The main focus of the technical part of my graduation evolves around the current construction culture in the area. For centuries this low cost and easy technique is used by the local inhabitants and is the key to a sustainable development in the area.

The problems that occur in the current development in the area are mainly due to the western used. Materials are expensive and the inhabitants need masonaries to construct their dwelling. Main reasons for inhabitants to construct such a house is the durability of the dwelling. Often these houses ignore climate and culture which are important values to the current dwellings.

For this reasons I will formulate an answer to these problems by using local materials and methods so that the construction culture will be improved so it hopefully can last another century.

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In the current development realized by Habitat for Humanity Kenya the inhabitants are not involved nor in the design process nor the actual construction of the new dwellings. Because of hired labor and unknown construction methods the inhabitants aren't capable anymore of constructing there own houses. Which means that they become more reliable on external constructors and financers.

From the research made, people are willing and very much capable of constructing there own house. They actually see the exclusion in the construction proces as an insult. The most important step that has to be made first of all is the reinstatement of the construction culture.

IMPROVING AND REINSTATING CURRENT CONSTRUCTION CULTURE

IMPROVE MATERIAL USAGE AND METHODS

From the interviews and long conversations with the inhabitants one of the main problems of the current dwellings is the amount of maintenance. Because of mud and feaces used in mixtures and the usage of branches as construction the walls easily collapse due to the working of construction materials. Often people have to patch their walls several times per year to keep the dwelling water tight.

Another problem are interior surfaces and their hard to clean finishes. Again mainly due to the materialization.

It doesn't mean that they want to have a cementbrick based house and cement finished plasters. They like the current idea that houses are fast build (local materials) and cheap. Most people like the joined labor invested in the dwellings because most of the times its a community activity. In this way they all help each other and by doing so know each other well. This is one of the main components for an involved active community and should by all means be preserved in the future. So that next generations will construct their future together and will make them selfreliant.

AIM

MAIN TARGET IMPROVING SENSITIVITY&SENSIBILITY FLEXIBILITY

FORMULATE A SYSTEM THAT IS SENSITIVE TOWARDS ITS SURROUNDING

Local identity is an extremely difficult part of the communal identity. Local cheap materials are preferred by the inhabitants because they are easy and fast to get and most of the times without any cost. Because almost every inhabitant is equal they are using the same materials and methods. This creates a communal identity.

We can't tell a group of people what is best and in their best interest they should make these discions themselves. Therefore in this project local products are used as much possible. The aim is to solve durability and cleanability issues by improving methods and mixtures. If needed new materials can be introduced but only if they can be produced and used by the community. Which means that the usage of the material for construction methods should be easy as their current constructions.

Hopefully in this way providing the inhabitants with good alternatives that have enhanced qualities but made out of well known local materials and methods

AIM

MAIN TARGET IMPROVING SENSITIVITY&SENSIBILITY FLEXIBILITY

Every group of people around the world develops itself. One faster then the other but, which depends on many different external factors that influence a group of people. However we can't provide with one suitable estimation or answer for a whole community, but that doesn't mean that we shouldn't look forward on how the inhabitants of mount elgon are developing the upcoming years. As described in the architectural booklet of this graduation project the project should provide the inhabitants with a proper system for the upcoming 60-70 years. In these years a lot will change. Electricity will come in general the inhabitants will have more capital and better education and healthcare will be available. This will also have its impact on the family size and organization.

For this reason the construction and dwelling type should be adaptable to the family usage, size and others change over the years. Based on the estimation in the architectural booklet estimations will be formulated and translated into a constructions system that can adapt to these changes.

FORMULATE A SYSTEM THAT CAN ADAPT TO THE FAMILY SIZE AND THE CHANGES IN USAGE

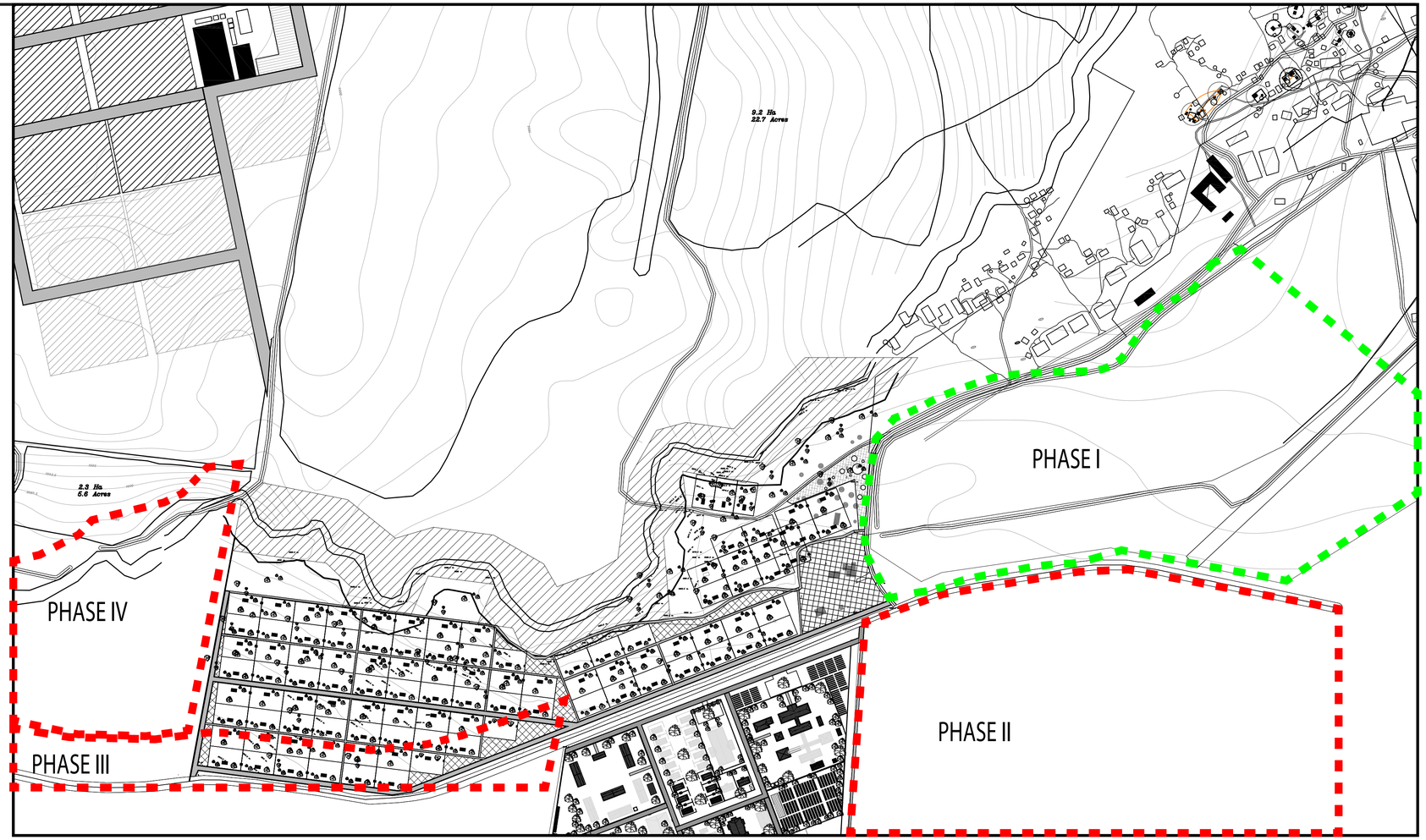
AIM

MAIN TARGET | IMPROVING | SENSITIVITY&SENSIBILITY | FLEXIBILITY

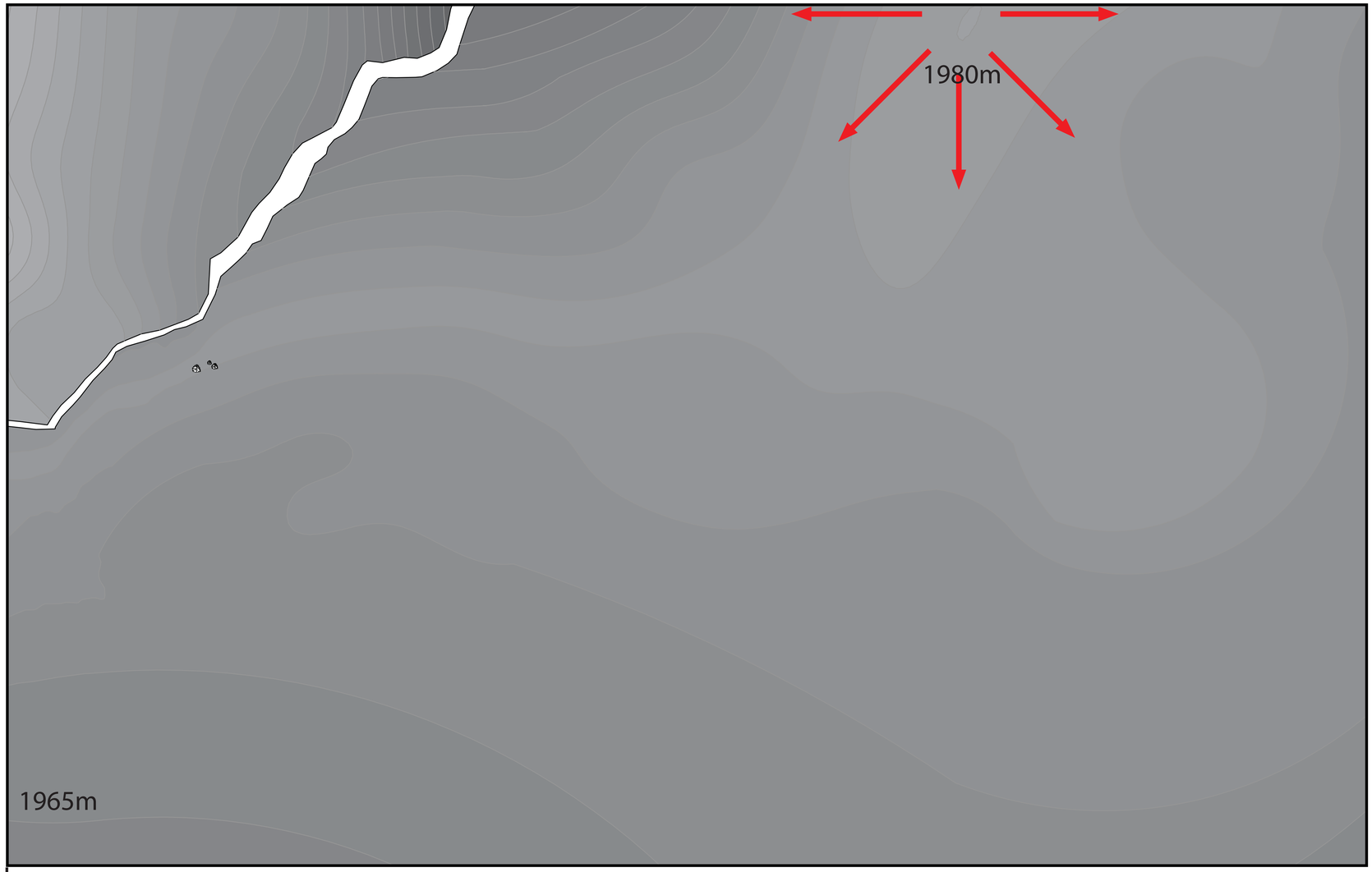
Due to the location of the farm the new development has a great potential for the region. The farm lays next to the road that is the first opportunity to cross the border with Uganda on the northern side of Mount Elgon. Besides that the farm is the largest employer of the region and has the best schools and hospital of the region.

For these reasons a lot of people migrate to the area and start to live and work there. In the calculations of the farm a rough estimated amount of 1200 households will have to eventually be resettled in new dwellings. The drawing on the left shows the first phase of 120 households. We can only imagine how much of the area in the future will be developed for housing and possibly will grow out to a small city.

The area marked in green will propably be the next area to be developed and is the aim for this graduation project.



