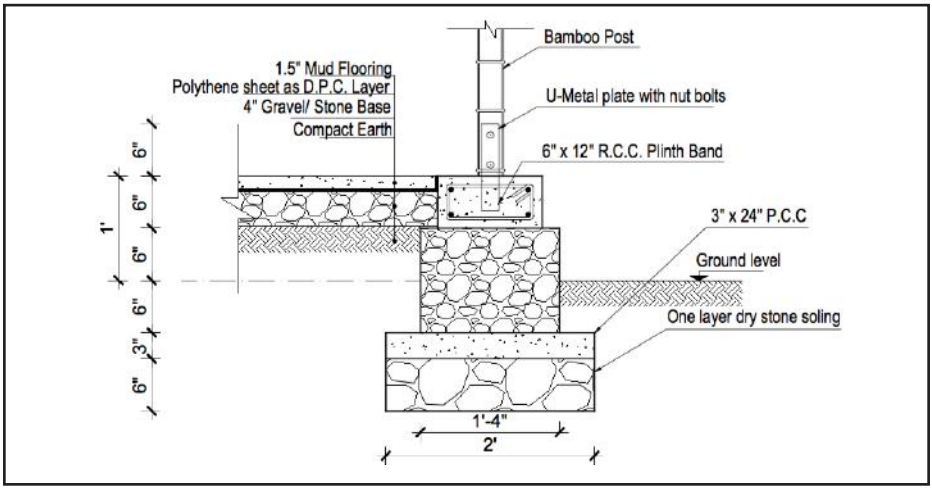
10. Wooden Tamper

11. Water Drum



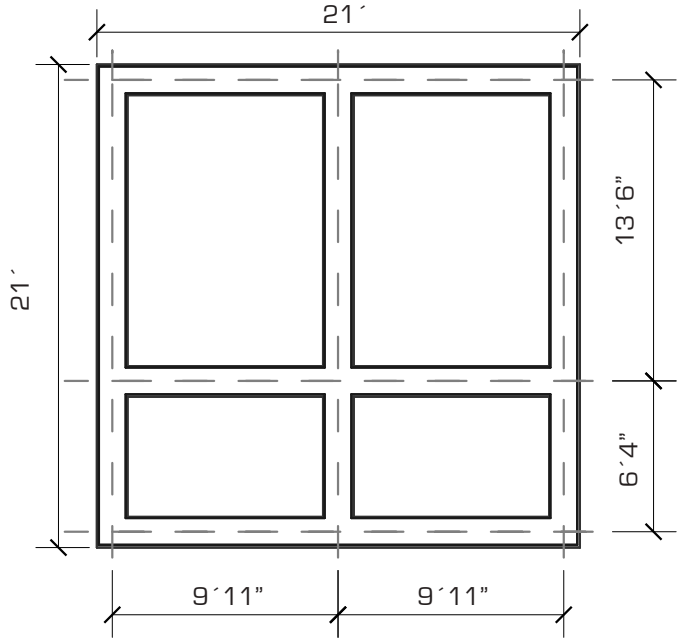
SECTION DETAILS





Section C-C

TRENCH PLAN



6| FOUNDATION

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.

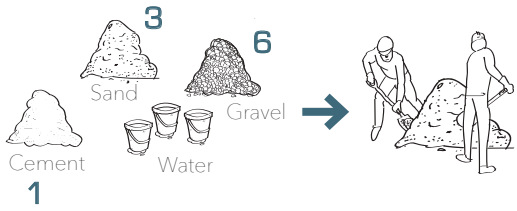
② Fill the gaps with gravel.

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

6 | FOUNDATION

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

PCC RATIO: 1:3:6



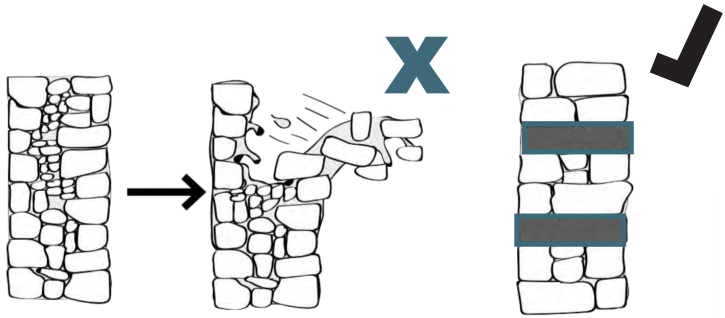
To ensure a good mix keep in mind the following tips:
- Use clean water.
- Do not mix directly on ground but rather use an impervious surface (tin/plastic)
- Mix it dry for 2 times and wet for 1 time.

④ After pouring the layer of PCC lay the stone foundation with cement mortar.

6 | FOUNDATION

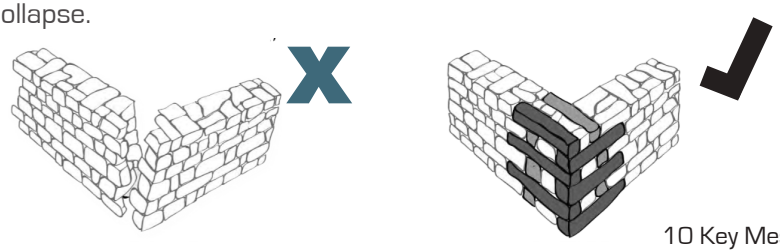
6.5 STONE WALL PRINCIPLES

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



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

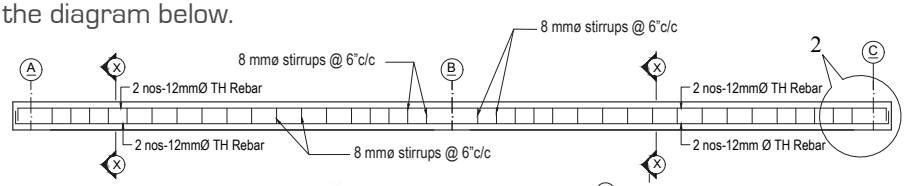
1 PART OF CEMENT

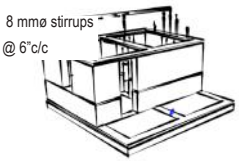
5 PARTS OF SAND

7 | PLINTH BAND

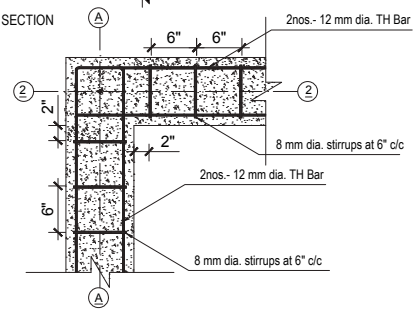
7.1 INTRODUCTION

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.

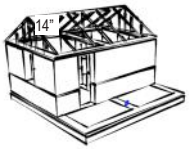




NAL LINTEL BAND SECTION



DETAIL AT
REINFORCEMENT IN SILL AND LINTEL BAND IN CORNER WALL



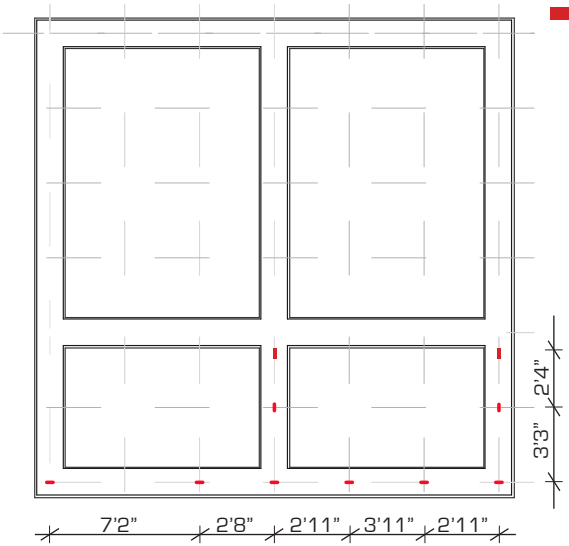
7.2 CONSTRUCTION STEPS

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.

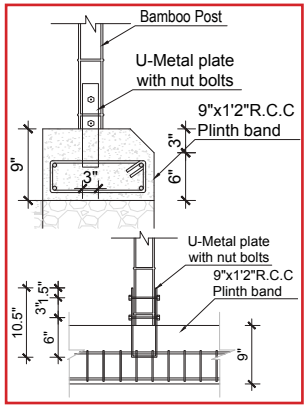
7 | PLINTH BAND

② Place rebars and stirrups

③ In the part of the kitchen and veranda, place U-Straps for connecting the bamboos to the foundation as shown below. The U-straps should be attached to the reinforcing steel.



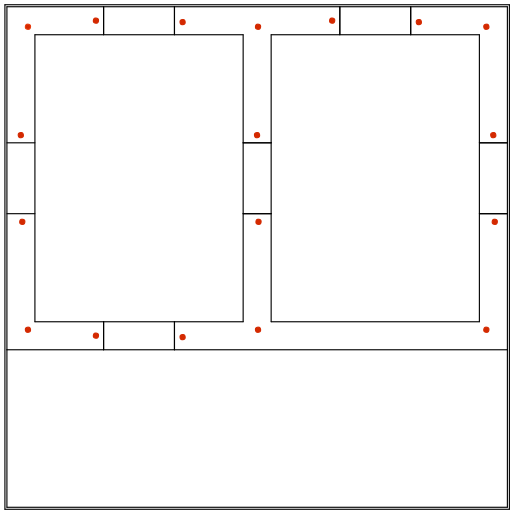
Placement of U-straps



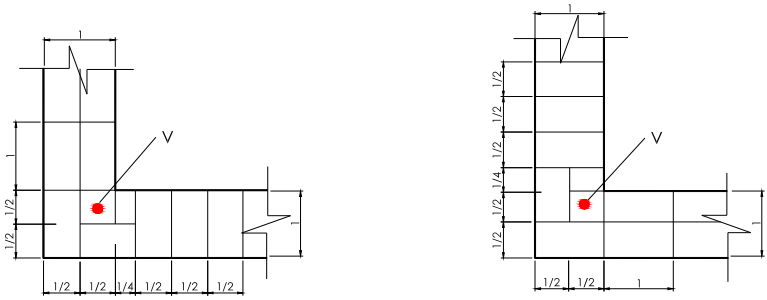
It's important to have a slope on the banding to protect the bamboo from rain.

Picture: Connection between reinforcing steel and U-straps

4 Place the vertical steel reinforcement attached to the plinth band. It will be placed at corners, openings and junctions.



7 | PLINTH BAND



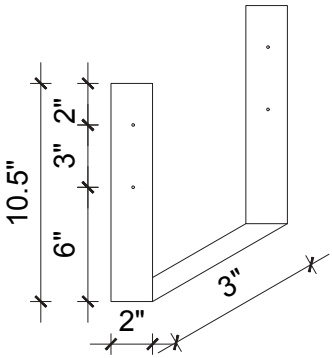
FIRST LAYER **SECOND LAYER**

CORNER JUNCTION DETAILS FOR ONE BRICK WALL FOR PROVIDING VERTICAL STEEL.

NBC 203: 2015

5 Once all the straps are in place or simultaneously proceed to place the form work.
Also, level the height of the concrete on formwork.

6 Mix and Pour the concrete.



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

RCC RATIO: 1:1.5:3

M20

1 PART OF CEMENT

1.5 PARTS OF SAND

3 PARTS OF GRAVEL

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

8| WALLS

8.1 INTRODUCTION

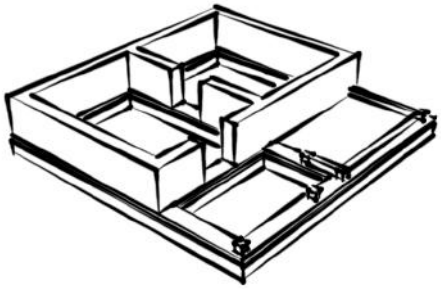
The walls are made of RCC banding and compressed earth blocks.

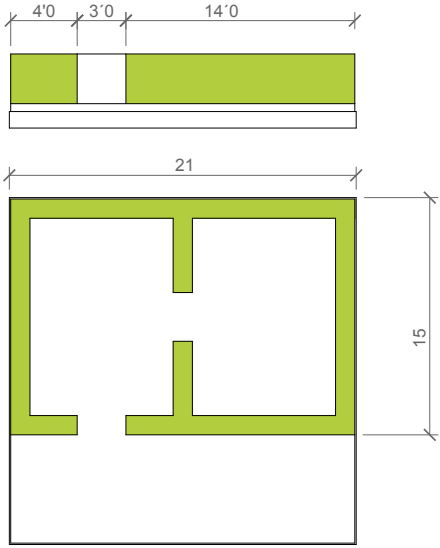
8.2 DOOR FRAMES

Before starting to build the wall we will place the door frames.

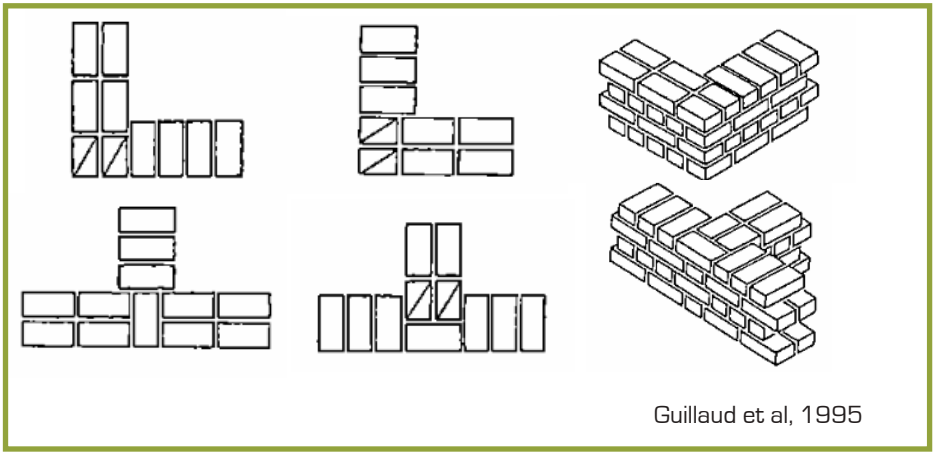
8.3 LAYING THE BRICKS

Once the bricks are ready, start laying them. Use mud or cement mortar to bind them together.
The mud mortar should have the same mix as the bricks.



