CLAY HOUSE PROJECT

CLAY CONSTRUCTION MANUAL

BASED ON THE BUILDING STANDARDS FOR BUILDING WITH CLAY AS DEFINED BY THE ECOSOUTH NETWORK

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CONTENT

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Introduction

The Clay House Project (CHP) is a non-governmental organization, based in Otjiwarongo, Namibia. Its overall aim is to promote environmental and social sound and sustainable development. As part of the international organization EcoSouth, the Ecological and Economical Habitat Network, the CHP is linked to a worldwide operating network, which provides knowledge transfer on the issues of ecological and economical construction methods and materials.
Since clay is an ecological and economical building material and since clay construction has a long tradition in Namibia, the CHP was founded in order to support, demonstrate and disseminate throughout Namibia the building of clay houses instead of cement houses. Through an immense reduction of energy consumption and the use of sustainable (ecological, economical, social, and local) construction technologies and materials, the building of clay houses throughout Namibia will contribute to the management of the global environmental concern of climate change. In addition, in the context of a growing poor population in Namibia, the current national problem states a significant housing deficit. To improve the living-conditions of parts of the population and as a means of poverty reduction in general, the CHPs overall objective is to help in creating capacities of Namibian communities, enterprises, farmers, and private households to address the community needs and interests. In particular the CHPs target is to demonstrate and disseminate community-level and community-led solutions to the national problem of Namibian housing deficit through the reduction of costs for shelter (use of economical construction technologies and materials). Furthermore, generally a clay house is 50% cheaper than the same-sized concrete house. Plus, compared to a cement house, five times more jobs for unskilled people are provided while constructing a clay house.

Due to the lack of a national building standard for clay houses, EcoSouth has provided an international applied building standard, which considers the Namibian environmental and social circumstances. The CHP has taken over these standards. Since one needs an official building permission for permanent houses, the construction method in accordance to the EcoSouth building standards enables the builder to construct the clay house with permission by the Namibian authorities. Hence, following the instruction given by the standard, this house won't be considered as an informal building, but will comply with the Namibian building regulations. By providing this manual, a community-based knowledge transfer concerning building with clay, the CHP helps enabling Namibian communities, enterprises, farmers, and private households to implement the given building standards. Working with the EcoSouth building standards and the CHP-clay manual and following all its instructions and advices, provides a permanent building. The clay house built according to the CHP-clay construction manual will be long lasting and will satisfy the house owner to a great extent.

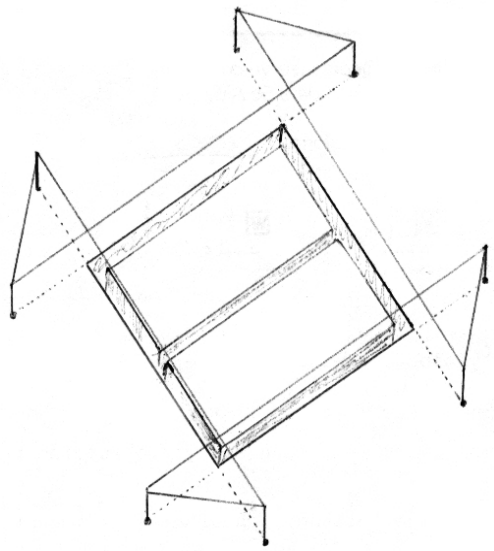
Since not everyone can consider oneself a skilled mason or self-builder, the CHP has established a building advisory service to provide local builders and construction companies with know-how and supervision assistance. People, interested in learning to build with clay, can contact the CHP for further information.

foundation	Consists of compacted clay, 50 x 50cm, only necessary for loadbearing walls. Generally outside walls are loadbearing, inside walls often don't serve as supporters of the roof and aren't considered loadbearing, they stand on plain house floor. In flooding areas the foundation must be built out of concrete. A concrete socket of appropriate height is to be employed. This could be built with rocks and cement mortar, or with bricks and cement mortar.
bricks	Adobe-bricks, made out of a sandy clay, should have a measurement of 30cm x 30cm. Half bricks should be 30cm x 14cm. Both should be between 8—10cm thick. Clay bricks must be strong and withstand the weight of a person standing in the centre, when placed with two edges on other bricks. They must be well dried and of regular shape.
outside walls	Width of 30cm. The wall has to be built according to the rules of masonry, with complete denting, and with thin mortar joints. The mortar should be of the same or similar material as the bricks.
inside walls	Width of 15cm, toothed with the thicker outside walls If they are longer than 3m without intersection, they have to be made thicker.
ring beam	The walls should be finished on top with a ring beam, made of reinforced concrete, minimum cross-section of 10 x 10cm. It is reinforced with at least one rod of reinforcement steel of at least 6mm diameter, embedded in the middle of the ring beam. Inside of the concrete this steel element runs through the holes of vertically installed devices which are then attached to the roof structure later on.
cleaning line	Installed at the bottom of the clay walls inside the house, to protect the foot of the walls. It consists of waterproof and impact resistant material like cement plaster, ceramic tiles or wood.
cement floor	Standards of cement houses are to be equally applied to clay houses.