TERRAIN

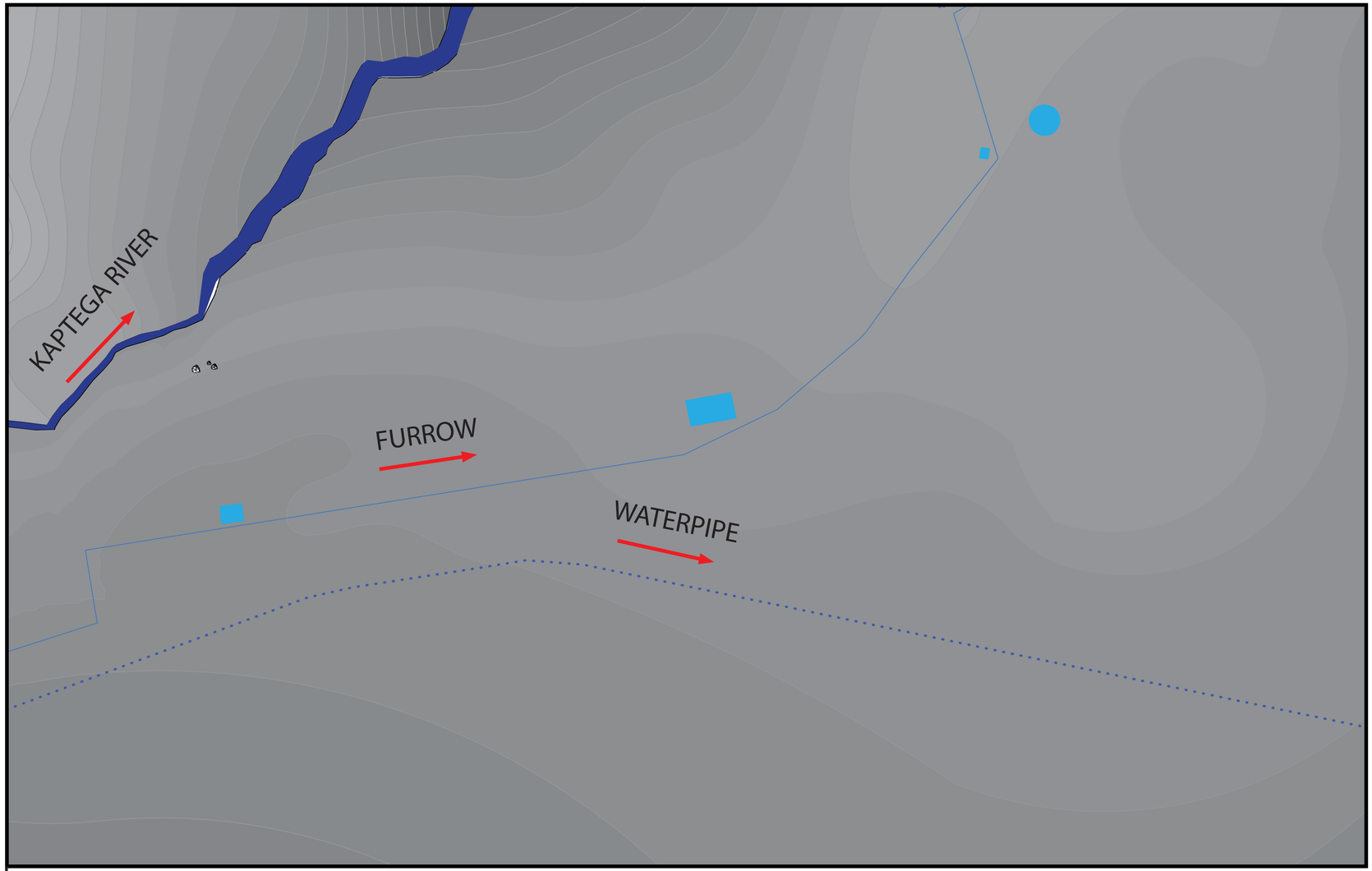


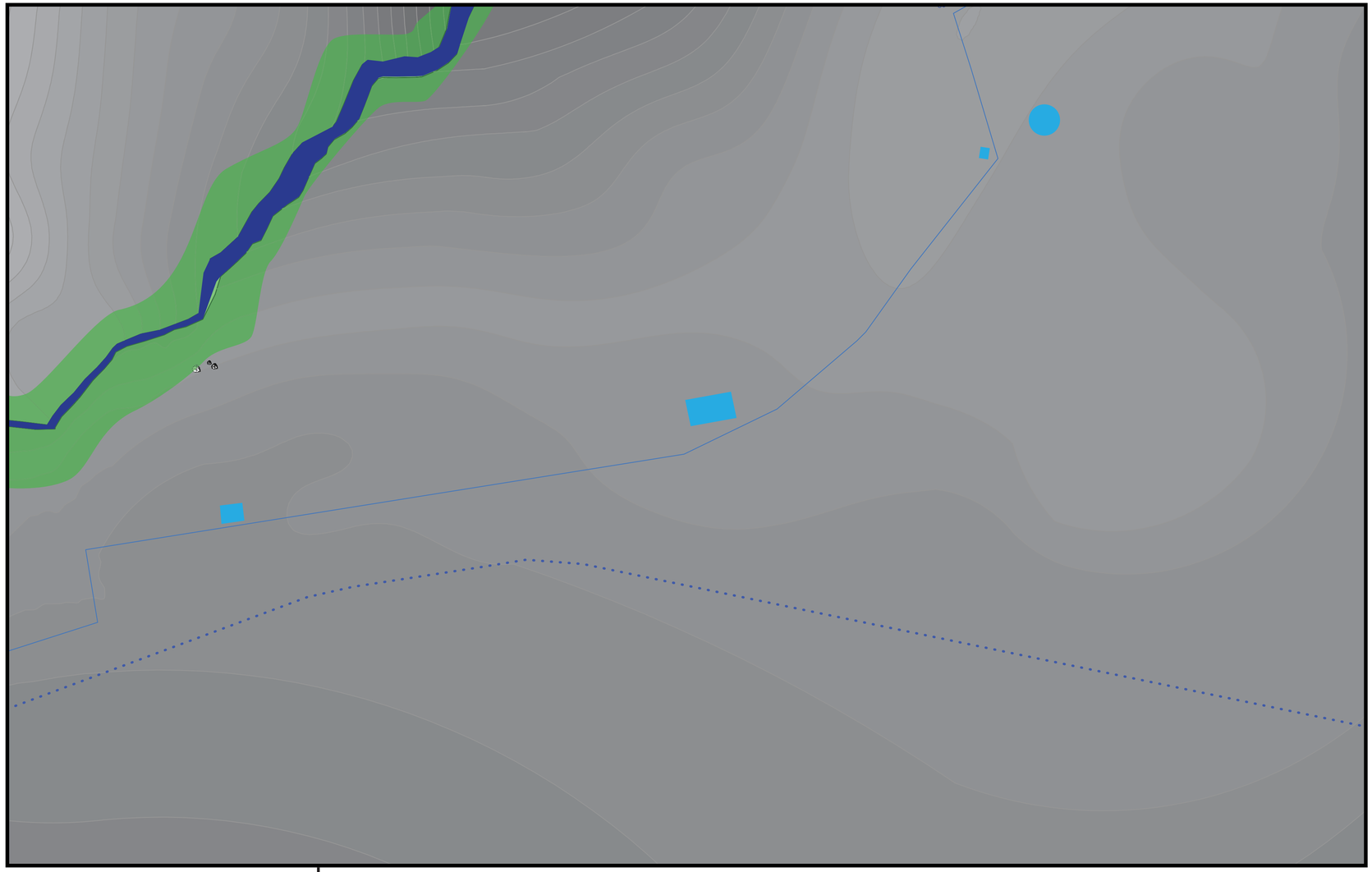
As described in the research the old farm is located on the right hill just next to mount elgon. The area that is pointed out for development between the 1975 and 1990 meter high. And has compared to both former location (new development and camps) a flatter surface.

Because of the small slope in the terrain it is suited for water channels that supply water from the Kaptega river into the construction area.

The furrow could be used to make central wells to supply the community with drinking and washing water.

The water pipe that runs from the river to surrounding farms can only be used for everyday use. The waterpipe has no pressure most of the times and for this reason is too instable to use by the inhabitans for drinking water.





The owner wants to replant the old forrest that use to be in this area. To provide the community with proper drinking water and a natural enviroment the farmer already started the replanting of trees in the area.

The owner also prohibited the inhabitants to do any kind of maintenance to there dwellings. By this rule eventually all dwellings will be left because it is impossible to live in them anymore. It is extremely questionable if this offers the best solution to current problems. Which are explained in the research.

An alternative for hardwood should be searched as firewood and construction material. Because this is the main reason the hardwood is almost completely vanished.

The current formal infrastructure of the farm is based on the orientation of the current greenhouses of the farm. To establish an informal community with infrastrusc-ture and general organization by themselves the current infrastructure should be removed. The community will start to develop their own roads and paths over time and by doing so creating their own internal communication and routing.

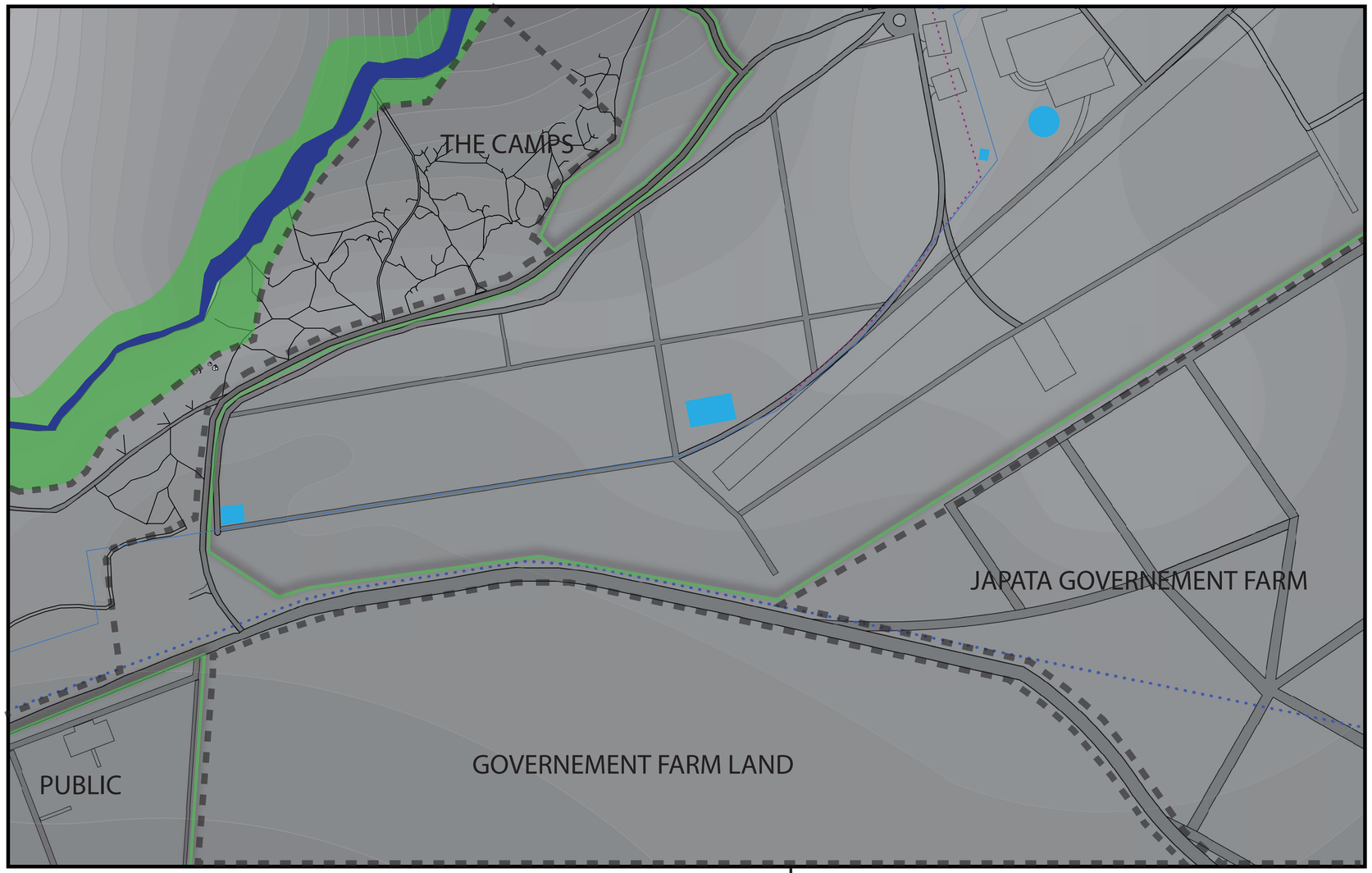
The camps infrastructure give us an idea how this informal network works.

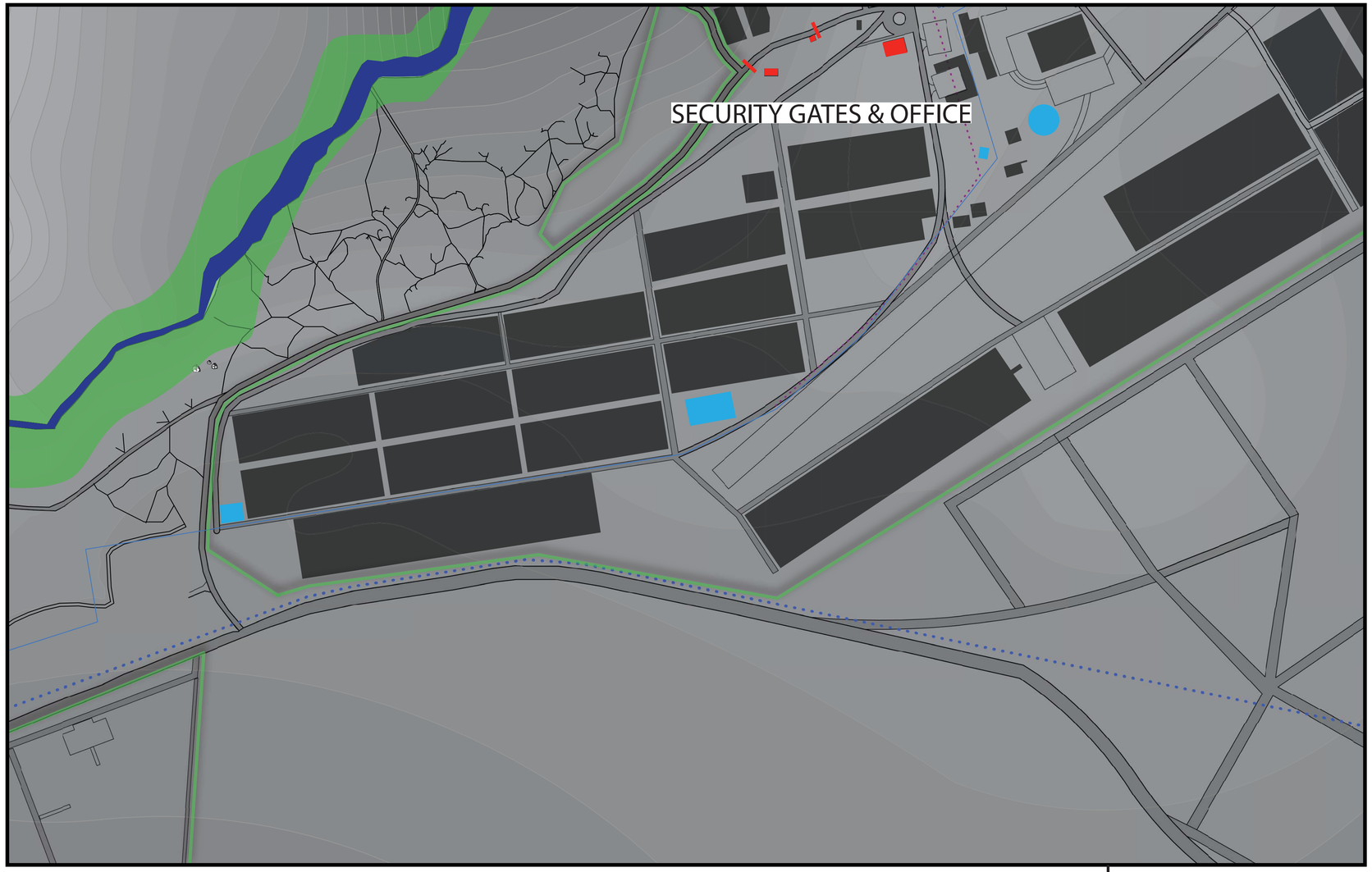
The study on these roads tells us the differentiation and importance of certain roads and profiles. These could help in sketching a possible scenario for the new communities.

The main road runs over the most flat and shortest distance from a to b. Smaller roads have many bends and sometimes drop several meters. By doing so providing every family with a unique connection to the public area. Which creates a distance but still allows communication between private family life and the public.

At the moment the owners of the farm use a high dense green hedge with spines and an electric fence to prevent people to gain entrance to the farm (marked in green lines).

This is a common use way of fencing in the region and is hard to penetrate. This way of fencing is also used in the camps to mark the borders of the family compound (are smaller and less dense). Even when we look at traditional compound spiny bushes were used to protect the community and cattle against outsiders.