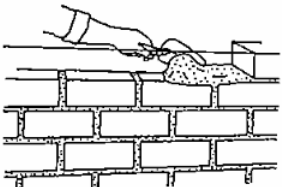


Example of brick patterns

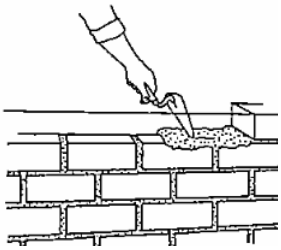


Guillaud et al, 1995

It is very important to tie corners and junctions well as they are one of the vulnerable areas of a masonry structure.

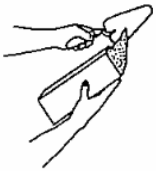


Place the right amount of mortar

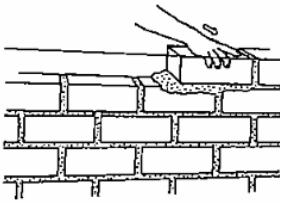


Spread the mortar uniformly

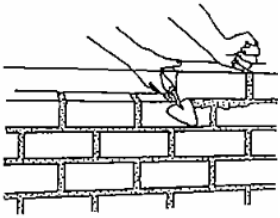
Wet the bricks before laying them



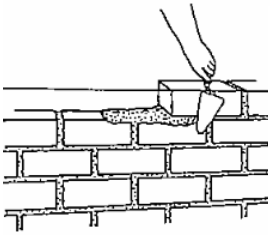
Place mortar on the faces to be joint



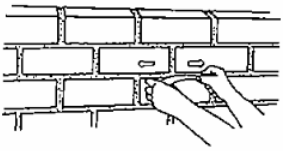
Lay the brick on the wall



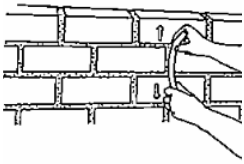
Stall the brick on its place



Remove the excess of mortar



Smooth horizontal joints

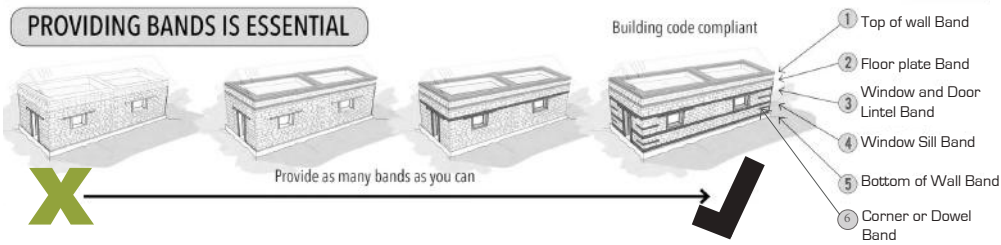


Smooth vertical joints

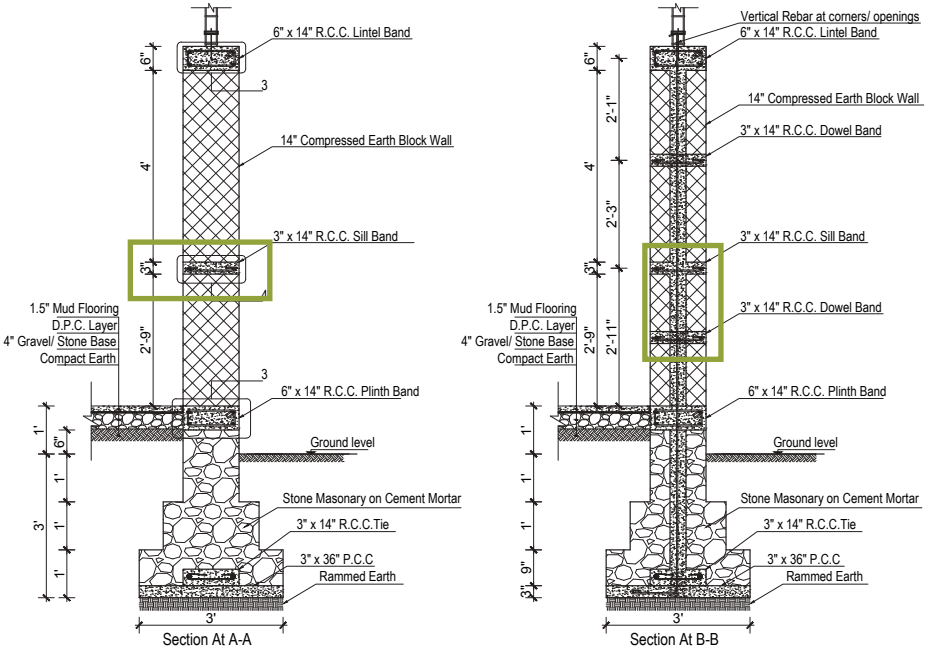
Guillaud et al, 1995

8.4 SILL, CORNER AND LINTEL BANDS

It is crucial, when building masonry structures to band your house.



8.4.1. SECTIONS

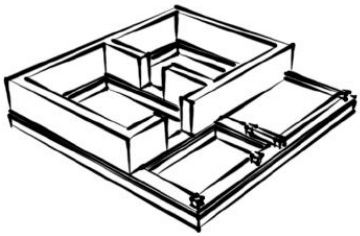


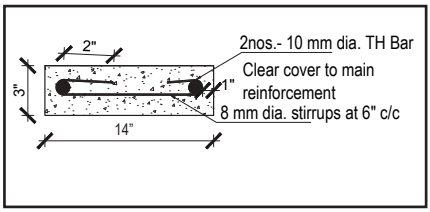
Sill and dowel bands

8.4.2 STEPS

8.4.2.1 Sill band

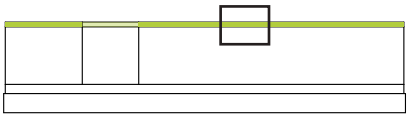
The sill band is the band that will go under the window. It is a continuous band running the entire house. The height of this band is 75mm. Sill band of cement & steel bars gives strength and stability to the wall and ties it together. The steel in the band are arranged as per detail below.



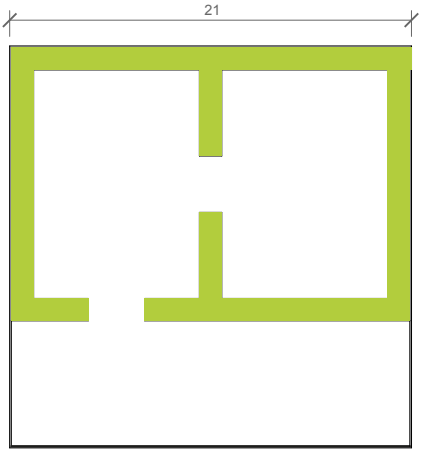


Detail 1

Detail 1



Front Elevation



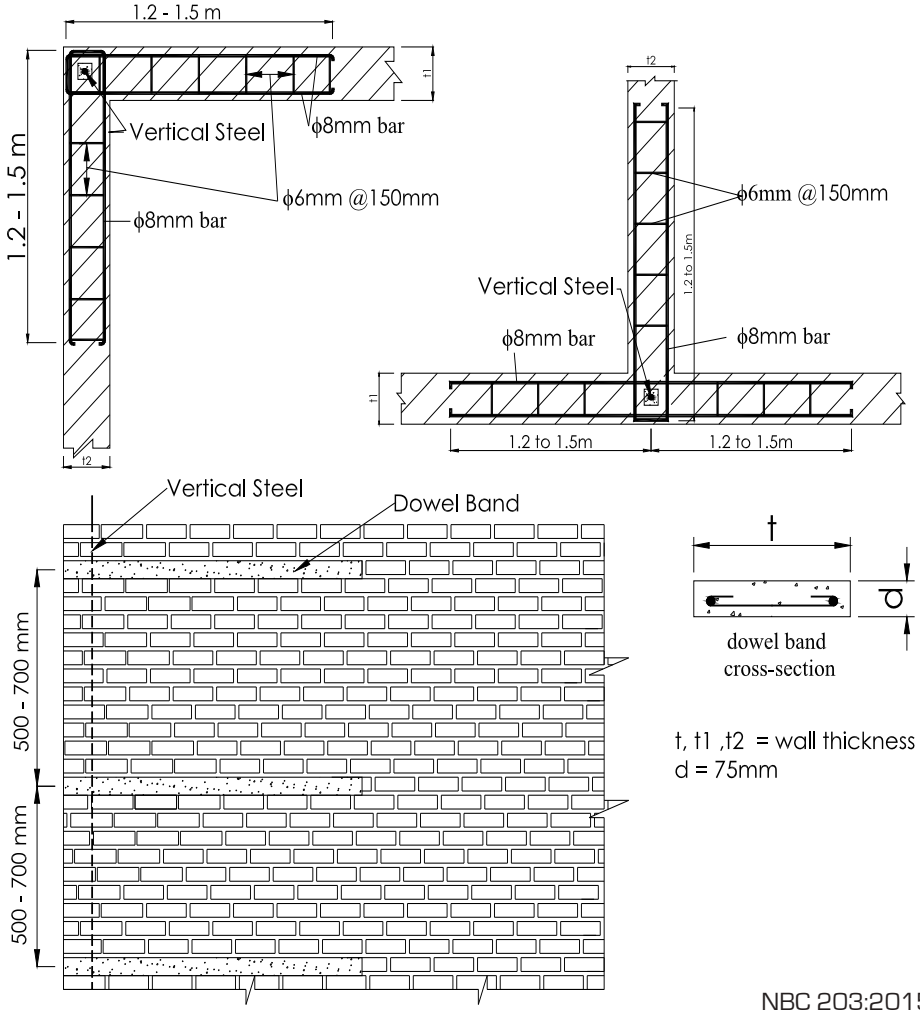
1. Build the wall and prepare the reinforcing steel for the banding. Then begin bending the stirrups.
2. Place rebars and stirrups
3. Place form work
4. Pour concrete

8.4.2.2 Window frames

Once the sill band is left to set for 24 hrs, place the window frames.

8.4.2.3 Dowel bands

The dowel bands go at mid height between the sill and plinth and sill and lintel band. These bands are placed on corner and junctions. The height of this band is 75mm.



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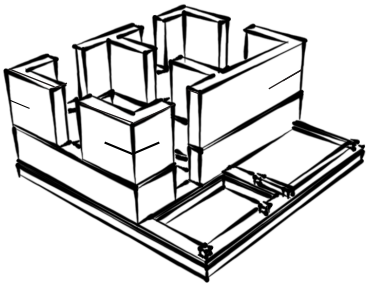
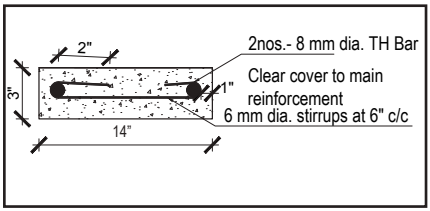
8 | WALLS

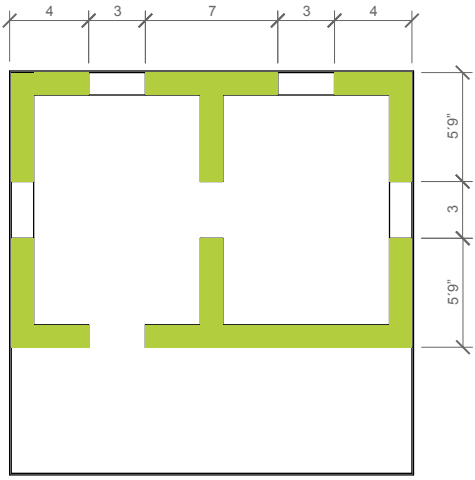




Detail 2

Detail 2

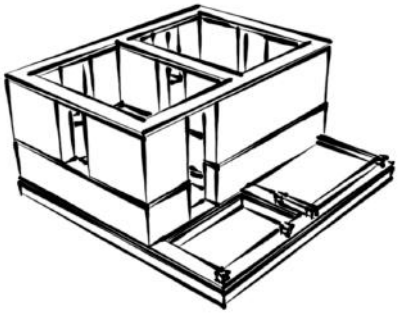
Front Elevation



1. Continue building the wall.
2. Place rebars and stirrups
3. Place form work
4. Pour concrete

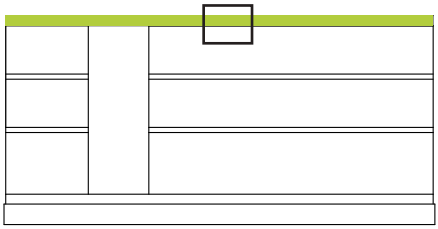
8.4.2.4 Lintel band

The lintel band is the last band, placed at the top of the wall. The height of this band is 150mm.

