Iran

Conservation and disaster risk reduction in Ardakan

July 2010

Tabayi house experience

Towards Community-based natural disaster risk reduction in IRAN
CRAterre-ENSAG / Hamyaran / Ardakan Municipality / Ardakan District / with the support of the European Union

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Introduction

Programme objectives

The on-site training activities described in this manual are part of the “Towards Community-based natural disaster risk reduction in Iran” project coordinated by Hamyaran and CRAterre-ENSAG. It involved local and regional stakeholders and authorities in the province of Yazd and at national level. The overall objective of this project is to contribute to the reduction of vulnerability to natural risks in rural settlements and poor urban communities in disaster-prone areas of Iran. It also aims to develop a safer, modern and sustainable built environment. The project has received the support of, and is co-financed by the European Union.

The specific objective of the project is to reinforce the capacities of local organisations, communities as well as professionals in the building sector to develop strategy and knowledge to reduce the vulnerability of the built environment, improve housing conditions, and facilitate the participatory rehabilitation of the historic district of Ardakan.

Apart from professionals, people involved in the Tabayi house restoration included representatives from the Ardakan Municipality, from ICHHTO (Ardakan and Yazd provincial offices) and from Hamyaran.

This particular intervention was made possible thanks to preliminary works conducted by the project partners and stakeholders in association with the community. It is part of complementary activities that are developed through the project.

The Tabayi house restoration

This manual was prepared in July 2010 during the restoration of an old house located within the Ardakan historic centre. This structure was selected for its poor state of conservation, its limited size but also because it is a good example of the traditional Ardakan house, and thus a perfect context for a demonstration project. Its owners, financially unable to restore it, discussed with the local community and obtained the agreement to move forward with the restoration process.

The project served as a platform to exchange experiences amongst various technicians, conservators and masons. 14 working days were spent in the house to reinforce its structure and eliminate all the weak parts which made it extremely vulnerable to earthquakes. 36 people participated in this experience.

The intervention not only improved the housing conditions for the family, it also allowed to make the structure more resistant to hazards by reducing its structural vulnerability.

The Manual

This manual, explaining the details of the works implemented, is intended to serve as a guide for house owners, technicians and decision makers working in Ardakan Historic district. It presents step by step procedures to treat the most common building pathologies observed in Ardakan. This manual is a tool that can be completed and improved by users. The authors are looking forward to receiving questions and remarks.

Organisations and people involved in the project

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Tabayi Family

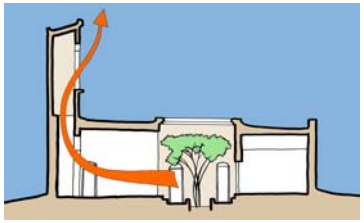
Tayyebesadat Hashemi, Hadi Tabayi, Moslem Tabayi

Plan of the House

Tabayi house reflects the traditional courtyard houses found in Ardakan Old Town. Even if many houses are far bigger in size than this one, the organisation remains the same. The floor plan is introverted, with all openings organised around a courtyard. The entrance door is the only opening to the street.

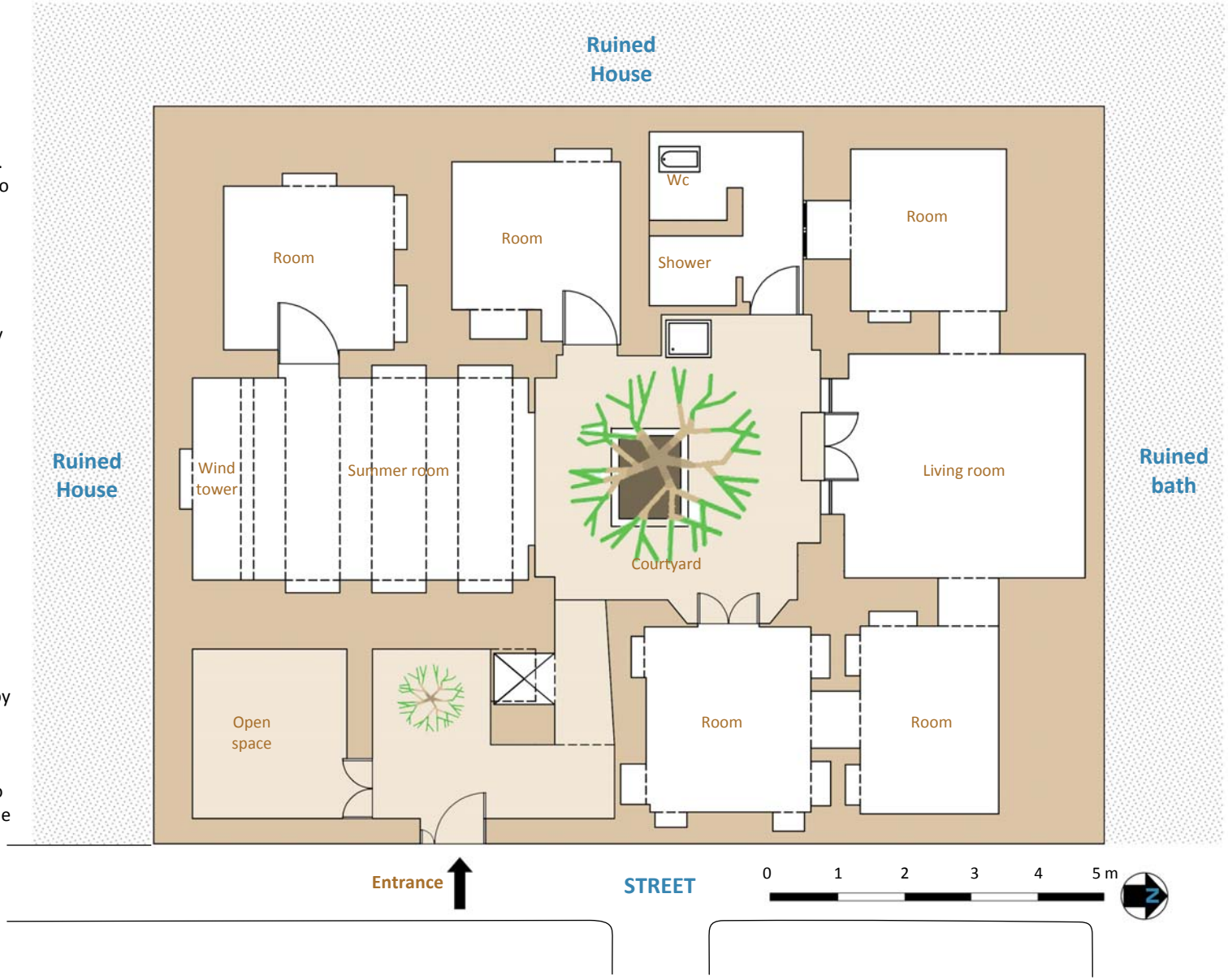
Winter house

On the northern side of the house is an enclosed living room, facing south, which can benefit from the solar energy in the wintertime.