window and door frames	Products of commercial quality are to be installed following the producer's instructions
shower wall	Preferably built with cement made bricks of 10cm thickness, arranged to be interlocked with the outside walls at a minimum of two connecting elements in the middle and on top of the walls. Alternatively the shower walls can be built of clay but plastered with cement mortar using a chicken mesh nailed into the clay wall to ensure the long-lasting performance of the materials.
inside window boards	Consist of clay or cement or other suitable materials, to be horizontally installed and smoothed.
outside window boards	Consist of waterproof materials like cast concrete, cement bricks or fired clay bricks, project from the wall below and slope to the outside of the house.
walls and roof	The clay walls are built up to the roof, good roof overhang has to be provided, at least 40cm.
outside plaster	Produced through the mixing of clay and sand. Mixing ratio is clay (6), sand (12). Cement based plaster is not recommended, it tends to separate from the wall and fall off after some time.
inside plaster	Produced through the mixing of clay and sand.
electricity and water supply	Standards of cement houses are to be equally applied to clay houses.
seal and painting	A water based isolator or seal-/fish-oil serves for making the outside plaster waterproof. If isolator is used painting may be employed afterwards, if seal-/fish-oil, paint can only be applied after a period of 3 month after applying the oil.
roof	Standards of cement houses are to be equally applied to clay houses, the roof structure is to be attached to the vertical elements of the ring beam.

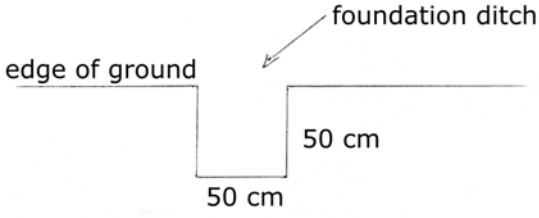
Laying foundation

In the first step mark the limits of the foundation. Namibian regulations define that the house has to have a distance of 3m to the street and a distance to the neighbouring erven of 1,25m.
The foundation is only necessary for the load-bearing walls. Generally outside walls are load-bearing, inside walls often do not serve as supporters of the roof structure and are not considered load-bearing, and they stand on plain house floor.
To mark the foundation, first plumb into the corners the string-lines, to guarantee straight limits of the foundation (pic.1).



picture 1

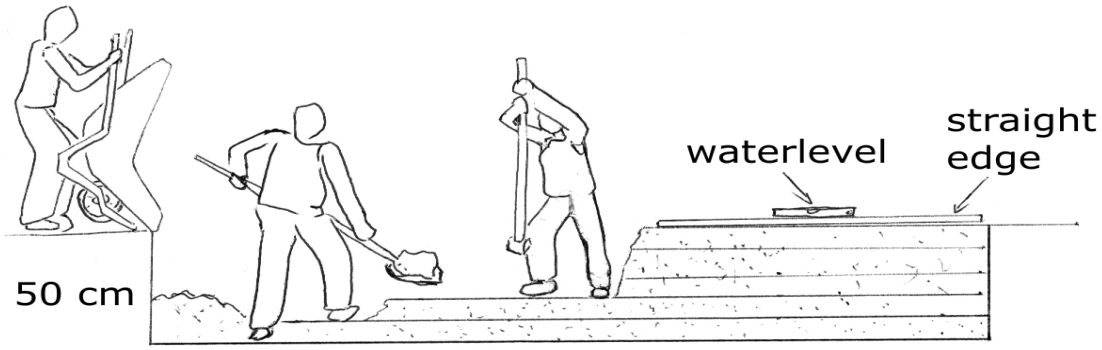
When you have marked the limits of the foundation, one can start digging the foundation. The foundation-ditch must be 50cm wide and 50cm deep. Both sides must be vertically, the bottoms horizontal (pic. 2). Remove any soil that crumbles down into the trench.



