

TERRABAYT

CONSTRUCTION

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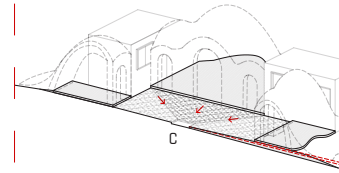
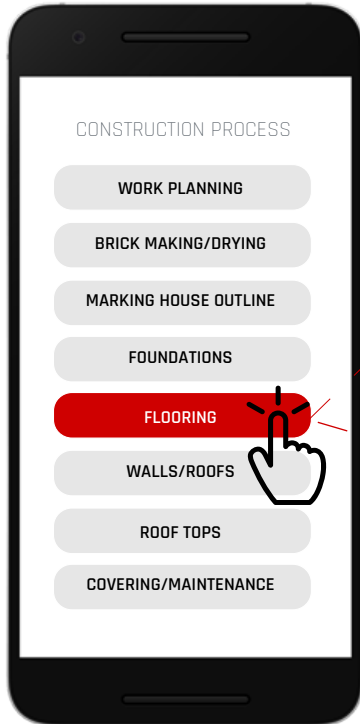
TU Delft

00 INTRODUCTION

Once the final design of the house is done, step by step instructions are provided to assist towards a low cost and easy construction process. The innovation comes in how these instructions are communicated to the user rather than the construction means themselves. More specifically, they will be part of the TER-RABAYT App and organized in the following screens:

1. WORK PLANNING/MATERIALS/TOOLS
2. BRICK MAKING/BRICK DRYING
3. FOUNDATIONS
4. FLOORING
5. WALLS
6. ROOFS
7. OPENINGS
8. COATING/MAINTENANCE

The user can select each of the following parts depending on the stage of the construction and find all the necessary guidelines, such as materials ,tools and detailed drawings. This booklet aims to provide a preview of the final App, but could also stand separately in a printed version to provide general information regarding the construction process. The advantage of the App in relation to the booklet is that it will provide each user with customized info, adjusted to his/her own house's layout and form.



Materials:

Tools:

Time needed:

STEPS:

- 1.
- 2.
- 3.

01 WORK PLANNING

The building planning should preferably allow for the water-proofing process to be done before rainfall periods, which can then be spent to inner finishing works. For the specific location of the Al Zaatari camp this means that the construction should start around March.

First up, the areas for each task need to be defined and groups of people for each task need to be formed. Main tasks before the actual construction are:

- Earth excavation
- Material collection
- Material transportation
- Brick making
- DIY tools preparation

Depending on the number of people available for the construction, they will be divided in groups for each task, and depending on the final number of people per group, the needed time for each task, offering an overview of the construction period.

INPUT:

No of people
available
for the construction



Coordination



Material transportation



Tools preparation



Mortar preparation



Brick laying



Coating application



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OUTPUT:










No of people per task
Time needed for task completion



02 MATERIALS

When selecting the necessary materials for the construction, our main goal was to minimize the import of materials by taking full advantage of those found in or nearby the camp. The main construction material is adobe brick. For its making the following materials are needed: Clay (collected from the creek located 1 km West of Al Zaatari Camp), sand (extracted from site), straw (collected and dried from the creek located 1 km west of Al Zaatari Camp) and water (taken from the water tanks located in every block within the Al Zaatari camp.) Apart from the materials needed for the mortar mixture, a list of materials that may be integrated in the house design or be used as tools, supports, and form-work is provided below. The materials are chosen based on their availability on site, taking into consideration the waste materials within the Al Zaatari camp. Most of the houses in the camp already have extensions comprised of small kitchens

and bathrooms, created from parts taken from public infrastructure such as fences and other facilities. In the new proposed earthy additions, these parts will serve as construction equipment. For example, metal parts that can easily bend, can be used as form-work for arch construction, while aluminium poles and beams can be used as horizontal support between two walls. Moreover, pieces of the old UNHCR tents can be used as shadings around the house courtyards, and their ropes as wall reinforcement.

Sand	Clay	Straw	UNHCR tents (poly-cotton canvas, Polyethylene tarpaulin)	Ropes	Cardboard	Metal sheets	Aluminium poles	Scrap wood
								

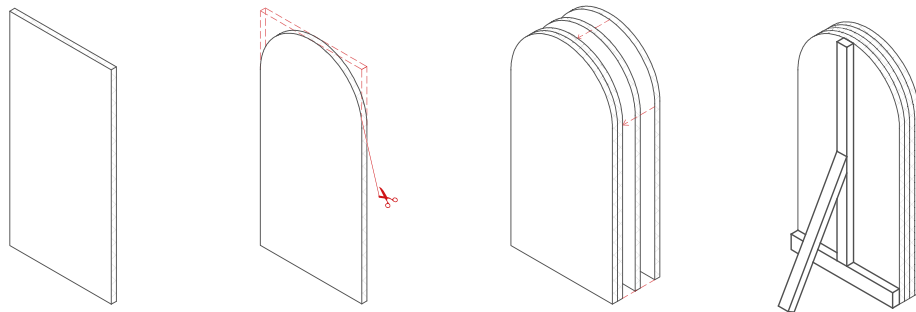
Application	Foundations Flooring Bricks Mortar Coating	Foundations Flooring Bricks Mortar Coating	Flooring Bricks	Shading	Measurement tool	Form-work	Supports/ Form work	Supports	Brick molds
Source	On site	Creek 1km west of the camp site	Creek 1km west of the camp site	On site	On site	Waste on site	From old caravans and other infrastruc- tures	(Already) Taken from the fences surrounding the camp	Waste on site
Re-usability	Yes	Yes	–	Yes	Yes	Yes	Yes	Yes	Yes

