

# Construction manual

## A step by step manual to build a bazaar



AR3B011 EARTHY (2019/20 Q1)

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# Introduction

This manual is made for the construction workers of the camp. In this manual a step by step instruction can be found of how to build the bazaar from adobe bricks. The building workers have a basic level of constructing which they learned during their education period in the camp. Next to this, they work together with Unicef, who provide them with the inflatable mould.

This manual is implemented in the app. The app itself has all the data of the camp, knows the existing structure of the camp and the guidelines. The future shop owner can implement his wishes and choose his location. The app shows the construction worker each step he needs to follow to construct the shop in this building manual.

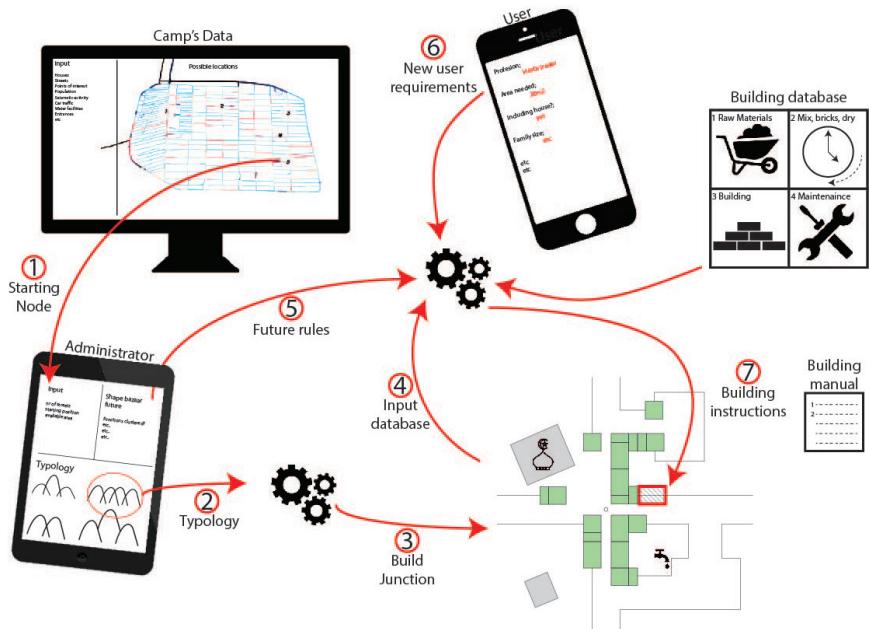
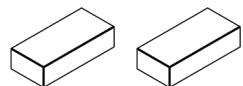


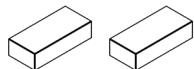
Figure 1. Working of the app.

# Needed Materials

**Big Adobe bricks:** Width size 250x100x360



**Small Adobe bricks:** Width size 150x50x25



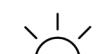
**Rocks and or stones:** For the foundation



**Soil:** For bricks, mortar and coating



**Water:** For making the bricks



**Sun:** For drying the bricks



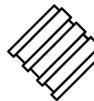
**Straw:** To strengthen the bricks



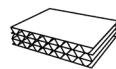
**Feathers:** To strengthen the bricks



**Corrugated sheet:** For doors and scaffolding



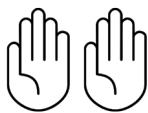
**Cardboard:** For the mould of the windows



**Wood:** For the adobe mould



# Required Tools



Hands



Feet



Pencil



Rope



Wheelbarrow



Pickaxe



Broom



Shovel



Hammer/Nails



Saw



Trowel



Plumb Line



Scale



Measuring tape



Brush



Glue



Magnifying glass



Blow dryer

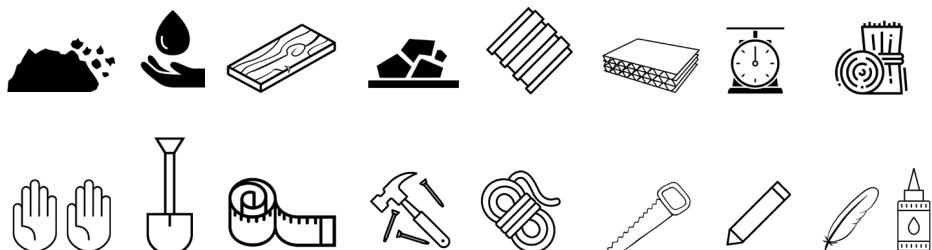
# Preparations

## The Location

Make sure that the building location is not the lowest place around you. This is to prevent water coming into your building. Also, increase the height of the ground around the edges of the walls to protect the construction from water penetration.

Warning: do not extract the ground next to the construction for creating a slope or getting material.

## Material and Tools



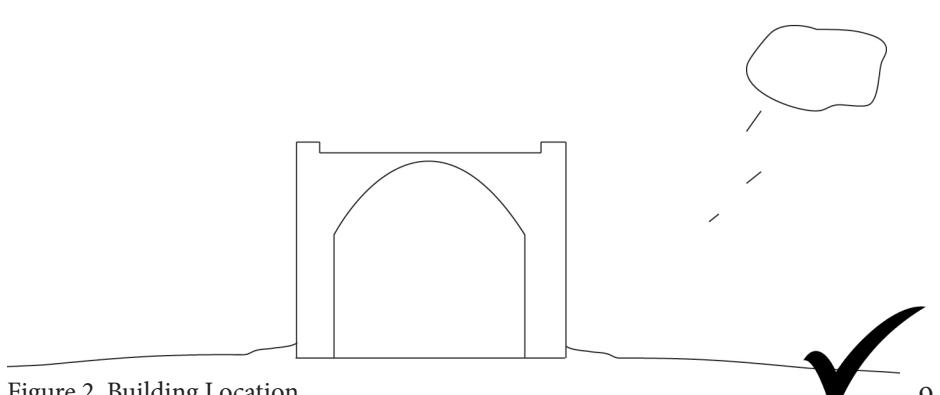
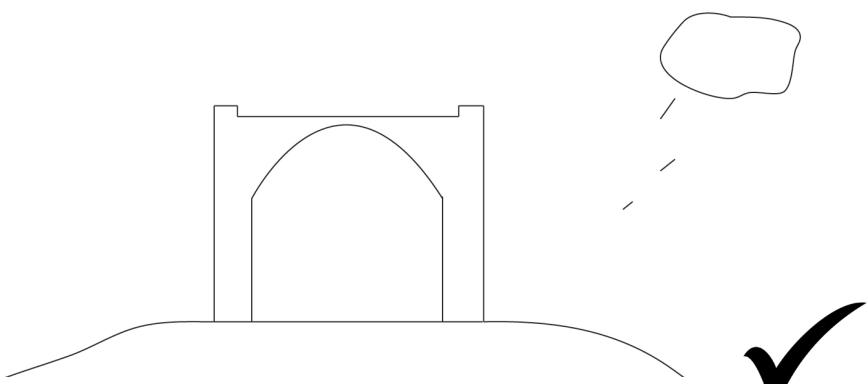
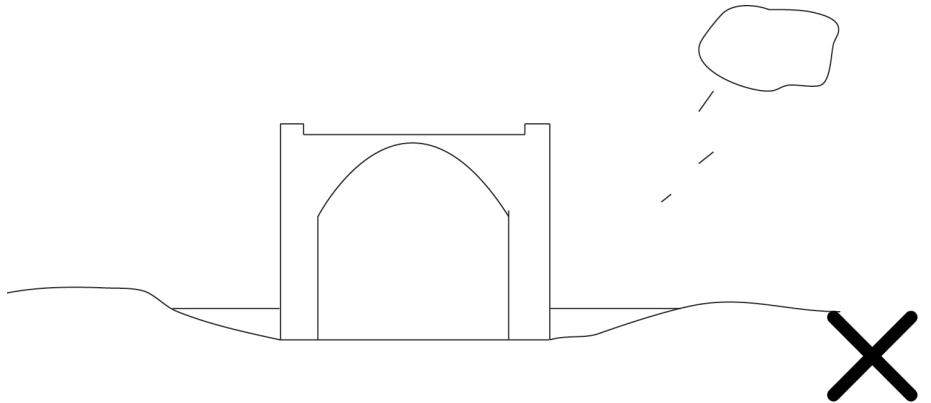


Figure 2. Building Location.