picture 2

Backfilling of foundation ditch

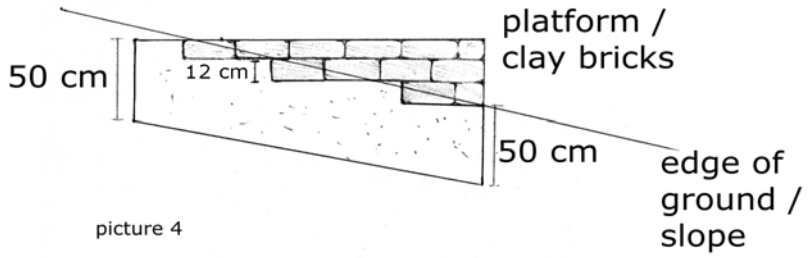
The foundation consists of compacted clay, 50 x 50cm. Once the digging of the foundation-ditch is completed, the ditch is backfilled in layers with a maximum thickness of 10cm. The clay is filled into the ditch in an earth-moist condition and is compressed with a tamper/ram. Ram each layer step by step. Make sure the last layer is in a waterleveled horizontal position.
In flooding areas the foundation must be built out of concrete and a concrete socket of appropriate height is to be employed. This could be built with rocks and cement mortar, or with bricks and mortar made with cement.



picture 3

The drawings above show in vertical cross-section the making of the layers of the tamped clay foundation (pic. 3).

If the foundation has to be built on a sloping ground one has to dig foundation steps. The height of each step should be of 12cm. Once the foundation is dug and backfilled, one has to level the foundation steps. This is being achieved by building with clay bricks (thickness of 10cm) and clay mortar on top of the steps until the height of the highest step is reached (pic. 4).



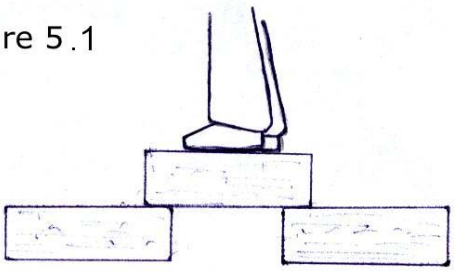
picture 4

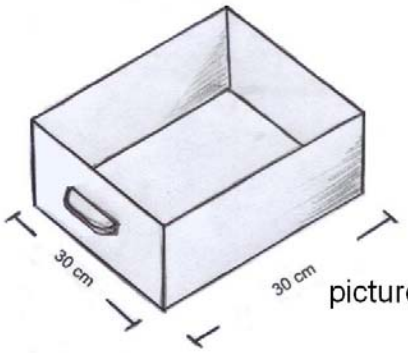
Brick production

Sun dried earth bricks, called “adobe”, are used for clay construction. A mould, preferable in quadrangular shape, has to be made (wood or metal) in order to manufacture the bricks. The mould needed for the bricks for the

outside wall should be 30cm x 30cm (pic. 5.2). Half bricks, needed for the inside walls and for the corners of the outside wall, should be made in a mould of 14cm x 30cm. Both brick types should be ideally between 8 - 10cm thick.
While finishing the foundation, one has to prepare the bricks for construction. In general, clay bricks must be strong and withstand the weight of a person standing in the centre, when placed on two sides on other bricks (pic. 5.1). The bricks must be well dried and of regular shape. Once the bricks are dried but crack, one has to add more sand to the mixture.
The mixing material for the brick should be a sandy clay. The mixing process of the material should continue until there is a uniform distribution of materials with uniform consistency. Water the mixture and let it stay for two or more days in wet state before using, because most clays tend to brake into small dry clay clusters surrounded by a coat of wet clay. Prolonging the moist condition improves the breakdown.
Place the moist clay properly mixed with clean water in the mould. Press it into the mould by hand, so there is no air left in the mixture. Level the mixture off and flatten the top with a ruler. Let the brick dry for at least two days, top and bottom for one day respectively.