03 TOOLS

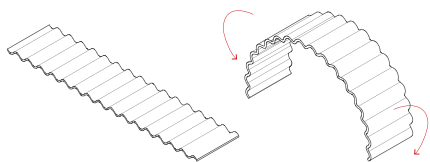
For the accomplishment of the construction, a list of tools is provided. Some of them are standard tools such as shovels, pickaxes etc while a range of DIY tool is provided as well, , made of the available on site materials. These include ropes from the old tents that can be used as measurement tools to guide the construction. In addition to that, cardboard may be used as form work. Being the No1 waste material in the camp, It can be cut to the proper arch shapes and used as form-work to make the arch construction easier. Thick pieces can be then glued together to create a stiffer surface. Most of the houses in the camp already have extensions comprised of small kitchens and bathrooms, created from parts taken from public infrastructure such as fences and other facilities. In the new proposed earthy additions, these parts will serve as construction equipment. For example, corrugated metal sheets that can easily bend, can be

used as form-work for arch construction, while metal surfaces, beams and aluminium poles can be used as horizontal support between two walls.

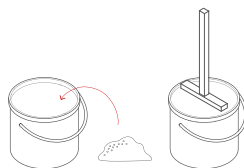
1 Cardboard pieces can be cut in the shape of the wanted arch, glued together and supported in scrap wood pieces to be used as form work.



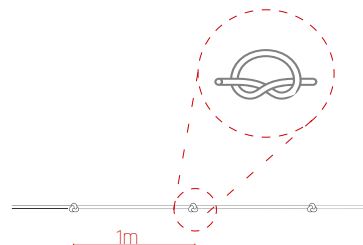
2 Corrugated metal sheets can be bended in the wanted shape and be used as form-work



2 Buckets can be filled with sand and wood/metal poles can be used as handle to compact soil



2 Knots can be made on ropes in a distance of 1m, to be used as measurement tools



04 BRICK MAKING

It is estimated that the brick composition, as previously described, will provide the most optimal performance given the soil composition and climate conditions. Nevertheless, the exact composition shall be determined through field tests. For now, we consider that bricks consist of 1% straw, 20% clay and 80% sand. Brick size is determined to be 190x90x40 mm in order to be easily lifted with one hand and also fit the grid of the existing caravans. Before preparing the mortar, foreign matter should be removed from the soil. It should then be mixed thoroughly and uniformly. Once the mixture is done, it is put on plastic or wooden containers that have been prepared with the right dimensions.

Materials: Sand, clay, water, straw

Tools: Buckets, shovels, brick molds (made of plastic containers or metal/wooden pieces)



Soil can be left with water for one day before the mortar preparation so that water is better integrated with the clay particles, activating the cohesive properties



1 Collect the right quantities on site

recipe:

Dry mixture: 80% sand, 20% clay
Add 10% (of the dry mass) water
Add 1% (of the total volume) straw

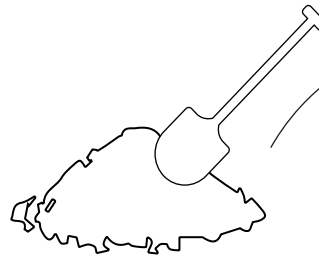
sand: 738 kg/ 1000 bricks

clay: 182 kg/1000 bricks

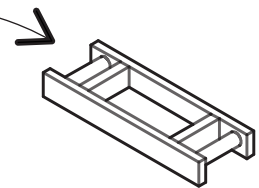
straw: 0,35 kg/ 1000 bricks

water:

2 Mix the mortar uniformly



3 Put the mortar in the molds



05 BRICK DRYING

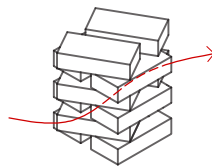
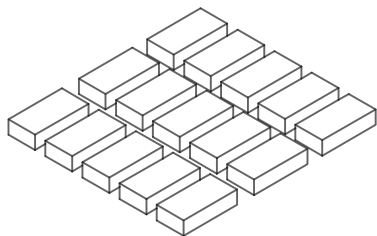
In order to ensure homogeneous drying and avoid cracking, adobe bricks should be dried in the shade. Assuming that there is enough space, all bricks are laid in rows on the ground, otherwise they are put in columns, in such a way so as to allow air passing through. On the 3rd day, they should be put on their edge and on the 7th day, they will be ready to be stacked.

Tools: Transportation trailers

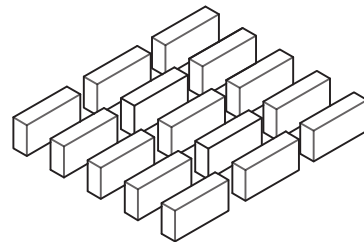


It is recommended that bricks are clean and wet before stacking them so as to improve the wall's total cohesion. This can be achieved by soaking them for 5 seconds in a bucket of water.

1 Lay the bricks in rows on ground. If there is limited space, arrange them in columns in such a way that air passes through them.