## Quality control: Adobe

Not all the earth that can be found around you can be used for making the building. To decide which soil should be used the following test need to be conducted.

### The drop test

- Create a round ball of earth in your hand.
- Straighten your arm on shoulder level.
- Drop the ball on the ground.

1. If the ball does not break don't use it.  
-> too much clay.
2. If the ball breaks in a lot of small pieces don't use it.  
-> too much sand.
3. If the ball breaks in some large pieces, use it!  
-> good.

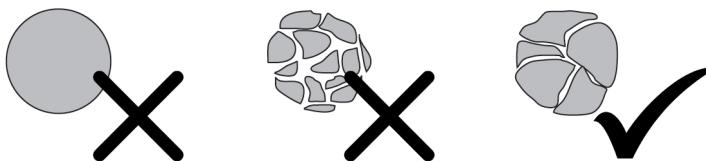
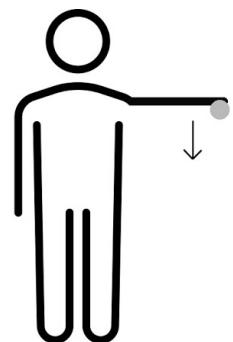


Figure 3. Drop test.

## The workspace

A location needs to be defined as mixing and drying area. It is important that the drying place is protected from rain as this negatively influence the quality of the adobe bricks.

- Dig a big hole to mix the clay, fine sand, coarse sand and the straw or feathers in.
- Fill the hole with water and drain it out.
  - This is to make sure the hole stays intact during the mixing and does not crumble.
- Let the hole dry for a day.
  - > Mixing workspace is ready.

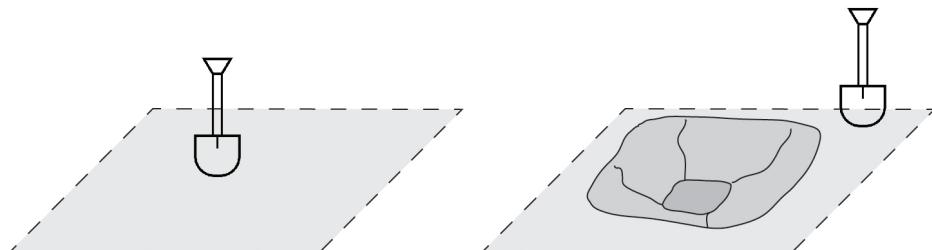


Figure 4. The workspace.

## **The adobe mould**

There are 2 different types of brick with their own dimensions. The large brick is used for the straight structural ribs and load bearing walls, with the size 25cm x 10cm x 36cm. The second type of bricks is a bit smaller and thinner. These are used as the fill in of the roof structure and for the ribs of the smaller domes. These domes have a steeper curve, what is possible with thinner bricks. Finally some key stones are made on site.

### **Brick type 1**

A large brick has the following dimension: 25cm x 10cm x 36cm what will give an average weight of 16kg.

- Collect the wood for the mould.
- Make the width of the wooden strips 10cm, this is the height of the brick
- The inside of the wooden frame should have the width and height of the brick.
  - > Take into account that the brick shrinks during drying.
- To save time a “Ladder” mould can be created of wood instead of a single mould.
- Leave some space on the side to make it possible to lift the mould.

### **Brick type 2**

A small brick has the following dimension: 25cm x 5cm x 15 cm.

- Collect the wood for the mould.
- Make the width of the wooden strips 5cm this is the height of the brick
- The inside of the wooden frame should have the width and height of the brick.
  - > Take into account that the brick shrinks during drying.
- To save time a “Ladder” mould can be created instead of a single mould.
- Leave some space on the side to make it possible to lift the mould

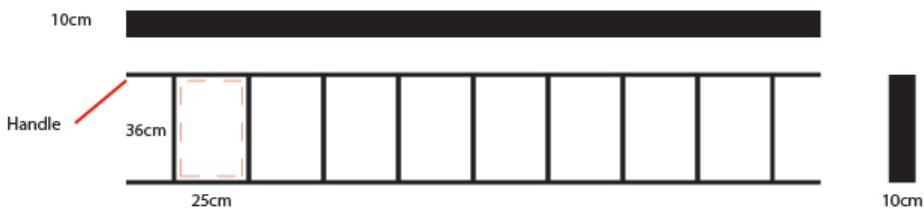


Figure 5. Big mould.

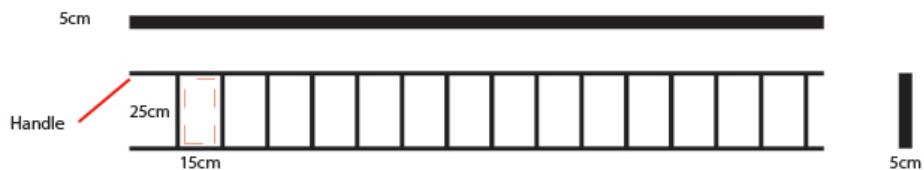


Figure 6. Small mould.

## Type of bricks

There are six ingredients needed to make the adobe bricks:

Clay, fine sand, coarse sand, bricks, water and if needed straw or feathers. The exact mixture depends on what kind of brick is needed. These proportions need to be controlled at all times to make sure the adobe bricks have the right properties.

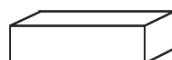
1. Brick to fill in between the ribs structure and partition walls:

-30% clay.

-30% fine sand.

-40% coarse sand.

-1 liter of water.



2. First meter of inside rib structure:

-30% clay.

-30% fine sand.

-40% coarse sand.

-1 liter of water.

-1% of total volume straw.



-> This is the place with the most concentrated stress. Straw is needed as reinforcement.

3. Upper part of the rib structure and load bearing walls:

-30% clay.

-30% fine sand.

-40% coarse sand.

-1 liter of water.

-1% of total volume feathers.



-> The stresses are slightly lower than in the bottom part but reinforcement is still needed. Straw is only used in the needed places due to scarcity. Now feathers should be used.

4. For the first meter of exterior wall:

-Layer of small bricks.

-30% clay.

-30% fine sand.

-40% coarse sand.

-1 liter of water.

-1% of total volume feathers.

-> To strengthen and protect the first meter of wall against water and other impacts. When this is not possible, fire bricks could be used.



## Mortar

When the adobe bricks are made and dried, the mortar can be made immediately before constructing.

-Mix the same ingredients together as for the adobe-only bricks without the feathers or the straw.

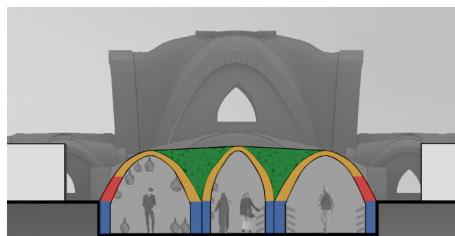


Figure 7. Location brick types.

## Quality control adobe bricks

The adobe bricks can be made after choosing the right material. The bricks need to be tested for their strength after they are formed and dried. This is to make sure the construction will not collapse.

### The strength test

- Place two bricks 30cm apart from each other, this is around one feet in between.
- Place a third brick on top of these two bricks.
- Let one average weighted adult stand on the brick.
  - > If the brick breaks don't use it
  - > If the brick does not break, use it!

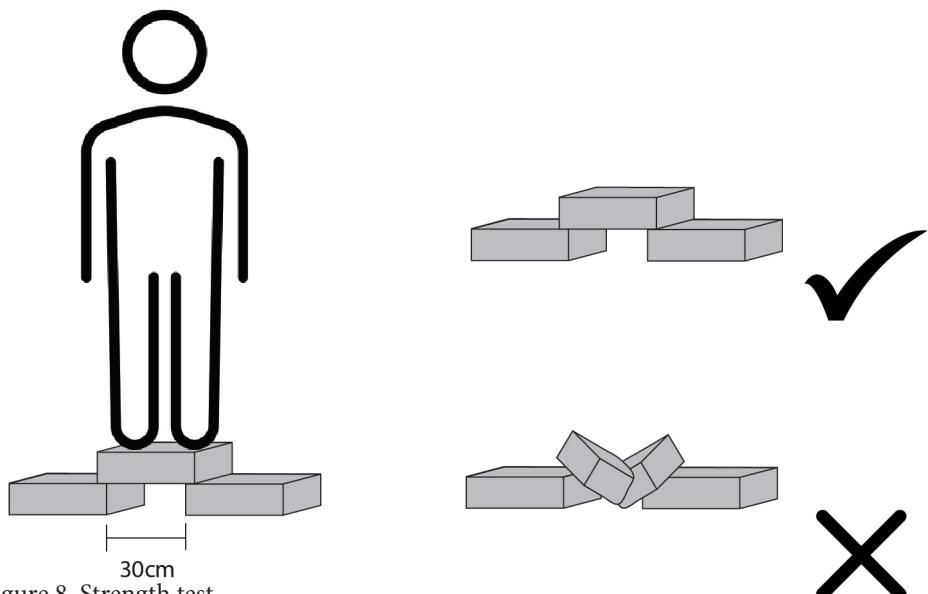


Figure 8. Strength test.