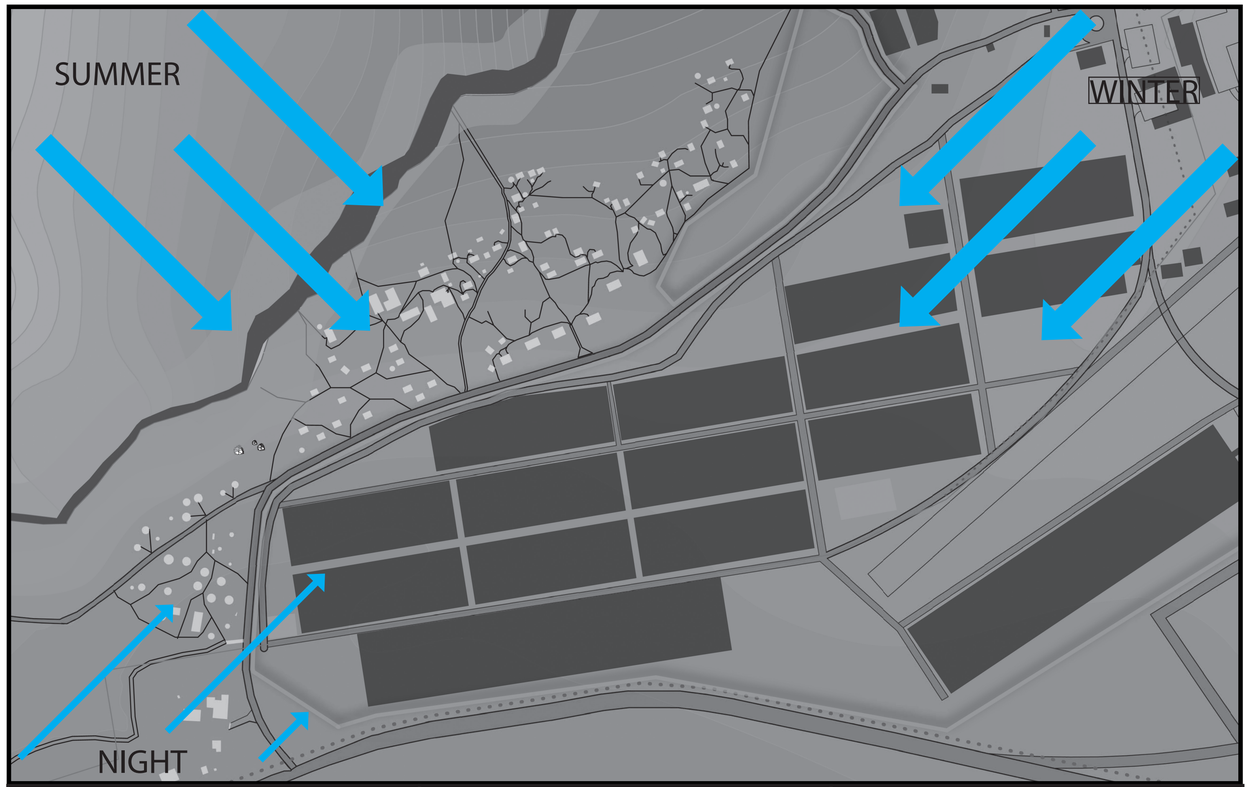


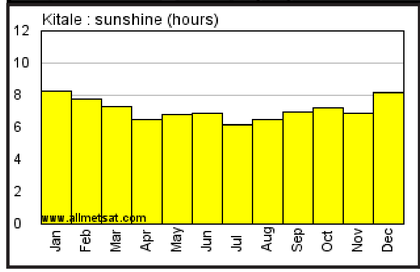
At the moment the grading of the flowers is performed in the old farm. This is also why the offices and main security are positioned there. In the future this whole centre will be relocated on the other hill on the left side of the farm.

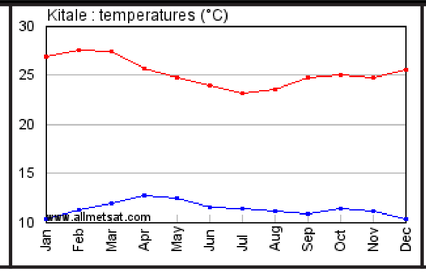
The two gates on the farm are checking up every vehicle or person that wants to enter the farm. Which is also the position where the main camp road connects too.

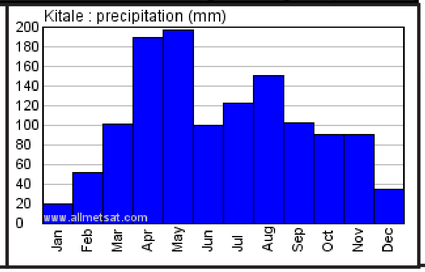
The large dark grey area's are the greenhouses of the farm. These are at the moment being removed. At their former place hardwood is being planted as an future investment. My personal angle is to prove to the owner that it will be a more durable investment to house his employees then planting hardwood.

As you can see in the light grey structures the camps naturally evolved over times in the perimeter of the farm. The position and orientation tells us how people prefer to live and what the contradiction is with the current build habitat living area.









Most of the seasonal winds will be bricked due to the mountains. The most important windflow especially in the new pointed area for development is the windflow that comes from the mountain during night. This is a cold wind that constantly blows throughout the year. It is important that this wind flow will be bricked or broken in the new development. In the top diagram on the left you can see that during night its really cold in the area and for this prupose during nighttime their should be additional radiation heat needed inside the dwellings.

When we compare the other diagrams with each other we can notice that the amount of sun hours is almost the same during the year. But that the amount of rainfall changes heavily through the year. This indicates large flushrains during raining season. In the new development there should be a proper solution handed to guide the water down the hill. Smart positioned small water basins could provide the horticulture land with enough water throughout the year. Also small water tanks should be installed to provide the family with additional drinking and washing water.

CASE STUDY POKOT TRIBE

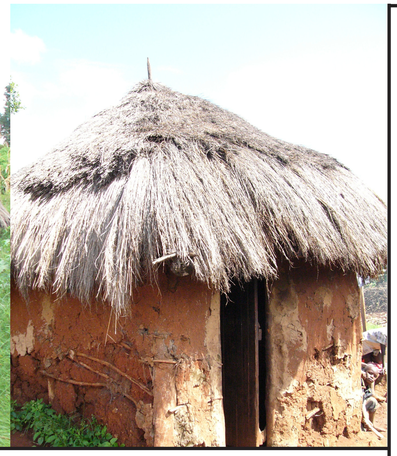
SHAPE	SIZE	CONSTRUCTION	WORKFORCE
ROUND	2,5 - 4,5	NO FOUNDATION	FAMILY & WHOLE
SQUARE	2,5 x 2,5 - 4,5 x 4,5	BRANCHES DROVEN INTO SOIL	COMMUNITY
RECTANGULAR	2,5 x 3,5 - 4,5 x 6,5	INTERWEAVING WALLS & ROOF	

MATERIALS		APPLICATION	ORGANIZATION
BRANCHES	THATCH	MIXING FAECES, GRASS AND MUD FOR WALLS APPLIED BY HAND. FLOOR FINISHED WITH FAECES AND MUD ONLY.	COMMUNITY BOARD&CHAIRMAN
MUD	ROPE		
FAECES	HARD WOOD		
GRASS			

One of the last traditional living tribes in the region is the Pokot. In the main research this tribe is already explained on culture and tradition, but what was left to explain is their dwelling form. It tells us a lot about the traditional way of constructing and usage of materials.

Although most of the methods and materials are currenlty still used form, size and density is left to explain. Inner organization is explained in the architectural booklet

CASE STUDY FARM CAMPS



SHAPE	SIZE	MATERIALS		ORGANIZATION
ROUND	2,5 - 4,5	BRANCHES	THATCH	FAMILY MEMBER
SQUARE	2,5 x 2,5 - 4,5 x 4,5	MUD	ROPE	
RECTANGULAR	2,5 x 3,5 - 4,5 x 6,5	FAECES	HARD WOOD	
		GRASS		

CONSTRUCTION	APPLICATION	WORKFORCE
NO FOUNDATION BRANCHES DROVEN INTO SOIL INTERWEAVING WALLS & ROOF	MIXING FAECES, GRASS AND MUD FOR WALLS APPLIED BY HAND. FLOOR FINISHED WITH FAECES AND MUD ONLY.	FAMILY & WHOLE COMMUNITY

DWELLING ANALYSIS

When compared to the Pokot analysis we can see that most a lot of dwellings have attached extensions. Where in traditional situation alle houses are free standing.

Another issue is the state of the dwellings. But this is because the inhabitants are prohibited to perform any form of maintenance to their dwellings.

In general methods and materials are the same as in the past habitation

PAST ARCHETYPE

CURRENT ARCHETYPE

NEW ARCHETYPE

CASE STUDY FUTURE FARM CAMPS



SHAPE	SIZE	MATERIALS	WORKFORCE	ORGANIZATION
RECTANGULAR	4,5 - 6,7 5 - 7	R.I.C COMPRESSED BRICK HARD WOOD CONCRETE PLASTER	HIRED	UNDIFNIED

CONSTRUCTION	APPLICATION
CONCRETE FOUNDATION SLAB CONCRETE GROUNDFLOOR CONCRETE ROUNDBEAM HARD WOODEN TRUSS	MIXING CONCRETE ON SIGHT WITH SHOVELS. ALL CASTING AND APPLYING IS DONE BY HAND

The current dwellings being constructed are completely different when compared to traditional way of constructing. Not only are the materials completely different but also are there no local methods used nor are the inhabitants involved during the construction proces.

We could say that from these dwellings we can start to understand what´s going wrong and what should be changed to alter the course of the development.

DWELLING ANALYSIS

PAST ARCHETYPE

CURRENT ARCHETYPE

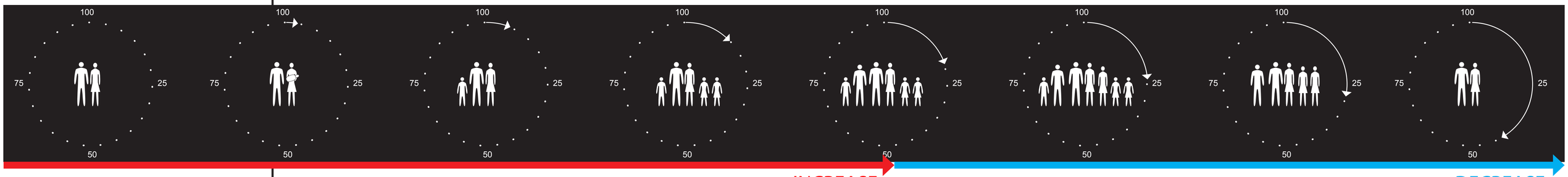
NEW ARCHETYPE

The images on the right only show a fraction of the available products in the area. I choose to only show the materials currently used in the camps.

As you can see there is only one product that is not a natural found product. My personal aim is to use the materials in the best way I can to improve the methods and ultimately the durability of the dwelling.

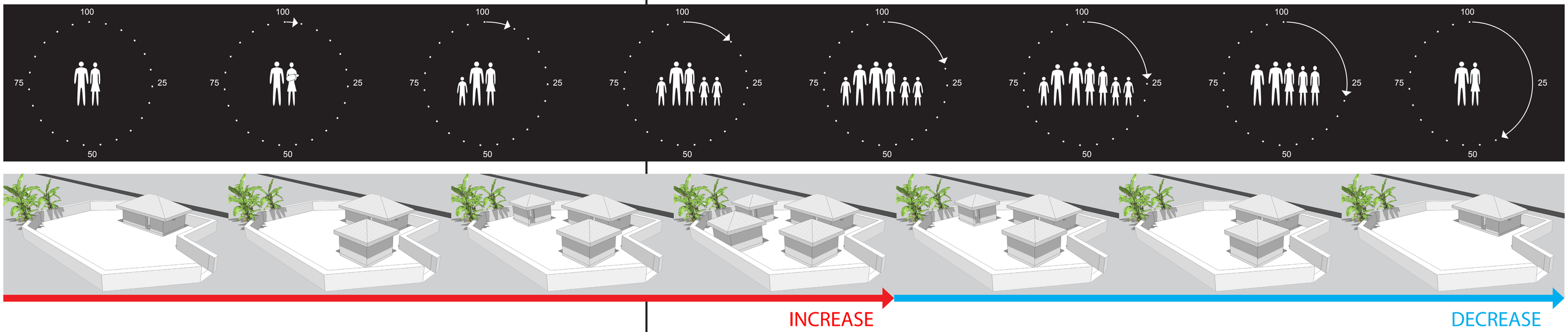
MARRAM	LIME	BANANA LEAVES		LEAVES	SAND
GRAVEL CHIPS	THATCH	ROPE	COW DUNG	BARCK	RIVER SAND
LARGE GRAVEL	HARD WOOD	MAYS	GOAT SKIN	CHICKEN FEATHERS	CLAY
RIVER STONES	BRANCHES	GRASS	PLASTIC BAGS	HENNEP	BONES

In order to understand what in terms of a construction system is needed for a family I took the average family size. Based on the data explained in the architectural booklet a lifecycle is formulated to show how the construction system should adapt to the increase and decrease of the family. As you can see the children are staying at home up to they are 20/25 years old. Then they leave the family compound and get married. the space which is left is often used as storage space or to rent the room to others.

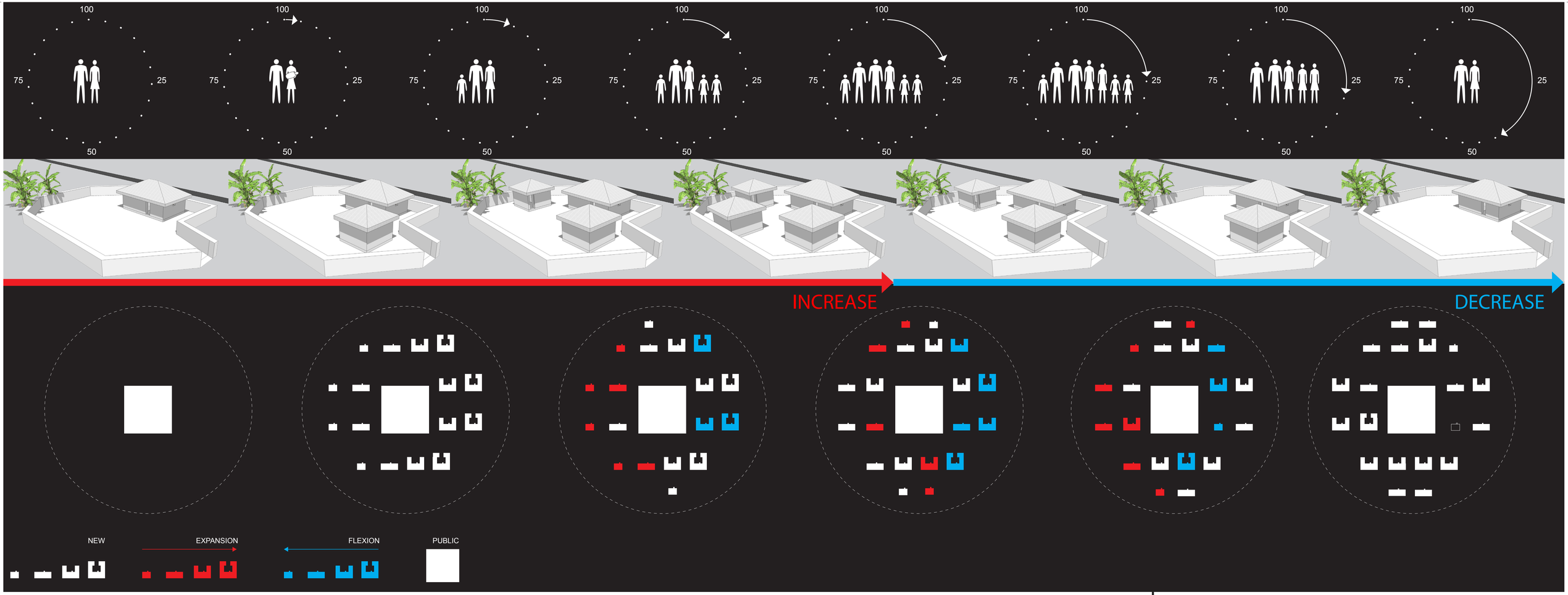


FAMILY HOUSE&COMPOUND COMMUNITY

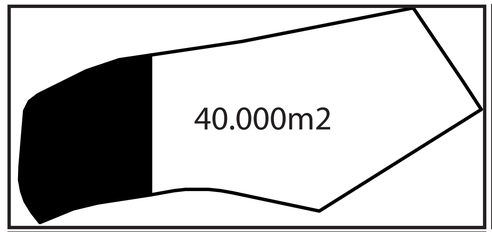
In this page you can see the family compound of the 24 hour observation I made of a family inside the camps. In this way you can see that it is common that a dwelling adapts itself to the growth of the family. After death of the inhabitants or departure of the children the compound dies of and remains untouched. When the community decides it is time the compound will be inhabited by a new family.