picture 5.1



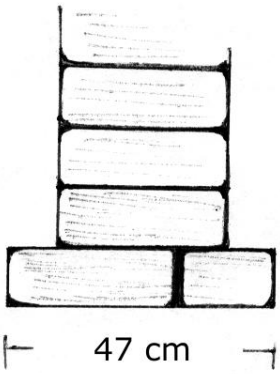


picture 5.2

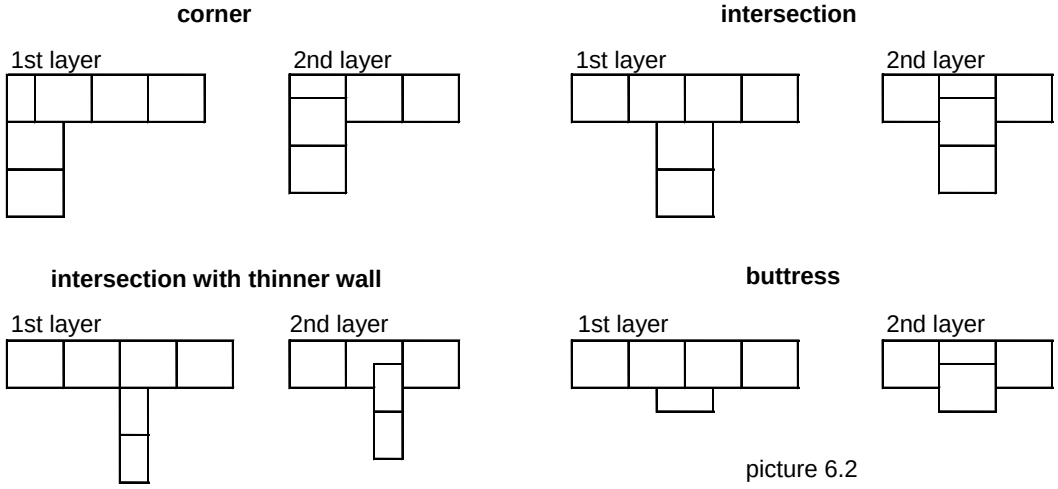
Building of the foot of wall, outside and inside walls

The wall has to be built according to the rules of masonry, with complete denting, and with thin mortar joints (not more than 2cm). The mortar should be of the same or similar material as the bricks.
The foot of the wall is laid out with 1 ½ clay bricks (width of 47cm). One should begin the base with the corners. After the foot of the wall is finished, start with the corners of the outside walls, centered on the foot of the wall (pic. 6.1). Check the corners to be plumb and vertical. Use string-lines stretched between the corners to line up the bricks to get straight walls. Use a waterlevel to ensure vertical walls. Start all layers with the corners.

picture 6.1



Load bearing walls should at least be 30cm thick. Internal divisions may be of 15cm, if well indented with the outside wall. The corners and intersection of walls give strength to the building, they should be well worked. If quadrangular shaped bricks are used, a half-size adobe is used to start in the corners in order to guarantee proper overlays (pic. 6.2).



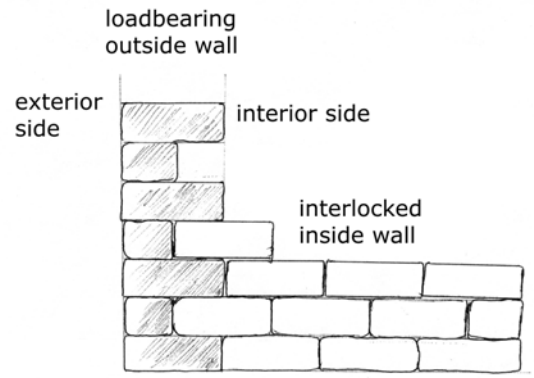
picture 6.2

The outside walls should have a minimum width of 30cm. The distance between each horizontal brick should be not more than 2cm. The joint consists out of a clay-water mortar. To make the mortar easier to handle, one can add sand into the clay. Level the bricks each time one layer is laid out.

The minimum height of each outside wall must be 230cm. Adding the ring-beam on top of the wall you will get a height of 240cm, which is according to the Namibian building regulations. Measure the height from the surface outside the house.

Mark a gab from the interior side of the wall, where the inside wall will be connected. Here each second layer of bricks should be of 15cm width, so that the later built inside walls can be interlocked with the thicker outside walls (pic. 6.2). Inside walls must be 15cm width. If they are longer than 3m

without intersection, they have to be made thicker. Make sure each inside wall is toothed with the outside walls. This is being achieved by starting each second layer of the inside wall from the interior gab at the outside wall (pic. 6.2 & 7).