## Scaffolding

- Place two bricks 10cm from each other on the ground
- Place two bricks on top, 10 cm from each other, turned 90 degrees compared to the 1 row.
- Duplicate this process once the other side.
- Place a corrugated sheet on top.
- Test if the corrugated sheet does not break.
- If not continue the process till the needed height.
- Place the corrugated sheet.
- Create a ramp or some small steps to get safely on the scaffolding.

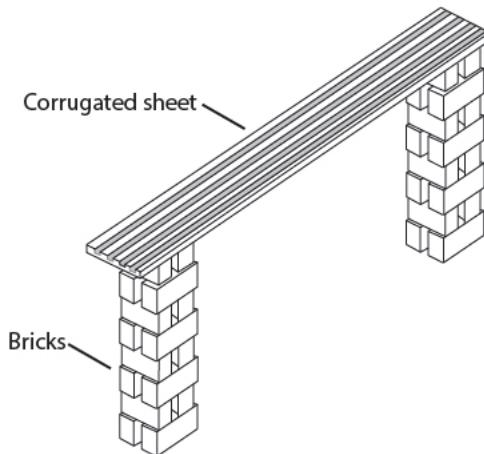


Figure 9. Scaffolding.

## **Cardboard mould**

- Get a cardboard piece from the camp with minimum dimension of 600mm by 600mm.
- Draw two circles with a radius of 600mm.
- The shape of the lancet arch is formed (Red dotted lines).
- Cut this piece from the cardboard.
- Re-do these step till the cardboard has a minimal thickness of 36cm (depending on stone)
- Connect the cardboard pieces to each other with rope or glue to make it a rigid final structure.

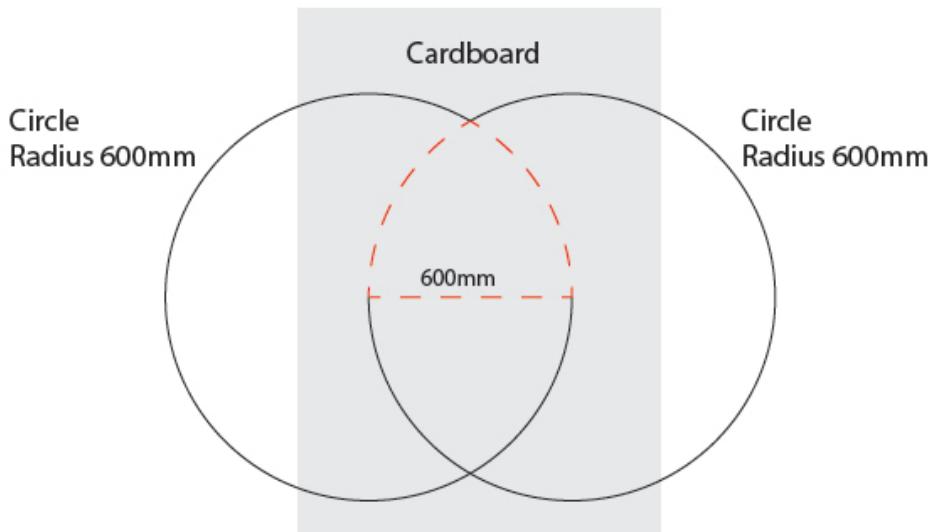
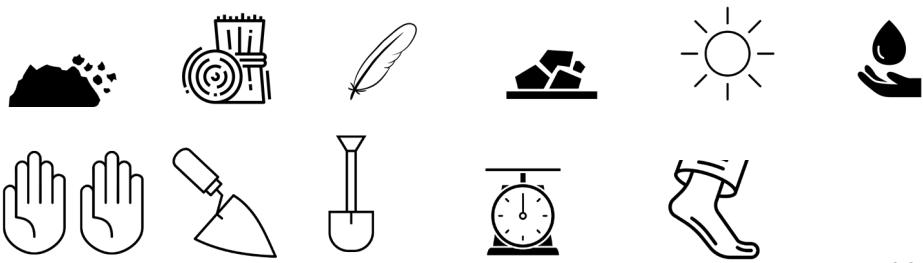


Figure 10. Cardboard mould.



# Making the bricks

## Material and Tools



## Making the bricks

If all the materials are collected the mixing process can start.

- Put all the ingredients in the right proportion in your mixing workspace.
- Mix the ingredients by walking through the mixture or by using a shovel.
- Put some sand on the side of the mould, to make sure the mixture will get out.
- Put the mixture into to mould.
- Even the surface of the mould by hand or with a trowel.
  - No air pockets or gaps should be in the mixture.

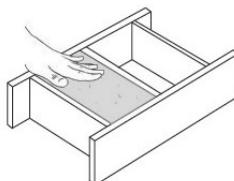


Figure 11. Smoothen surface.

-Leave the bricks for 2 hours to let the adobe set.

-Then remove the mould.

-Clean the mould before using it again.

-The adobe bricks need to dry for three days.

-After three days, or changing colour on the sides, the bricks can be put on their side. Let them dry after this for 7 more days.

-Clean the bricks, scrape off excess mud.

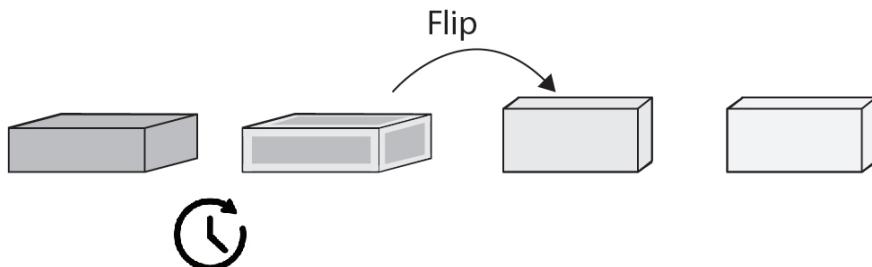


Figure 12. Drying process.

# Outline

## Material and Tools



The outline of the building will come from the app. Before constructing the building the outline need to be marked on the ground. To make sure the layout of the construction is straight some basic groundwork has to be done.

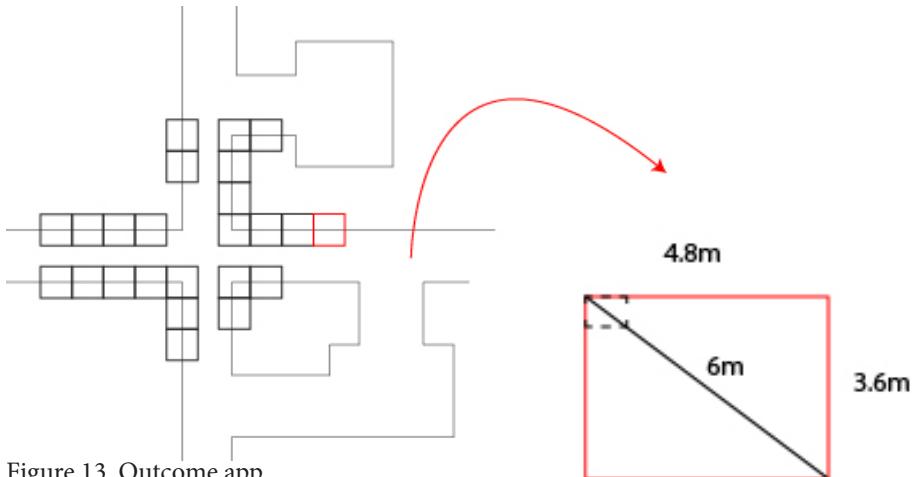


Figure 13. Outcome app.