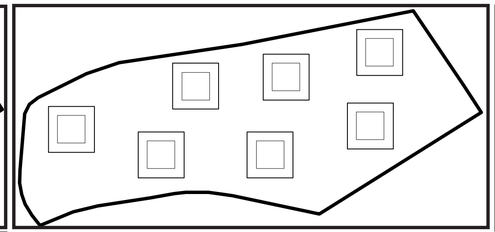


LIFECYCLE ANALYSIS FAMILY HOUSE&COMPOUND COMMUNITY

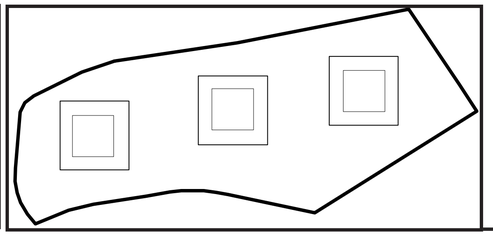


The growth of the family compound is also affecting the community. Which means that the community makes arrangements between the inhabitants on where, when and with how many people they can occupy a space within the community.

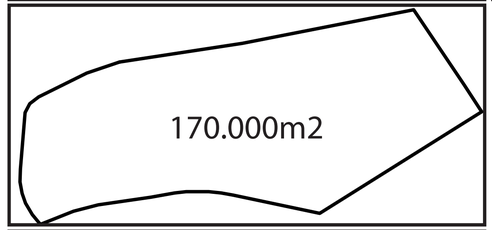


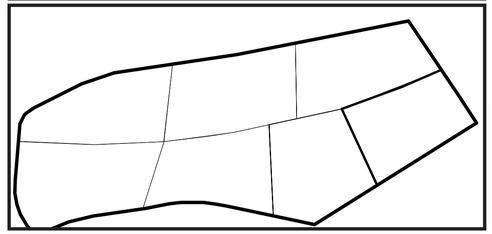


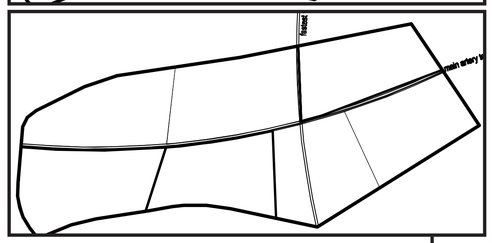
MAX. 7 CORES

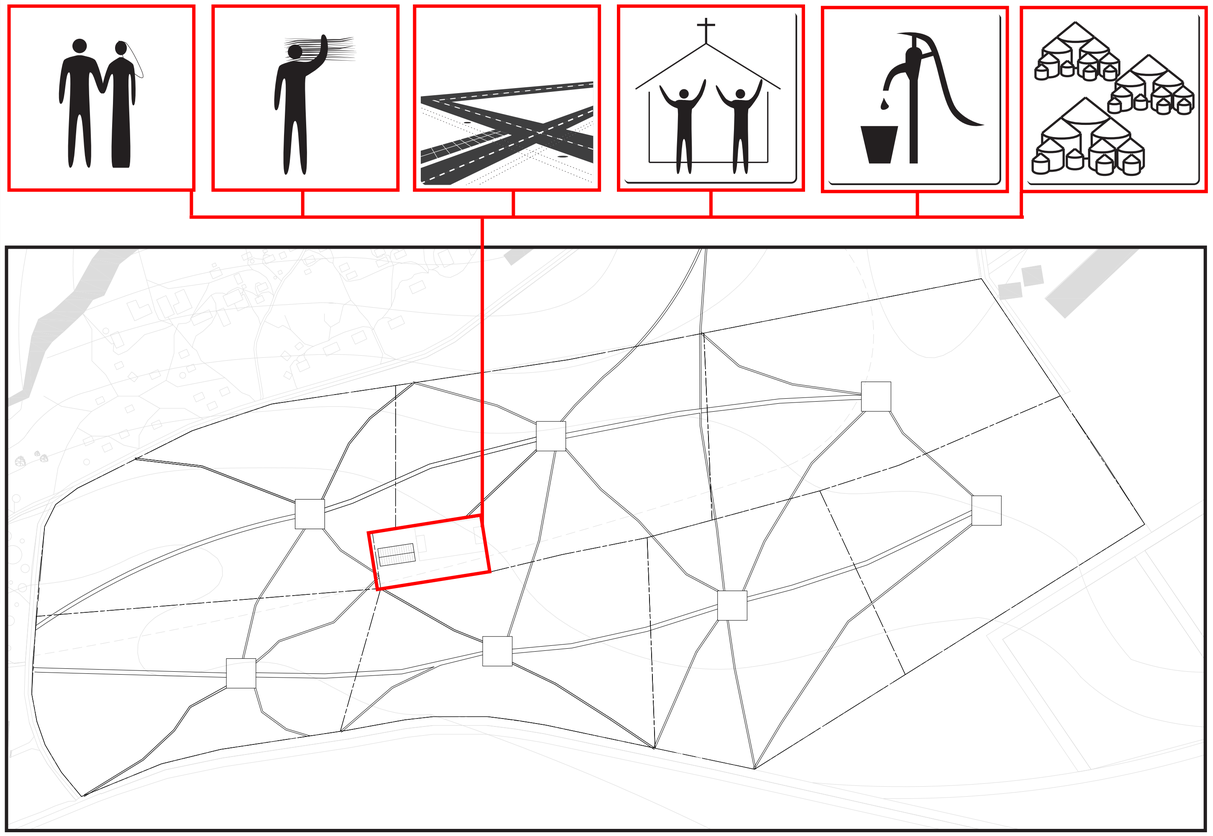


MIN 3 CORES









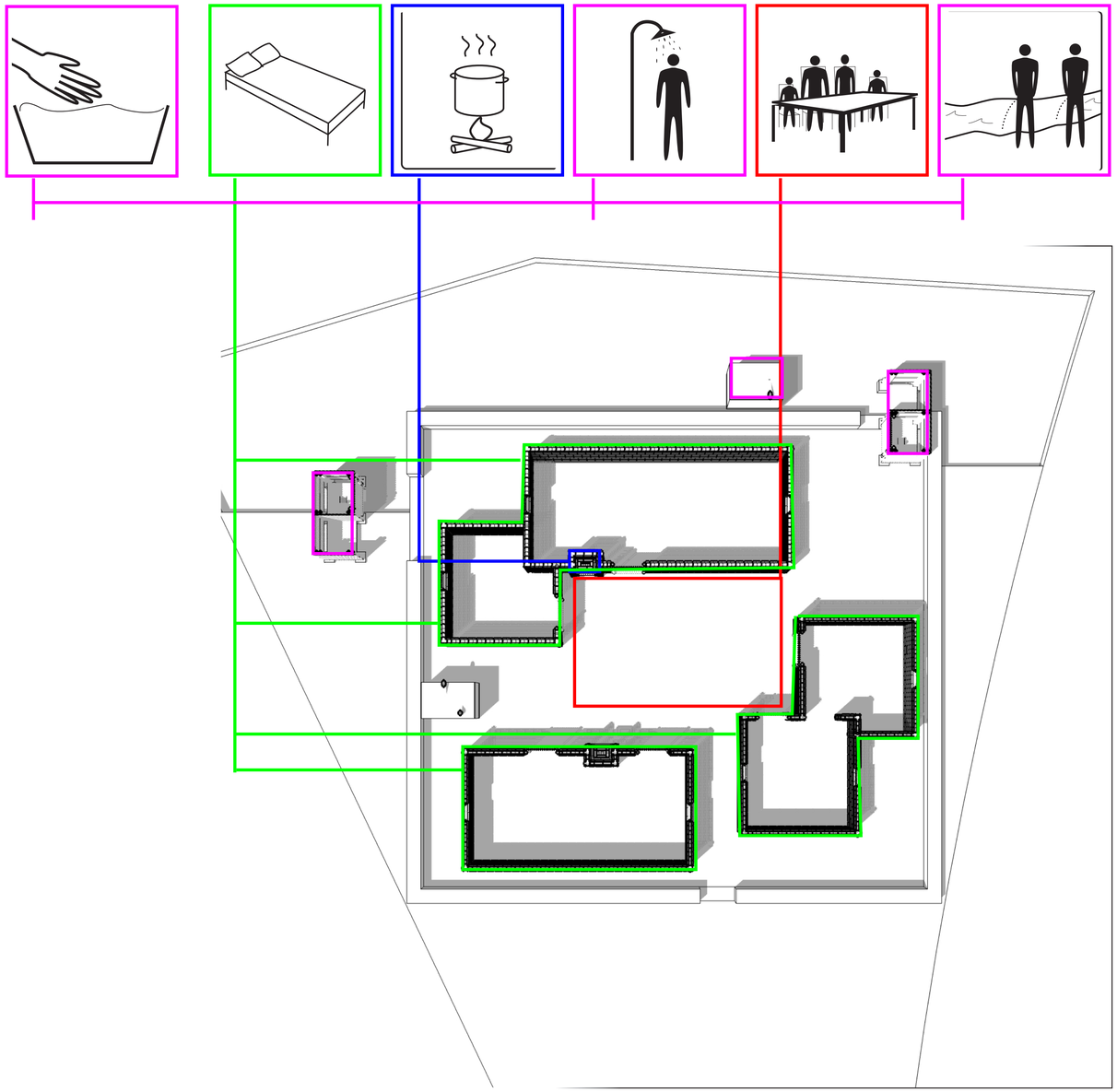
In order to provide enough different living groups and still offer enough plots and horti-culture without becoming a high density area the amount of communities is set on 7. Every community will each have around 17.000m2 of land.

To organize the whole area well and to talk about the settlement of every community the first phase of area should be the realization of a large community center. This area will be around 2500m2 and is large enough for large celebrations and to offer a large indoor space.

In this indoor space meetings will be organized but also a registration office will be positioned. Eventually every construction activity or new members per community will be registrated here and communicated to the owners of the farm. This indoor space could also function for religous purposes.

As in the largest scale also in the community scale the first building that will be erected will be a community centre. As in the first step the community central area of 500m2 is set the building will be constructed wherever the community wants. Every community will have a maximum amount of 6000m2 to use for the creation of plots. Which should result in plots of around 350m2 .

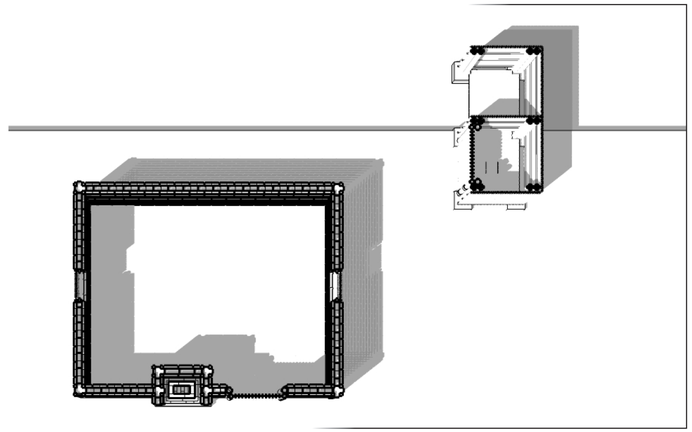
This means that they will have around 11.000m2 of horticulture ground and that can feed about 150 inhabitants. Which means that every plot should not have more then 10 people. But not every plot will have the maximum amount of inhabitants so it could differ. But by all times this should be agreed by the whole community.

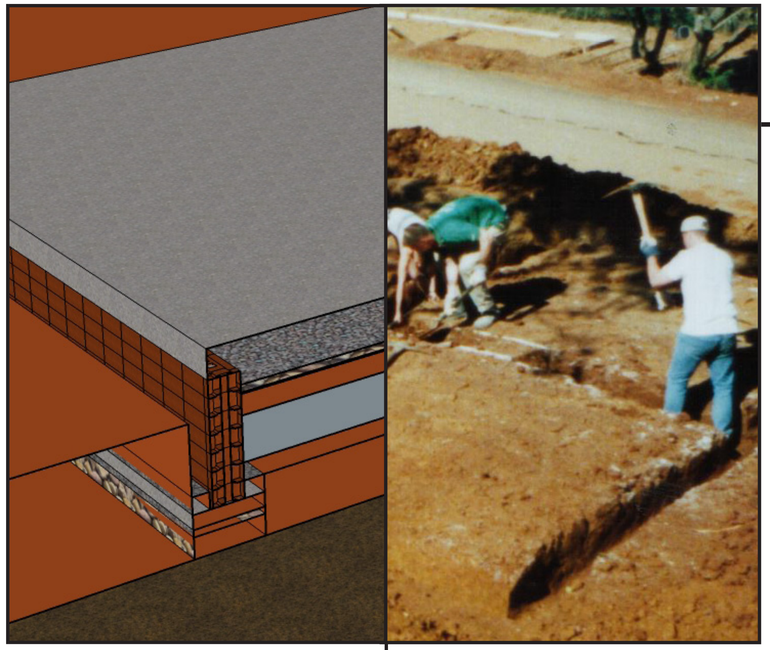


So the set size plot is 350m2. To prevent high density communities a maximum amount of 6 extensions is allowed per plot. In the example on the right 5 extensions are made to the basic family dwelling beneath this text. Every extension should not exceed the size of 3x4 meters.

In purple the water management of the compound is visualized. Every compound will have a mobile bamboo toilet and bathroom. When the pit of the latrine is filled the structure can easily be removed. For cooking an outside chimney should be provided and also an outdoor living space where the family can meet.

As an additional water source water reservoirs should be provided at every house. In this way they don´t rely fully on the central well of the community and can provide themselves from time to time with drinking water.





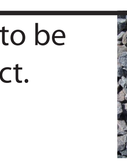
Alternatives for the total foundation is to make a slab foundation. But the materials needed are more expensive (steel needed) and couldn't be made out of local products (will also be more expensive). But more important the slab foundation is more instable and more expensive than the suggested foundation. For this reason the slab foundation is rejected.