Summer house

On the southern side is a completely open living room used in the summer, which never receives any sunlight. This summer room is constantly ventilated by the wind tower, a 4 metre high rectangular structure that sits on the roof, above the room. The tower faces the north and acts as a solar chimney to draw air out of the building. Shade in the courtyard is provided by a tree planted in its centre.



Main pathologies

The pictures below show the main pathologies observed on the house before the restoration started. Most of them were humidity related pathologies.


→ Deformation of the wall tops with holes and cracks in the roof

← Decay of the wall bases






→ Uncontrolled plant growth

← Deformation of the wind tower with cracks on all sides



→ Ruined buildings around the house. Accumulation of rubbish and poor drainage

← Use of inappropriate materials, such as metal for the doors.
Wooden doors poorly maintained


Summary of works done

Clearing debris

Debris have been removed from within the building, from the roof and from the ruins on the western and southern sides

Drainage

Drainage slopes have been modified on the southern and western sides, as well as on the roof

Wall bases

All the wall bases inside the building have been cleaned and restored, after the introduction of waperproof barriers

Wall tops

Reconstruction of the top of the western wall and reconstruction of the missing parts of the vaults above the rooms. Reconstruction of parapet wall along the roof

Structural reinforcement

Structural reinforcement was done on the wind tower mainly, and also along the western wall.
A tie rod was introduced at the base of the arch supporting the wind tower. Several layers of plastic mesh were also inserted in the reconstructed walls

Wind tower

The wind tower has been restored without dismantling it. All the cracks were stitched, and the tower itself stabilised with a reinforced mortar

Floors

The cement slabs covering all the floors inside the buildings have been removed and replaced with porous burnt clay bricks

Gypsum plasters

All the gypsum plasters within the rooms and around the courtyard were renewed

Bathroom

The bathroom was completely redone to avoid humidity related pathologies. The shower wall was demolished and reconstructed 10 cm away from the load bearing mud wall, to allow for the ventilation of the structure

Roofs

The old layers of mortar were removed and a fresh coating was applied in 2 layers

Implementation planning

Day 13	Day 12	Day 11	Day 10	Day 9	Day 8	Day 7	Day 6	Day 5	Day 4	Day 3	Day 2	Day 1	Activities
													Clearing debris
													Destruction of the weak wall in the south-East corner
													Removal of plaster layers all around wind tower
													Propping up weak structures
													Reconstruction of the wall in the south-East corner
													Destruction of weak gypsum layers
													Modification of the drainage slopes at the base
													Cleaning of wall bases
													Destruction of bathroom and removal of tiles
													Reconstruction of the bathroom
													Restoration of the wall bases
													Reconstruction of the top of the western wall
													Reconstruction of the parapet wall
													Reinforcement of the base of the wind tower
													Reinforcement of central part of the wind tower
													Restoration of the top of the wind tower
													Destruction of the arch under the wind tower
													Insertion of a tie rod under wind tower, to reinforce arch
													Removal of cement slabs from the room floors
													Laying of the new floor tiles (burnt clay bricks)
													Filling joints between floor tiles
													Levelling of the wall surfaces with Kah-Gel
													Removal of cement slabs from the courtyard
													Arch reinforcement under wind tower
													Laying of new floor tiles in courtyard
													Removal of mortar layers from the roof
													Restoration of the ventilation hole on the kitchen roof
													Restoration of the roof surface
													Restoration of the gypsum plasters

Site safety

Be cautious when working in old houses

All working sites are dangerous, but working in a partly abandoned historic city centre is particularly risky, because of the crumbling structures and the instability of certain elements. Inexperienced workers should not be sent alone to the sites, they should work together with qualified ones and conservators who can easily identify the dangerous areas.

Basic safety measures

- Conduct a hazard assessment with the site team to ensure that everyone is aware of the dangers.
- Provide all workers with safety shoes, helmets, nose and mouth protection masks.
- Secure the fragile structures with temporary propping.
- Make sure the site is dry and remains dry (no water should be poured near the walls).
- Block access to risky areas.
- Provide time in the planning for daily cleaning of the site. A dirty site is far more dangerous than a clean one.
- Provide safe scaffoldings and reliable ladders to work on high walls.
- Inform the neighbouring community and stop pedestrian traffic in the street if necessary.

Dangerous works described in this guide are marked with this sign

Insurance

In any case, insuring the workers is a requirement.

6 5 4 3 2 1

Anchor the scaffolding tubes deep into the walls.

Place scaffolding tubes on a solid base, not directly in the debris.

Support weak elements (Temporary propping of a fragile wind tower for example).

Provide helmets.

Provide nose and mouth masks for the dusty tasks.

Conduct a risk assessment with the site team.

Selecting soil

Testing a soil requires approximately 2 days

Laboratory equipment

Soil samples

Trained laboratory technician

Can any soil be used for conservation?

No. Different soil samples can have very different properties, even if they look the same to the eye. An excessive amount of clay, or an insufficient sand content can lead to poor results. This is why expert advice is recommended when selecting a soil.

How to proceed?

- ICHHTO technicians know where the good soils are located around Ardakan. Information can be obtained from the ICHHTO office. ICHHTO is also equipped with a laboratory for testing soil samples.

Technical difficulties

Selecting the perfect soil is not enough. To obtain a good brick or a good surface protection, the preparation of the soil, the curing of the mix and the preparation of the wall are equally important.

6

This test gives indications on the type of clay contained in the sample, and may help to reject samples which contain very active clays.

5

The methylene blue test measures the capacity of the fine particles to absorb methylene blue.

4

During sedimentation, the grains placed in a suspension fall at different speeds according to their dimension.

3

Sedimentation analysis complements the wet sieving, and prThis test indicates the type of clay contained in the sample, and may help to reject samples which contain very active

2

Wet sieving tells if the grain size distribution is balanced.

1

Wet sieving of the sample separates the soil into several classes of grains of decreasing sizes.

Preparing Kah-gel

(Kah-gel: mud-straw plaster)

3 hours for 1 cubic meter
1 to 2 days of curing

Shovel, feet, water hose, wheelbarrow + vehicle to bring the soil

Earth
Water
Straw

1 to 3 people depending on transportation needs (distance between the mixing area and the working site)

Is Kah-gel the best protection?

Kah-gel has proven to be the best suited plaster for earthen walls. It adheres to the bricks, allows humidity movements and insulates the bricks from the heat.

How to proceed?

- Identify an appropriate soil. Bricks from ruined buildings can be recycled if considered suitable.
- Mix the soil, water and chopped straw several days in advance to allow the straw to soften and avoid cracks in the plaster.

Technical difficulties

The only difficulty is to identify a good quality soil. The ICHHTO office can assist you in identifying suitable soils.
A good result can not be obtained if the mixture is not prepared long in advance. A Kah-gel prepared in haste is difficult to apply and leads to cracks and poor adherence.

6

Remix the earth-straw-water mixture before use.

5

Cover the mix for some days to allow the straw to deteriorate in a humid atmosphere.

4

Allow the mix to soften up for a few hours and mix with a shovel or by foot.

3

Add the straw to the soil mixture. The volume of straw should be approximately the same as the volume of soil.