2 On the 3rd day, put them on their edge

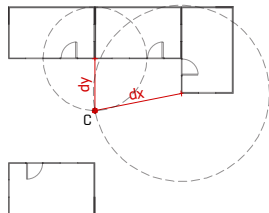


06 MARKING HOUSE'S OUTLINE

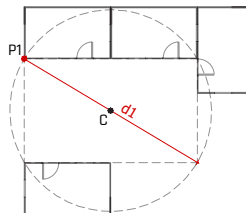
Based on the generated layout of each house, caravans have to be slightly moved and rearranged while the outlines of the new spaces need to be marked. Firstly, the center of the courtyard is defined in relation to the existing position of the caravans, and then one by one the points and edges of the courtyard are marked. Once the outlines of the courtyard and the earthy additions are determined, the caravan positions are adjusted

Tools: Ropes with knots every 1m are used as measurement tools, transportation trailers, pickaxes to mark the outlines on the ground, nails.

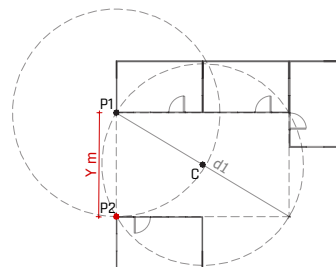
1 Mark courtyard center point C in relation to the existing position of caravans.



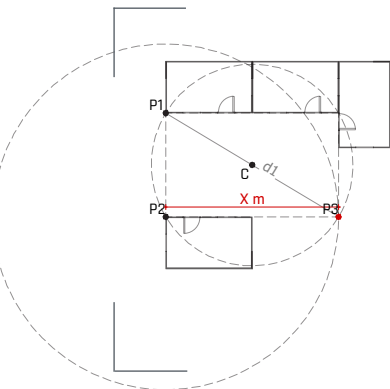
2 Mark diagonal d1 and take as a starting point P1.



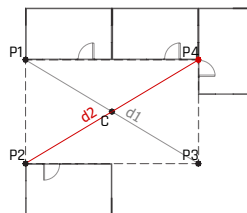
3 Determine P2 as the intersection of the two circles.



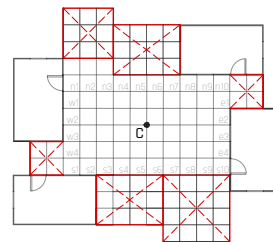
4 Similarly, determine P3.



5 Determine P4 as the end point of diagonal d2, where $d1 = d2$.



6 Mark the outlines of each space taking as a reference point the perimeter of the courtyard.



07 FOUNDATIONS

Foundations should be built to provide damp proofing for the adobe walls. Again the method was chosen as the one which demands the least import of materials. Assuming a wall thickness of 400mm, trenches of 800mm width should be initially dug all around the outline of each room, down to a sufficient depth (approx. 1200mm). These trenches are then filled with sand-stabilized earth, rammed in layers of 200mm each. Finally, baked bricks with increased strength and durability, are placed to create a water resistant base for the wall.

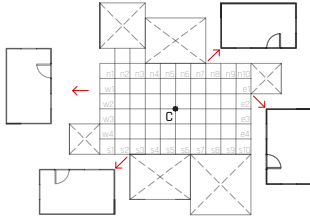
Materials: Sand, baked bricks, aggregates (if any)

Tools: Shovels, pickaxes, cylindrical containers/buckets filled with sand to compact the sand layers, ropes as measurement/level tools.

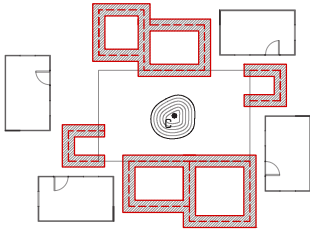


Replace the first two layers of rammed sand with broken stones when available.

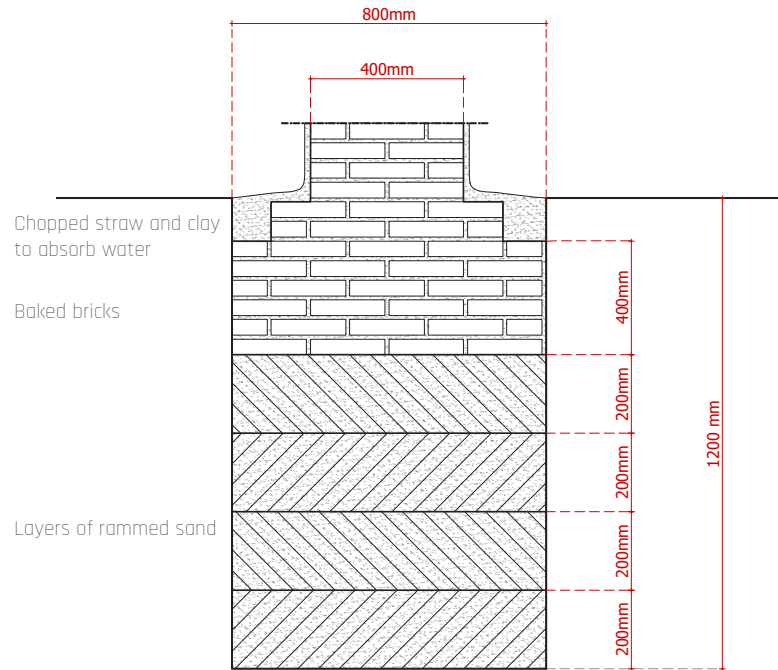
1 Move the caravans aside



2 Dig trenches of 800mm width around the outlines.



3 Fill the trenches of layers of compact sand and baked bricks.



08 FLOORING

Earthen floor can be made with 3 layers of a mixture that consists of clay soil, sand and chopped straw. Each layer must dry before the next one is applied. The first two layers are each 50mm thick and quite rough. The 3rd and final layer is 20 mm thick and quite fine. Applying three of these layers instead of one, minimizes the possibilities of cracking and ensures a smoother surface. Finally, 4 to 6 coats of linseed oil may be applied, to offer water resistance. Both the courtyard and interior flooring are slightly elevated from the road level so as to direct water outwards. This happens through a channel which distributes the water that is collected in the center area of the courtyard, to the outside road channels