To make a pole foundation would be useless because you would simply add the poles to the total foundation and would be more expensive then the suggested foundation and is not needed in this rocky area where a stable layer of soil is fuond between the 600-1500 mm.

Excavation of the trench around 1200mm deep. (depends on the depth of the marram layer 500-1700mm)

Poring heavy gravel into trench 250mm thick

Poring marram on top of the heavy gravel. After poring, bashing marram between the heavy gravel, and add water where needed to let the marram set between the heavy gravel.



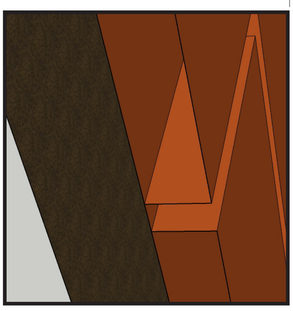
Lime based concrete mixture has yet to be tested and set for the usage in a project.

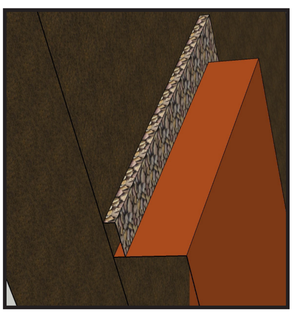
Components for compressed earth brick mixture ratio 4-4--2 (buckets) tested in this area to be the strongest.

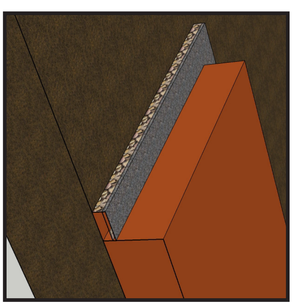
Compressing soil by bashing (add water for higher density)

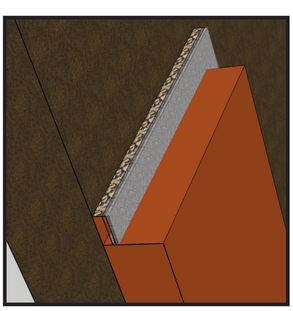
Poring heavy gravel over floor surface.

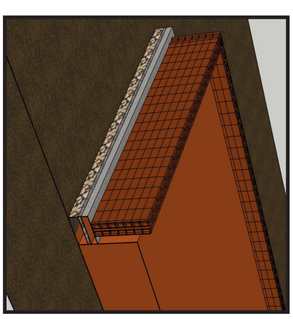
Poring marram on top of the heavy gravel. After poring, bashing marram between the heavy gravel, and add water where needed to let the marram set between the heavy gravel

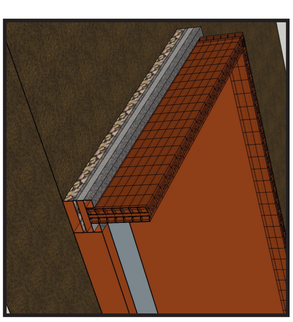


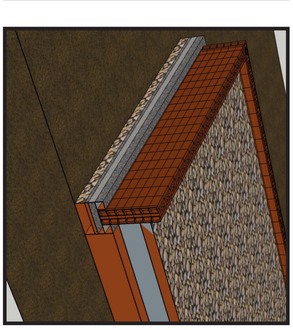


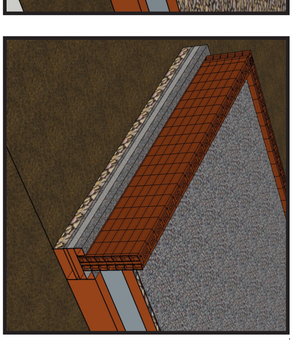


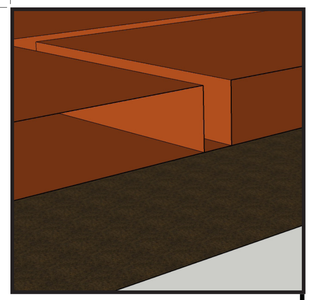
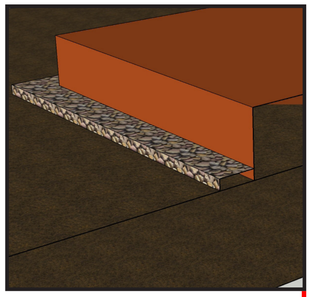
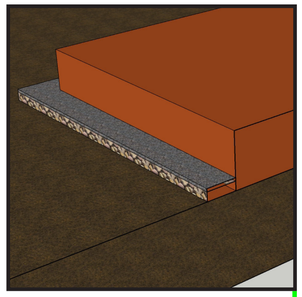
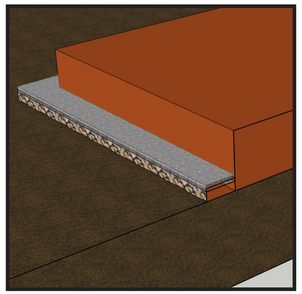
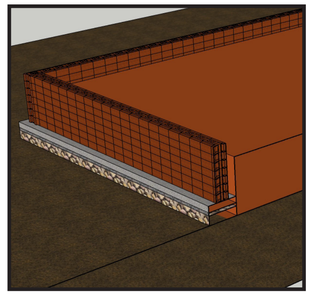
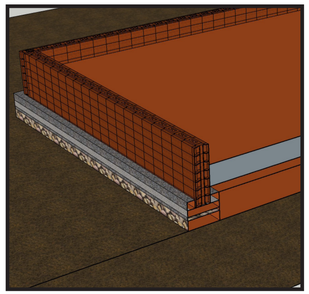
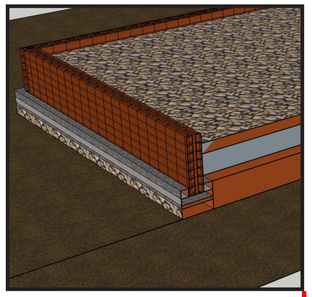
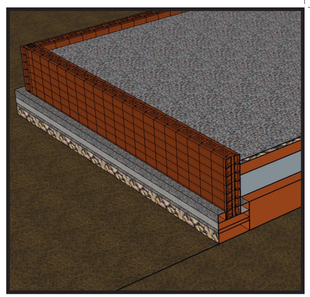










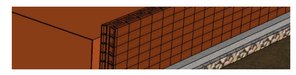









Alternative for excavation. Is to dig a maximum of 800mm and poor a layer of marram (200mm) in the trench and bash it. The costs are higher and in general the marram layer is found at maximum 1500mm. The costs for digging would still be much lower and the layer and house would be much more stable.

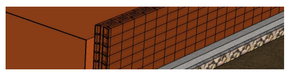
Alternative heavy gravel is to collect boulders in the area and bash them up to the same size of the heavy gravel. Alternatives should be searched for fillers of the lime mixture (for example: old pottery) . Main focus should lay on finding fillers that are available in large quantities.

Alternative for the marram could be sand, clay or small gravel. But compared, the marram is the fastest and cheapest option of the four. Sand will be washed away, for clay you will need large amount and also might be flushed away between the heavy gravel. Small gravel is more expensive than marram. Marram can easily fill up larger gaps but because of the mixture of stones and clay gives a high pressure seal on top of the heavy gravel.

The only other alternative for lime as an additive is cement, but is at least 5 times more expensive and is a product that needs to come far (Kitale). The alternative for small gravel is river gravel or chipped boulders. Problem for both options is that they are more expensive than the small gravel collected from a pit close to the farm.



Alternatives for the compressed earth bricks are: burned bricks these are cheap but need a lot of wood to produce and the quality of the brick is inconsistant. For laying the bricks a lot of mortar (cement) is needed but also fundi's who build the walls. Cement bricks need a higher amount of cement then the last example and will be to expensive compared to the compressed earth bricks improved with lime.

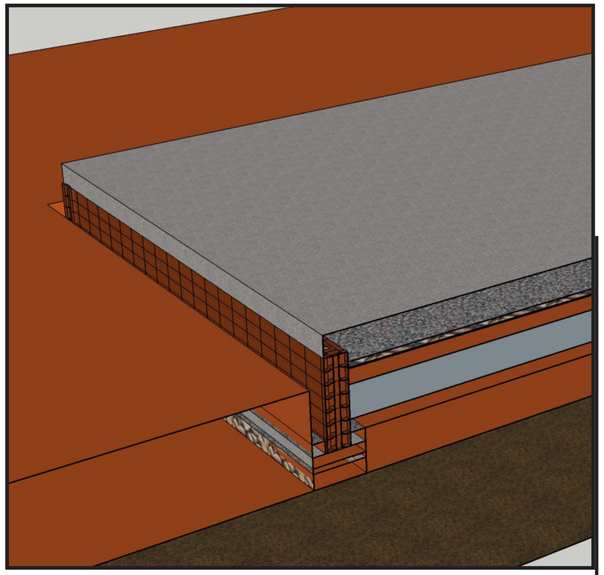


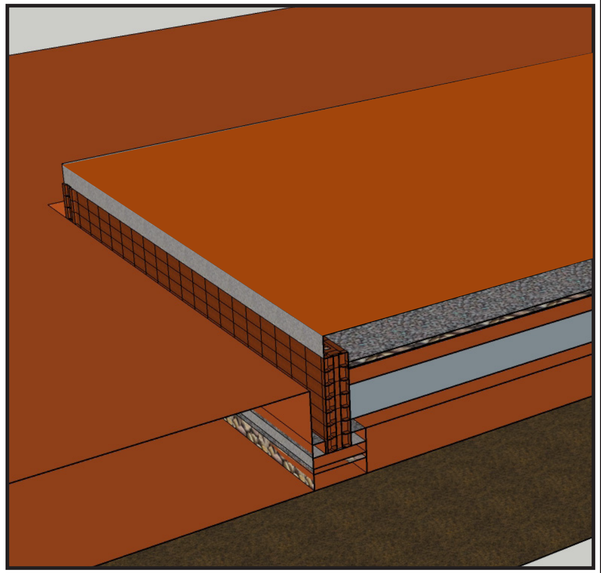
The compressed earth brick I'm suggesting is the cheapest to build up a foundation wall and there are no masonries needed or additional mortar. All materials come from the surrounding accept for the lime. This should be bought in large quantities by the developers. The lime compared to cement will always form the cheapest supplement even bought in bags!

Alternatives for the total foundation is to make a slab foundation. but the materials needed are more expensive (steel needed) and couldn't be made out of local products (will also be more expensive). But more important the slab foundation is more instable and more expensive than the suggested foundation. For this reason the slab foundation is rejected.

To make a pole foundation would be useless because you would simply add the poles to the total foundation and would be more expensive then the suggested foundation and is not needed in this rocky area where a stable layer of soil is found between the 600-1500 mm.

TECHNICAL DATA





FLOOR CONSTRUCTION

In the current dwellings large boulders and a mixture of mud, clay and faeces are used to make the floor of the dwelling. Main problem of this floor is that is difficult to clean and needs a lot of maintenance. Positive points are that the floor has a soft touch and that the faeces act as a repellent against mosquitos. Target for the new suggested floor is that is keep certain characteristics and loose some others. Most important is to keep as much of the same methods and techniques used as possible.

To make a surface that is hard enough to resist against cracks and pressure , easy to clean and which has a low maintenance, an additive is needed to harden the floor. A problem that arises is that faeces would weaken the working of the lime in the mixture and therefore should be left out. So again cement and lime are each other's opponents as an additive. The surface of lime has a softer touch then concrete and lime has the ability to breath which would be better for the living environment close to the floor.

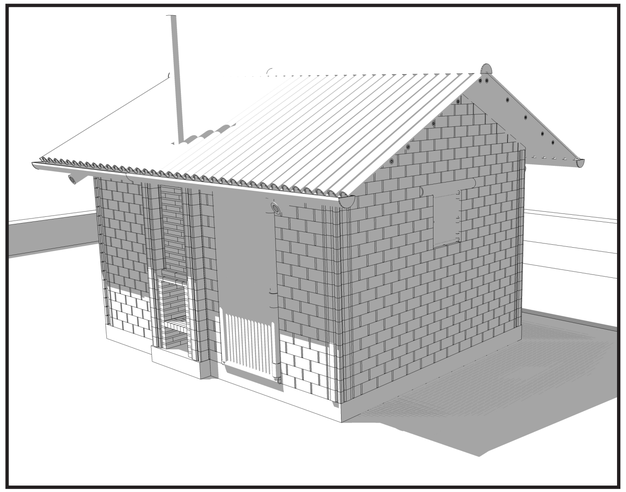
There is an option to use other additives to mix with the concrete. Problem is that in the direct surrounding there are no other additives available to use. Again a possible additive should be searched.

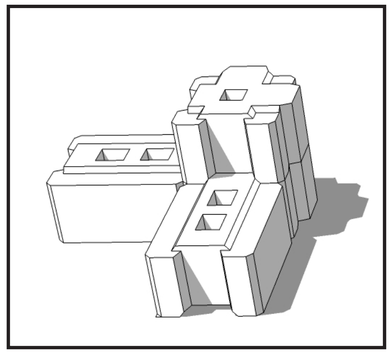
FLOOR FINISH LIME SCREEDING

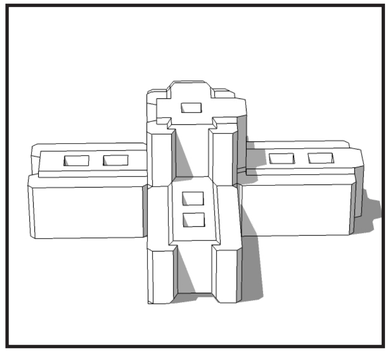
In the current dwelling main problem of the cow dung was its high maintenance. The floor should have the hardest finish of all surfaces in the dwelling. For this reason this finish should have the highest amount of lime to prevent cracks and eventual breaking of the floor. Although the floor becomes less repellent against insects this will be compensated by the walls.

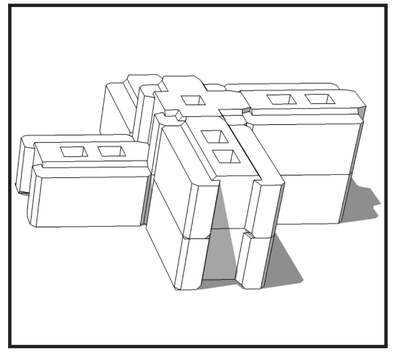
CONSTRUCTION = COMPRESSED EARTH BRICKS

As described in the page before radiation heat is important during the night to heathen the interior. The current used technique is time consuming and uses a lot of hardwood. To improve radiation and to decrease the amount of hardwood used is the main aim for the walls. For this reason I want to introduce brickwork to the dwelling. To save vertical construction material in the form of columns or mortar I want to introduce an interlocking brick. This brick is a compressed earth brick reinforced with lime. Both give the brick additional strength against erosion. Because we use this compressed interlocking earth brick the inhabitants can build the houses easily themselves. Compared to other bricks this is the cheapest and fastest way to build.