2

Add water to the soil until the mix becomes almost liquid.

1

Soil can be brought from a quarry, or can be recycled from ruined walls.

Controlling drainage slopes

Cleaning a 80 m² ruined plot requires a whole day + a day to cover some parts with Kah-Gel

Wheelbarrows, shovels, rakes, hose, line, spirit level, security equipment

The soil is moved from one place to another. Bringing soil from outside is therefore not necessary

1 mason to control the levels
2 helpers to shift materials and compact the soil

Dangerous Work

Keeping structures dry

Drainage slopes within and around buildings are essential to divert water away from the walls and avoid water-related pathologies. Water should not be allowed to seep into the ground or infiltrate the walls, as it can weaken the foundations and create serious structural defects.
This applies both to standing and ruined structures!

How to proceed?

- Analyse the slopes all around the building.
- Identify areas where water could stagnate or infiltrate walls.
- Identify safe areas where the water can be directed to.
- Correct the shape and direction of the slopes with thin layers of wet soil (4-6cm).
- Compact the surface to avoid infiltration.

Technical difficulties

When a standing structure is surrounded with ruins, working on the drainage slopes may entail shifting tons of materials.
The work can also be dangerous!

… 6 | 5 | 4 | 3 | 2 | 1

Check the slopes with a line to control their regularity.

Adjust each layer with a rake.

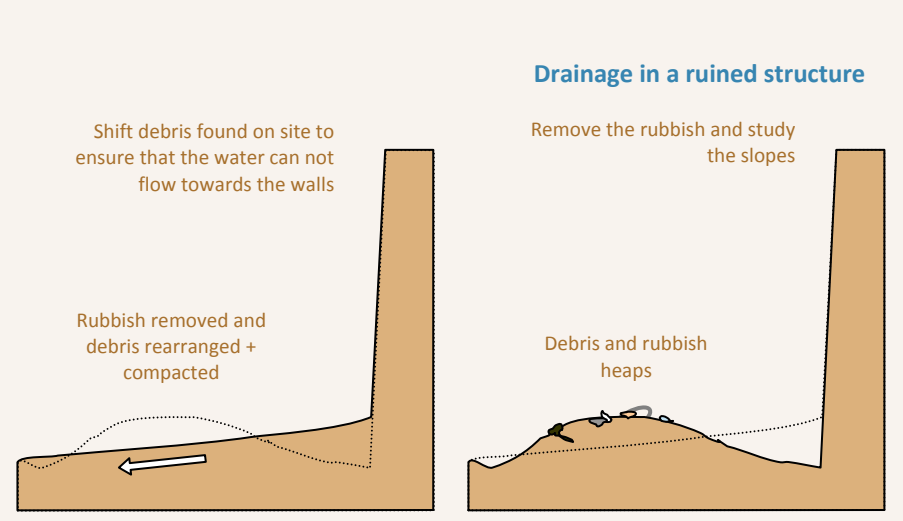
Sprinkle each layer with water to reduce amounts of dust and make compaction easier.

Add thin layers (4-6cm) until the required slopes are obtained. Gentle slopes with less than 10% gradient are sufficient.

Shift materials from the centre to the sides, to create slopes slanting from the standing walls towards the streets, where water can be drained away.

Clean the surface to remove all the rubbish and reveal the shape of the ground.

Controlling drainage slopes



9 8 7 ...

Once the first layer is dry, a thin second layer should be applied to fill in the hair cracks.

The drainage slopes can be covered a few weeks later with a layer of Kah-Gel, especially along the walls.

Allow the ground to completely settle down for several days before applying the finishing coat.

Cutting a brick

2 1

to the other end of the line.

Hit gently along the line starting from one end…

Cutting to an exact line

For cutting a brick to an exact line, hold it with one hand and hit it gently along the required cutting line. Hit as many times as required until the brick splits.

You can tell when the brick is ready to break because the sound changes

Mason hammer or trowel

Splitting into two halves

To split a brick into two halves, hold it with two hands and hit it on another brick laid on the edge.

4 3 2 1

Hold the brick firmly and hit it firmly on the other one.

Hold a brick on its edge with your knees, if possible use a more resistant brick (fired brick or cement tile).

4 3

The sound of the hammer tells you when the brick is about to break.

Laying a brick

For simple straight walls, a mason with 2 helpers can lay 400-500 bricks per day

building line, plumb bob, spirit level, trowel, mortar box

bricks, water, Kah-gel

1 mason, 2 helpers

The strength of the wall depends on the quality of the bricklaying. Bricks pilled up in haste, without filling the mortar joints properly, will produce weak walls that will easily collapse in the event of an earthquake.

How to proceed?

- Wet the wall and the bricks.
- Apply mortar on the wall, but also on the brick edge.
- Set a brick down in the mortar bed.
- Tap it down with the hand until it is level and parallel to the line of the wall.
- Check if all the mortar joints are filled up.
- Cut away the excess mortar with the trowel.

Technical difficulties

One of the difficulties is to keep the bricks dampOne of the difficulties is to keep the bricks wet before using them, to ensure that the mortar can dry slowly. If the bricks are used dry, they will suck all the water contained in the mortar
before using them, to ensure that the mortar can dry slowly. If the bricks are used dry, they will suck all the water contained in the mortar

1

Soak the bricks in water before use. Bricks must be damp but not wet.

2

Spray the wall with water.

Apply mortar on the wall and on all sides to create the mortar bed.

3

Set the brick down in the mortar bed and push it down.

4

Adjust level if necessary by hitting the brick with the trowel or by hand.

5

Make sure all mortar joints are filled up. Remove excess mortar before laying the next brick.

6

Repairing a damaged wall base

1 week: 1 day to clean, 1 for drying, 1 to insert the foundation, 1 to build the wall, 1 to complete the reconstruction, 2 for the finishes

Hammer, shovel, wheelbarrow, trowel, spirit level, mason line, security equipment

Mud mortar, lime, burnt bricks or cement tiles to build the waterproof foundation, wood to prop the wall

A mason, 2 helpers

Dangerous Work

Why are wall bases eroding?

The wall bases erode when they become humid. Many sources of humidity can affect a wall base, including capillary rise, a leaking pipe, the covering of the plinth with a waterproof layer, or the infiltration of water from a damaged roof. The process accelerates when the capillary movements are charged with salts.

How to proceed?

- Identify the source of humidity.
- Block the humidity infiltration (in this case, the roof was repaired, the cement plinth removed).
- Remove all the soil which has lost its cohesion.
- Insert a capillary barrier before rebuilding the mud-wall.

Technical difficulties

The main difficulty is to identify the various factors which led to the wall deterioration, to make sure they are eliminated before the wall base is reconstructed.
Another difficulty is to avoid the collapse of the wall. Working in small sections and propping the wall can be necessary.

… 6

Reconstruct the wall with mud bricks without reaching the top level. Allow to dry and settle for at least a day before closing the gap at the top.

5

Create a moisture barrier on top of the foundation with cement or ceramic tiles, burnt bricks or any other material which prevents humidity movements.

4

Pour the soil-lime mixture and allow to harden before proceeding further.