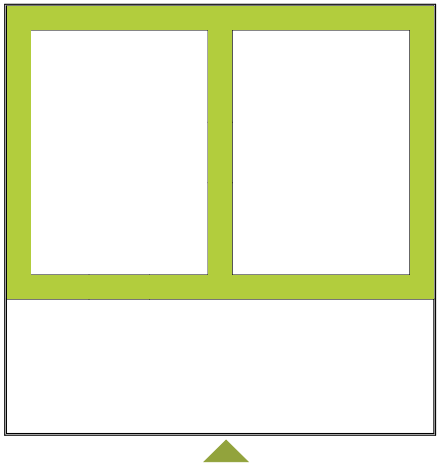


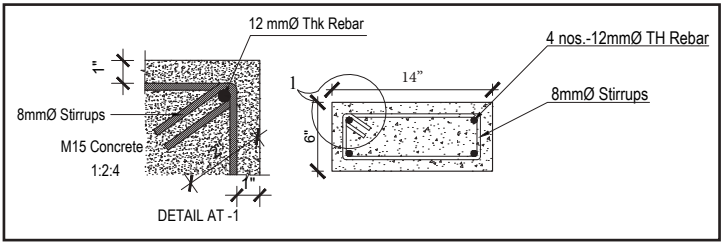
1. Continue building the wall.
2. Place rebars and stirrups

Detail 3



Front Elevation

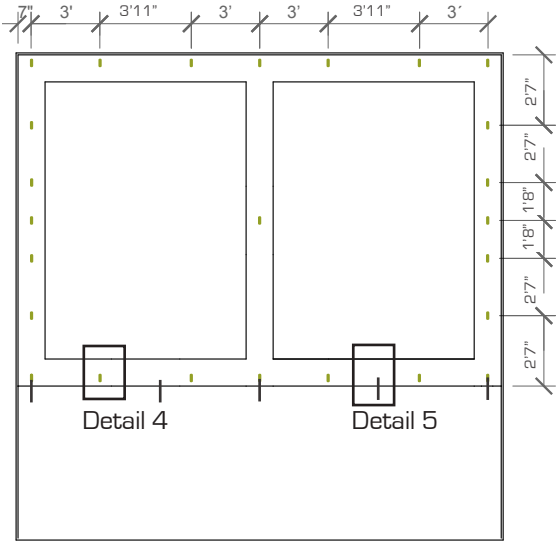


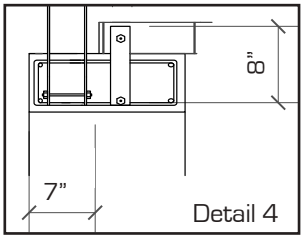


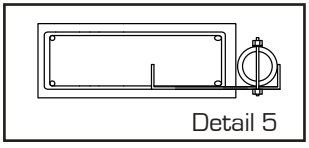
Detail 3

8 | WALLS

3 Place U straps where detailed on the plan below to connect the gable columns and the beams to the lintel band. On the same plane we will place straps for connecting the joists of the floor and an L strap will be placed for the beams of the stairs .







4 Place form work

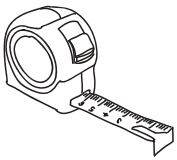
5 Pour concrete

9.1 INTRODUCTION

The roof is composed by a bamboo structure covered by CGI sheets

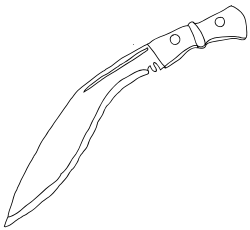
9.2 TOOLS NEEDED

1 Measuring tape

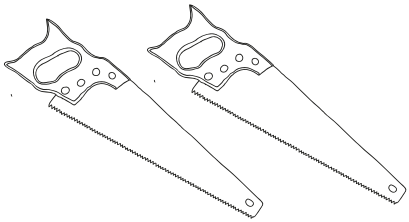


2 Markers

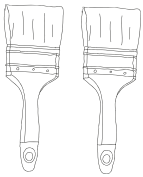
3 Gurkha Knife



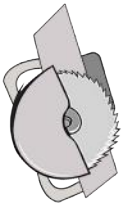
4 Saws



5 Brushes



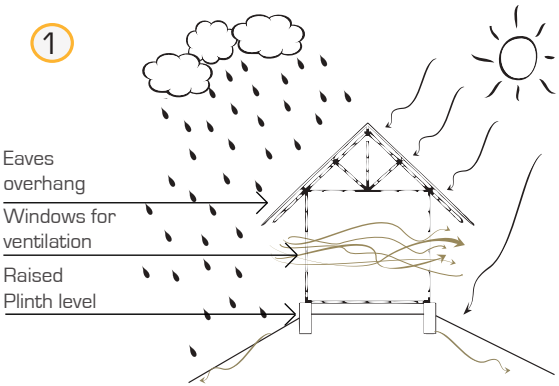
6 Electric Cutter



9.3 BAMBOO DESIGN PRINCIPLES

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

1

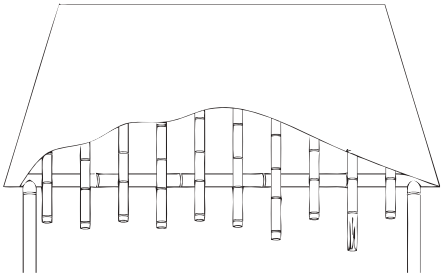


Bamboo should always be well protected from rain and sun. Moreover bamboo should be treated with a boron compound to be protected from fungi and insects and increase its durability.

9| ROOF

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 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

9.4 CONSTRUCTION STEPS

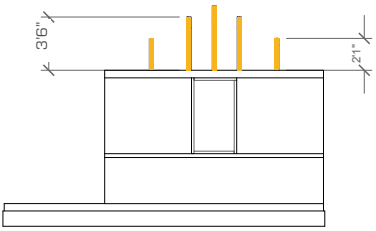
9.4.1 BAMBOO STRUCTURE. PART ONE

1 Cut the columns and mark them .

Optional: Apply 2 coats of varnish to protect the bamboo further and to give a nice finishing.(Picture 1)

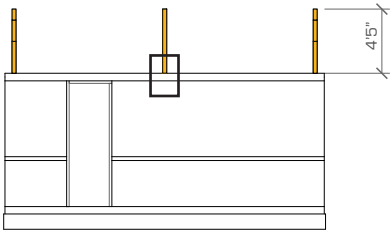
Picture 1

2 Bolt the columns to the metal straps. Ensure that there is a small gap (2-4 mm) between the bamboo base and the lintel band to stop the column from rotting.



Elevation A

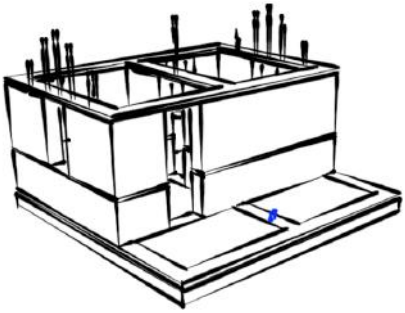
Detail 1

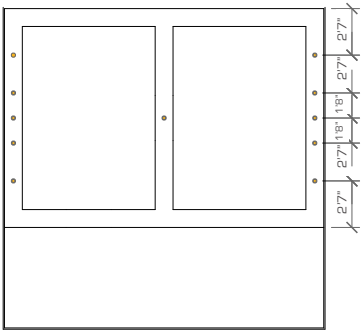


Elevation B

Columns:

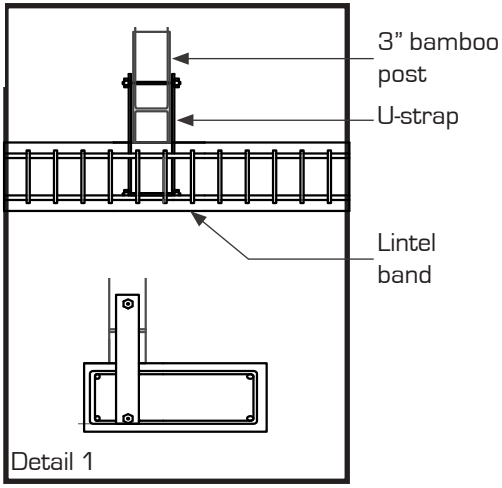
Sn.	Diameter	Length	Quantity
1	3"	4'5"	3
2	3"	3'6"	4
3	3"	2'1"	4





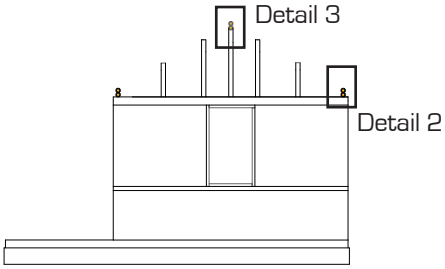
Elevation A

Elevation B

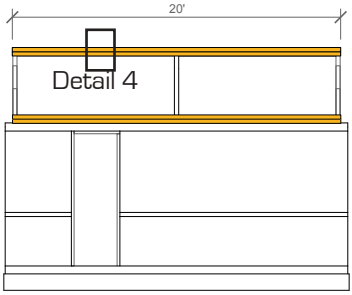


9 | ROOF

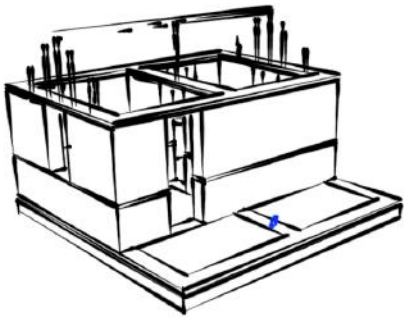
3 Bolt the beams to the columns with T-bolts (Detail 3) and to the lintel band with U-straps (Detail 2). The middle beam is composed of 2 members and are joined together using metal straps and bolts (Detail 4).

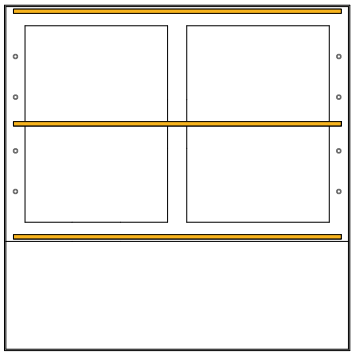


Elevation A

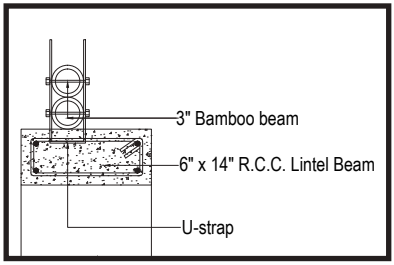


Elevation B

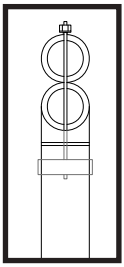




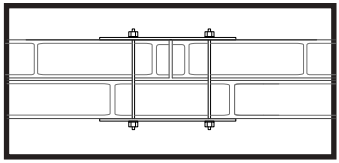
Elevation B



Detail 2



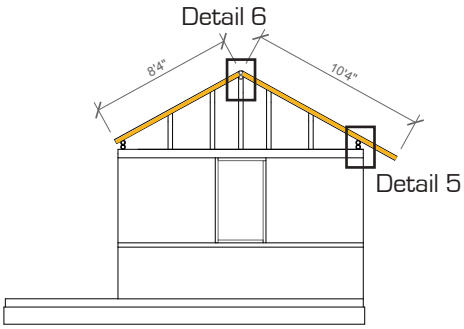
Detail 3



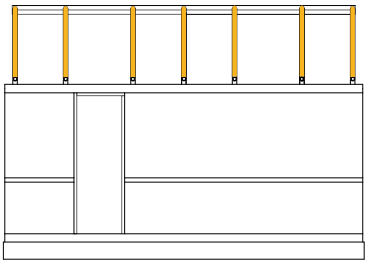
Detail 4

Sn.	Item	Diameter	Length	Quantity
1	Beam	3"	20'	6

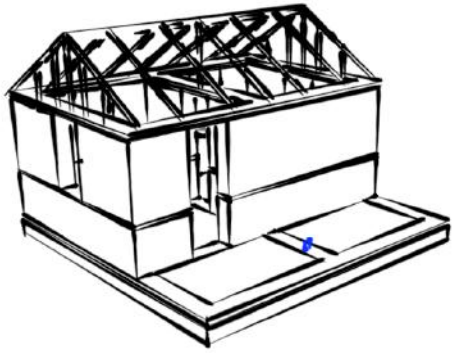
4 The next step is placing the rafters. The rafters will be joined to the beams and columns through metal straps and bolts as shown below.

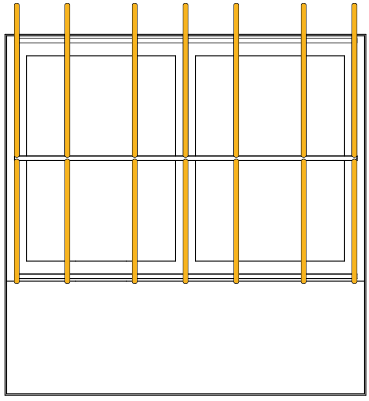


Elevation A

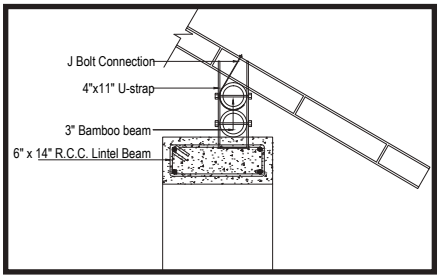


Elevation B

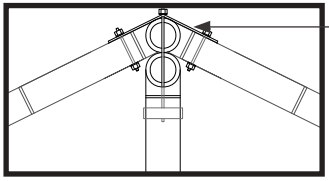




▲ Elevation B



Detail 5



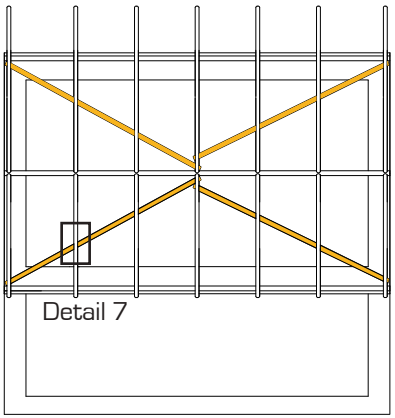
Detail 6

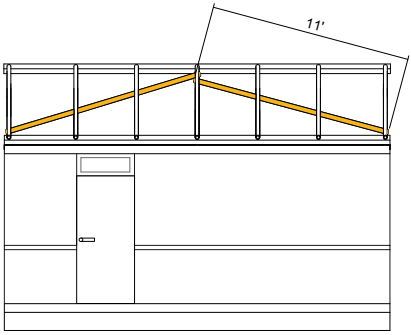
Rafters:

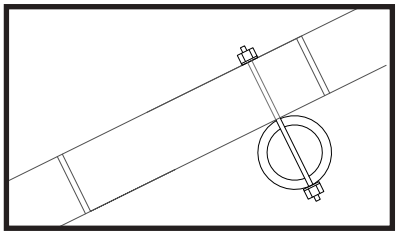
Sn.	Diameter	Length	Quantity
1	3"	8'4"	7
2	3"	10'4"	7

9| ROOF

5 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 stiffen it.