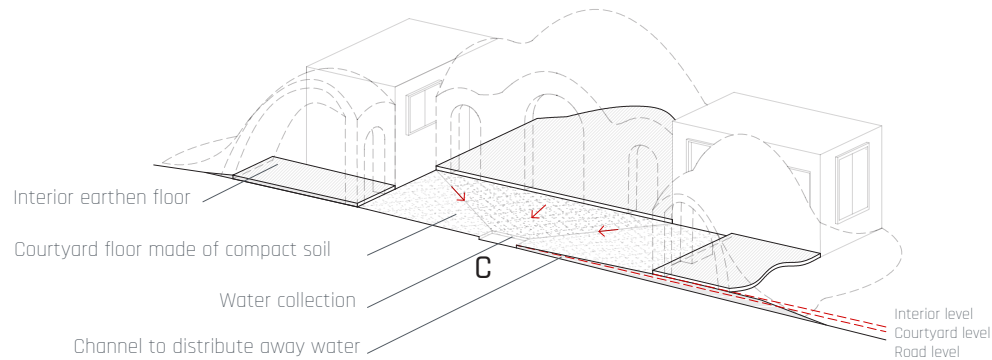
Materials: clay, soil, sand, straw, water

Tools: Metal sheets/wooden pieces to level the flooring layers.

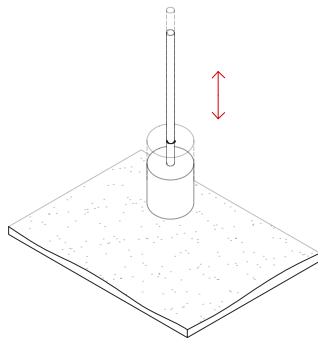


To save time and energy is suggested that the flooring layers are compacted simultaneously with the rammed sand layers needed for the foundations.

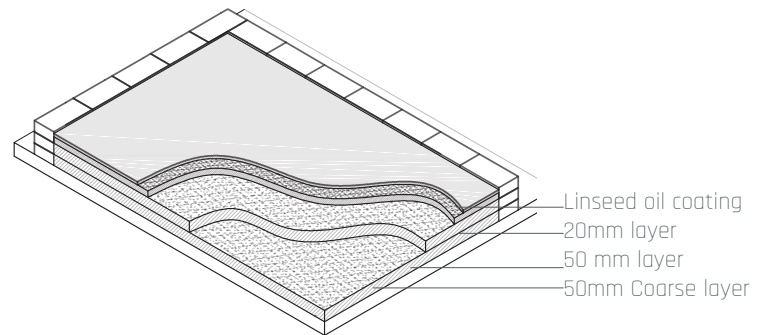
1 Level the courtyard flooring so as to direct water to the center of the courtyard. Create a channel to distribute water to the road.



2 Compact soil



3 Apply layer of 50mm and let it dry. Lay second layer same as the first one. Apply a final layer of 20mm and coatings of linseed oil.



09 WALLS

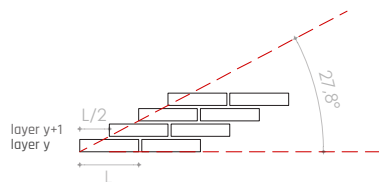
Our proposal consists of straight vertical walls towards the courtyard side, to preserve the identity of traditional Syrian architecture, while the roof smoothly converts into landscape towards the outside public space. To make the construction process easier, all the rooms are built layer by layer, in courses. The construction of the brick wall begins by laying the leads, which helps define the wall plane and the course height. The bricks between the leads are laid to a line, a heavy string/rope, stretched taut between line blocks at each lead. The brick laying procedure is supported by either a mobile app or printed drawings. This way each layer -provided by the Grasshopper script- can be visualized in relation the previous one, thus assisting those building the wall in applying the correct brick pattern. For building the curved walls, the offset step of each brick course is also given in relation to the previous one. Offsets are set as divisions of the brick length

or width, so that it is easier for people to estimate even by eye. Two main brick patterns are suggested based on the inclination of the wall/roof, applicable on various curvatures. There is a certain height, (maximum height for stability of the horizontal forces) after which extra supports are needed in order to hold the walls.