3

Prepare a soil/lime mixture for the foundation (1 vol. lime / 2 vol. soil)
If the soil removed from the wall is not salty, it can be reused.

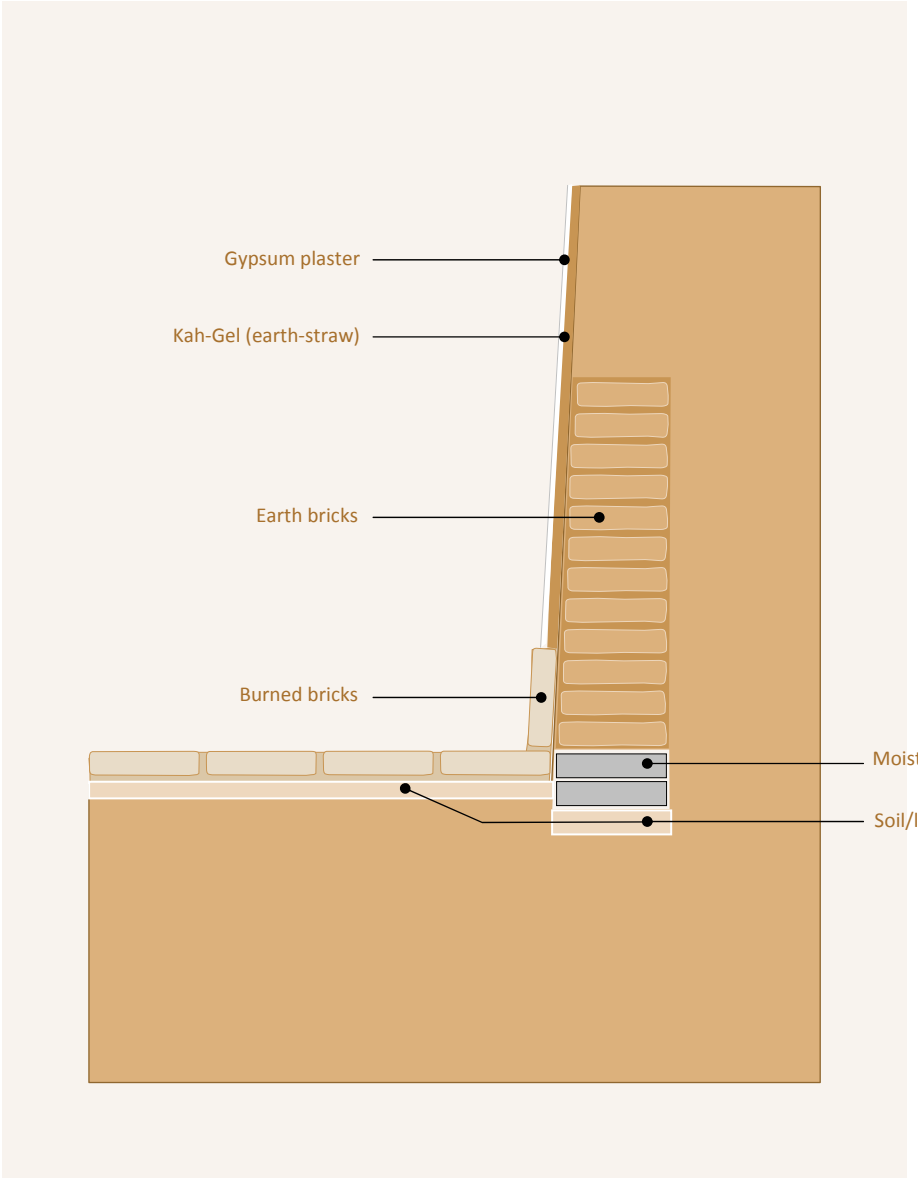
2

After allowing the wall to dry for a day, dig 5 cm below the ground floor level to prepare for the stabilised soil foundation.

1

Remove all the loose soil from the wall base.
If the damaged part is very wide and deep, proceed in small sections at a time.

Repairing a damaged wall base



9 8 7 ...

Apply the mud plaster to level the wall. This will reduce the amount of gypsum needed to finish the wall.

Allow the brickwork to set before applying the mud mortar

After complete drying of the reconstructed base, insert the final layer of bricks, by forcing the bricks with mortar into the gap.

Installing or restoring a shower

1 week

Trowel, mason line, spirit level, plumb bob, wheelbarrow, bucket basin, Plumbing tools

Burnt bricks, sand, cement, ceramic tiles, ventilation grid, plumbing equipment

1 mason
1 helper
1 plumber

How to protect the walls from humidity?

Bathrooms are very sensitive areas, since any leakage can seriously damage the earth structure. The water supply system should be accompanied by an efficient wastewater disposal system, in order to avoid water stagnations on the lanes or at the base of the walls.
It is advised to keep water pipes apparent, for easy repairs in the event of a water leak.

How to proceed?

- Prepare a waterproof surface on the ground to receive the shower base. The ground should slope towards the courtyard of the house, in case of a water leak.
- Install the shower base and the pipes.
- Build the second wall along the earthen wall, leaving a 10 cm gap for ventilation.
- Apply the tiles and finishing layers.

Technical difficulties

The difficulty is to conciliate wall ventilation and wall waterproofing.
The double wall system shown on next page offers good protection against humidity.

6

Install the ventilation holes and grids on the outside wall.

5

Protect this new wall with tiles to avoid water absorption.

4

Build a brick wall 10 cm away from the earthen structure to create a ventilation gap.

3

Prepare the waterproof surface on the ground, with cement and bitumen. This is to avoid water infiltrations in case of a water leak under the shower base.