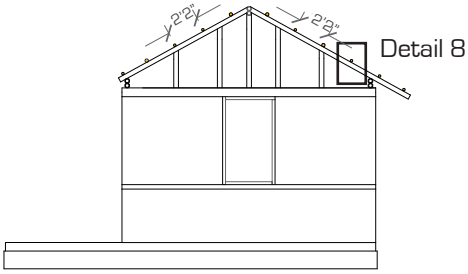


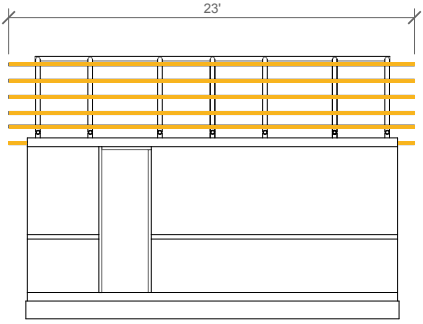


Detail 7

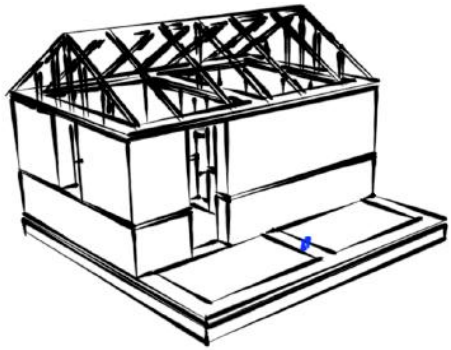
Connection between bracing and beam

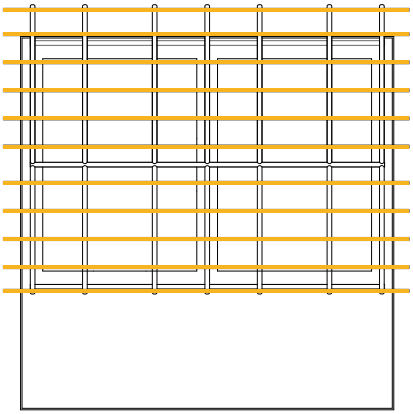
6 Connect the purlins to the rafters using bolts as shown in detail 8.

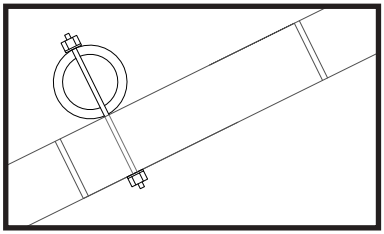




Sn.	Item	Diameter	Length	Quantity
1	Bracing	2.5"	11'	4
2	Purlins	2"	23'	11

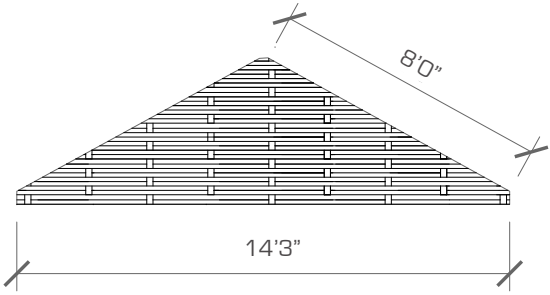






Detail 8

7 Once the bamboo structure of the roof is finalized, place the gable walls which are composed of bamboo weave and mud plaster. Build them aside and then put them in place to save time. Attach the walls to the bamboo structure from outside with wire/nails.



- Refer page 77 on how to build a woven bamboo wall.

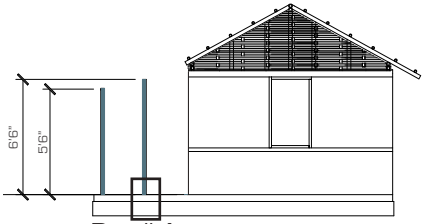
10| KITCHEN AND VERANDA

10.1 INTRODUCTION

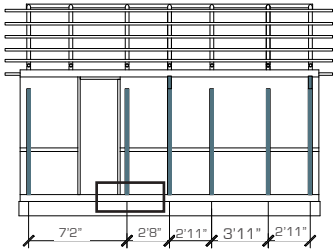
The kitchen and veranda are composed by a bamboo structure. The kitchen is then covered with woven bamboo and mud.

10.2 CONSTRUCTION STEPS

1. Attach the bamboo columns to the plinth band through the metal straps embedded in it.



Detail 1 Elevation A

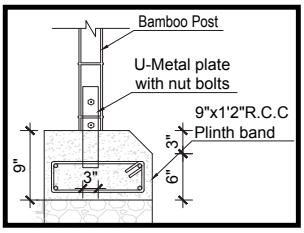


Detail 2

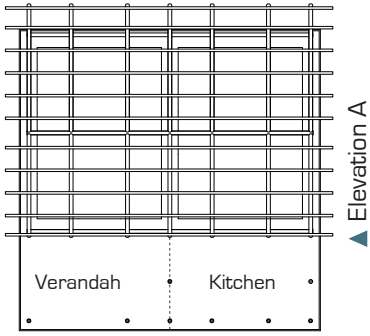
Elevation B

Columns:

Sn.	Diameter	Length	Quantity
1	3”	5’6”	6
2	3”	6’6”	2

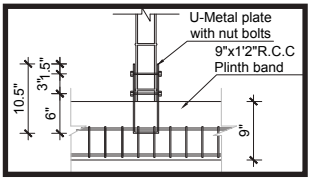


Detail 1

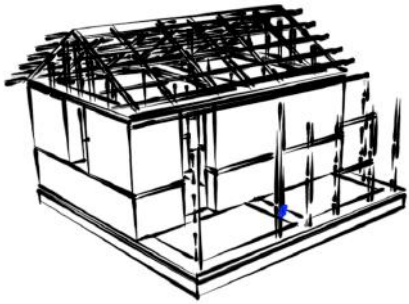


Elevation A

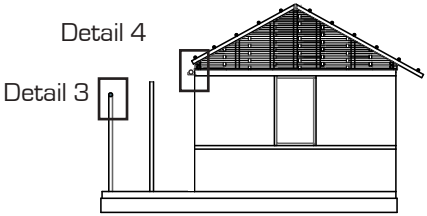
Elevation B



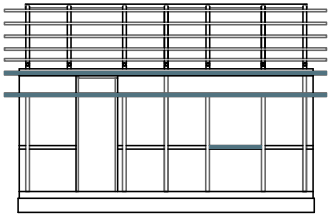
Detail 2



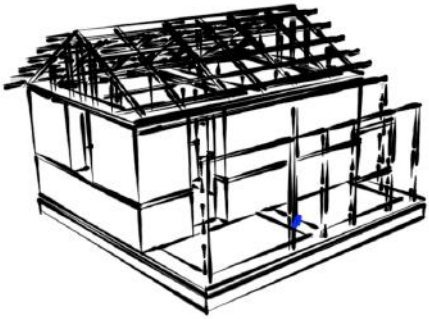
② Place the bamboo beams and the window frame.

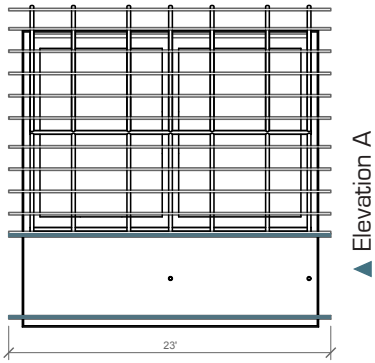


Elevation A



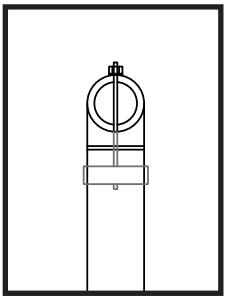
Elevation B



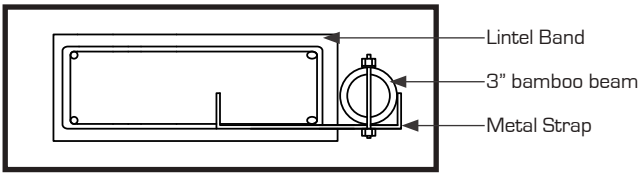


▲ Elevation B

Sn.	Item	Diameter	Length	Quantity
1	Beam	3”	23’	2



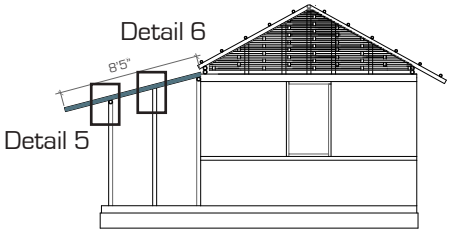
Detail 3



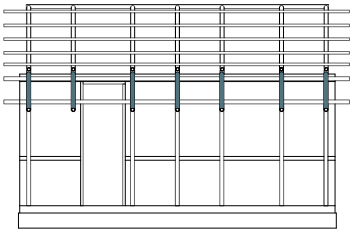
Detail 4

10| KITCHEN AND VERANDA

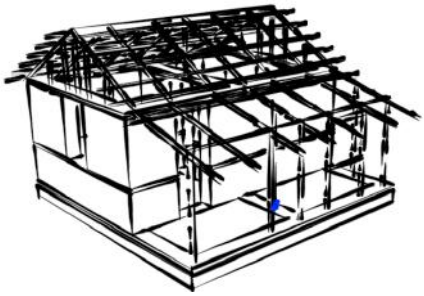
③ Place the rafters and connect to beam and columns using nut bolts.

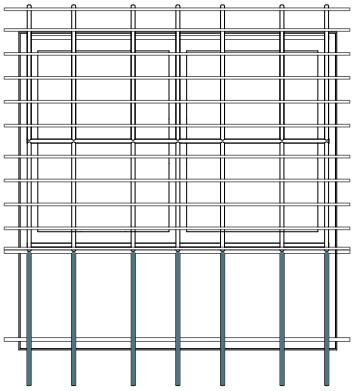


Elevation A



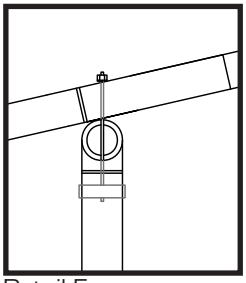
Elevation B



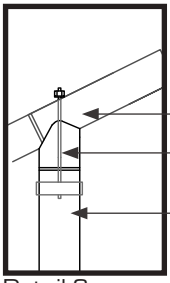


▲ Elevation A

▲ Elevation B



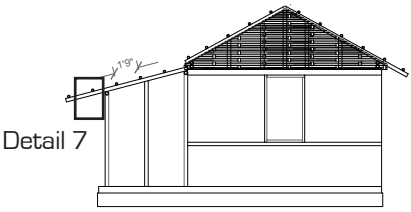
Detail 5



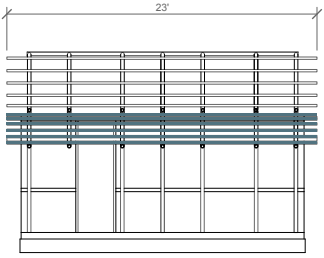
Detail 6

Sn.	Item	Diameter	Length	Quantity
1	Rafters	3"	8'5"	7

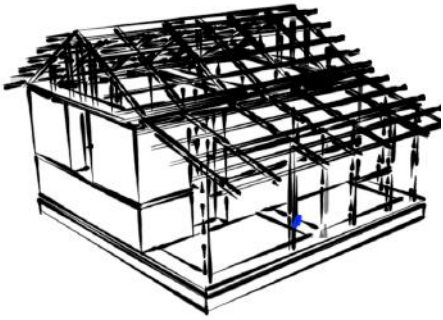
④ Connect the purlins to the rafters with bolts as shown in detail 7.