- Use the 3-4-5 rule to create straight corners.
- Make sure that A=A B=B and C=C
- Marker the corners and put the rope in between as guideline.

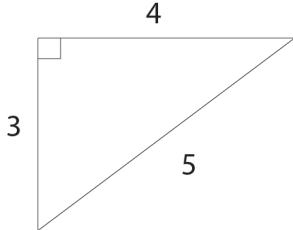


Figure 14. 3-4-5 rule.

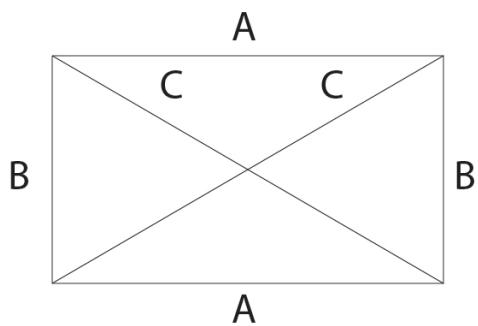


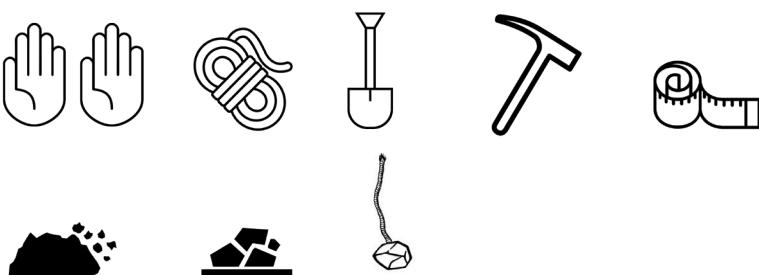
Figure 15. Even sides

# Foundation

## Foundation

A foundation is necessary for several reasons, it is needed for structural/ load bearing reasons, to keep moisture outside and against seismic activities.

## Material and Tools



## Width

- Use the rope as guideline for the outer lines of the foundation.
- Make the foundation of the load bearing walls 10cm wider than the thickness of the wall.
  - 50cm wide walls ->60cm wide hole for the foundation;
  - 60cm wide walls ->70cm wide hole for the foundation.
- Make the foundation of the partition wall the same width as the thickness of the wall.
- Dig out the hole for the foundation.
- Check of the underground is flat before going to the next step.

## Depth

The depth of the foundation depends on the type of wall and the type of ground digging in.

When the underground is from soft or weak soil the hole needs to be deeper.

When the underground is from hard ground/ rocks the hole can be more shallow.

Normal ground:

Load bearing wall      -> 60cm deep

Partition wall      -> 40cm deep

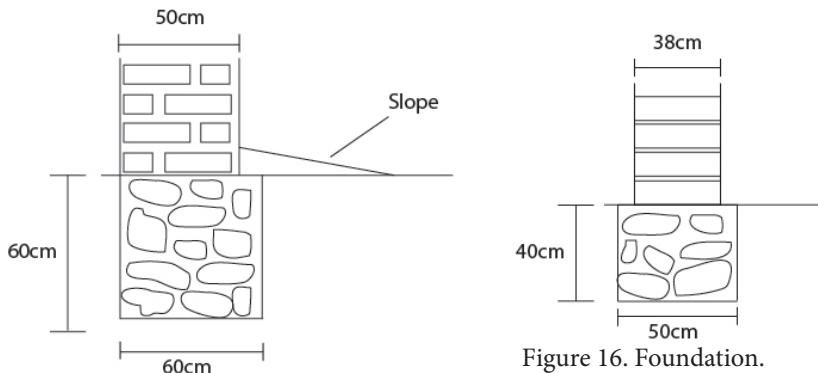


Figure 16. Foundation.

## Filling the foundation

- Place the biggest rocks first on their flat side in the hole.
- Fill up with smaller stones, earth and mortar.
- Make sure the top layer is filled up with earth and mortar for a flat surface.
- Start placing the adobe bricks, keep the extra 10cm on the outside of the construction.



Figure 17. Placing the rocks.

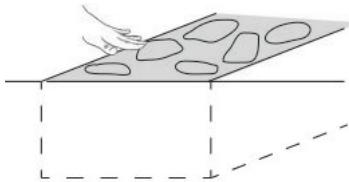


Figure 18. Flat surface foundation.

## Straightness Walls

- Get a plumb line, or a rope with something heavy on the end.
- Hold this next to the load-bearing wall or partition wall to check if it is straight.

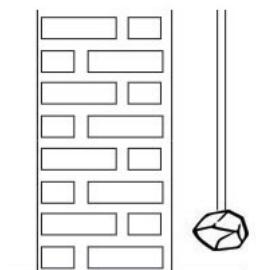


Figure 19. Straight wall.

## Alignment

- The alignment of the wall need to be checked after every row.

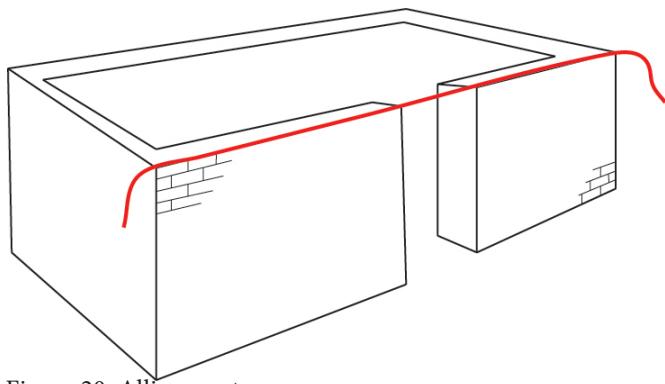


Figure 20. Alignment.

# Flooring

## Material and Tools



## Flooring

The flooring consist out of a minimum of two layers.

- The first layer is hardcore compact layer of ground 40mm.
  - > use you feed or something heave to compress the soil
- To minimize cracking a second layer of hardcore compact layer can be added 40mm.
- To prevent damping add a stone bedding.

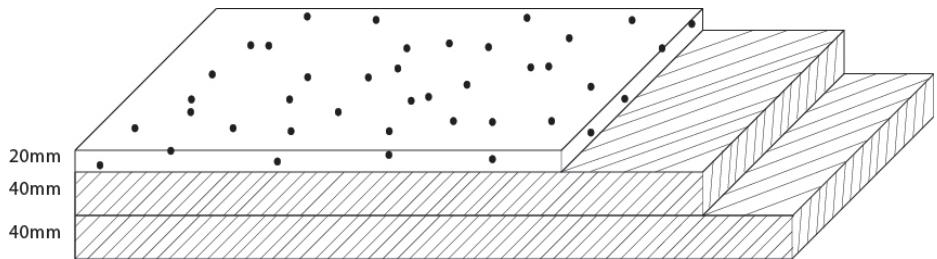
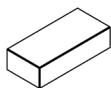


Figure 21. Impression floor layers.

# Walls and openings

## Material and Tools



## Walls and Opening

When the outline is ready, the foundation is made and the floor is placed you can start with the walls. Notice that load bearing walls have different measurements than the separation walls. Mark the openings, doors and windows on the floor so it is known where and where not to place the bricks.

### Exterior Walls

-Use for the first meter of bricks, the stone bricks with feathers, see pages 14 and 15.

-Lay the bricks in crossbond pattern.

-> Row of stretcher.

-> Row of headers.

-> Repeat pattern.

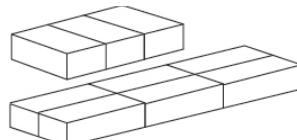


Figure 22. Crossbond pattern 3D.

-Place mortar between every brick.

-Measure the alignment after every row of bricks, see page 27.

-After this the feather bricks should be used.

-Continue the bricks in crossbond pattern.

->Leave a head open in case of a partition wall, see page 32.

-When you can not reach the top.

-> make the temporary scaffolding, see page 17.

-Finish the wall.