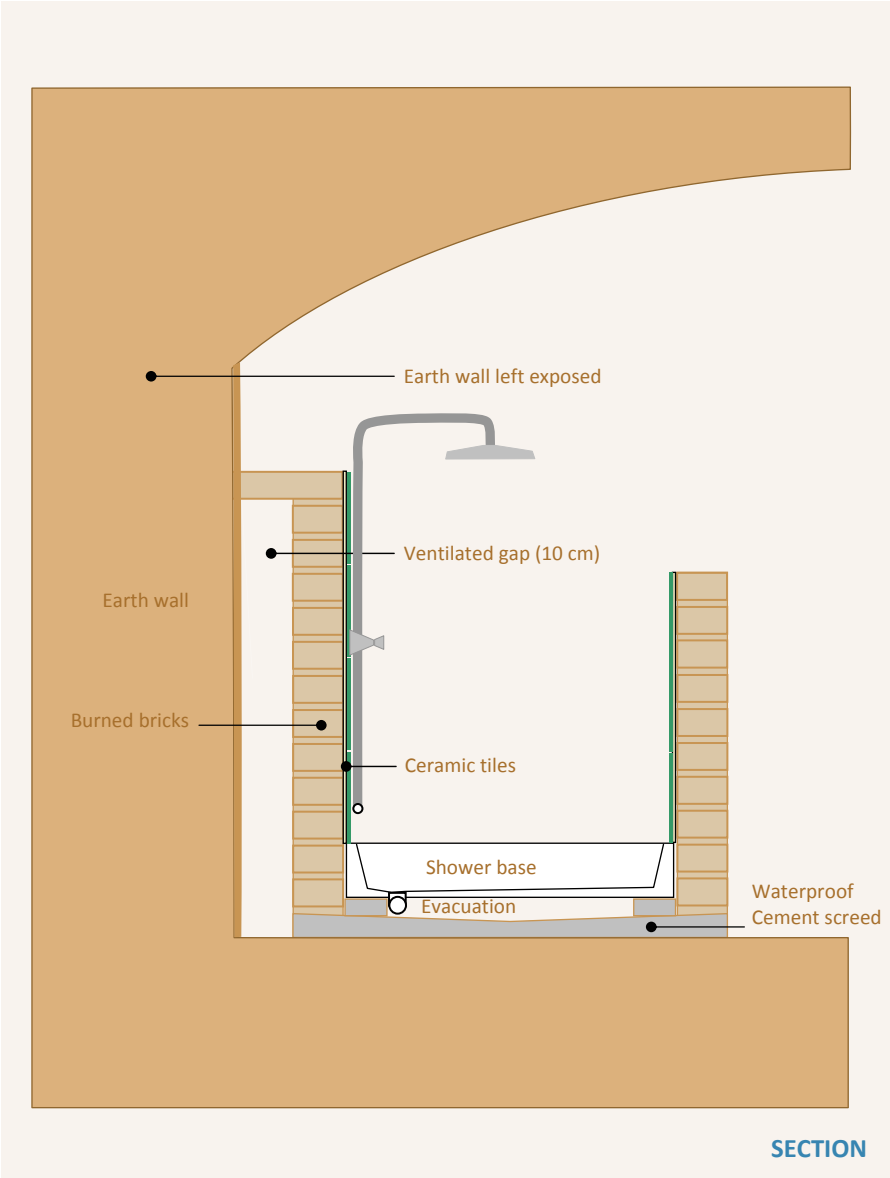
2

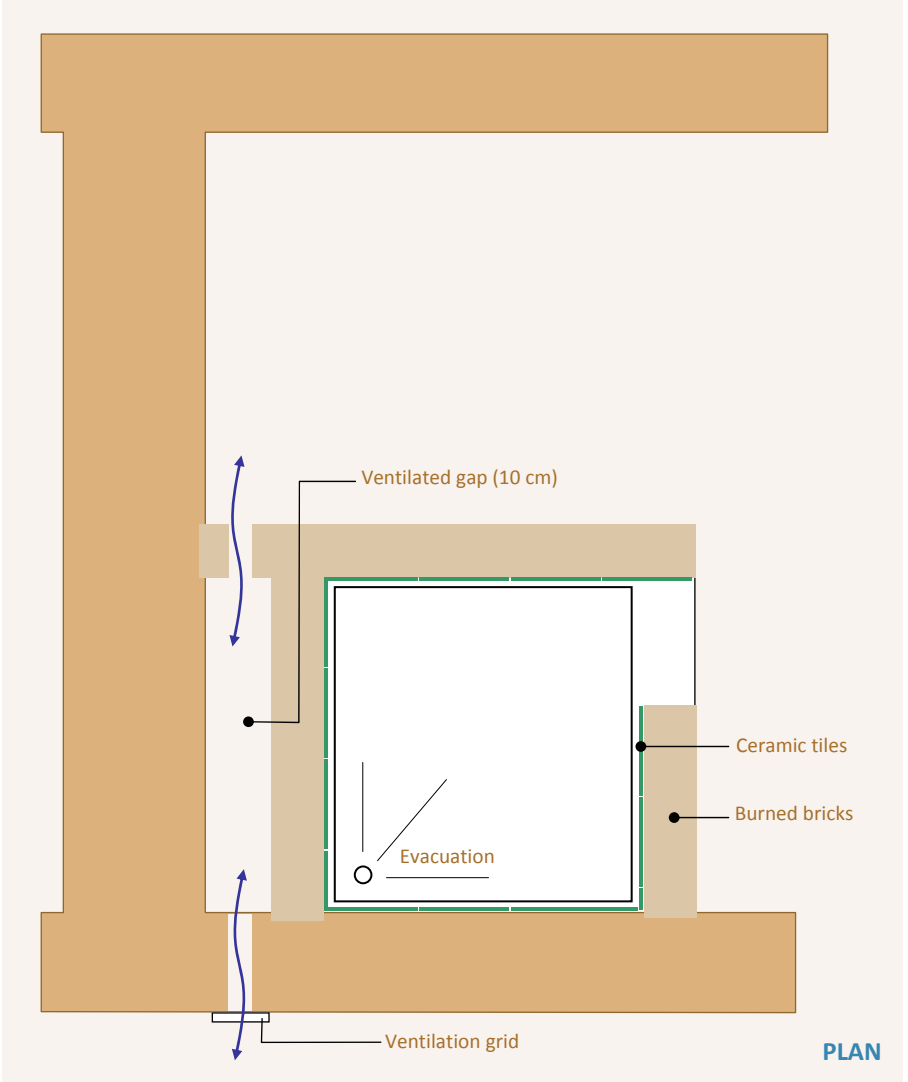
Remove the plaster layers and ceramic tiles to expose the walls

1

Demolish all the areas damaged by moisture

Installing or restoring a shower





Monitoring cracks

30 minutes to place a plaster pad
several months to monitor the movements

a trowel, security equipment

water and gypsum

one mason

Understanding what caused the crack

A crack signifies a structural deformation. All cracks are not necessarily dangerous. To measure the potential threat linked to a crack, it is necessary to check if the crack evolves, or if, on the contrary, it indicates a problem that has stabilized.

To verify if a crack evolves or not, it is recommended to monitor it over several months. One or more plaster pads placed over the crack will help determine its evolution.

If the shape and size of the crack evolve, the cause of cracking should be identified and located. To treat a crack without eliminating the cause of the deformation is not a solution. It is necessary to first understand what caused its creation, by analysing the deformed element on a large scale. The cause for a deformation can be found far from the crack, at the base of the building for example.
The deformation is generally due to the accumulation of water at the base of the building, following an accidental change in the topography (collapse of a wall, material deposits or waste deposits, etc.), or by seismic vibrations.

The stabilization of a crack can take several weeks after the treatment.

4

Monitor on a regular basis to see if the crack is stable or if it continues opening up.

3

Apply gypsum on both sides of the crack. Make sure the plaster adheres to the wall. Reduce the size of the plaster pad in the centre, to make sure that any tension or movement will break the pad in its centre.

2

Remove the dust and wet the area where the plaster pad will be placed.

1

A variety of devices can be used to monitor a crack. They help to know if the structure is moving or stable.

Stitching small cracks

Approximately 30 minutes per stitch

Bucket (for water), hammer, trowel, mortar box, wood saw, security equipment

Pieces of wood
Kah-Gel
PVC mesh

1 mason
1 labourer

How to proceed?