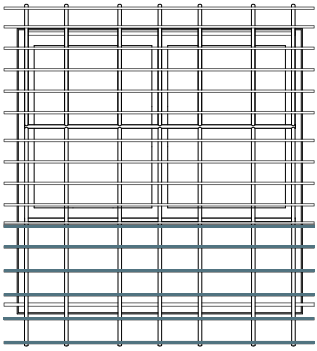


Elevation A



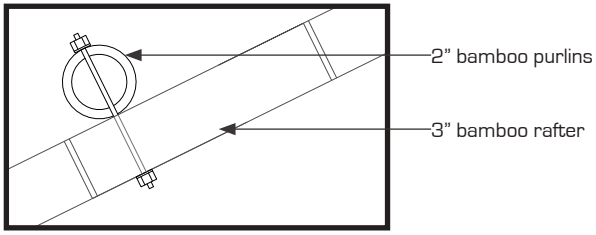
Elevation B





▲ Elevation B

◀ Elevation A

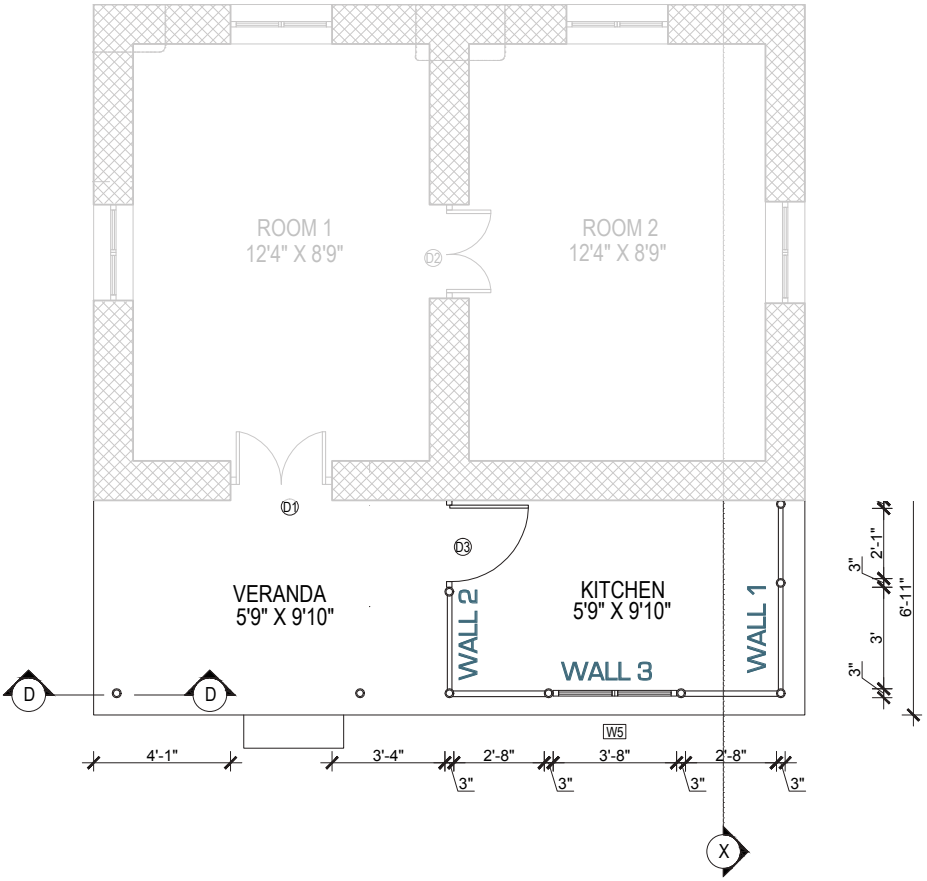


Detail 7

Sn.	Item	Diameter	Length	Quantity
1	Purlins	2"	23"	6

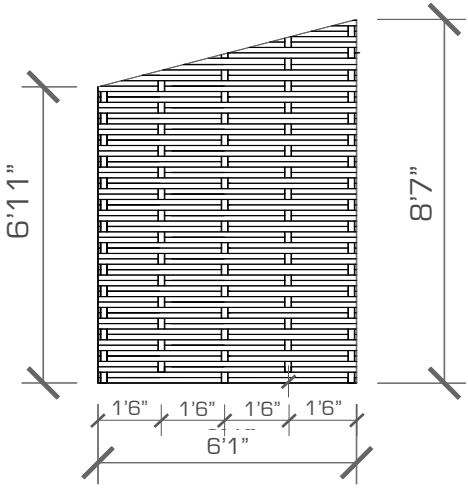
10| KITCHEN AND VERANDA

5 Now put the walls in place. The walls are build aside to save time. The walls should be attached to the bamboo structure on the outside.

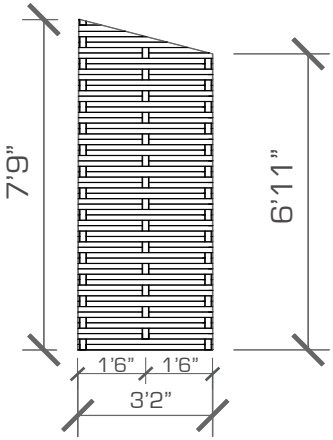


KITCHEN AND VERANDAH
FLOOR PLAN

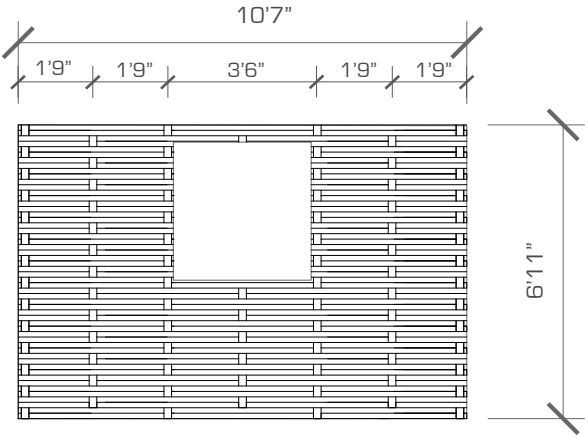
The dimensions of the wall panel are as follows:



WALL 1



WALL 2



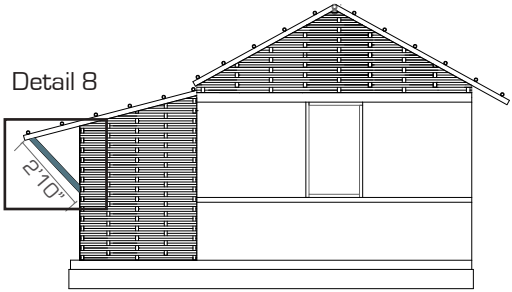
WALL 3

Walls attached to structure on outside using wires/nails

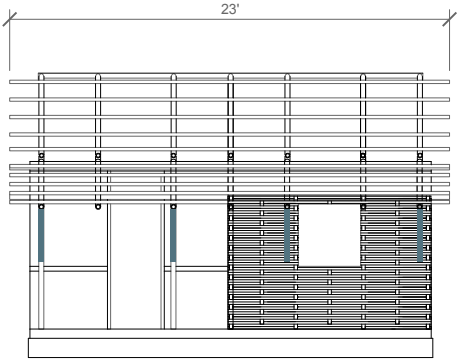
Walls built aside on ground

10| KITCHEN AND VERANDA

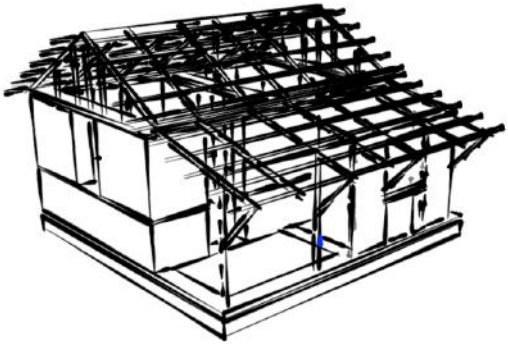
⑥ Proceed to attach the vertical bracing between rafter and post on the front facade. This bracing will strengthen the structure and allow longer eaves to protect the walls and bamboo from rain and sun.

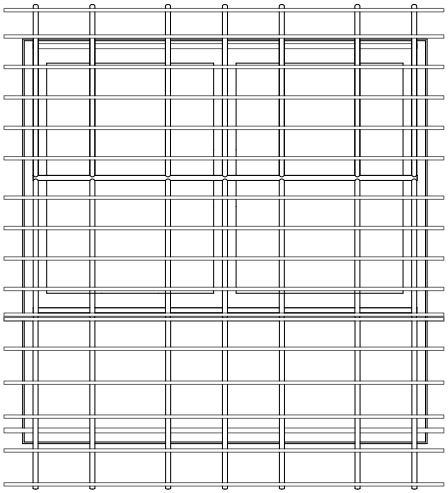


Elevation A



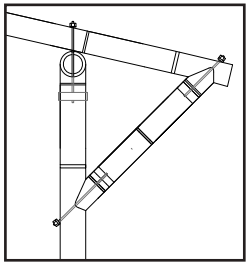
Elevation B





▲ Elevation B

◀ Elevation A



Detail 8

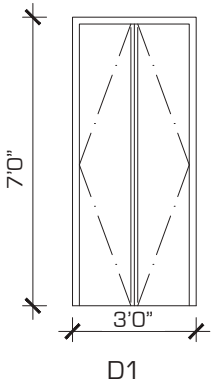
Sn.	Item	Diameter	Length	Quantity
1	Bracing	2"	2'10"	4

11.1 INTRODUCTION

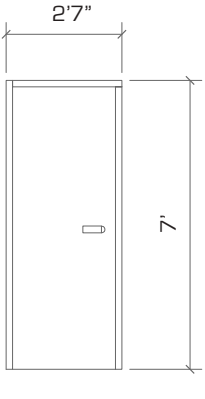
After the bamboo structure and woven walls of bamboo are erected proceed to work on the finishing elements which are roofing cover, plaster, flooring and doors and windows.
These elements can be placed simultaneously by different workers saving time.

11.2 DOORS AND WINDOWS

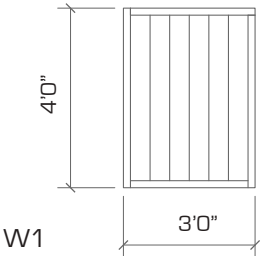
Doors and windows can be done preferably with timber. If not available or too expensive, the alternative would be aluminium or metal.



D1



D3



W1

Sn.	Description	Length	Height	Nos.
1	D1	3'	7'	1
2	D2	2'9"	7'	1
3	D3	2'7"	7'	1
4	W1	3'	4'	4
5	W2	3'8"	4'	1

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.

11 | FINISHING

11.3 ROOFING

For the roofing use CGI sheets and attach them to the bamboo through J-hooks. Ideally a bamboo mat or similar would be placed underneath to improve thermal comfort and increase sound insulation.

11.4 MUD PLASTER

The walls of the kitchen and veranda along with the attic are made from woven bamboo mat and mud plaster.

11.4.1 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.

11| FINISHING

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.

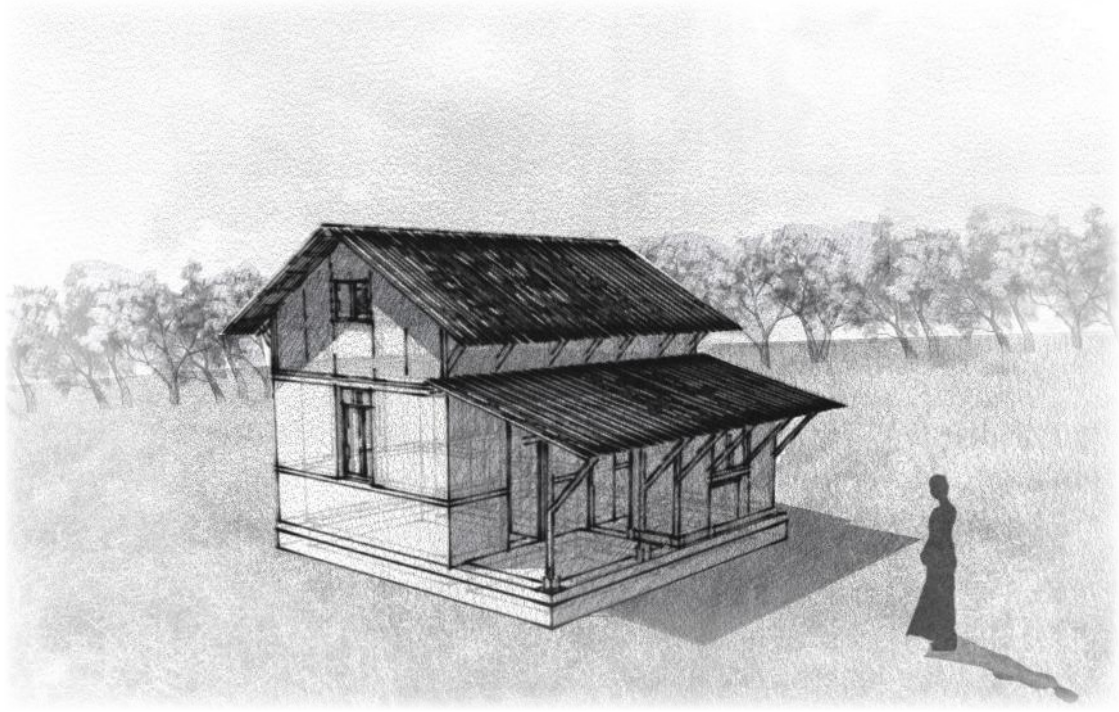
- The plaster should be thrown with strong impact (slapped on) to achieve a higher binding force.

- 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.

11.5 MUD FLOORING

Level the surface and trim any extra mud.

PART TWO
ATTIC

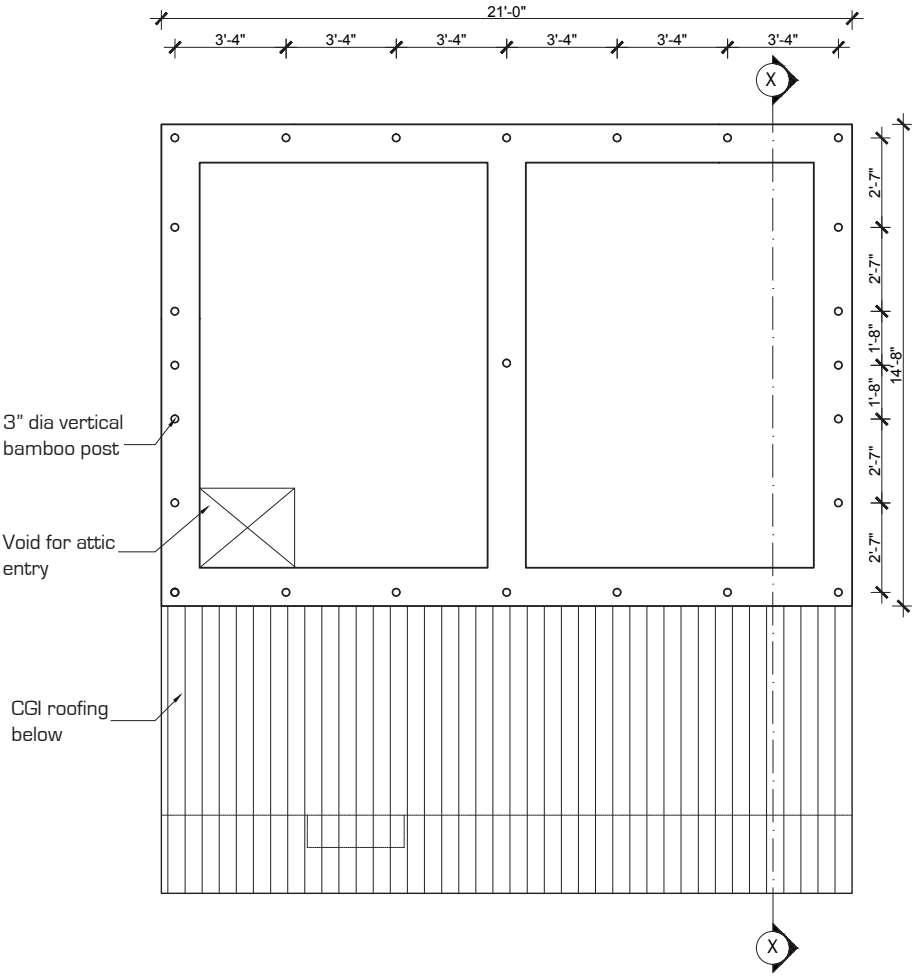


12 | HOUSE PLANS

12.1 INTRODUCTION

This demonstration house has been designed to be increased in the future with an attic or a second floor. The materials proposed for the attic are bamboo with mud plaster. The reason behind this is to reduce cost and increase safety. Light structures work much better in case of an earthquake.