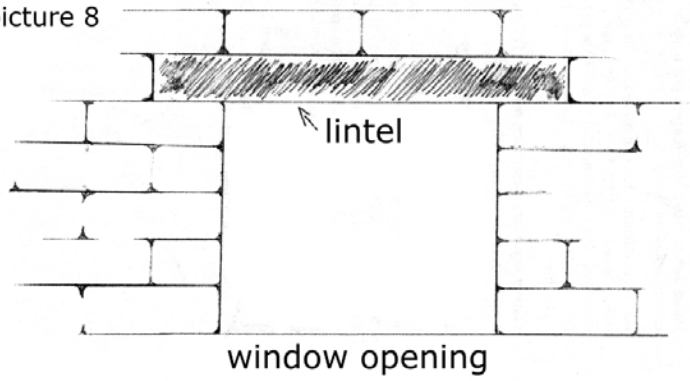


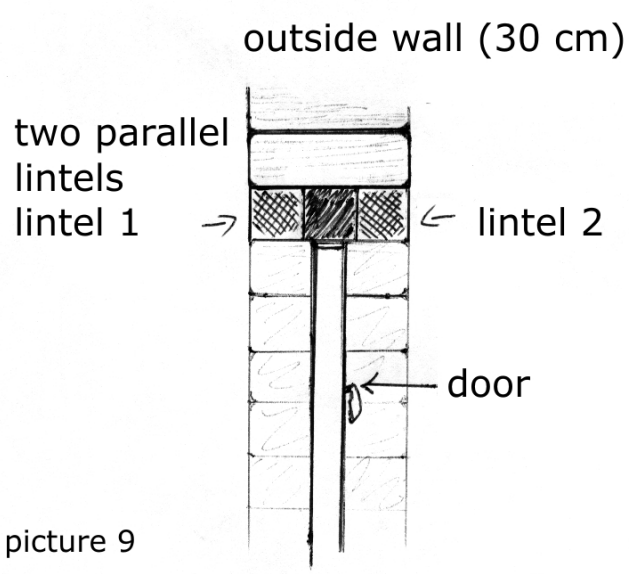
picture 7

Window- and door-frames

When designing your house, plan the exact position of doors and windows in advance. While laying the base and building the walls mark the positions of the window and door openings. All openings and wall endings must be strictly plumb and vertical. Make sure to leave enough space to install the window- and door-frames. The products of commercial quality are to be installed following the producer's instruction. In most cases anchors for attaching frames and linings must be integrated into the wall construction, therefore decide what sort of openings are appropriate for you.
Make sure the lintel are placed horizontal and is connected with the wall by mortar joints. Lintels have to penetrate into the wall for at least 10cm in order to achieve a good bond (pic. 8). If you place lintels into walls of 30cm thickness, 2 parallel placed lintels are recommended (pic. 9). To fill in the mortar in-between, one should place a shuttering underneath the lintel. If the walls are of 15cm thickness, one lintel is necessary.

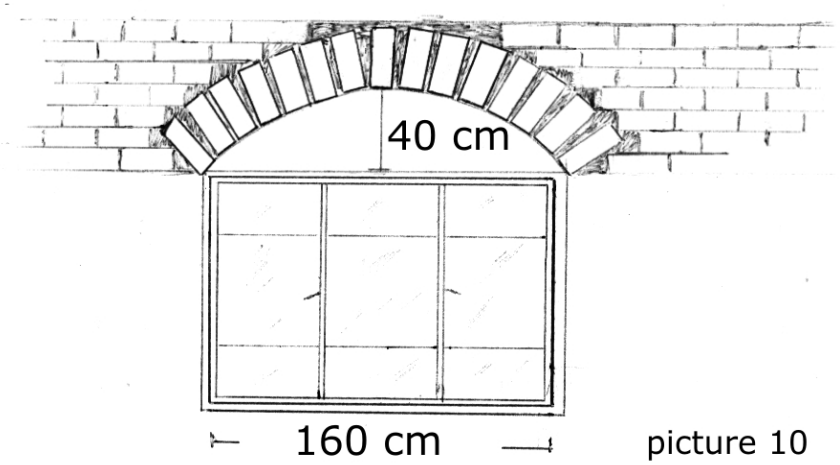
picture 8





picture 9

If you plan to build a vaulting/arch on top of the opening/frame, make sure the height of the arch has at least 25% of the length of the horizontal opening. Place the first layer of bricks vertically (pic. 11). Use a well curved shuttering for the building process. Leave the shuttering in place until the mortar is quite dry.

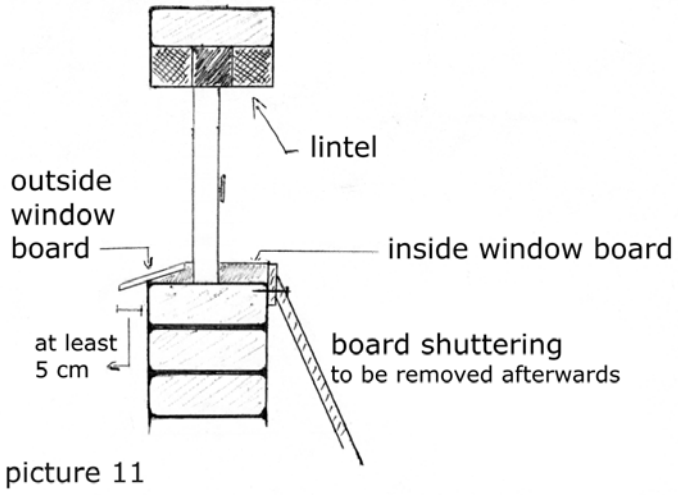


picture 10

Window-sill: Inside and outside window board

After having inserted the window frame, one can install the window-sill. The sill consists out of an inside window board and an outside window board (pic. 11). The inside window boards consist out of clay, cement or any other suitable materials. The board has to be installed horizontally and smoothed.
To help installing the inside board, one has to construct a board shuttering made out of timber or any other suitable material. Fix this shuttering onto the wall underneath the sill; use therefore nails or timber. Now do the fill-in. Once the inside window board is dried, the shuttering can be removed.