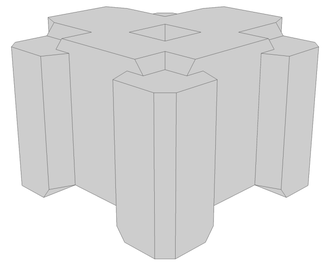


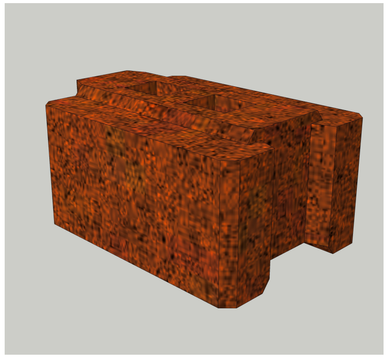
COMPRESSED EARTH BRICK: MIXTURE

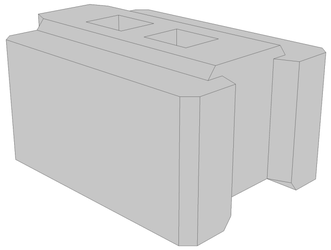
In the manual for compressed earth bricks a soil with a high plasticy is required to make a compressed earth brick that has a high compression (in this manual also proved the higher the compression the stronger the brick) clay is also better resistant to rain. To offer a brick that has the same characteristics as cement based bricks (the strength of these bricks without cement can only be reached with mechanical compression) I introduce also lime to the brick mixture. From extensive testing (also by government of Kenya on made earth bricks in the habitat project) habitat for humanity came to the ideal mixture of 5-5-3 (river sand, clay and cement buckets). Lime needs a longer period to dry but is in cost cheaper and breathes so the brick will dry easier than a cement based brick would.

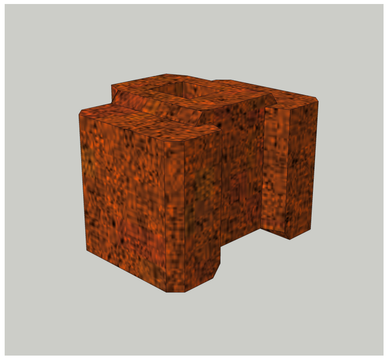
COMPRESSED EARTH BRICK: PRESSING

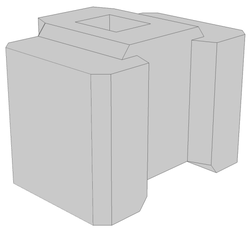
To make designed forms and strength possible consistent a steel mould is needed. This will be the only external needed tool for the inhabitants to build their houses. The mould should be bought by the central community centre and distributed from there to the communities on a daily basis.









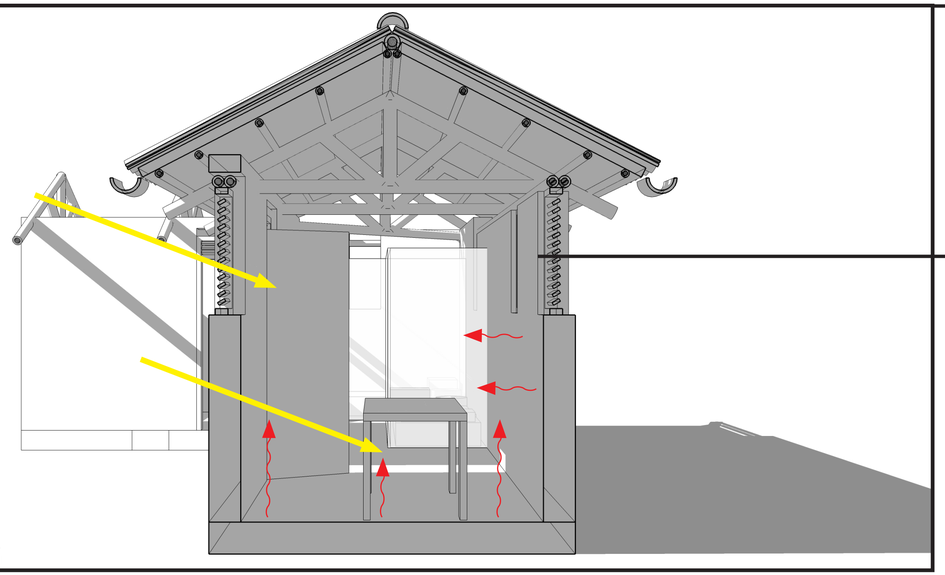


BRICK TYPES & DIMENSIONS

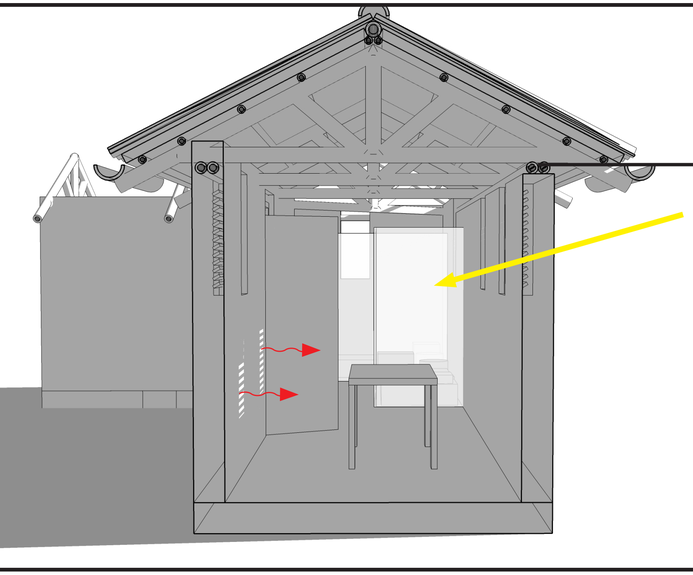
Corner brick 180 x 180 x 120mm

Full brick 240 x 180 x 120mm

Half brick 120 x 180 x 120mm



MORNING



EVENING

OPENINGS HEATING
Should only focus on east and west for heating in morning and evening.

Openings for cooling should be reduced as much as possible towards north and south to prevent extreme heat getting in during the day and cold air during the night.

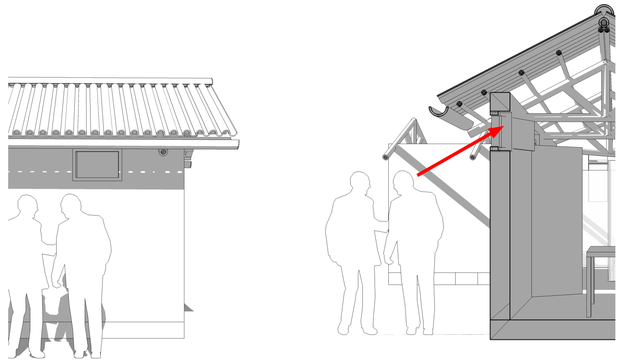
Entrance door should always be pointing from the public space or main road

LINTELS

To prevent lintels to get loose because of opening and closing doors they need to be made more heavy then they are in natural state. Therefore a mixture of clay, lime and sand is used to fill them up (same for foundation slab and floor).

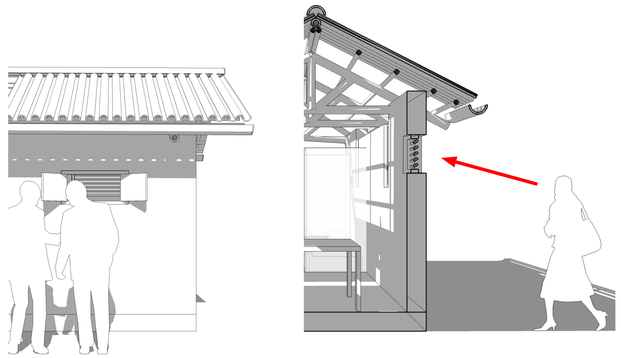
NOW

After the analysis inside the camps we can conclude that the dwellings that even have windows are between 200mm x 300mm and 300mm x 500mm. They are often positioned as high as possible which in terms of privacy and ventilation (during day)is positive. But in terms of light and communication is negative. Because the living area outside the dwelling is already semi-public the indoor living room doesn't have to be. On the next page you will find the details for this type of window in bamboo.



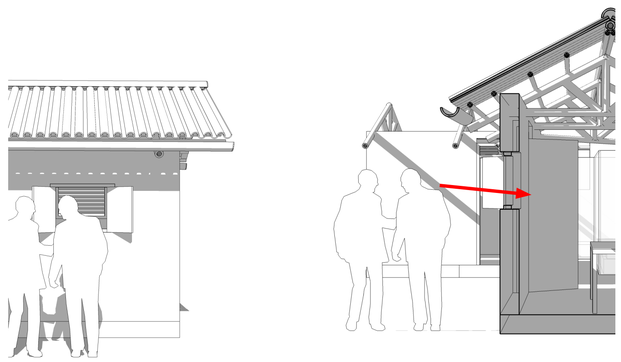
SOON

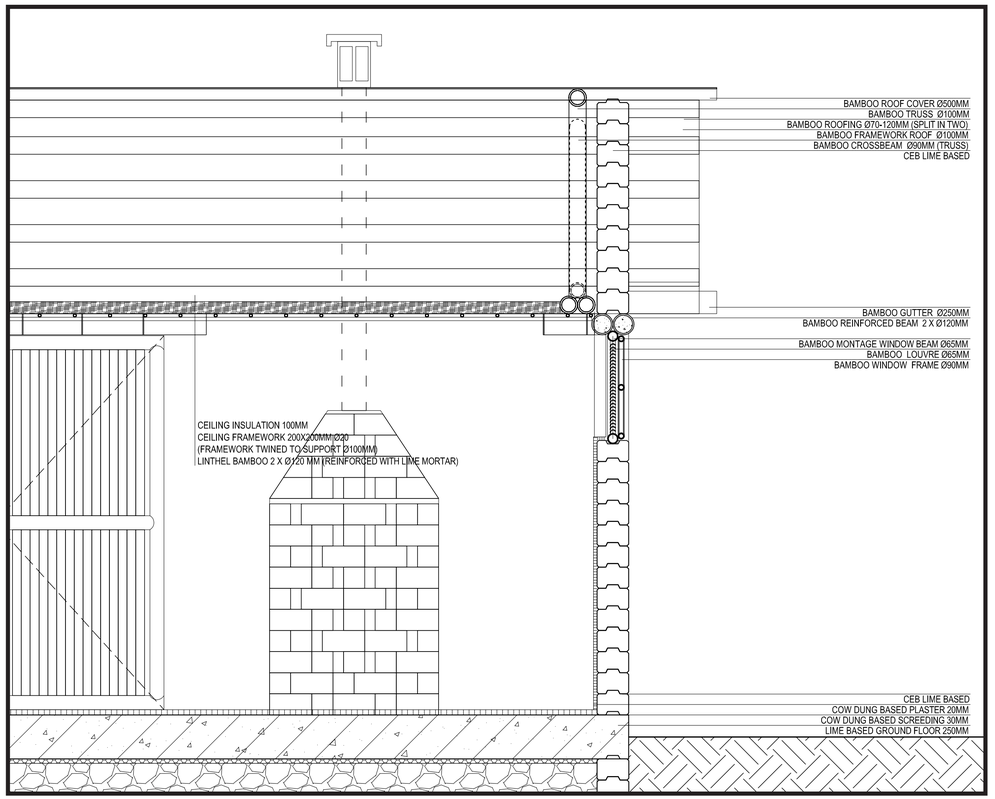
Slowly the family life will occur more and more inside. To keep communication with the surrounding a larger type of window but also the height it is positioned should be changed towards the centre of the wall. For the internal windows we could use just simple shutters. But for the external faced windows we should make a combination of shutters with louvers.

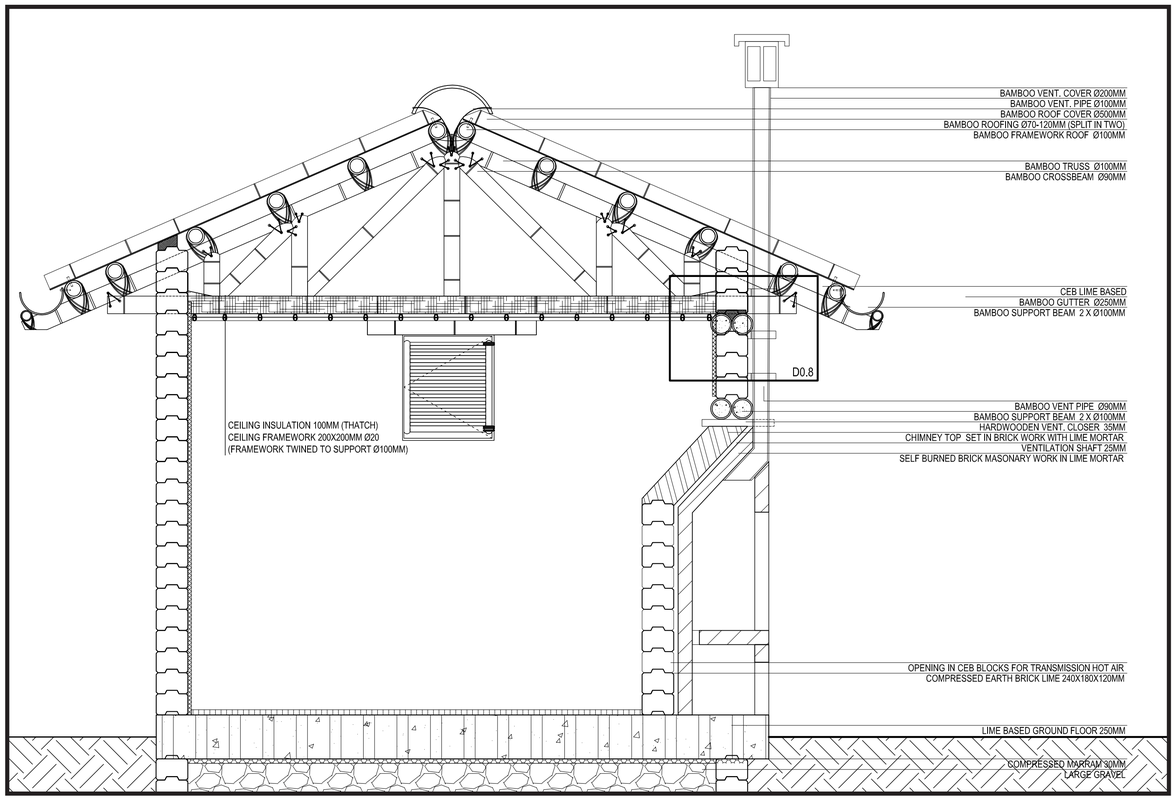


FUTURE

In future development the density of the plot will become higher and the need of alternative window height and sizes should be implemented. Therefore we introduced an even larger window with only shutters.

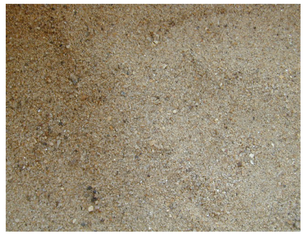






CHIMNEY

To provide the family with additional heating during the night the chimney of the kitchen heats up the bricks on the inside of the dwelling. To prevent the lime bricks to be damaged there is an air gap of 25 mm. This gap will transport hot air through gaps between the compressed earth bricks inside. If the hot air is not needed a hatch (on top of the chimney) can be closed to stop air flowing. The fire place of the chimney will be build up from burned clay bricks (regional already being done, only here done with burning bamboo). Again this is another way of preventing the compressed earth bricks to be damaged by the fire. Another safety regulation is to put the fire at the bottom and close this off with brick work. In this way the fire doesn't affect pans or the bamboo ventilation pipe.