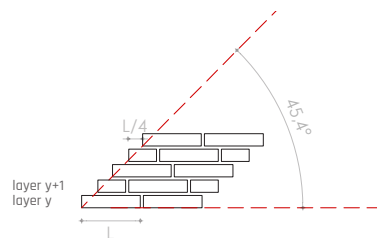
Materials: Bricks, mortar, water

Tools: Ropes, aluminium poles, metal sheets (as supports)

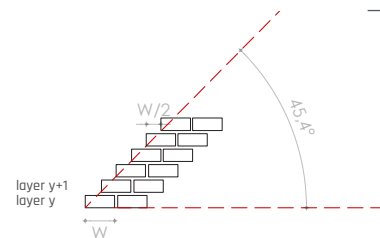
1 Different brick patterns



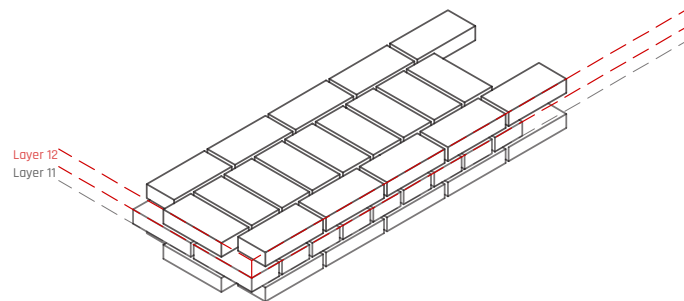
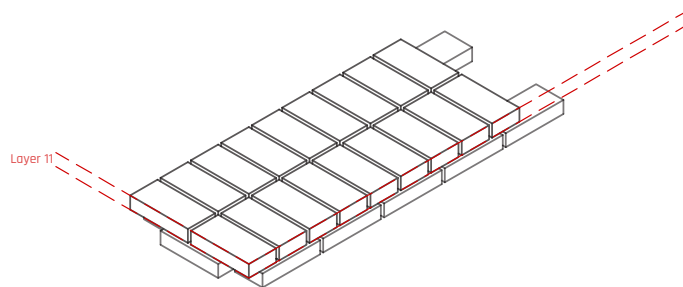
Brick pattern
Type 1A



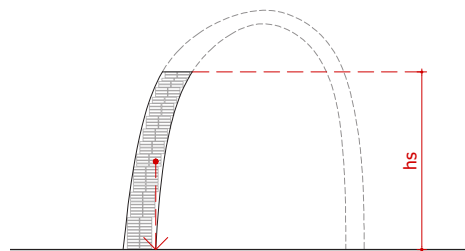
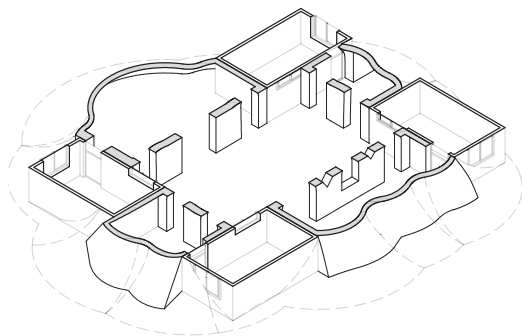
Brick pattern
Type 1B



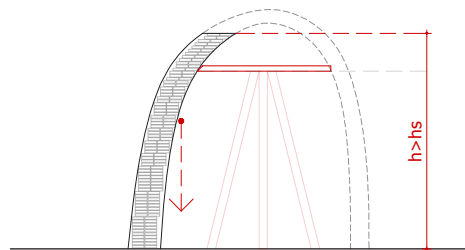
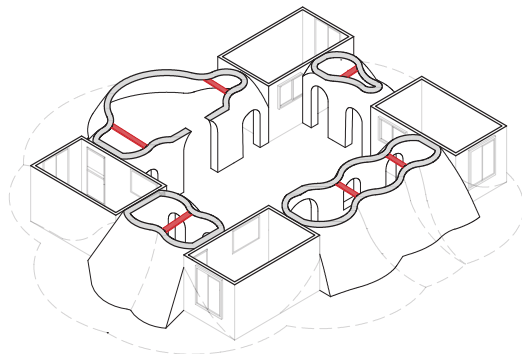
Brick pattern
Type 2



2 Laying of the brick courses before the maximum height of horizontal forces



3 Laying of the brick courses aided with supports after the maximum height of horizontal forces



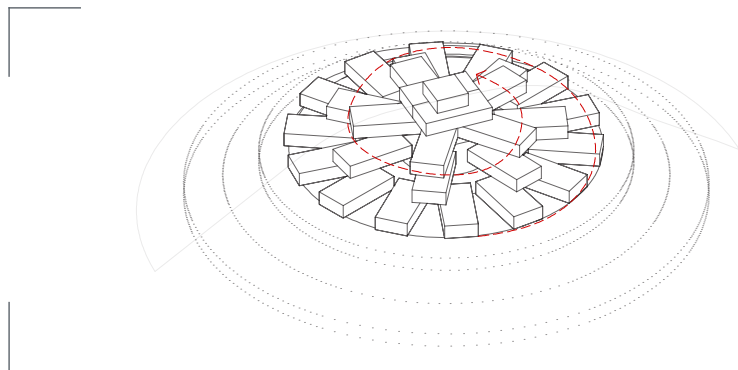
10 ROOFS

For roof construction, a lighter type of bricks, with higher percentage of straw, is suggested. Additionally, a firmer mixture of mortar should be used, to achieve a more stable connection between the bricks. Depending on the roof inclination, the covering of the top part of the roof may vary. When inclination is steep enough, horizontal brick layers, form the top, similarly to the walls. After a certain inclination though, bricklaying needs to switch from horizontal to vertical courses. When this happens, extra attention should be given to the placement of mortar between the bricks. More specifically, no mortar should be put between the connecting ends of the bricks in each course, as its shrinkage could cause the roof to collapse .