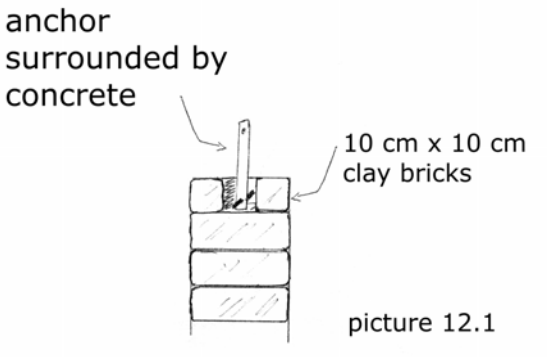
The outside window boards consist out of waterproof materials like cast, concrete, cement bricks or fired clay bricks. The board has to project from the wall below and slope to the outside of the house. There should be a sill overhang of at least 5cm. Make sure every sill finishes properly at the window frame and the edge of the window opening.



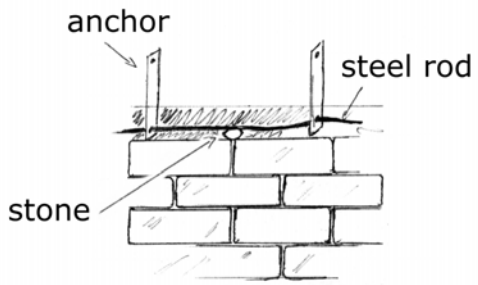
picture 11

Concrete ring-beam

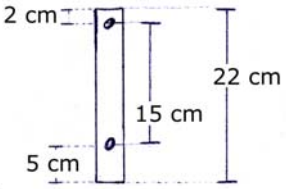
When the walls are built, a concrete ring-beam is placed on top of the outside walls. Its task is to prevent cracks. It further acts as direct support for the roof construction.
To ensure a proper ring beam, one has to place one layer of clay bricks (10 x 10cm) on top of both sides of the outside wall (interior and exterior side). By doing so, a 10cm wide channel between both sides of the bricks is created. Into this channel the ring-beam is installed (pic. 12.1). The ring-beam is made out of reinforced concrete; with a minimum cross-section of 10cm wide and 10cm high. Make sure it is positioned centrally over the wall. The ring-beam is reinforced with at least one rod of reinforcements steel of at least 6mm diameter, embedded in the middle of the ring-beam. Inside the concrete this centrally positioned steel element runs through the holes of vertically installed devices/anchors (pic.12.3), which are to be attached to the roof structure later on. Place small stones underneath the steel rod between the anchors, so that the steel is fully surrounded by concrete and doesn't touch the wall/ clay bricks (pic. 12.2).
If the wall is to be continued over the ring-beam or a gable has to be built (e.g. for a 2-sided roof), go on building the wall in a usual manner.



picture 12.1



picture 12.2

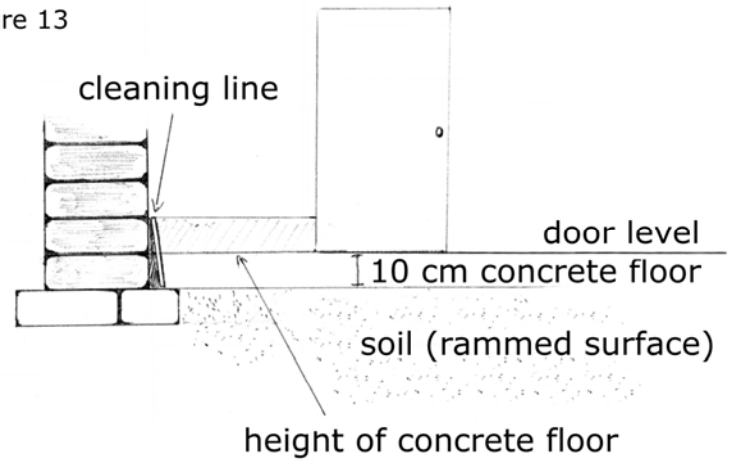


picture 12.3

Cleaning line

After finishing the loadbearing walls, one can start installing the cleaning line. It is installed at the bottom of the clay walls inside the house to protect the plastered walls from impact (e.g. brooms) and washing water. Therefore the cleaning line must consist of a waterproof and impact resistant material like cement plaster, ceramic tiles or wood. The cleaning line should have a minimum height of 10cm above the later laid out floor (pic. 13).