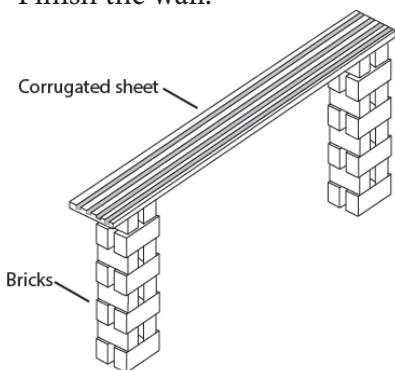
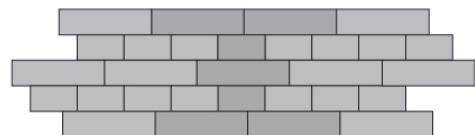


Figure 23. Crossbond pattern 2D.

Figure 24. Scaffolding.



## Partition wall

- Connect the partition wall to the side wall at the place of the gabs.
- Clean the gabs and surface.
- Make the foundation of the partition wall, see page 24-26.
- Use the adobe only bricks for the partition wall.
- Lay the bricks in crossbond pattern.
  - > Row of stretcher.
  - > Row of headers.
  - > Repeat pattern.
- Place mortar between every brick.
- Measure the alignment after every row of bricks, see page27.
- Finish the wall.
- This is needed fot the walls of the shop facing the next shop.,

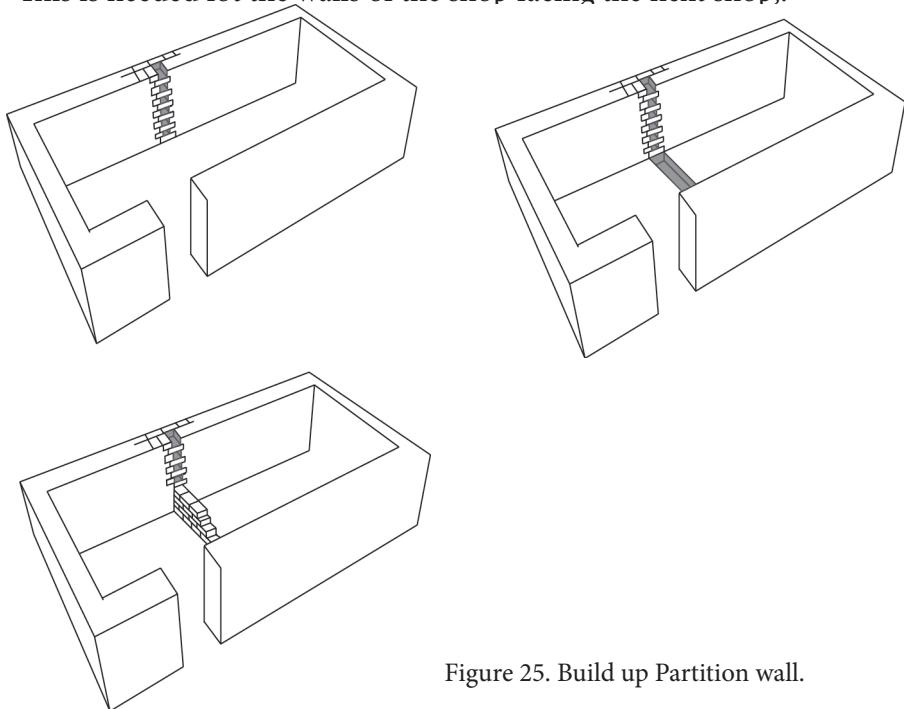


Figure 25. Build up Partition wall.

## Constructing the door

- The side of the domes are formed by not building the wall.
- Place the mould on the needed height on a temporary construction or scaffolding.
- Make sure you are on the right height, on a scaffolding.
- Place the bricks on their side simultaneously from the two sides.
- Place mortar between every brick.
- Work towards the middle.
- Place the keystones.
- The mould can be taken away.
- As door itself a corrugated sheet should be used.

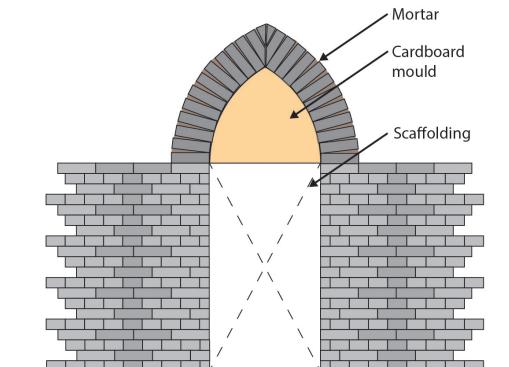


Figure 26. Mould for the door.

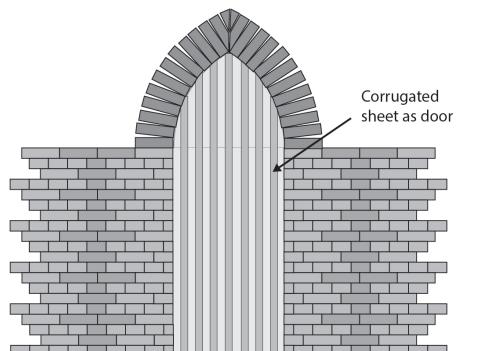


Figure 27. Corrugated sheet as door.

## Constructing the window

- The base and the side of the windows are formed by the walls.
- Place the mould on the needed height.
- Place the bricks for the windows on their side, but make sure the inner corners connect

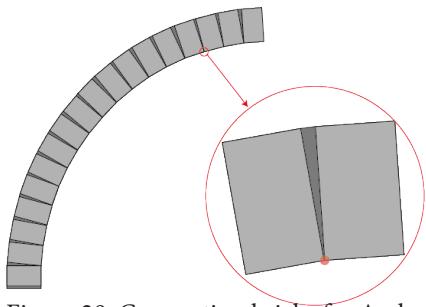


Figure 28. Connection bricks for Arches.

- Place mortar between every brick.
- Work towards the middle.
- Place the keystones.
- The mould can be taken away.
- Finish the rest of the wall.
- The stones next to the window need to be cutted in the right shape.

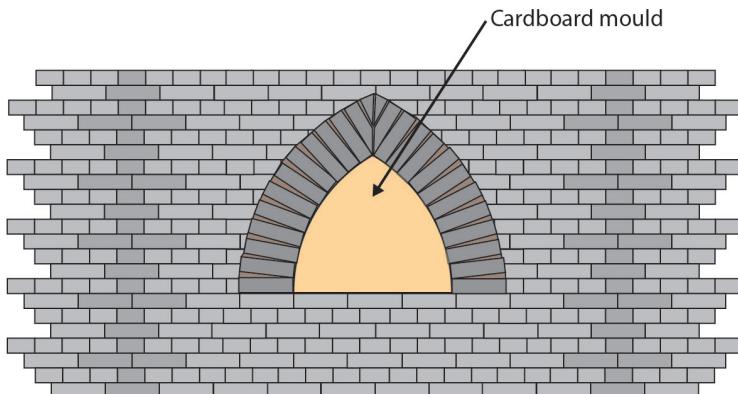


Figure 29. Mould for window.

## **Pattern for ventilation holes**

Different patterns can be used to create ventilation holes.

- place the bricks as a triangle.

- Use plastic pipes or glass bottles as ventilation pipes.

- Leave one header out of the brick pattern.

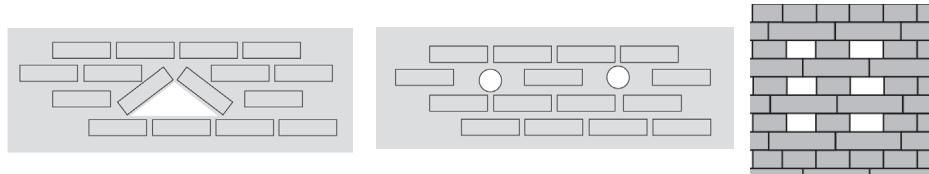
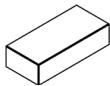


Figure 30. Opening types.

# Columns

## Material and Tools



## Columns

- Find the outline of the column.
- Stack the column in crossbond pattern.
  - > Row of stretcher.
  - > Row of headers.
  - > Repeat pattern.
- Place mortar between every brick.
- When needed place a temporary scaffolding to stand on.
- Continue till the needed height.