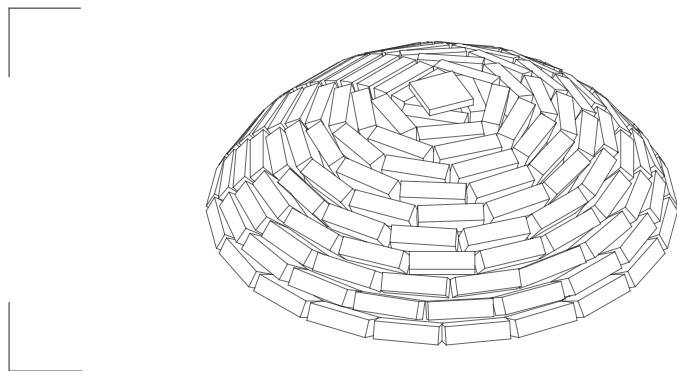
Materials: Bricks, mortar, water

Tools: Ropes, aluminium poles, metal sheets (as supports)

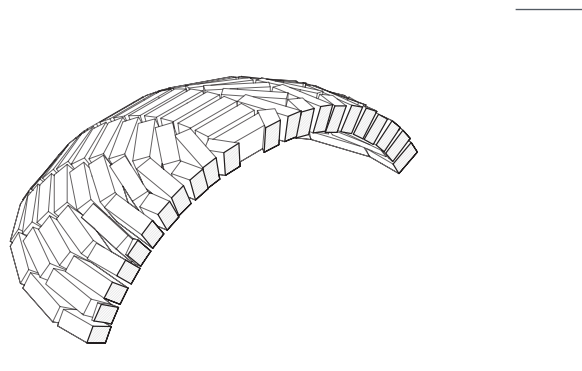
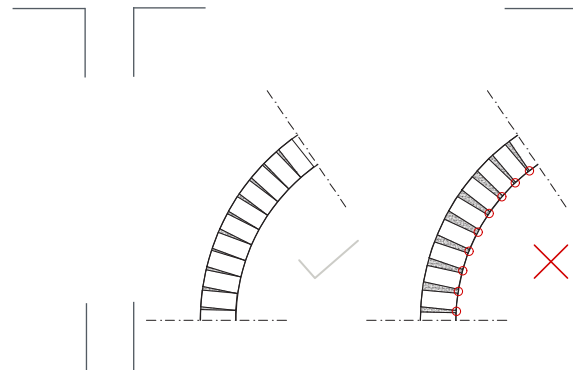
1 Roof top with horizontal layers



2 Roof top with inclined layers



3 Mortar in between inclined bricks



11 OPENINGS

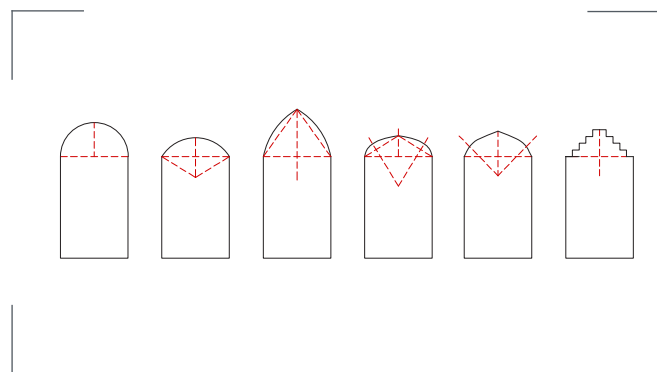
To fit the cultural context of the inhabitants, bigger openings are placed towards the courtyard, which is the core of the house, while smaller openings are formed towards the outside, to ensure privacy, proper ventilation and adequate sunlight. Thus, two different construction systems are introduced. The openings facing the courtyard are composed of arches in various sizes and shapes, elements typically used in traditional Syrian architecture. To ensure structural stability the opening area does not cover more than 30% of the wall. On the contrary, the openings towards the outside are formed by just removing some bricks from the regular brick pattern or by applying different densities to it. They are placed in 'strategic' areas, where less stresses occur, to relief the structure. Regarding the constructability of the arches, and since we have modular sizes for the openings, form-work made of the available waste materials is used, so as to make

the construction process easy and quick. The form-work can be removed immediately after construction and be reused straightaway

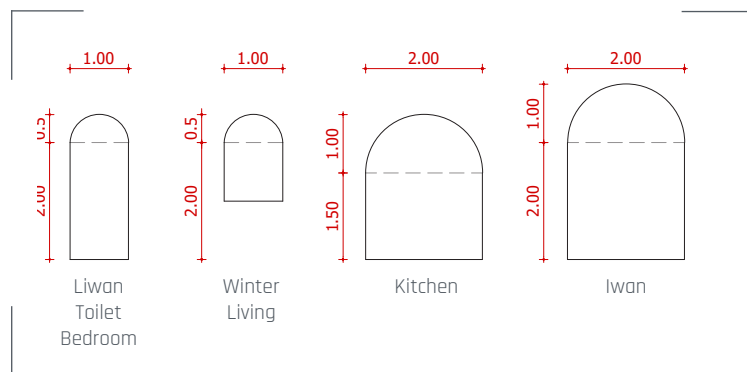
Materials: Bricks, mortar, water

Tools: Form-work (Cardboard, metal sheets, buckets)