picture 13



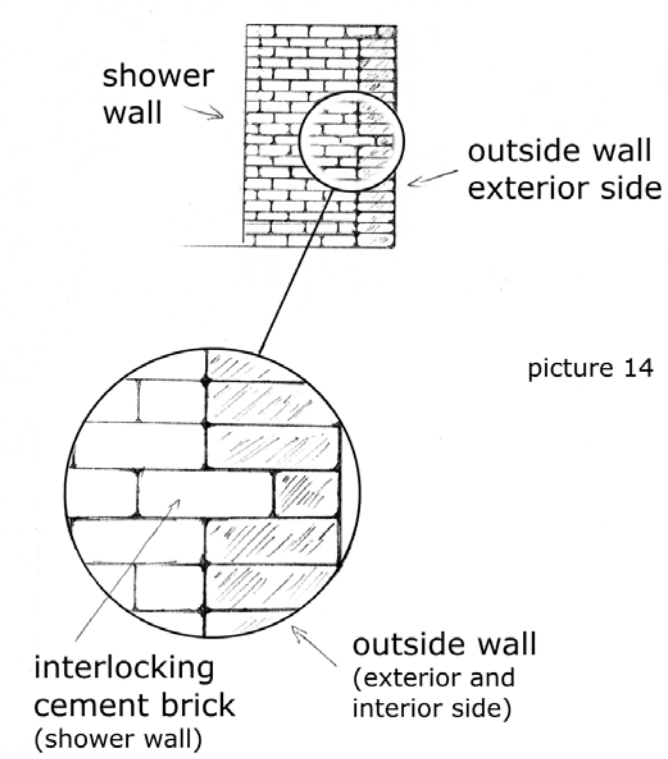
Cement floor

Here the standards of cement houses are to be equally applied to clay houses. To get the correct floor level in accordance to the door level, one must level the soil first. Level the soil 10cm deeper than the door level (pic. 13). Once the soil is sufficiently removed, ram the surface in a moisten condition. Then one has to mix concrete. The mixing ratio of sand, stones

and cement is 10 x 3 x 2. If the unit for the sand and stones is a wheelbarrow, the measurements for 2 units cement are 3 cement bags. The cement floor has to be at least 10cm thick.
Use a straight edge and a waterlevel to ensure a horizontal floor. After laying out the floor, smoothen the moisten cement floor with a rubber flat. Don't let the floor dry out. Water the floor for two more days. Make sure that you install a drain into the concrete floor, where the shower will be placed.
Once the floor is laid out, one can build a door threshold. Door thresholds are normally the surface of the foundation. If not, the threshold must be placed on top of a firm surface. Often it is advantageous to recess the foundation wall to accommodate the threshold. Use a timber sheltering to form the threshold. Use a waterlevel to provide a plumb and horizontal threshold.

Shower wall

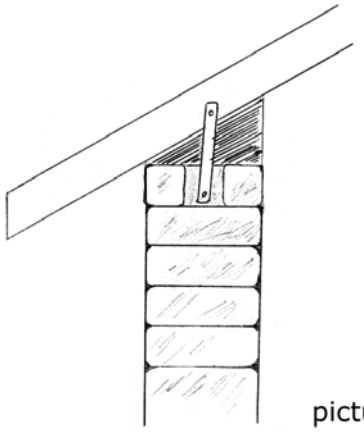
To separate the shower from the toilet, one has to build a shower wall. The shower wall is preferably built with cement made bricks of 10cm thickness. Interlock the shower wall with the outside wall at a minimum of two connecting elements in the middle and on top of the walls (pic. 14). Alternatively the shower walls can be built out of clay bricks but plastered with cement.
To ensure that the plaster inside the shower adheres better, it is recommended to use latching in form of galvanised hexagonal wire mesh (rabbit or chicken mesh) or plastic mesh. Nail the mesh into the wall before plastering.



picture 14

Roof

Standard of cement houses are to be equally applied to clay houses. The roof structure is to be attached to the vertical elements (anchors) of the ring beam. Once the roof structure is installed, additional fixing of the wall is needed. Place mortar joints from both sides of the wall (interior and exterior) into the gap between roof and wall (pic. 15). If there is enough space, put clay lumps into the mortar.
A method of preventing rain from coming in contact with the later plastered outside walls is to provide a roof overhang. The roof overhang has to be at least 40cm to all sides.



picture 15

Plaster

The clay surface has to be sufficiently rough in order to develop a good physical bond with the outside and inside plaster.