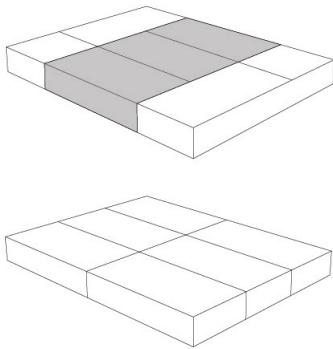
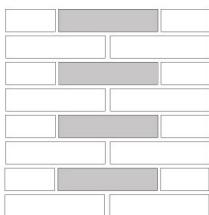


Figure 31. Build up column.

# Inflatable mould

## Material and Tools



## Using the mould

- Know which mould you need.
- Get that mould at UNICEF building.
- Place the mould on the temporary scaffolding when needed.
  - > keep in mind that you also have to stand on the scaffolding.
- Place a textile tarpet before the mould is rolled out.
- Role the mould out on the designated place.
- Place the mould 40cm from the wall.
  - > This is because the mould will expand. The mould should not push the wall away.
  - > There should also be space to lay the bricks.
- Notice what is the front side and the back side.
- Make sure that the zipper, velcro or rope is closed.
  - > this is to deflate the mould.
- Connected to the electric ventilator.
- Check if there are no problems with the mould e.g. leaks or other structural issues.
- Check if the mould is fixed to the ground and walls after it is inflated.
  - > this is to make sure the mould cannot move when it is in use.
- The brick laying process can start.
- Place the bricks in crossband pattern for the ribs.

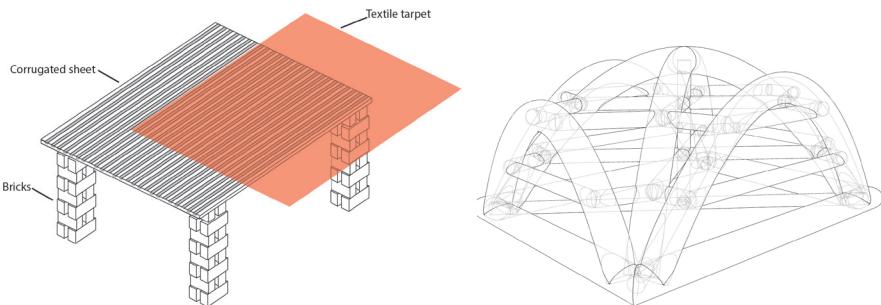


Figure 32. Build up scaffolding.

## Repairing the mould

There are two ways to repair the inflatable mould. The material to do this can be obtained at Unicef.

### Option 1: Blow dryer

- Warm up the blow dryer.
- Cut a piece from canvas, this should be bigger than the crack.
- Make sure the corners are round.
- Put a roller on the middle of the canvas.
- Put the blowdryer under the canvas and heat from the middle to the side.
- Follow the blow dryer with the roller.
- Work from the middle to the outside
  - (-when there is no electricity and glue available a magnifying glass could be used to melt and glue the canvas)

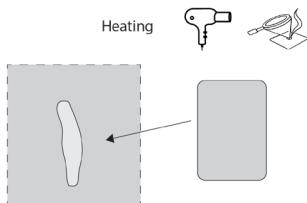


Figure 33. Repair with blow dryer.

### Option 2: Glue

- Cut a piece from the canvas bigger than the crack in the canvas.
- Clean the canvas (with water or when possible with acetone).
- Put glue on the new part.
- Put glue on the cracked part.
- put the new part on the cracked part.
  - >preferably on the inside.
- Put something heavy on it.
- Let it dry for 24 hours.

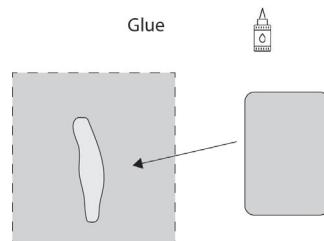
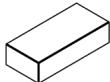


Figure 34. Repair with Glue.



# Roof and opening

## Material and Tools



Use the inflatable mould for constructing the roof.

## Rib Vaults

- See page 39 how to use and place the inflatable mould.
- Make sure the inflatable mould is connected to the scaffolding.
- Start with placing the straw bricks for the first meter of the ribs, see page 14-15.
- Start from all sides at the same time.
- Lay the bricks in crossbond pattern.
  - > Row of stretcher.
  - > Row of headers.
  - > Repeat pattern.
- Place mortar between every brick.
- After this the feather bricks should be used.
- Continue the bricks in crossbond pattern till the rib structure is finished.
- Fill the place in between the ribs with the thinner bricks in stretcher bond.

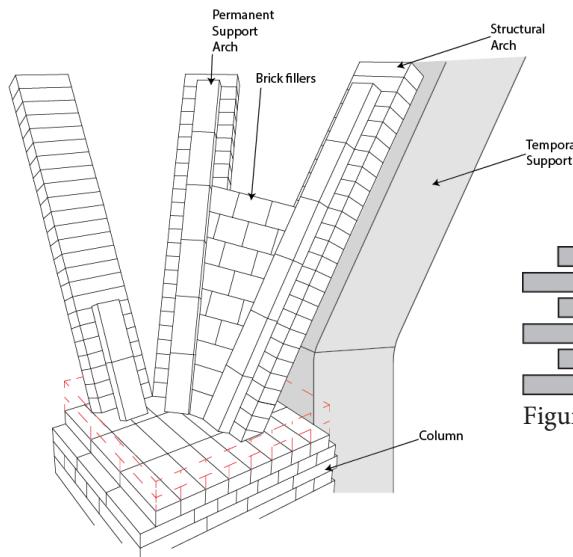


Figure 35. Connection column and ribs.

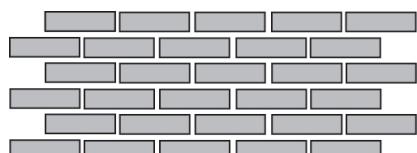
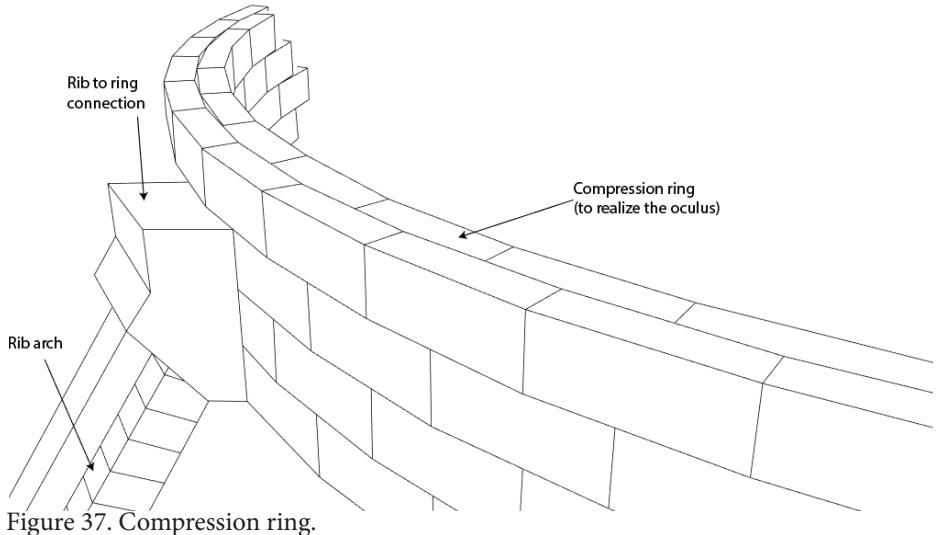


Figure 36. Stretcher bond.

## Oculus

- The inflatable mould is still active as a support and guideline.
- When brick laying the rib structures are finished, add a connection stone on the top.
- Start from here to brick the compression ring to realize the oculus by following the inflatable mould.



## Openings wall/ Roof

It is not allowed to build windows in the roof due to structural forces. Windows can be created in the straight walls for example the walls between the walkway and the shop.

## Prevent rainwater

To prevent rainwater laying on the structure an extra ceiling or filling is needed. Earth is used to make sure that the rain does not stay still and for extra weight what is good for the structural forces. A gutter is added to the sides of the street to guide the rainwater what will flow inside over the ground to the fountain in the middle.

-Fill the holes with earth.

-Put the coating on top.