Once the cause of the cracking is removed and the structure stabilized, it is possible to stitch the crack to reinforce the wall:

- Clean the crack to remove loose parts and dust particles.
- Chisel the wall on both sides of the crack to provide space for the wood (the size and number of wooden keys depends on the size of the crack).
- Water the wall to avoid fast drying of the mortar.
- Insert the wooden keys into the wall, sealing them with earth or with gypsum at least 15 cm deep into the masonry.
- The wood should be treated against termites (soaked in a lime slurry).
- In addition, the surface of the wall can also be reconnected with a PVC mesh embedded in the Kah-Gel plaster.

Technical difficulties

Chiselling the fragile wall can be difficult. The wall should be hit gently or carefully cut with a hand saw to avoid the collapse of big chunks of wall.

6

In addition to stitching the crack, covering it with PVC mesh also contributes to its reinforcement.

5

Insert the wood and push it deep into the mortar.

4

Fill in the groove with mortar.

3

Cut the wooden key at the required length.

2

Clean the crack, remove all loose particles. Open a groove on both sides of the crack with a chisel or a saw. Wet the wall.

1

Minor structural cracks are often found under the plaster layers. If an element seems unstable, remove the kah-gel layers to reveal all the weak points.

Sealing major cracks

2 days

Trowel, spirit level, hammer, bucket, mortar box, helmets and other security equipment

Bricks, mortar, water, pieces of wood wooden beams or metal tubes for propping up the walls

1 mason, 1 helper

Dangerous Work

Preliminary

Major cracks reveal serious structural deformation. The source of deformation should be fixed before attempting to seal the crack.

How to proceed?

- Secure the site (prop-up the wall).
- Clean the surroundings and remove all loose elements from the crack.
- Chisel the sides to ensure proper bonding of the new bricks with the wall.
- Wet the wall and the bricks.
- Secure the top part to ensure that nothing can fall on the workers.
- Rebuild the wall gradually. Do not lay more than 6 layers of bricks in a day, to allow the repair to set before continuing.
- Insert wooden keys if necessary.
- Work on the drainage, to keep rainwater away from the wall.

Technical difficulties

Understanding the cause of the crack and stabilising the structure.

1	2	3	4	5	... 6
					
Secure the site. All the threatening elements above the crack should be propped-up.	Clean the surroundings for better access and increased safety.	Remove all loose elements.	Find a means to secure the top part of the crack, to make sure that nothing can fall on the workers. A wooden key can be inserted as a base to reconstruct the top.	Reconstruct the top, respecting the bonding with the brick courses on both sides.	Allow the repairs at the top to dry completely before proceeding at the bottom.

Sealing major cracks

12

Level the surface once the brick work is completely dry.

11

Fill in the last layer. Bricks and mortar should be pushed in by force to ensure that the upper gap is completely filled up.

10

Allow complete drying of the brickwork before inserting the final layer at the top.

9

Proceed slowly to allow each layer to set.

8

Start reconstructing from the base. In this case, the mason decided to build an arch to distribute the load on the side walls, because the ground was too weak.

7 ...

Clean the base to reveal the ground level.

14

Create a drainage slope in front of the repaired wall to avoid future deformation.

13

Refill the base of the wall.

Reconstructing an element

Depends on the size, accessibility and complexity of the element.
For the example shown below : 3 days

Building line, spirit level, trowel, shovel, hammer, mortar box, bucket, security equipment

Bricks, Kah-gel, water, PVC mesh for horizontal reinforcement

Depends on the size of the element.
For the wall shown on the photos below : 1 mason and 2 helpers

Conserving or reconstructing?

Major restoration and reconstruction should be avoided as much as possible, unless we are dealing with extremely weak or badly deformed structures. When a wall is only partially collapsed, the standing portion should be conserved rather than destroyed. Reconstructing an element anew inevitably alters the authenticity.
The reconstruction of a wall can be a good occasion to insert horizontal and vertical reinforcement which will reduce the risk of collapse during earthquakes.

How to proceed?

- Document before dismantling (photographic survey minimum).
- Dismantle and recycle materials that can be re-used.
- Prepare an even base for the reconstruction.
- Apply water on the base before laying the bricks.
- Insert reinforcement or waterproofing barriers if needed.

Technical difficulties

The crucial point is to understand why the element became fragile or deformed and treat the deterioration cause to minimize its future effects before reconstructing.

… 6

Insert a PVC mesh in the first mortar layer for a better load distribution on the ancient wall.

5

Clean and level the surface.

4

Stop demolition once you reach the strong base.

3

Clean the wall debris, and keep aside bricks which can be recycled.

2

Dismantle the wall.

1

Demolition is only justified if the wall has been poorly built and can not be reinforced as it is.

Reconstructing an element

12 11 10 9 8 7 ...






Continue reconstruction until the required height is reached. Here the wall was not fully reconstructed. It was only brought up on one side, to serve as a permanent buttress for the wind tower.

15 14 13



Reinforcing an arch

2 days, 1 to install the tie rod, 1 to reinforce the arch

Spirit level, plumb bob, trowel, ladder, bucket, mortar box, shovel, welding machine, security equipment

20 mm steel rod, 2 steel plates with home in the centre, nut, bricks, gypsum, sand

1 experienced mason
1 helper
1 welder

Dangerous Work

Which part should be reinforced?

An arch carries important stresses to the walls supporting it. Cracks in the arch reveal weaknesses in the side walls. Repairing the cracks does not help. The side walls need to be reinforced. The stresses can also be diminished by inserting a tie rod that will prevent the lower ends of the arch from spreading.

How to proceed?

- Analyse the cause of the structural problem.
- Secure the arch (propping up weak elements).
- Treat the cause (drainage for example).
- Install the tie rod.
- Reinforce the arch if necessary.

Technical difficulties

Ensuring security is always difficult, because important stresses are involved. The work should be handled slowly with a very experienced mason. Only one helper should be involved.

... 6 | 5 | 4 | 3 | 2 | 1

Insert the iron rod in the two holes.

Drill the side walls just below the arch, using an electric drill with a long peg, or an iron bar with a hammer. The electric drill is safer because of reduced vibrations.

Demolition of an old and obsolete reinforcement system
Before destroying similar elements, make sure they are not load bearing. If the element is not in contact with the arch, then it does not carry the arch and can be safely dismantled.

Take time to assess the situation and understand all the potential risks.

Reinforcing an arch

12

Build the pillar in stages, to allow the brickwork to set.

11

Reinforce the arch, starting from the pillars on both sides.

10

At the other end, mount the steel plate and tie the rod with a bolt.

9

At the first end, weld the rod to the steel plate.

8

Clean the wall around the rod to mount the steel plates.

7 ...

18

For the top of the arch (last third), place a wooden board at the back, and build the arch against the board.

17

16

15

Even if the bricks stick to the arch, prop them up with a wooden beam.

14

Once the pillars are completely dry, continue with the arch, using a soil and gypsum mortar (2:1).

13

Maintaining a roof surface

2 days for 50 m²

Shovel, pickaxe, rake, buckets, mortar box, building line, spirit level Wheelbarrow and vehicle if soil has to be moved away.

water, Kah-gel

1 mason to supervise the slopes, 2 helpers

Why maintaining the roof surface?