WALL FINISH: PLASTER
Because we can't use feaces in the floor because it will weaken the floor surface. But feaces are essential to make a dwelling repellent against mosquitos. For this reason the traditonal mixtures will be used. But because this mixture has a high insulation value and the dwelling is using thermal massheating the mixture should only be applied on the northern and southern walls.
In this way the cold of the northern and the extreme hot southern heat will be kept out.

A mixture with more lime is used on the east and west facade of the dwelling (right image). This plaster will radiate heat coming from outside in the morning and afternoon. To make sure the plaster will attach to the wall grass could be placed between the layers of brickwork and should be pushed flat to integrate in the plaster.

Currently the inhabitants are using a mixture measured by hands. For screeding and plaster they use 1 hand of sand, 1 hand of cow feaces, half a hand of grass (sometimes) and they fix water to get the right plasticity (depends on moisture in sand and feaces).

WHY BAMBOO?
It's an extreme light fast growing construction material that is the best alternative for hardwood construction methods used in the area.

BEST METHOD CURRING OF BAMBOO WITHOUT CHEMICAL TREATMENT

CLUMP CURING
For this method you hang the bamboo on an uncut pieces of bamboo. Important note is that the bottom of the bamboo has to be covered to prevent insects and fungus to penetrate the bamboo.

AIR DRYING
For this method the bamboo is stored inside free from changes in climate and insects. Only problem is to have a storing place large enough for the bamboo.

ADDITIONAL ADVANTAGES BAMBOO
- ALTERNATIVE FOR FIREWOOD
- ALTERNATIVE AS FENCING MATERIAL
- CLENSING WATER
- WINDBREAK
- FURNITURE

Arundinaria Alpina, (traditional bamboo Kenya)
Specifics:
- Mostly used for fencing
- 2-19 meter max height
- 5-12,5 cm max wide
- Contains spikelets
- Spread in Nairobi

Dendrocalamus Giganteus
Specifics:
- 35 meter max. height
- 30 cm max wide
- Growing speed average 45 cm a day
- Ideal species for Nairobi

Oxytenanthera abyssinica
Specifics:
- Can grow almost everywhere
- Survives fire in natural habitat
- Strongest of the bamboo species.
- 5-10 meter height
- Grows in full sun best

Bambusa vulgaris
Specifics:
Specifics:
- Erosion control
- 12 meter max height
8 cm wide
- Grows in Nairobi

CONSTRUCTION

GUTTERS & ROOFING

Bambusa balcooa
Max height;18 m
Max. diameter; 15,20 cm
Min temp; -4 C
Native to; India
Type; Clumping
Harvest; After 3 -5 years.
Native to India, this strong variety is used for construction, crafts and food. Harvest is sometimes difficult due to its tangled clumps. Clump bamboos have underground stems that sprout vertical shoots much closer to their parent plants, growing slowly outward.

Bambusa. blumeana
Max height;18 m
Max. diameter; 10,20
Min temp; -1
Native to; India, Indonesia
Type; Clumping
Harvest; After 3 -5 years.
Native to India and Indonesia where it is eaten, woven into baskets and used for building. This tall bamboo also grows thorns.

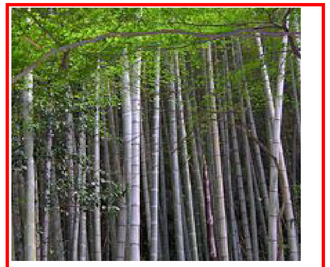
Bambusa. stenostachya
Max height;21 m
Max. diameter; 15,20 cm
Min temp; -2 C
Native to; Vietnam
Type; Clumping
Harvest; After 3 -5 years.
Useful for building due to its nearly solid lower culums. Culums are thorny with persistent sheaths.

Dendrocalamus calostachyus
Max height;21 m
Max. diameter; 12,70 cm
Min temp; -2 C
Native to; Burma
Type; Clumping
Harvest; After 3 -5 years.
From Burma. This large, tufted bamboo is used for small buildings, water vessels and domestic utensils.

Dendrocalamus. yunnanicus
Max height; 24 m
Max. diameter; 17,80 cm
Native to; Vietnam
Type; Clumping
Harvest; After 3 -5 years.
This pale green bamboo grows in Vietnam and south-east Yunnan. It is often used for construction, water pipes, and rafts. The shoots are eaten.

Guadua angustifolia
Max height;30 m
Max. diameter; 22,90 cm
Min temp; -1 C
Native to; South America
Type; Clumping
Harvest; After 3 years, but before 5 years.
Native to north eastern S. America where it is the best species for construction. Culums have short internodes, are durable and pest resistant.

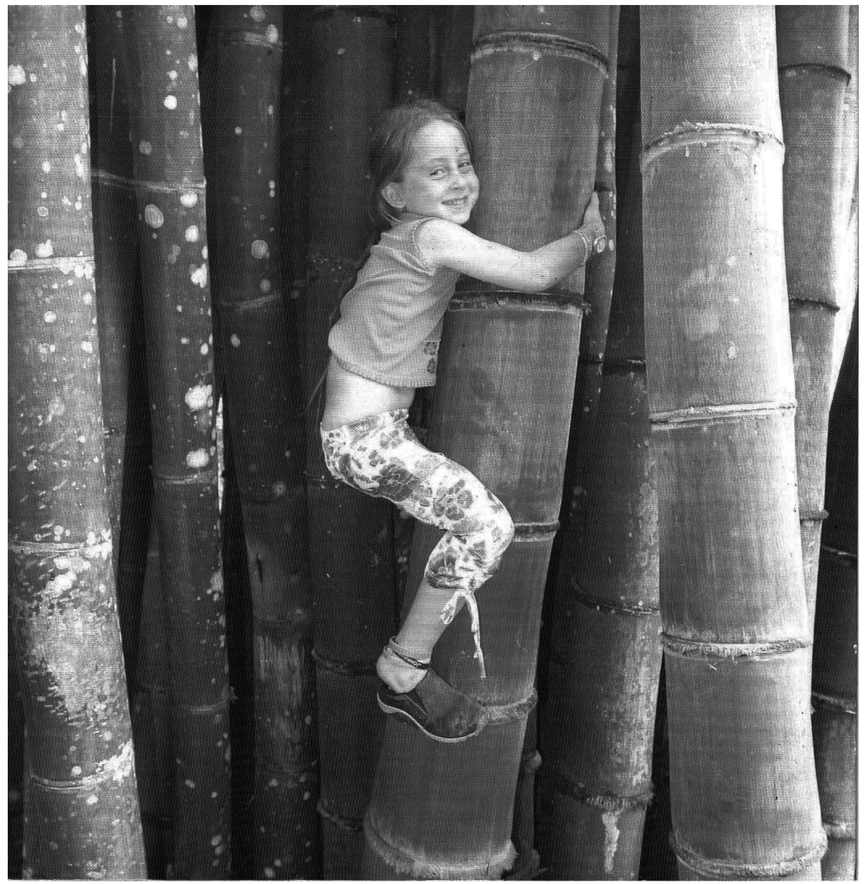
Phyllostachys. bambusoides (GIANT JAPANESE TIMBER, MADAKE)
Max height; 22 m
Max. diameter; 15,20 cm
Min temp; -15 C
Native to; Japan
Type; Running
Harvest; After 3 -5 years.
Japanese Timber Bamboo also called Madake. This bamboo has very thick walls making it one of the best bamboo species for timber.



Phyllostachys. Edulis (MOSO)
Max height;23 m
Max. diameter; 17,80 cm
Min temp; -18 C
Native to;
Type; Running
Harvest; After 3 -5 years then every 2 years
All Moso has on and off years for shooting and a two year leaf replacement cycle. The largest of the hardy bamboos. Shoots in spring. It is one of the most used bamboos in China where it is used for food, timber, paper, plywood, flooring and many other things.

TECHNICAL DATA

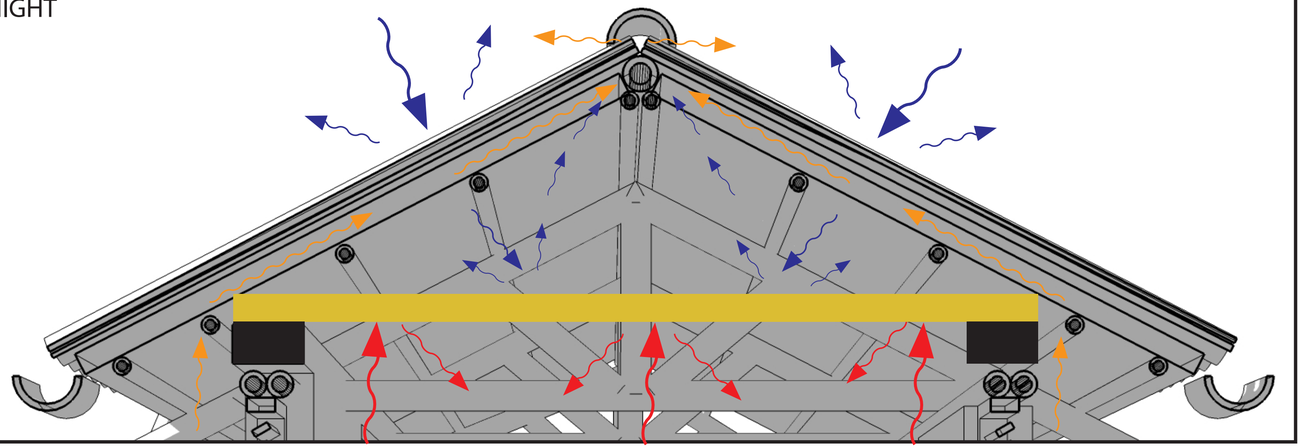
FOUNDATION FLOORS WALLS'''''' ROOF' LINTELS BORDERS & ZONES



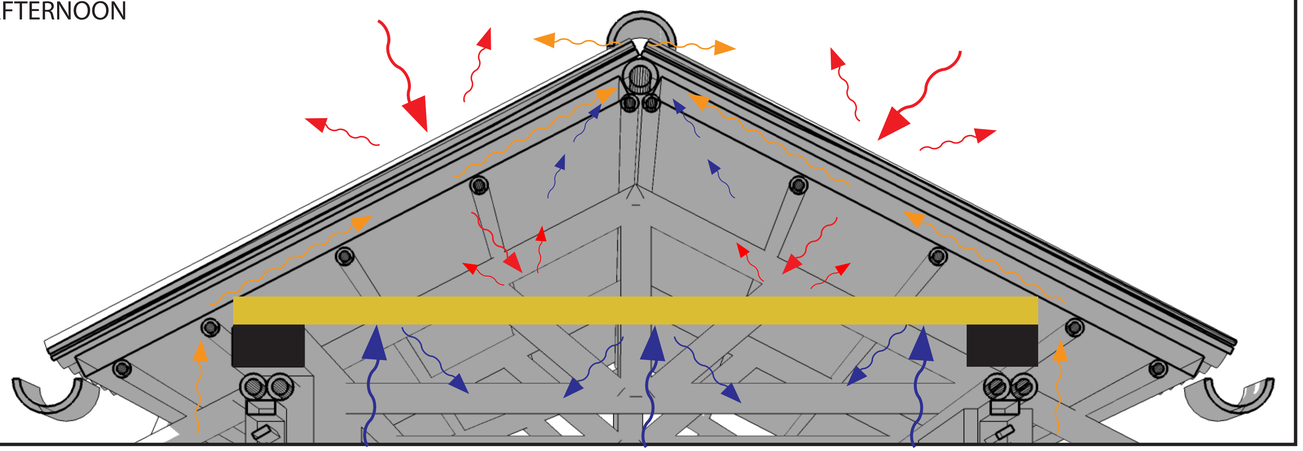
ADDITIONAL ADVANTAGES BAMBOO
- HOLLOW FORM, STRONG AND STIFF
- CUT AND SPLIT WITH SIMPLE TOOLS
- THE SURFACE IS HARD AND CLEAN
- BAMBOO CAN BE GROWN ON A VILLAGE SCALE, OR EVEN ON FAMILY SCALE
- THE RETURN OF CAPITAL IS QUICKER THAN FOR WOOD
- BAMBOO BEHAVES VERY WELL IN STORM AND EARTH QUAKE. (OR A PASSED BY TRAIN)

STRUCTURAL CHALLENGES BAMBOO
- LOW NATURAL DURABILITY
- CONTACT WITH WET SOIL, IT WILL ROT
- FIRE IS A VERY GREAT RISK
- A BAMBOO CULUM IS NOT STRAIGHT
- NO STANDARDIZATION, DUE TO THE VARIATION IN SIZES.

NIGHT



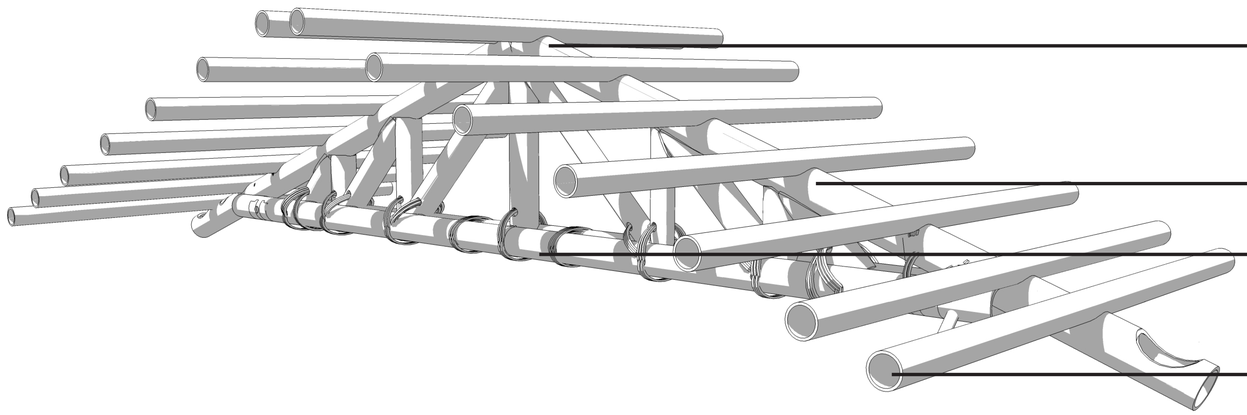
AFTERNOON



ROOF INSULATION

(Is not final yet)
To prevent the raster from bending it will be support every 1000mm by a piece of bamboo carrying on the shortest side of the dwelling(l=3000). As advised by J.Jansen (bamboo expert) the rough calculation of bamboo is very close to that of regular timber. For the inner support beams of the truss we should calculate h/l = 1/10.

The height of the truss = 1000mm
Which makes the support beams 100mm



22157, ISO/DTR-23157.2).