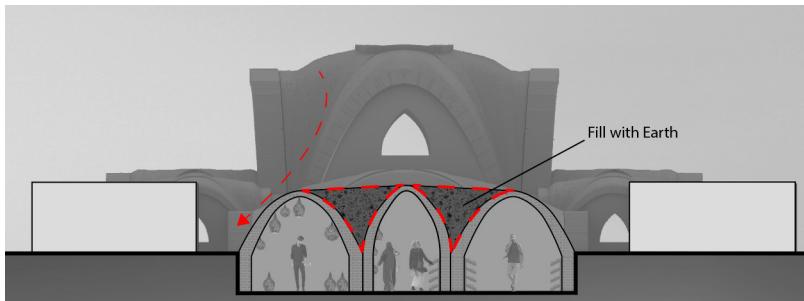


Figure 38a. Rain flows.

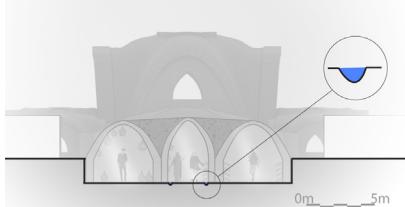


Figure 38b. Gutter in section

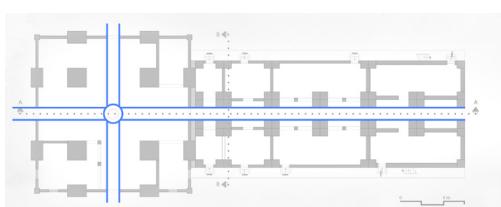
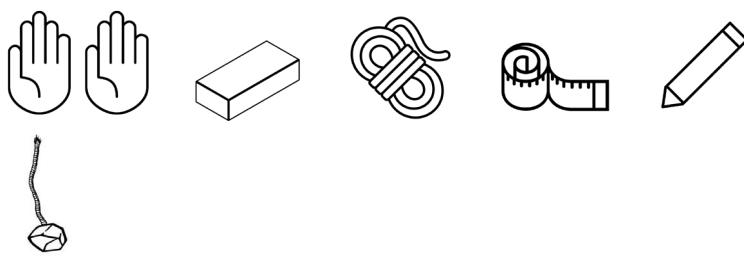


Figure 38c. Gutter to fountain.

# Staircase

## Material and Tools



## Staircase

Depending on the space two types of stairs can be made, a "normal" staircase and a "steep" staircase.

Normal staircase: W=30 cm/ H=17 cm.

Steep staircase: W=24 cm/ H=20 cm.

Height/ steps = number of steps.

Length/ number of steps = width of steps.

-Calculate the number of steps and the length of the stair.

-Draw the outline of the steps on the wall.

-Build the steps with the crossbond pattern.

-> Row of stretcher.

-> Row of headers.

-> Repeat pattern.

-Place mortar between every brick.

-Make holes in the wall to connect the staircase firmly.

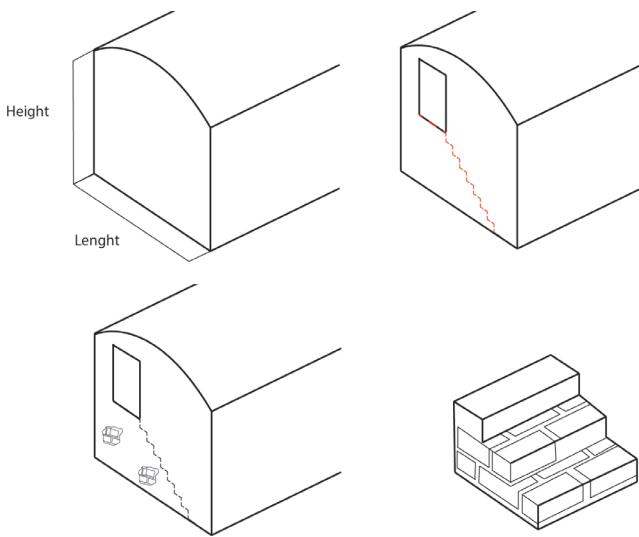
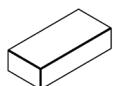
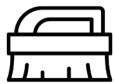
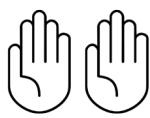


Figure 39. Build up staircase.

# Coating

## Material and Tools



## Exterior coating

-Mix the adobe earth together with the cattle dung.

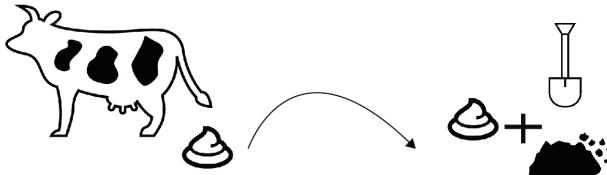


Figure 40. mixture coating.

-Roughen the surface by scrubbing the joints.

-Make the wall wet.

-Apply the coating a few mm thick.

-> apply the coating when possible in the shade to prevent cracking.

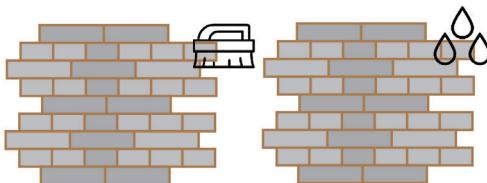


Figure 41. Applying exterior coating.

## Interior coating

-A mortar mixture can be used as interior coating.

-Clean the walls.

-Moisture the wall.

-Draw a line till where the wall coating needs to come.

-Apply the coating.

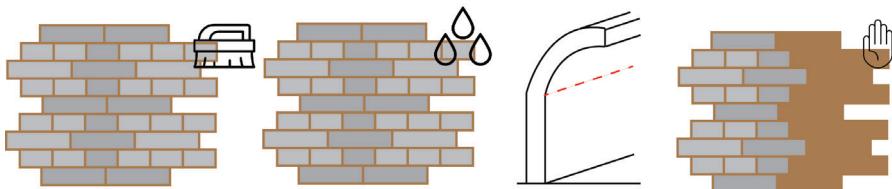
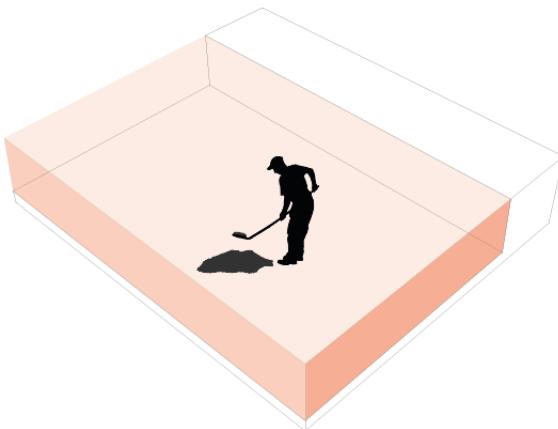


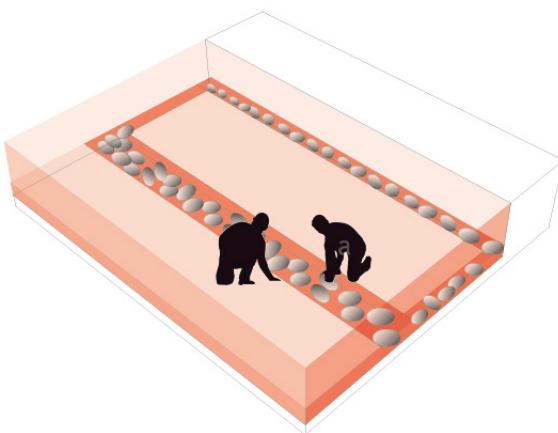
Figure 42. Applying interior coating.

# Construction phases shop



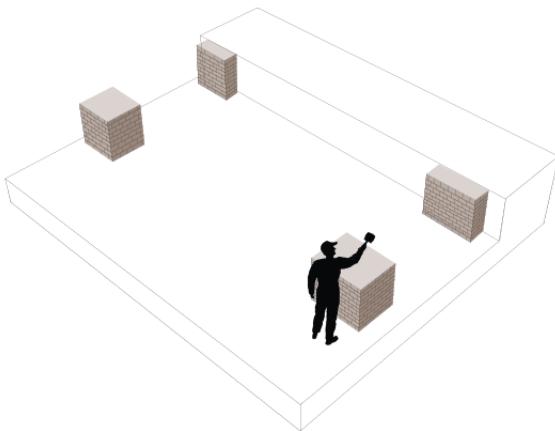
## Phase 1: Digging the ground

The bazaar is being dug in for climate and structural reasons.