The top of the structure is as important as the base. Any small crack in the surface can lead to water infiltration with serious structural consequences. Drainage slopes should be controlled every year.

How to proceed?

- Remove the accumulated soil layers from the roof surface (thickness can reach 50 cm).
- Control the slopes with a line and a spirit level.
- Level the surface with a rake, using wet soil to create the required slopes.
- Allow the surface to dry and set before continuing (24 hours).
- Apply the first layer of Kah-gel and allow to dry completely overnight.
- Apply the final thin layer. Insist at the junction with the parapet wall.

Technical difficulties

The roof should not be overloaded. New layers of soil are often added onto the roof every year. This accumulated load is dangerous for the structure, and for the inhabitants in the event of an earthquake. This is why the surface should be scraped off first.

1

Remove the old layers of Kah Gel from the entire roof surface. Do not recycle the soil as it has been washed by the rain, and has lost part of its clay content.

2

Adjust the slopes with wet soil. Check the gradient with a spirit level and the regularity of the slope with a line. There should be no holes or bumps.

3

Apply the first layer of Kah-gel, if possible when the sun is not too hot. Where the roof is unstable, a PVC mesh can be inserted in the Kah-gel.

4

Allow to dry completely.

5

Small cracks always appear once the first layer is dry.

6

Apply a second layer of Kah-gel to seal off all cracks. Insist at the junction between the roof and the parapet wall

Repairing a damaged roof

6 days

Mason line, plumb bob, spirit level, bucket, mortar box, trowel, pickaxe, hammer, security equipment

Bricks, mortar, PVC mesh, water

2 masons, 2 helpers

Dangerous Work

How can damages occur at the roof level?

Minor movements of the walls because of humidity at the base can cause major deformations at the roof level. Water infiltration in the roof can also deteriorate the load bearing walls and lead to structural defects. In this case, the roof started deteriorating because of humidity accumulation in the adjacent plot, where the house is abandoned.

How to proceed?

- Locate the cause of the deterioration and fix it (in this case : drainage of the ruins).
- Dismantle all weak parts.
- Rebuild the wall and the roof, and reconnect them with PVC mesh.
- Work slowly to allow the masonry work to set.
- Apply several layers of Kah-gel to seal off all cracks.

Technical difficulties

Securing and accessing high places makes the work difficult. Experienced masons should be asked to handle such tasks.

... 6 | 5 | 4 | 3 | 2 | 1

Remove the soil until the vaults are visible.

Remove all the mud layers from the roof.

Proceed until the sound structure is fully revealed. The wall should be dismantled to reach a firm base where reconstruction can start.

Dismantle all the fragile elements.

Install a safe scaffolding along the wall.

Correct the drainage at the base of the wall.

Repairing a damaged roof

12

Allow the brick work to dry overnight after 5 layers.

11

Continue with the brickwork, and insert a mesh every three layers.

10

Cover the mesh with another mortar layer.

9

Place a PVC mesh in the mortar to reinforce the wall.

8

Lay a first layer of mortar.

7 ...

Wet the wall before starting the brickwork.

18

Work on the roof finishes.

17

Reshape the drainage slopes on the roof.

16

Rebuild the parapet wall once the wall is completely set. The top of the parapet wall should have a curved shape for better resistance against rain.

15

Reconstruct the missing parts of the vault as the wall goes up.

14

Use the PVC mesh to reinforce the connection between walls (T-junctions).

13

Continue building with a mesh every 3 layers. This creates a beam which will be more resistant to deformation.

Conserving a wind tower

6 days

Square trowel to plaster the surface, smaller trowels for the details, hammer, bucket, mortar box, security equipment

Water, Kah-gel, PVC mesh, concrete nails to hold the mesh

1 mason, 1 helper

Dangerous Work

Dismantling or conserving?

Wind towers are fragile elements, which are often cracked and deformed. Dismantling them is a risky exercise, as elements of the tower can fall on the roof or inside the house, weakening the structure. We therefore recommend keeping the towers and reinforcing them. This also leads to a more authentic result in terms of conservation.

How to proceed?

- Secure the tower, by propping-up all weak elements.
- Install a scaffolding.
- Remove the surface plaster.
- Analyse the cracks and study the structural defects.
- Stitch the major cracks.
- Apply the first layer of Kah-gel, after wetting the wall.
- Integrate the PVC belt in the fresh mortar.
- Cover the PVC belt with a second layer of Kah Gel.

Technical difficulties

Accessing the top and working on a fragile element is the major difficulty.

... 6 | 5 | 4 | 3 | 2 | 1

Treat the cracks one by one, by stitching them, and eventually covering them with a mesh.

Reinforce the base of the tower with buttresses.

Secure the inside of the tower if necessary.

Observe the structural pathologies and assess extent of damage.

Remove the surface plaster to check the quality of the masonry work underneath.

Prop-up all the weak elements to secure the workers.

Conserving a wind tower

12

The mesh should be long enough to go all around the tower and overlap. Here, 15 m strips were used for a 10,5 m circumference.

11

Cover the PVC mesh with Kah-gel.

10

Use long concrete nails with rubber washers.

9

Hold the mesh in place with nails.

8

Apply a layer of Kah-gel at the base of the tower and fix a first strip of PVC mesh. Start from a corner.

7 …

Allow all the crack repairs to dry before proceeding.

… 18

Allow to dry completely before working on the top of the tower.

17

This reinforcement should not be too thick (less than 5 cm), to avoid overloading the structure supporting the wind tower.

16

For this tower, three strips of 15 m length were installed at the base.

15

Proceed with another strip. Several layers can be necessary to create a real belt at the base.

14

Completely cover the first strip of PVC mesh.

13

Cover the mesh with Kah-gel.

Conserving a wind tower

24	23	22	21	20	19 …
					
	Repair the decorations.	Allow to dry before doing the finishes.	Continue until the entire tower is plastered.	Cover the top with Kah-gel. Treat the slopes on top carefully, to avoid water infiltration.	Clean and wet the top.

Laying floor tiles

Approximately 20 m²/day

1 trowel, 1 tape, 1 mason's line, mortar box, bucket, hammer

sand
porous fired clay tiles
lime, water

1 mason
1 helper

Which type of floor finishes is adapted to earthen structures?

The floor treatment should allow the evaporation of humidity from the ground, to reduce the amount of moisture in the walls. Ceramic tiles or concrete slabs should be avoided. Fired clay tiles can be used if they are porous. They should be laid either directly on a sand layer, or on a lime and sand mortar which can breathe.

How to proceed?

- Remove the existing tiles and allow the ground to dry.
- Level the surface with a layer of soil and lime (2 volumes soil/1 volume lime).
- Lay the first tile in a corner.
- Lay the second tile at the other end of the same line.
- Install a line in between the two tiles and lay tiles in between.
- Proceed along another wall.
- Ensure that the first two lines of tiles form a perfect square angle (3-4-5 triangle).

Technical difficulties

Once the tiles are laid, workers should not be allowed to walk on them for some days, to allow the mortar to set. If the tiles are laid on sand, this difficulty does not exist.