12.2 ATTIC FLOOR PLAN



12.3 ELEVATIONS

Front Elevation

Side Elevation 1

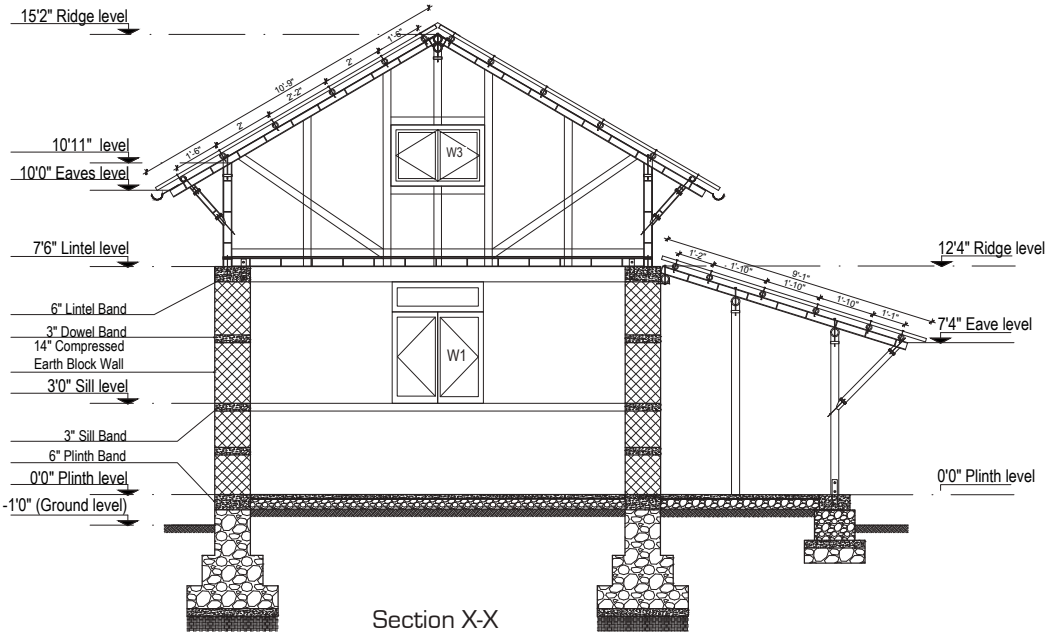
Side Elevation 2

Back Elevation

3D Render of the demonstration house

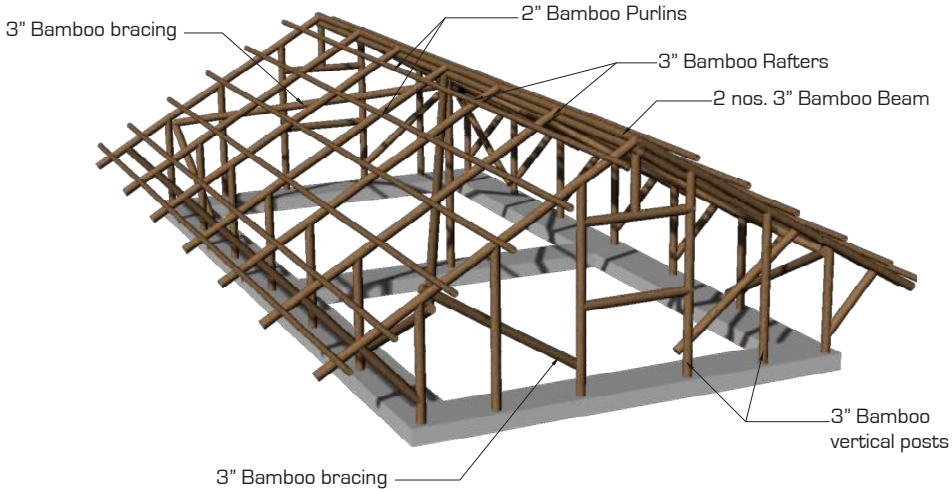
11| HOUSE PLANS

12.4 SECTION



Section X-X

12.5 ROOF



13 | BILL OF QUANTITIES

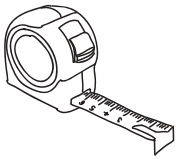
13.1 CONSTRUCTION MATERIALS AND MANPOWER

	ATTIC	Unit
MANPOWER		
Skilled Labour	22	Md
Unskilled Labour	49	Md
MATERIALS		
3" dia Bambbo	71	Nos
2.5" dia Bamboo	22	Nos
2" dia Bamboo	26	Nos
Mud	3	Cu.m
CGI Sheets	16.5	Sq.m

14| ATTIC

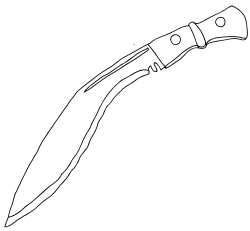
14.1 TOOLS NEEDED

1 Measuring tape

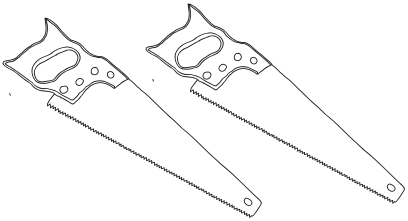


2 Markers

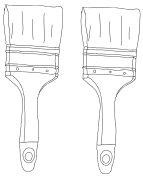
3 Gurkha Knife



4 Saws

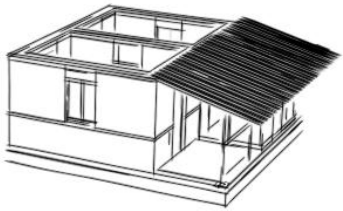


5 Brushes

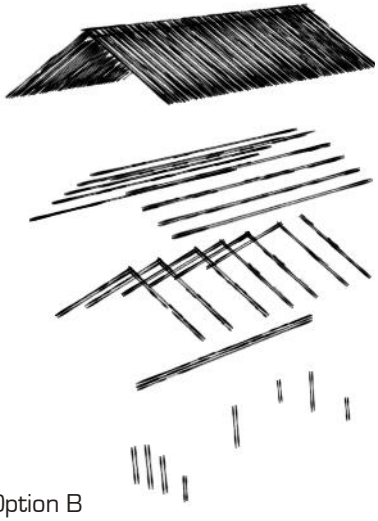


14.2 STEPS

1 In case of availaibility of labour, the roof structure can be moved to the ground in its entirety from the house. (Option A)

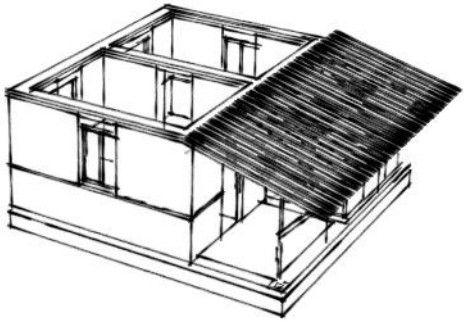


Option A

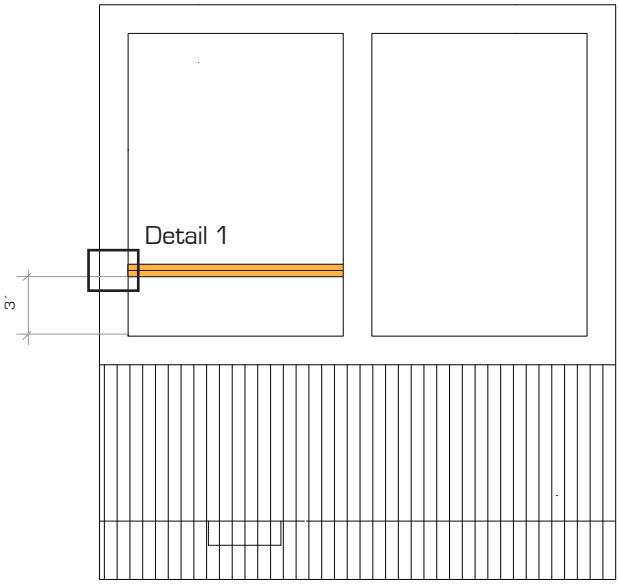


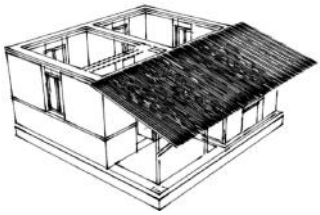
- In case of unavailabiltiy of labour, the roof structure can be dismantled (Option B).

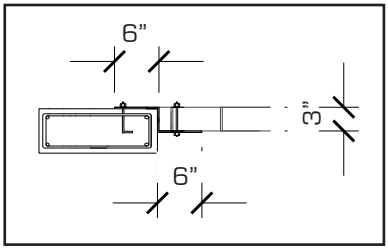
Option B



2 **Flooring:** Install the bamboo beams for the flooring as shown in figure below.



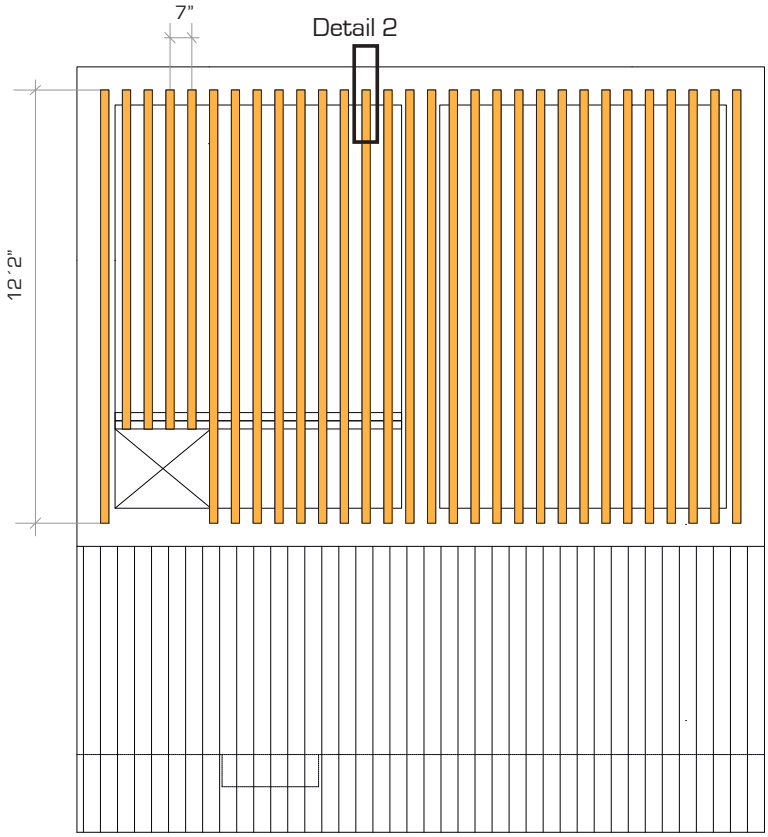


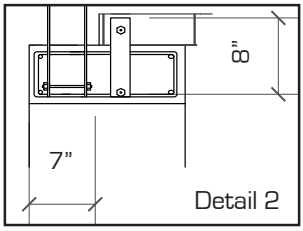


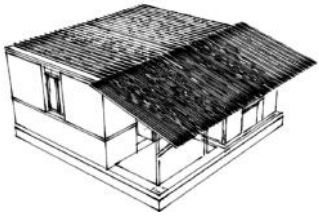
Detail 1

14| ATTIC

3 **Flooring:** Then install the bamboo joists. Not every joist will need a strap, just place on the band the same straps as for the columns (next page).



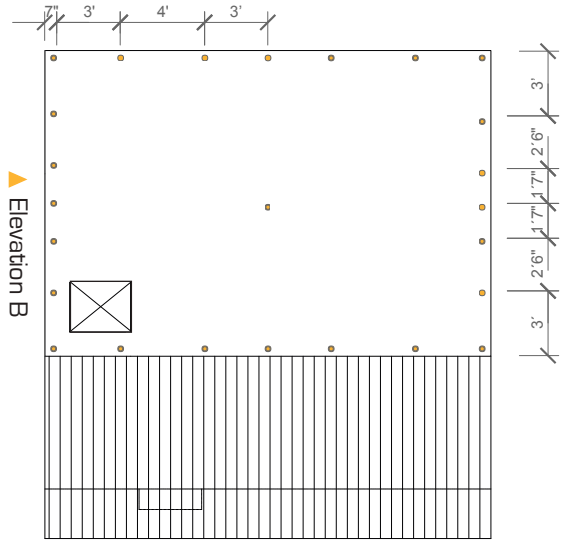




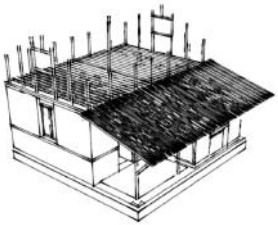
Sn.	Item	Diameter	Length	Quantity
1	Joists	3”	12’2”	30

4 **Flooring:** Once floor joists are installed cover them with flattened bamboo and mud, split bamboo and mud, plywood or other materials.

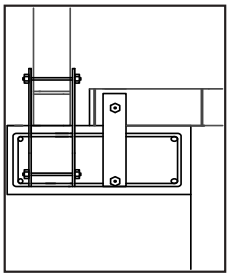
5 **Columns:** After the flooring, place the columns attached to the metal straps embedded on the lintel band.