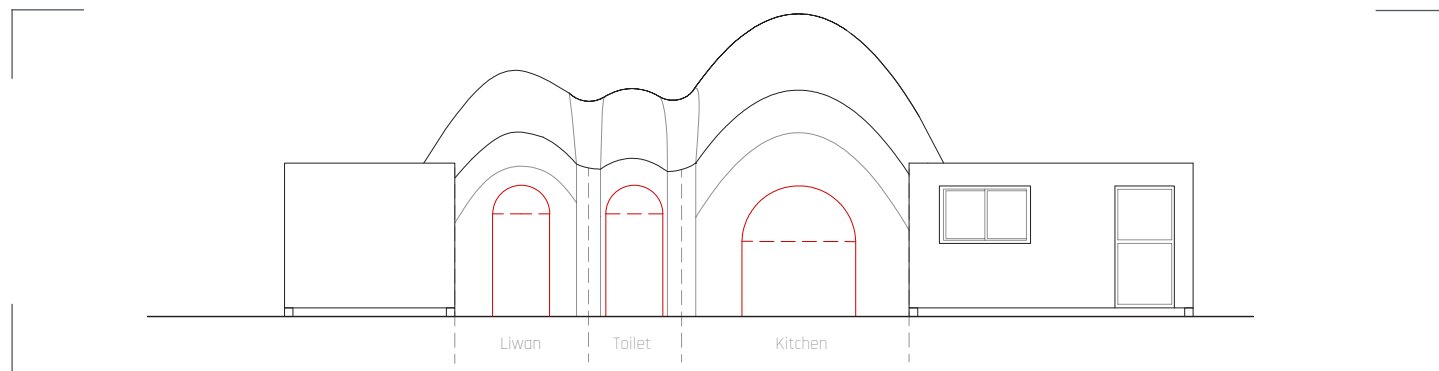
1 Arch vocabulary



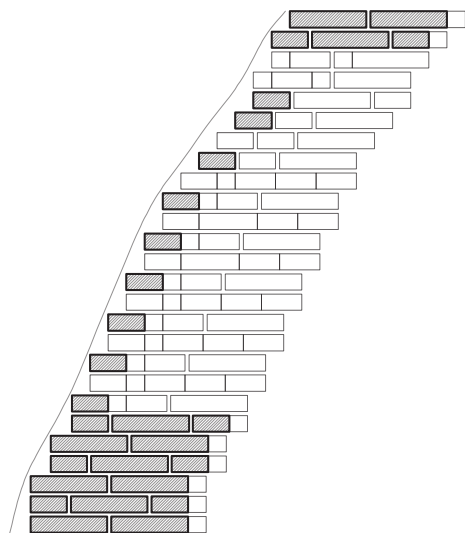
2 Modular sizes of openings depending on the space function



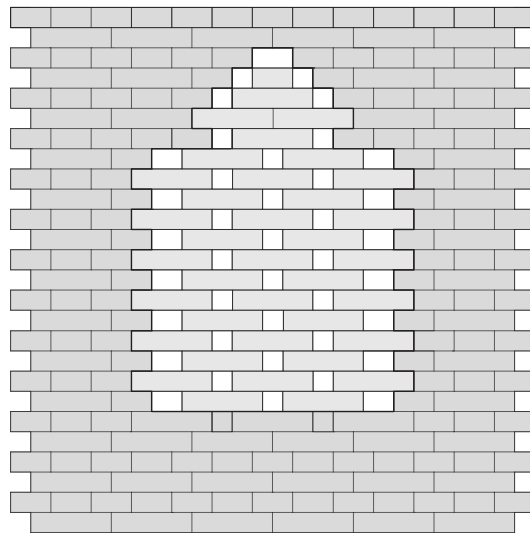
3 Example of a final facade towards the courtyard



4 "Mashrabiya" type opening in the outdoor walls.

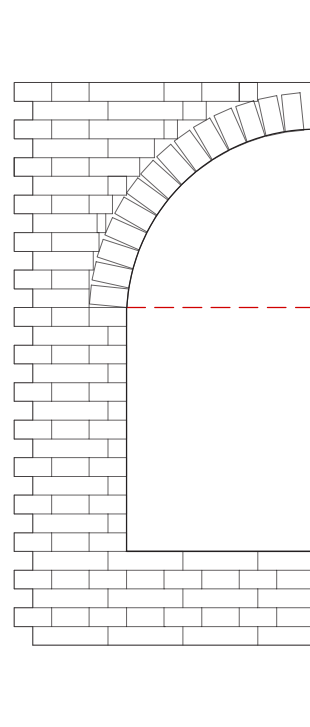
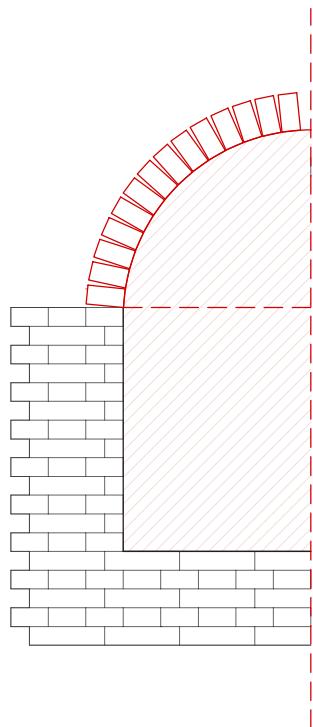
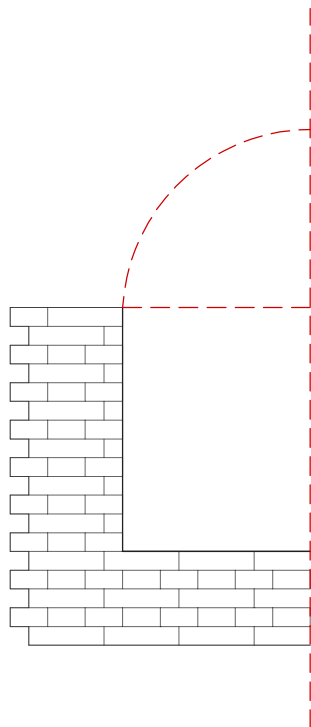