The outside plaster is produced through the mixing of clay and sand. Its mixing ratio is 6 x 12. Cement based plaster is not recommended; it tends to separate from the wall and fall off after some time.
Check the quality of the mixture. When the plaster sticks to a sloping metal trowel, yet is easily flicked away, the correct consistency has been achieved. If too much water is added, the plaster melts away. If the plaster is too dry, it will crumble and creates air pockets.
First the surfaces should be sprayed with water to get a better bond and the plaster permeates the moisten layer. When the outer layers are moisten and swelled, groove the surface diagonally. Then the plaster should be thrown with a heavy impact (slapped on) so that it permeates the outer layer of the ground and also achieves a higher binding force due to the impact. In a third step one must smoothen the plastered surface. Once the outside walls are plastered use the straight edge to even the surface and check if the plaster is plumb. Take special care for the corners. These are difficult parts to plaster. If needed one can use a shuttering to plaster the corners. Never stop the

plastering process directly at the corners. Always include the edges in one plastering process; otherwise one will get cracks at the corners.

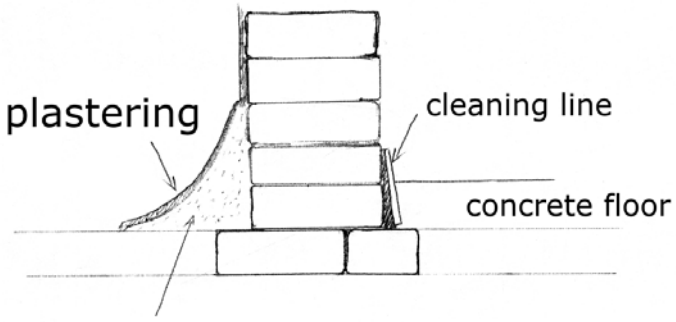
Plaster the inside walls in the same manner as the outside walls. For the corners one can also use an inside-corner-tool, so the corner can be plastered more easily.

Drain plinth

A method of preventing splashing rain is to provide a sufficiently high drain plinth (30cm). The connection of the wall with the drain plinth has to be carefully designed so that the rainwater can flow down unhindered and not into the joint between wall and the drain plinth. The joints between foundation and drain plinth have to have a good bond as well.

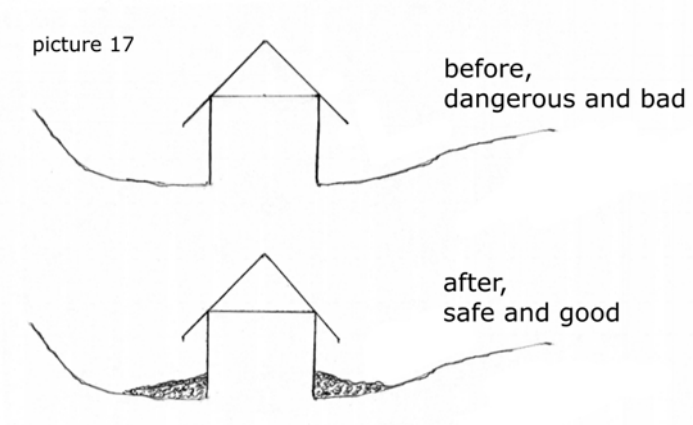
One method of creating a drain plinth can be to ram a clay drain at the exterior side of the outside wall (minimum height 30cm, length 25- 30cm). For the compacted clay drain, use clay of an earth-moist condition. Plaster this drain plinth with the same plaster as the entire outside walls (pic. 16).

picture 16



compacted clay drain plinth
min. width 25 cm, min. height 30 cm

Remember to protect the foundation against moisture and standing rainwater. If the house is built on a sloping ground, one has to prevent water to surround the house closer than 1m. Place a additional 1m wide drain around the house (pic.17). This additional drain can be made out of soil.



Seal and painting

For the outside plaster, it is recommended that the surface is made waterproof. A water based isolator (Isoliergrund) or seal- or fish-oil serves for making the outside plaster waterproof. Paint the surface with the isolator. To make the wall more water-resistant, one can add another layer of the isolator while the first layer is still humid. By doing so, one can be sure, that the first layer doesn't prevent the second layer from soaking into the surface. Both layers will soak into the plaster 3mm deep. Don't wait until the first layer of isolator is dry; then the second layer is useless.
If an isolator is used also painting may be employed. To get brighter colors, paint the outside walls with a white undercoat. Afterwards paint the surface in the chosen color. Use the same colors used for concrete houses (water based acrylic paints (PVA)). In case of using seal- or fish-oil as isolator, wait a minimum of three month to apply the paint, otherwise the surface is too oily.

Electricity and water supply

Standards of cement houses are to be equally applied to clay houses. Let an expert do the installation.