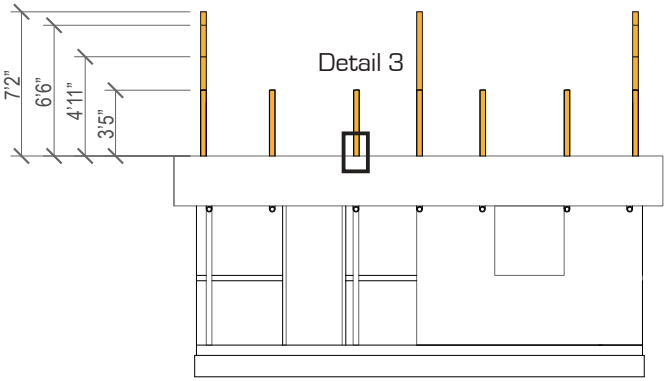
Elevation B



Elevation A



Detail 3



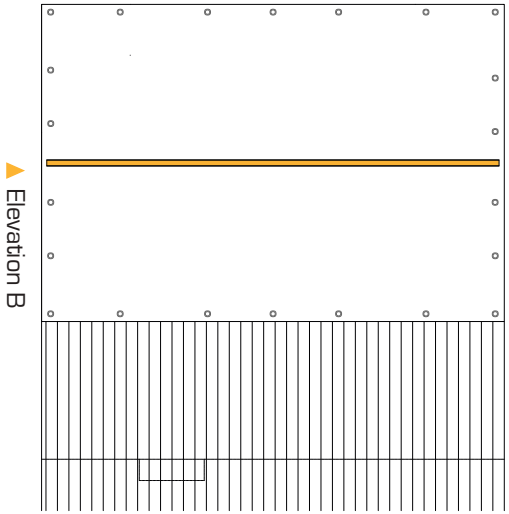
Elevation A

Columns:

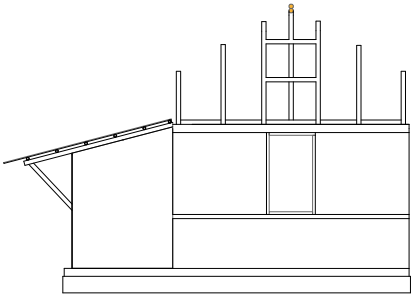
Sn.	Diameter	Length	Quantity
1	3"	3'5"	14
2	3"	4'11"	4
3	3"	6'6"	4
4	3"	7'2"	3

14| ATTIC

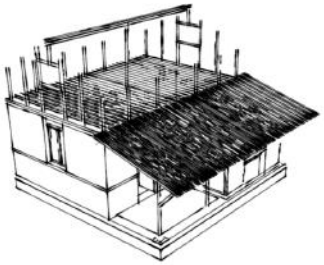
6 **Beams:** Put in place the entire roof or do it element by element. The process is the same as with the first floor roof.

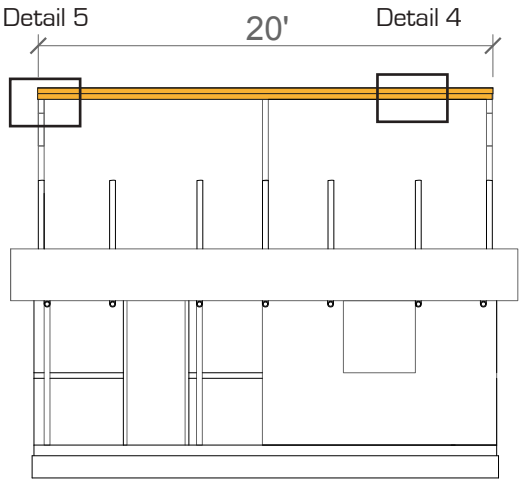


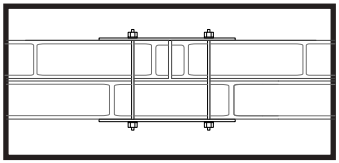
Elevation A



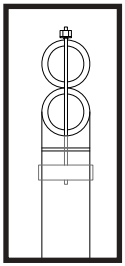
Elevation B







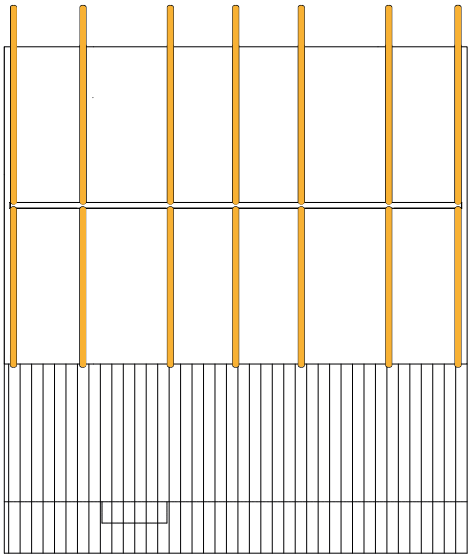
Detail 4

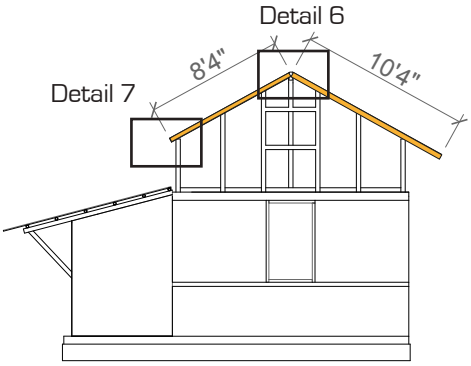


Detail 5

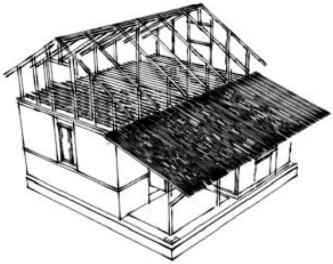
Sn.	Item	Diameter	Length	Quantity
1	Beam	3"	20'	2

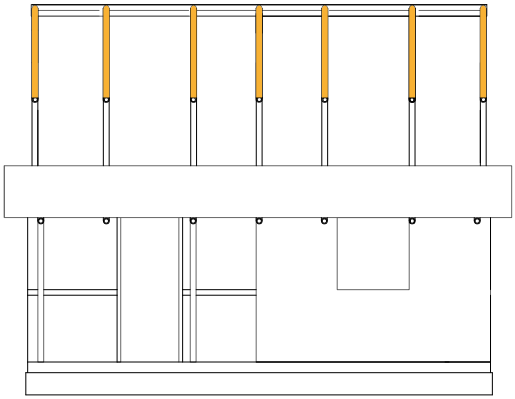
7 **Rafters:** Place the rafters from the previous roof and join them to the beams.



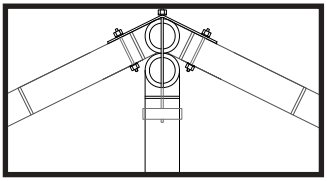


Elevation B

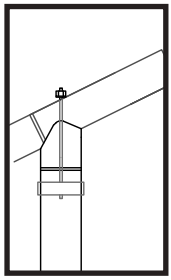




Elevation A



Detail 6



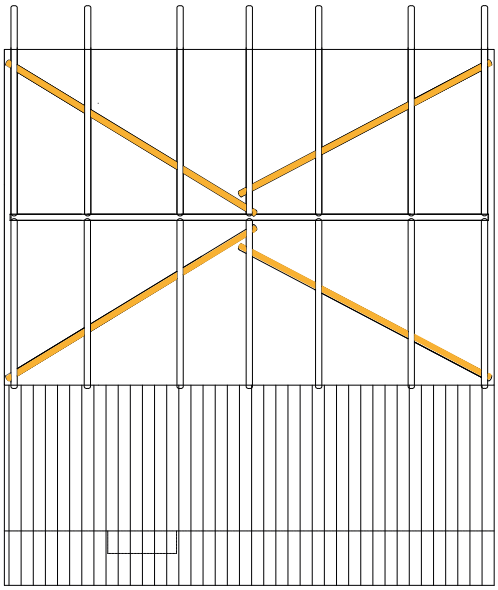
Detail 7

Rafters:

Sn.	Diameter	Length	Quantity
1	3"	8'4"	7
2	3"	10'4"	7

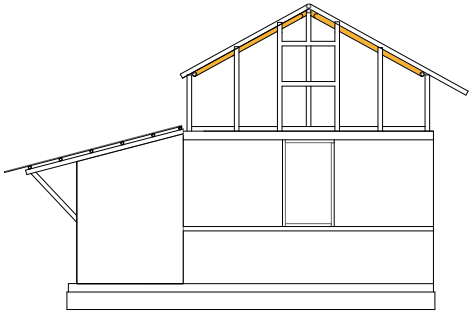
14| ATTIC

⑧ **Bracing:** Add the diagonal bracings to increase the strength of the roof.

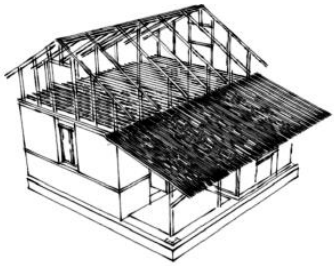


▲ Elevation A

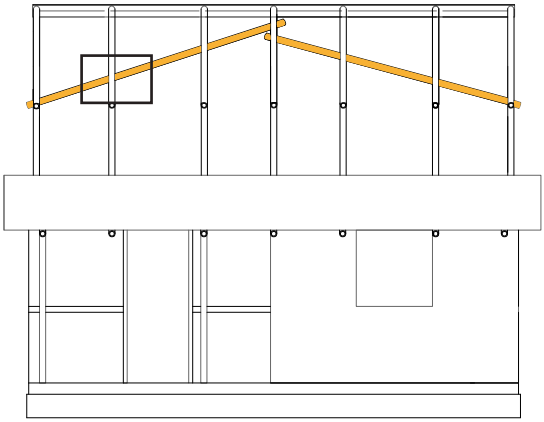
▶ Elevation B



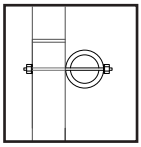
Elevation B



Detail 8



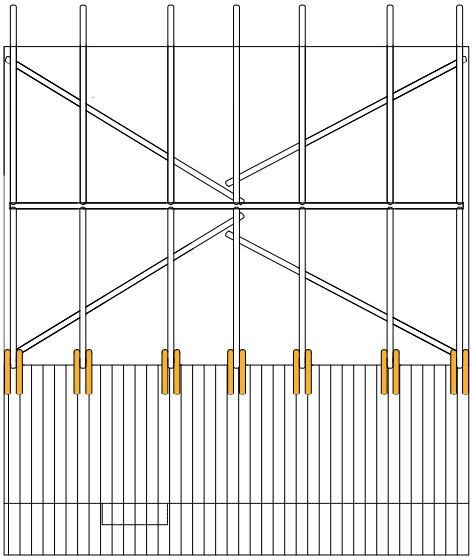
Elevation A

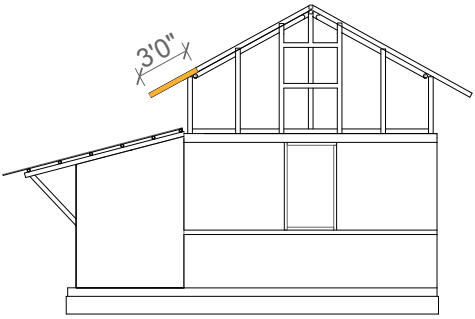


Detail 8

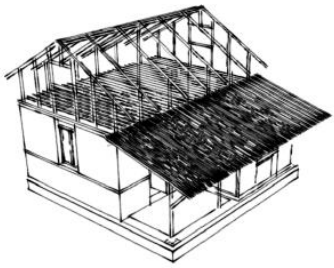
Sn.	Item	Diameter	Length	Quantity
1	Bracing	2.5”	11’	4

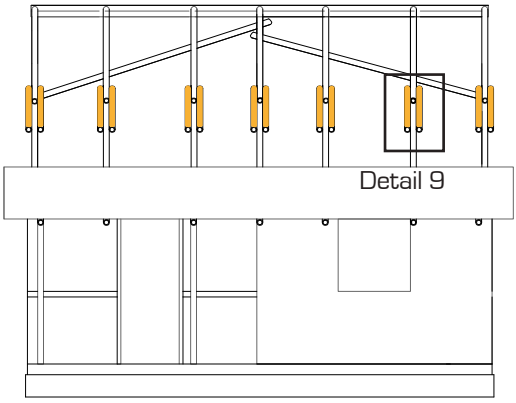
9 **Rafters:** As the rafters from the veranda side are shorter extend them as shown below.



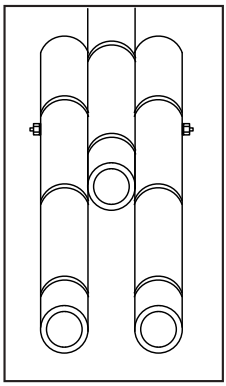


Elevation B





Elevation A

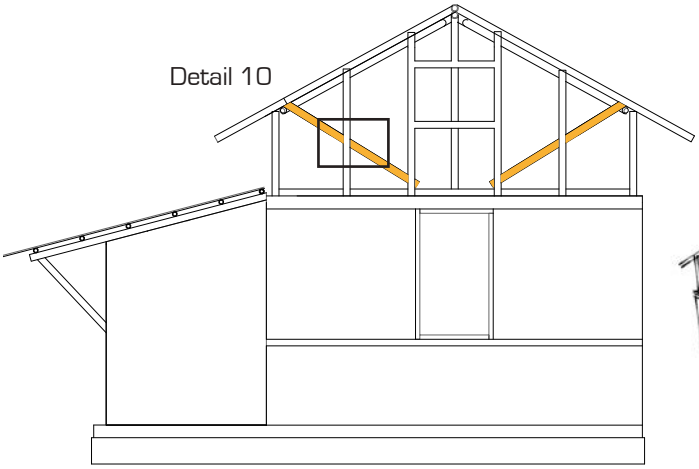


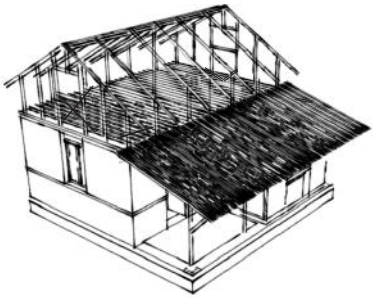
Detail 9

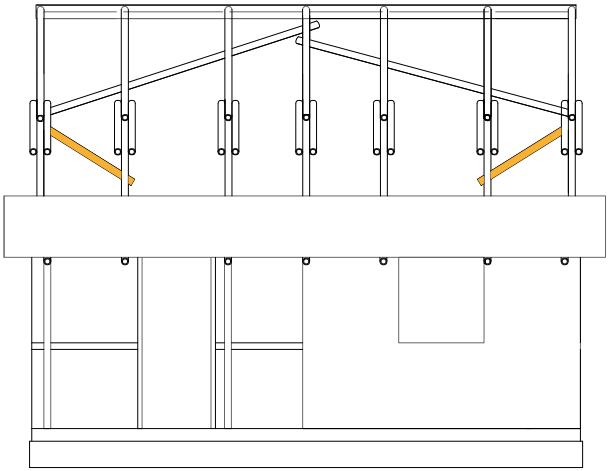
Sn.	Item	Diameter	Length	Quantity
1	Rafter	2"	3'	14

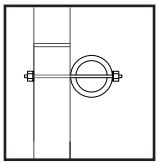
14| ATTIC

10 **Bracing:** Add diagonal bracings to the walls too.