Section



Elevation(from interior)

5 Arch opening: Build the vertical part up to the height where arch starts. Put form-work and place the bricks to create the arch. Fill in the rest of the wall and cut the bricks whenever necessary to fit in the gaps.



12 COATING

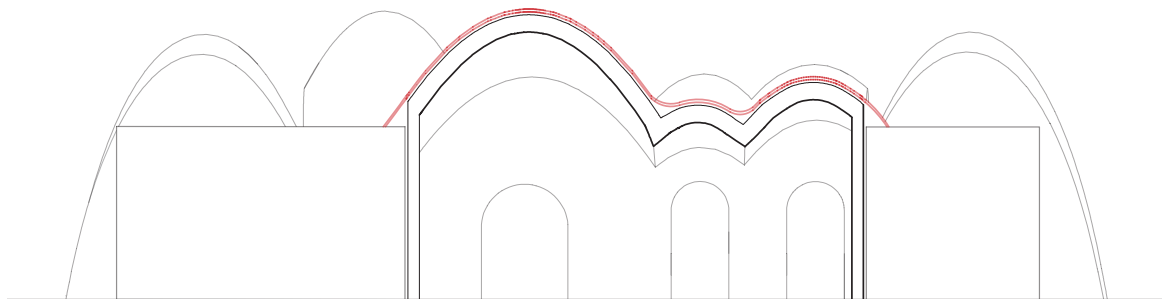
To avoid infiltrations and therefore risks of deterioration on the roofs and walls, rain water must be channeled away from the building, using waterspouts or downpipes. To achieve this, a layer of mud plaster is applied. Extra attention should be given to specific critical areas, where mud is needed not only as a covering but also as a shaping tool. For example, mud should be put between caravans and earthy additions, to ensure that water is not trapped in between but channeled away. Besides water protection and increased thermal insulation, the plaster also increases the stiffness and strength of the adobe walls, offering better seismic behavior. Mortar requires periodical maintenance whose frequency depends on the nature and the quantity of rainfall. In the case of the Al Zaa-tari camp, the fact that the soil is Calciorthid, (i.e. contains high amounts of lime making it more suitable for coating) will allow for less frequent maintenance work.

Once in place, the mud plaster must be smoothed. This is done either by hand or by using small, slightly rounded tools. To achieve a smooth ending of the house towards the outside, mud is put below a certain height of wall and until it reaches the ground level, creating an earthy slope that is to be used for vegetation but also to collect water.

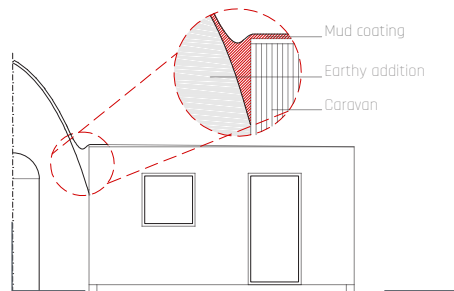
Materials: Mortar

Tools: Spatulas, rounded smoothing objects

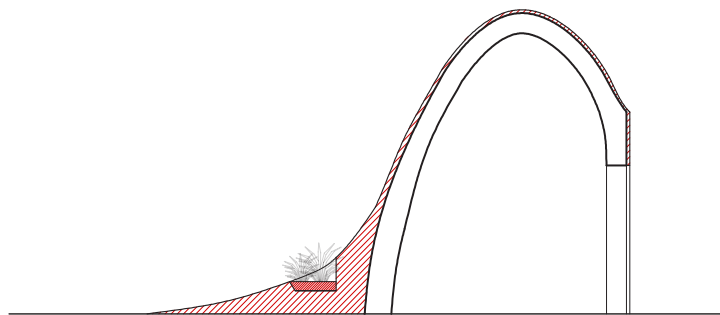
1 Mortar is put all over the walls to create a smooth surface between the different roofs preventing water collection. Caravans may be partly covered with mortar, to complete the roof form but also to take advantage of them structurally.



3 Connection between caravan and earthy addition: OPTION 2



4 Smooth ending of the house towards the outside. Slope is used for planting



CONCLUSION

The content of this chapter offers an overview of the proposed construction process. Nevertheless, further research and field tests are suggested, in order to determine every step in a more detailed way. Once all the necessary info is collected, attention will be paid on how to communicate it in an interactive way to the user through the TERRABAYT App. To achieve this goal, all the parameters that are needed for the customization of each construction step need to be better defined and ways to illustrate the info (possibly through connecting everything to a central 3d model of each house) need to be further examined.