1	2	3	4	5	… 6
					
Remove existing tiles and slabs. Level the surface with a layer of soil and lime, mix ratio 2:1.	Lay the first tile in one of the corners, on a sand bed, or on a sand and lime mortar Mix ratio in volume: 1 lime - 3 sand.	Lay the second tile in the opposite corner, set a line for the alignment and lay the tiles in between.	Check horizontality of the tiles.	Start another edge using the same principle. The angle should be square.	Continue until the entire perimeter is laid.

Laying floor tiles

10

9

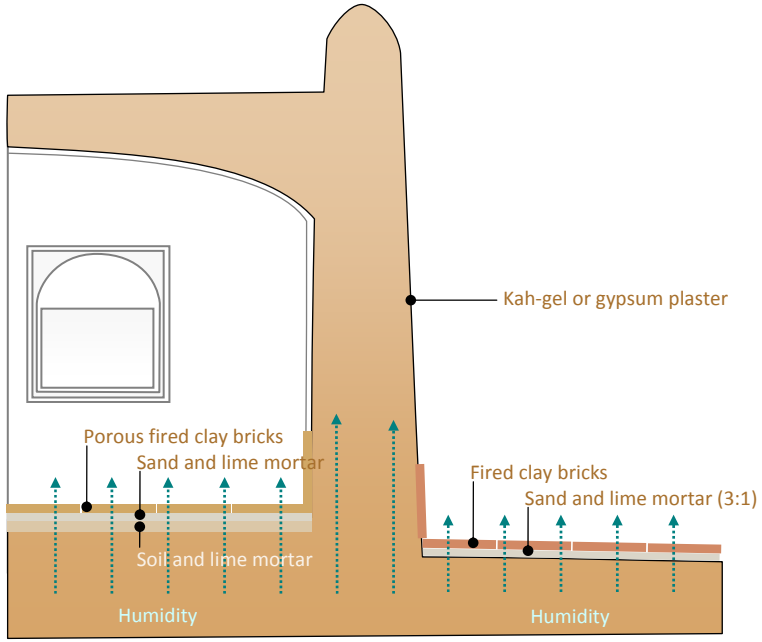
Once the plinth is dry, complete the gypsum work.

8

Tiles for the plinth can be laid with a mud mortar.

7 ...

After laying the tiles all around the perimeter, lay the plinth.



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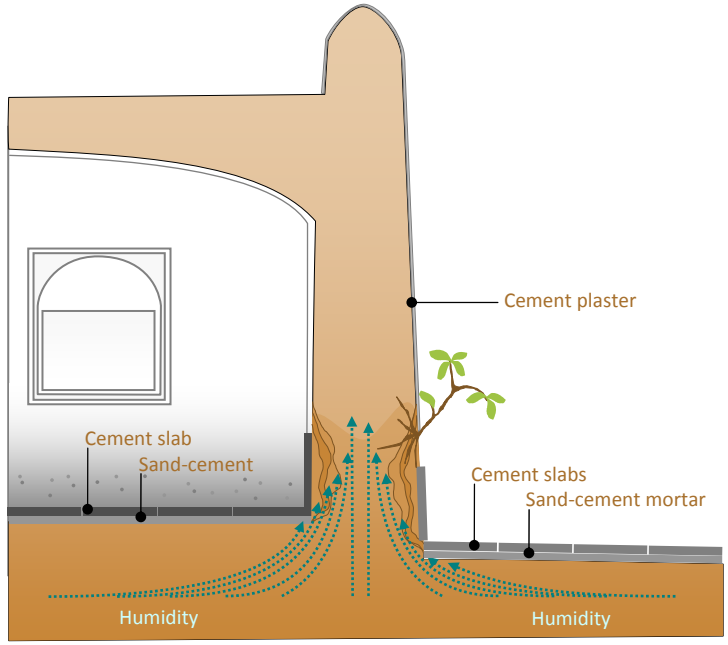

BEFORE

Applying a mud-straw plaster

A mason with two helpers can cover 50 m² per day, including the preparation and cleaning of the wall

A square trowel for levelling the surface, a mortar box, A hose or containers to keep water near the working place, security equipment

Kah-gel
Water

2 workers for each mason, 1 to bring the Kah-gel to the site, one to hand it over to the mason

Which role does the Kah-Gel plaster play?

The mud and straw layer is a protective coating which reduces the heat absorption and protects the bricks from the rain. It erodes gradually but can resist 5-10 years before a replacement is needed, depending on the wall exposure.

How to proceed?

- Clean the wall surface to remove old plaster layers, dust and loose particles.
- Treat the cracks.
- Clean the joints to make sure the plaster will enter the wall and hold fast.
- Fill holes and gaps the day before applying the plaster.
- Sprinkle water on the wall.
- Apply the mortar by throwing it firmly onto the surface.
- Smoothen with the hand.
- Add a thin layer the following day to fill-in the micro cracks.

Technical difficulties

If the Kah-gel has been prepared long in advance, there is no difficulty. Plastering should be done when the wall is in the shade to avoid fast drying and excessive cracking.

6

Add a thin layer the following day to fill all hair-cracks and increase durability of the plaster.

5

Apply the Kah-gel, if possible when the wall is in the shade, to avoid fast drying.

4

Wet the wall surface abundantly.

3

If necessary, make little holes in the wall, using a hammer.

2

Scrape the wall surface and clean the mortar joints.

1

Remove the old plaster layers.

Applying gypsum plaster

Duration depends on the complexity of the wall shapes. Niches and decoration details require days of work. Flat surfaces can be covered very quickly.

Basins to prepare the gypsum
Square trowels (ordinary + L-shape)
Paint brush for decoration details
Plastic scraper

water
gypsum

1 specialised mason
1 helper to prepare the mixes

Where is gypsum adequate?

Gypsum can only be applied on walls which are dry and protected from humidity. Applying gypsum on a damaged structure presenting humidity pathologies will not solve the problem. All structural problems and potential humidity infiltrations (from the base and from the roof) should be fixed before the gypsum is applied.

How to proceed?

- Clean old surfaces to remove dust.
- If applied over an old layer of gypsum, scratch the surface with a trowel to obtain a better connection between the 2 layers.
- Sprinkle water on the surface to be plastered.
- Sieve the gypsum powder to remove any lumps.
- Prepare a very liquid gypsum mixture and stir gently until it starts to thicken. Prepare small quantities at a time. Do not remix with water once the gypsum has become hard.
- Apply the gypsum in thin layers from the top down.

Technical difficulties

Very difficult, requires experience, precision and speed.

6

Smoothen the surfaces with a soft plastic scraper. The scraper will remove the marks left by the float

5

Use an L-shape square trowel to finish the corners

4

Apply starting from the top moving downwards

3

Prepare a very liquid mixture and stir gently. Hardening starts after 5 to 10 minutes. Prepare only a small amount of gypsum that the mason can apply within 5 minutes.

2

Sieve the gypsum powder to remove the lumps (1 mm mesh sieve)

1

Preparation : Scratch the old surfaces for a better connection of the new gypsum plaster