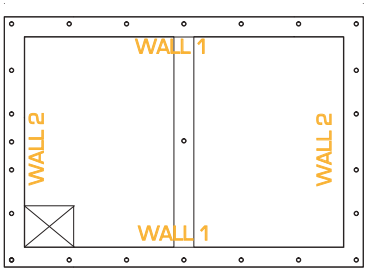


Detail 10

Bracing:

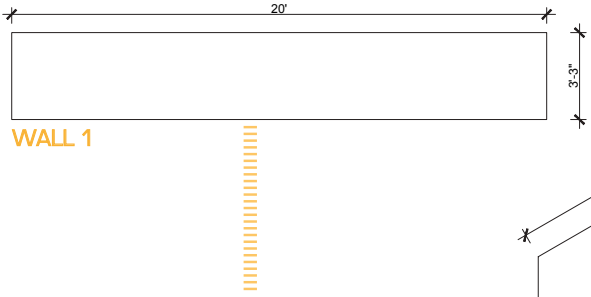
Sn.	Diameter	Length	Quantity
1	2.5”	5’9”	2
2	2.5”	4’2”	2

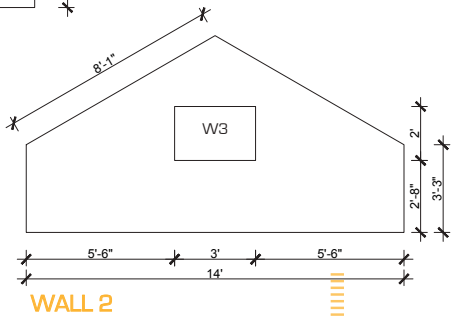
11 **Walls:** Add the woven bamboo walls.



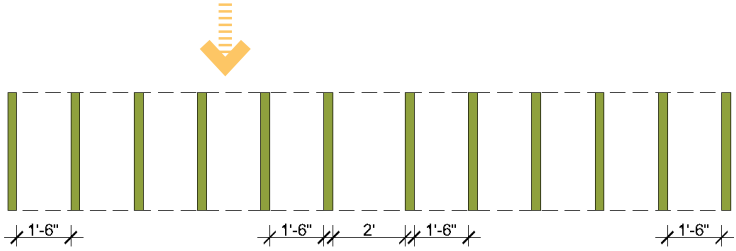
Process of making bamboo walls:

1. Measure the length and height of the wall.

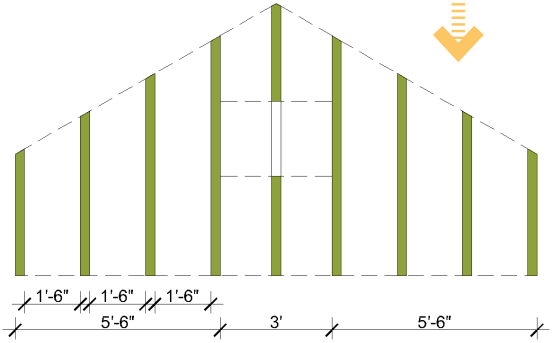




2. Cut the bamboo strips as per the dimensions and lay them on the ground. Lay the vertical members first at equal spacing or as per given dimensions. (Picture 1)

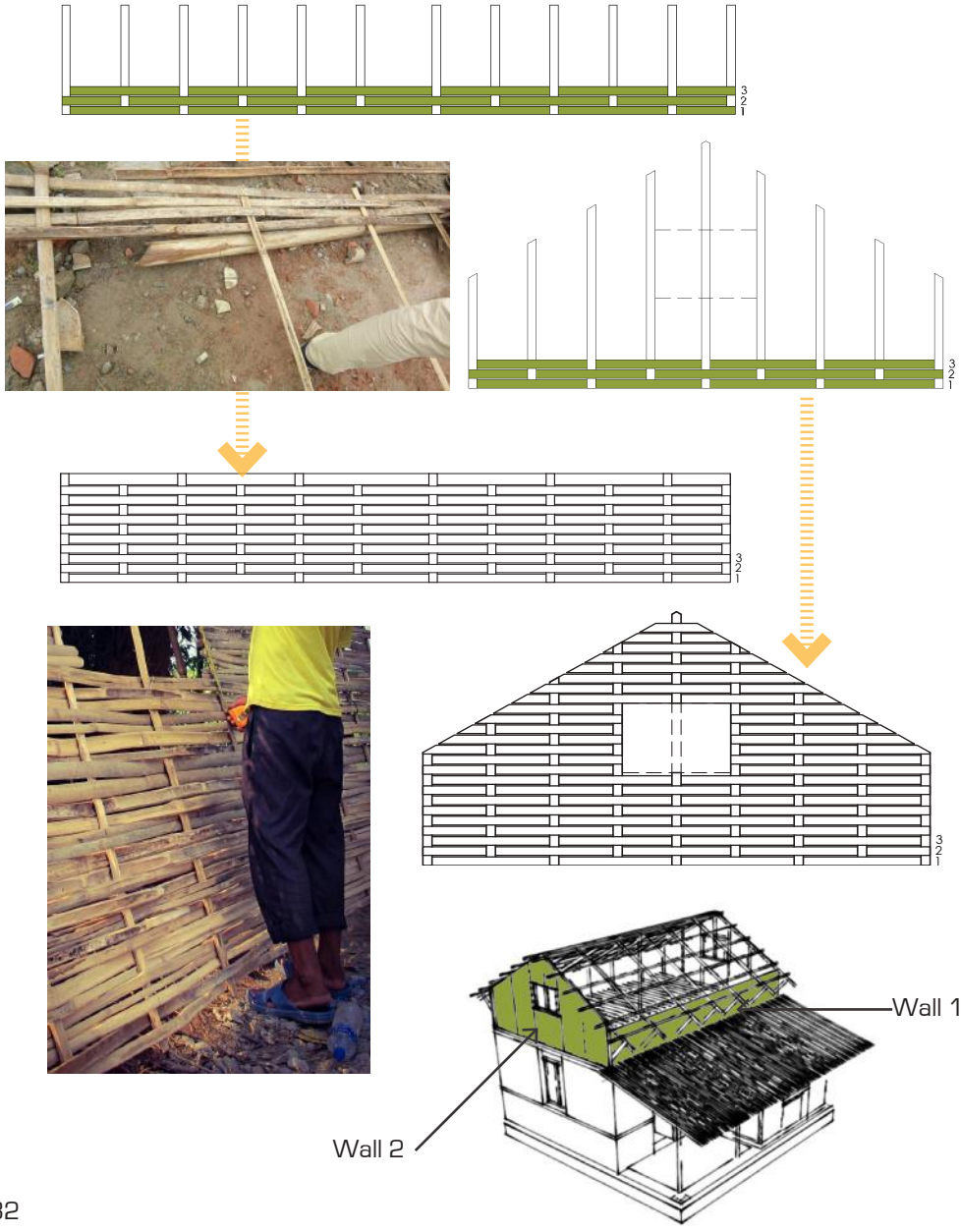


Picture 1



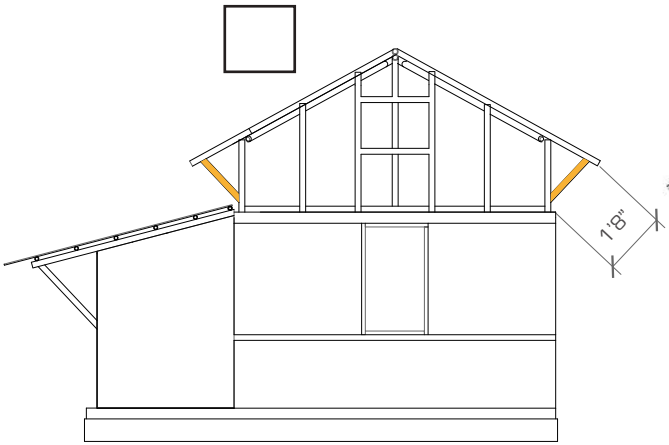
14| ATTIC

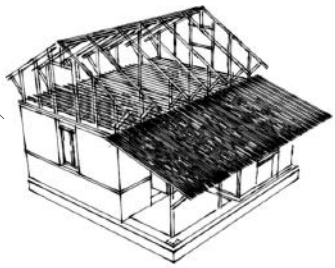
4. Start weaving the wall with bamboo strips horizontally one at a time.

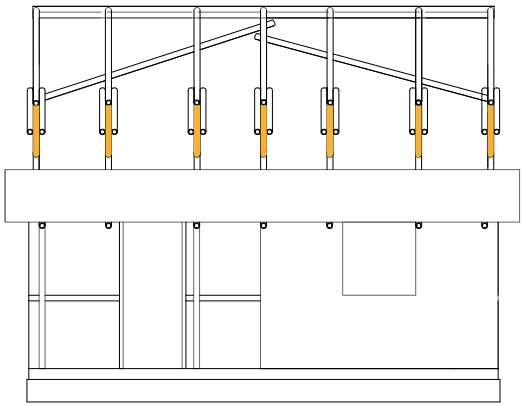


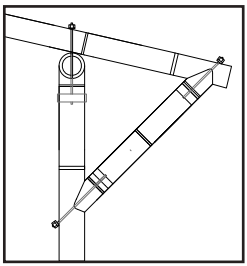
12 **Inclined columns:** To be able to have long eaves to protect the bamboo and mud plaster, place inclined columns on the exterior, bolting it to the vertical columns and rafters which will also help in strengthening the structure.

Detail 11







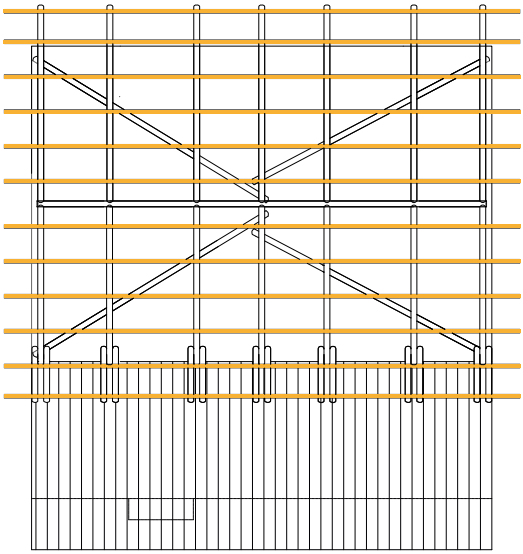


Detail 11

Sn.	Item	Diameter	Length	Quantity
1	Column	2.5"	1'8"	14

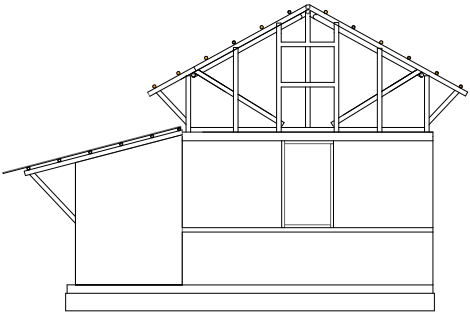
14| ATTIC

13 **Purlins and CGI:** Place the purlins and the CGI sheets. For more detail, go to page 48 & 49.

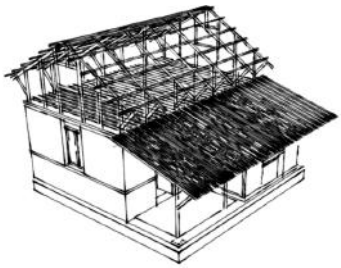


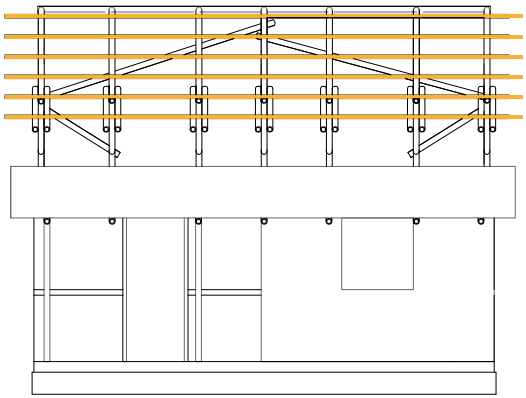
▲ Elevation A

◀ Elevation B



Elevation B



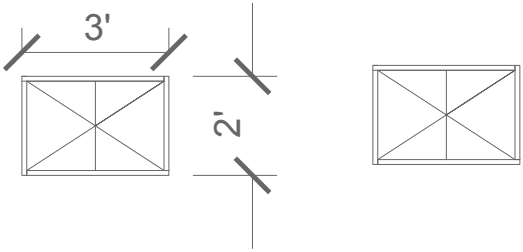


Elevation A

Sn.	Item	Diameter	Length	Quantity
1	Purlin	2”	23’	12

14 **Plaster:** Plaster the walls and finish the floor by levelling surface and trimming any extra mud.

15 **Windows:** Simultaneously, place the windows.



Sn.	Description	Length	Height	Nos.
1	W3	3'	2'	2

15| SAFETY TOOLS

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

Wear a mask and goggles 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

Keep the site tidy to help prevent accidents

Ask if you are uncertain about your task

15 | REFERENCES

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