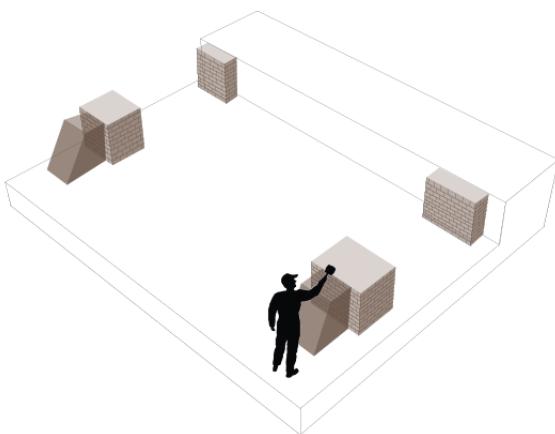


## Phase 2: Foundation

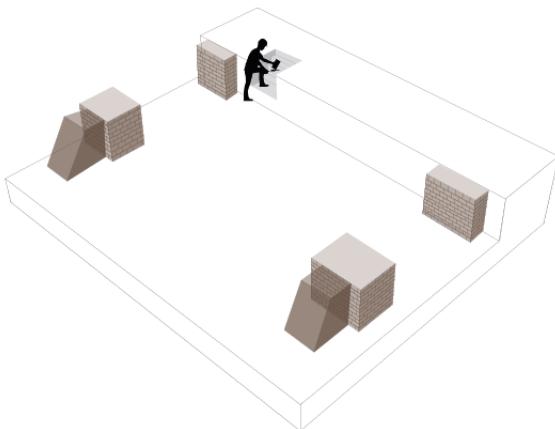
The base of the columns and walls with stones



**Phase 3: Bricklaying the columns**  
1m height to create usable walking space before the roof starts

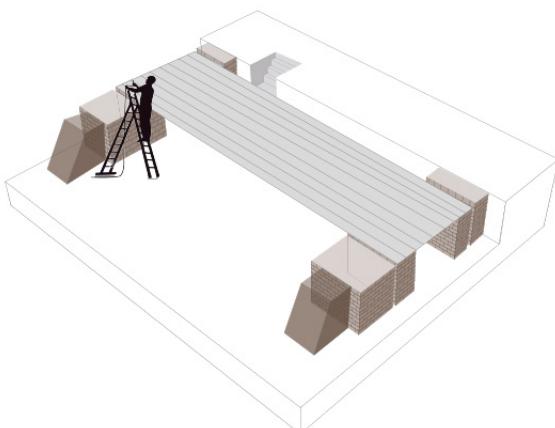


**Phase 3a: Bricklaying the buttresses**  
Required for the trustline of the construction.  
Buttresses can be used as columns when the rib arches are constructed of the walkway.



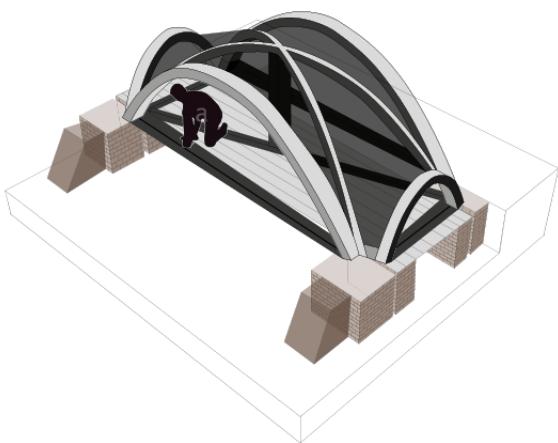
#### Phase 4: Stairs

To create back entrances for the shops.

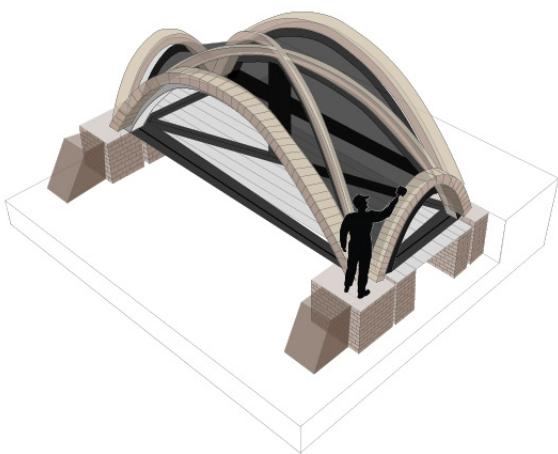


#### Phase 5: Scaffolding

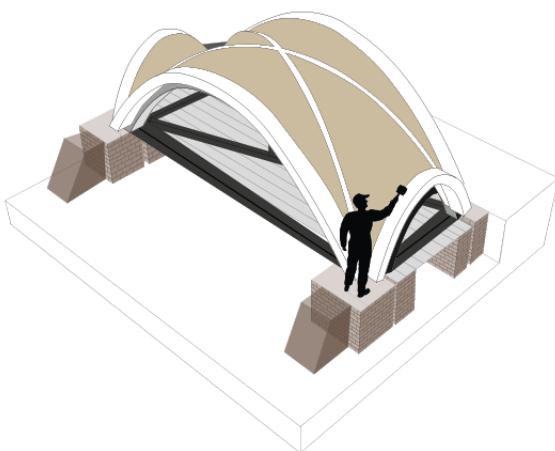
To create surface for the inflatable mould



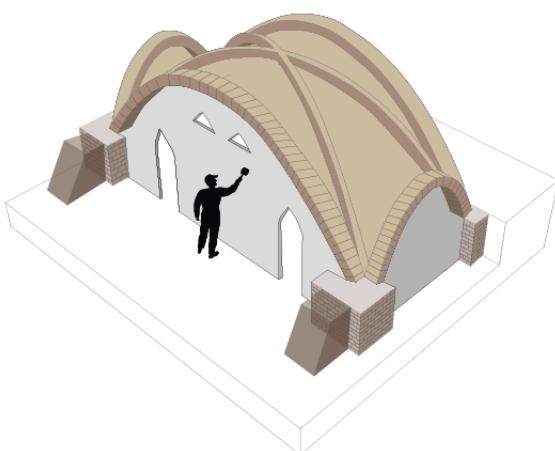
**Phase 5a: Placing the inflatable mould**  
To create a support and guideline for bricklaying the rib arches



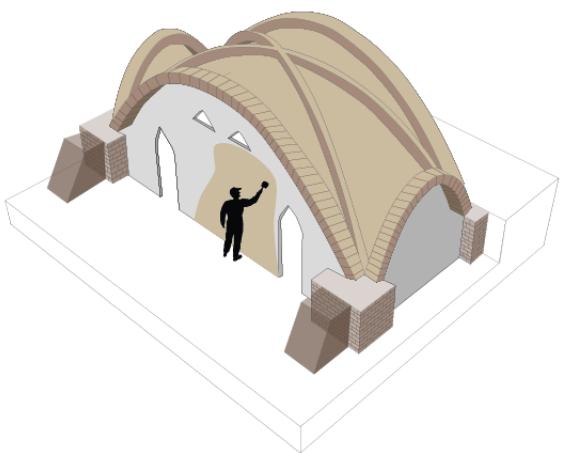
**Phase 6: Bricklaying the arches**  
With a inflatable mould placed on scaffolding as support and guideline.



**Phase 7: Bricklaying the fills between arches**  
With a inflatable mould as support and guideline.



**Phase 8: Bricklaying the walls and windows**  
Walls are not structural required for the the rib vaults.  
Opening with cardboard support



**Phase 9: Coating the outside of the walls and structure**  
To waterproof the building

# Cheat sheet materials

Application purpose	Source/ Owner	Raw materials for bricks	Raw materials for bricks	Ladder for the brick moulds	Raw materials for bricks	Guideline for bricklaying windows/ doors	Raw materials for bricks	On/ around the site (e.g. chickens)	On the site (Waste)	On/ around the site	On the site (Via Unicef)	Support/ guideline for bricklaying domes/ vaults
Sand/ clay												
Water												
Rocks												
Wood												
Corrugated sheet												