Table 1.0: **Comparative Mechanical Properties of Bamboo and Rectangular Lumber (*Janssen, 2001*)**

	Property	Bamboo	Rectangular Lumber	Assumptions
1.	Moment of Inertia, I	$I = 0.40A^2$	$I = 0.16A^2$	• For most bamboos, d = internal diameter = 0.82D • For timber, mostly h = 2 x b
2.	Optimum Material Use, EI	$4900A^2$	$2240A^2$	• Ecellulose = 70,000N/mm² • Efibre = 35,000N/mm² • 50% of cross-section of fibre is cellulose. • E≈350x% of fibres. • In bamboos, fibre is 60% on outside and 10% on inside, hence Eoutside = 350x60 = 21,000N/mm² and Einside = 350x10 = 3500N/mm² • Edahoma = 14,000N/mm²
	Bending	• Compression stress during bending may result in transverse strain in fibres of top face of culm. Lignin in fibres is weak in strain. Coherence in cross-section is lost and EI drops dramatically. • If load removed culm returns to original straight form.	• Timber will not regain original length when load is removed.	• Poisson coefficient for bamboo = 0.3.

TRUSS
l=4300, h/l=1/7, h=615mm
Height of the truss should be at least 615mm and is over 1000mm in project.

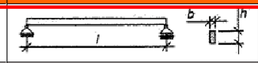
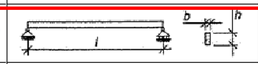
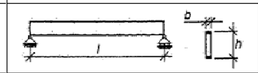
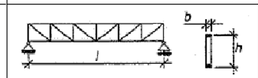
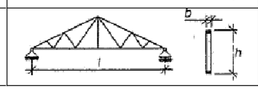
The diagonal only has to be ø100mm (is supported over its full length) support. Which also large enough for roof construction to connect.

Double vertical construction truss = 3000mm, h/l=1/15, h=200mm
To reduce thickness of the construction I use a double beam, which makes:
200mm = 2 x ø100mm

ROOF CONSTRUCTION
This part of the construction will carry the roof shingles which force is distributed over the entire length. distance is large (3800mm). This is the actual most crucial part in dimensioning the roof construction and should be over dimensioned to be capable of carrying the additional load of wind and rain therefore:
l=3600, h/l=1/20, h=190mm

=ø180mm

Vuistregels dimensionering houten liggers

Constructie element	Doorsnede en zijaanzicht	Overspanning l in m	Verhouding b/h	Verhouding b/a	Verhouding h/l	h.o.h. afstand a in m
Massieve ligger		2,5-8	1/3	-	1/15 - 1/20	-
Gelamineerde ligger		6-25	1/6 - 1/10	1/17 - 1/20	1/20	l/2 - l/3
Doosligger		6-35	-	-	1/12 - 1/15	3-12
Vakwerkligger		15-40	-	-	1/7 - 1/12	4-15
Kapspanten		6-24	-	-	1/5 - 1/7	4-8

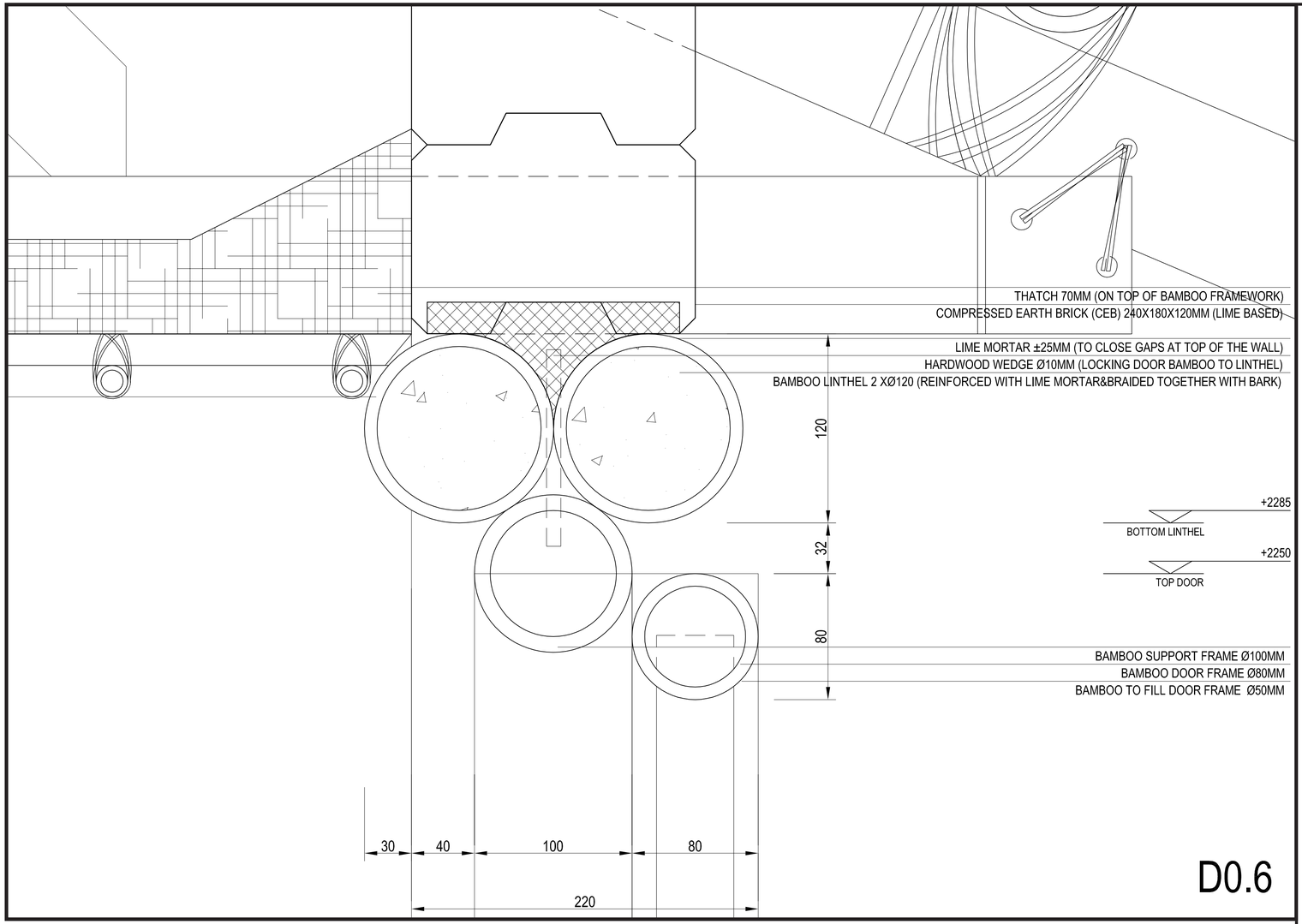
ROOF FINISH BAMBOO

In my point of view is the current way of constructing a roof not only the most economical option I also want it to work as a preservative of the construction culture and background of the community.
Besides that it is a great insulator against the hottest period of the day and keeps the heat inside during the night.

The only problem with the current used system and thatch is that it doesn't last for a very long time. In an effort to preserve the thatch from sun radiation and moist I want to introduce the bamboo roof. It is light, cheap and grows fast. It also looks very much like the corrugated roofing sheets currently used in the new development but only in a natural manner. The size of bamboo used for roofing is ø70mm-ø100mm in diameter.

TECHNICAL DATA

FOUNDATION FLOORS WALLS"""" ROOF"""" LINTELS BORDERS & ZONES

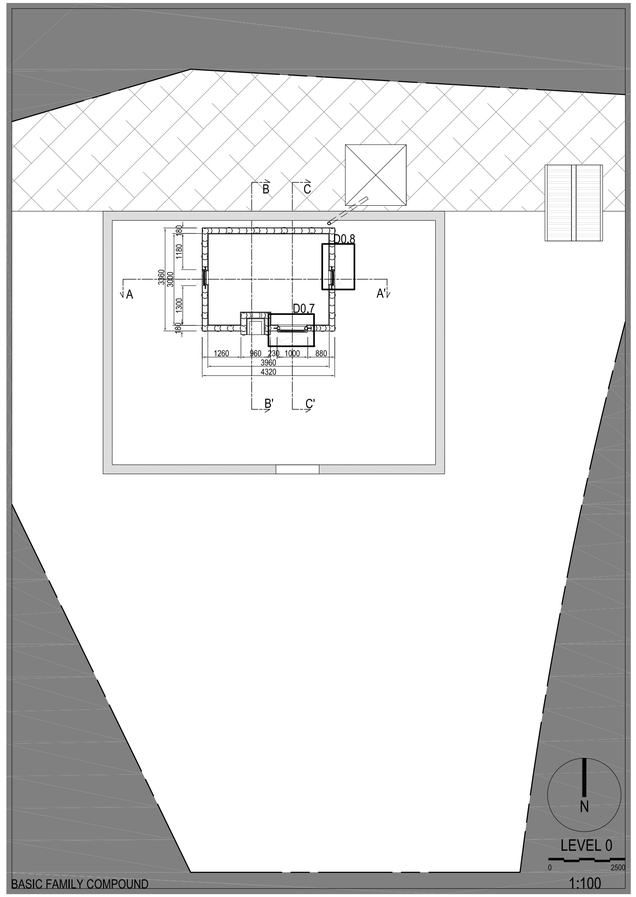


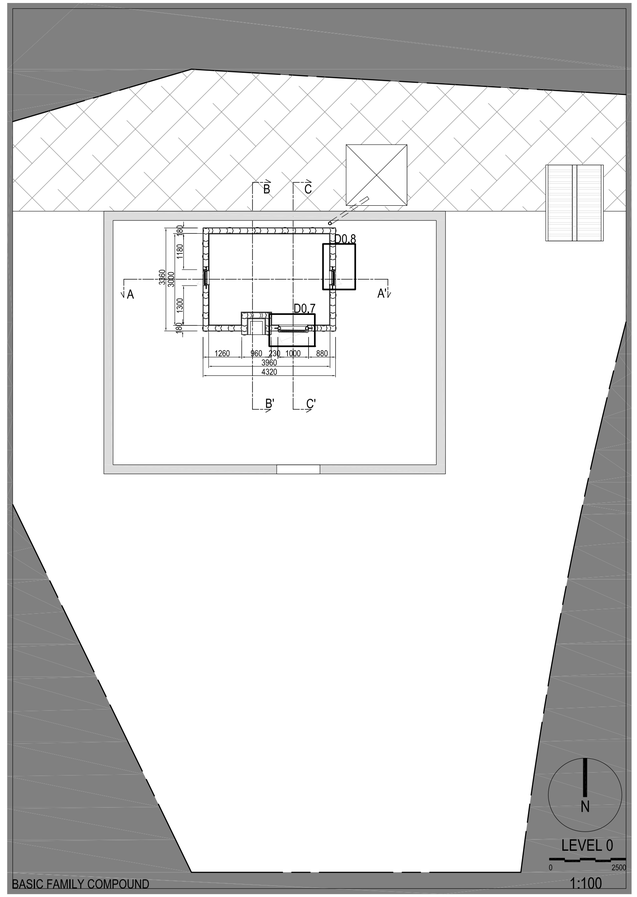
LINTELS

Bamboo is the strongest when pressured appendicular to the fibre. Which means that its most suited for horizontal application. This means bamboo is ideal for lintels in the project. Only issue is that the bamboo is so extremely light that when opening or closing a door it might weaken the wall. Therefore the pieces of bamboo are reinforced with lime mortar which makes them capable of carrying an even higher load.

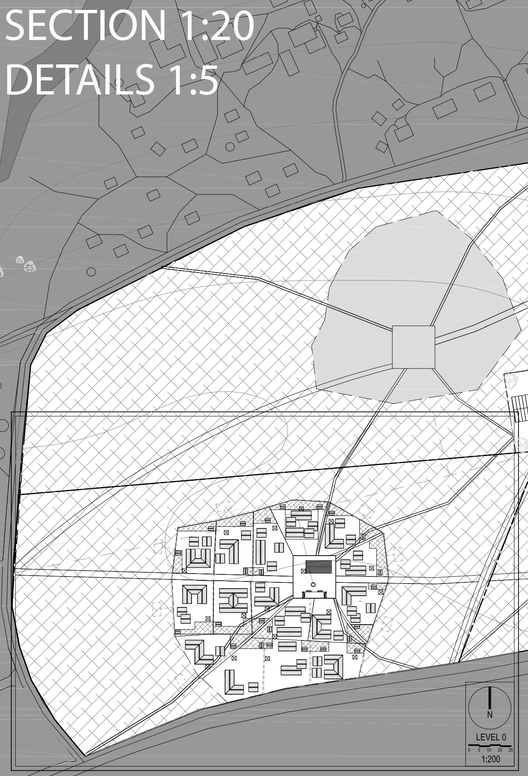
Current used method to mark a family compound is performed by green fencing. In the past this was a light separation to show where a family was living and what its borders were. There is no fence that marks the actual border of the land that is owned by the family. Which because of this reason gives this zone a kind of informal appearance.

In my point of view when this area is set by the community and they make an agreement on how many structures are allowed to be added the urban wild growth would be prevented. In the current plan a maximum of 6 additional structures are allowed. The green fence will grow with the family as in current habitation.





MASTERPLAN 1:1000
COMMUNITY PLAN 1:200
PLAN 1:100
FACADES 1:50
SECTION 1:20
DETAILS 1:5



N

LEVEL 0

0 20 40 60 80

1:1000

FINAL PRODUCTS

SUB CAMP ROAD 1500MM WIDE
IMPROVED FURROW 200X400MM PROVIDES COMMUNITY WELL WITH WATER (±0/-3500 UNDER THE GROUND)
MOBILE TOILET AND SHOWER UNIT (BAMBOO)
WATER RESERVOIR (FOR IRRIGATION)
BAMBOO PIPE Ø400 (WATER OVER FLOW)
VEGETABLE GARDEN (A PART OF THE PLOT IS 500MM LOWER THAN THE PLOT AND FUNCTIONS AS WATER BASCIN)
CHAIRMAN COMPOUND FULL BASIC TYPOLOGY

COMMUNITY BUILDING 80M2
WATER RESERVOIR 1500X1500MM
BAMBOO PIPE Ø400 (WATER OVER FLOW)
BUSH SHOPS (FOR SELLING SMALL PRODUCTS)
MAIN CAMP ROAD 3000MM

COMMUNITY WELL Ø1500MM
COMMUNITY CENTRE AREA 400M2
CLOTHING WASHING SPOTS OVERFLOW TO WATER BASIN
PUBLIC TOILETS
COMMUNAL GARDEN (A PART OF THE PLOT IS 500MM LOWER THAN THE PLOT AND FUNCTIONS AS WATER BASCIN)

BAMBOO PIPE Ø600 (EMERGENCY WATER OVER FLOW)
ROAD GUTTER 1000MM WIDE
COMMUNITY BORDER

1981,5m
1981m
1984,5m
1984m
1985m
1983,5m
1983m
1982,5m
1982m
1981,5m
1981,8m

N

LEVEL 0

0 5 10 20 25

1:200

MASTERPLAN 1:1000

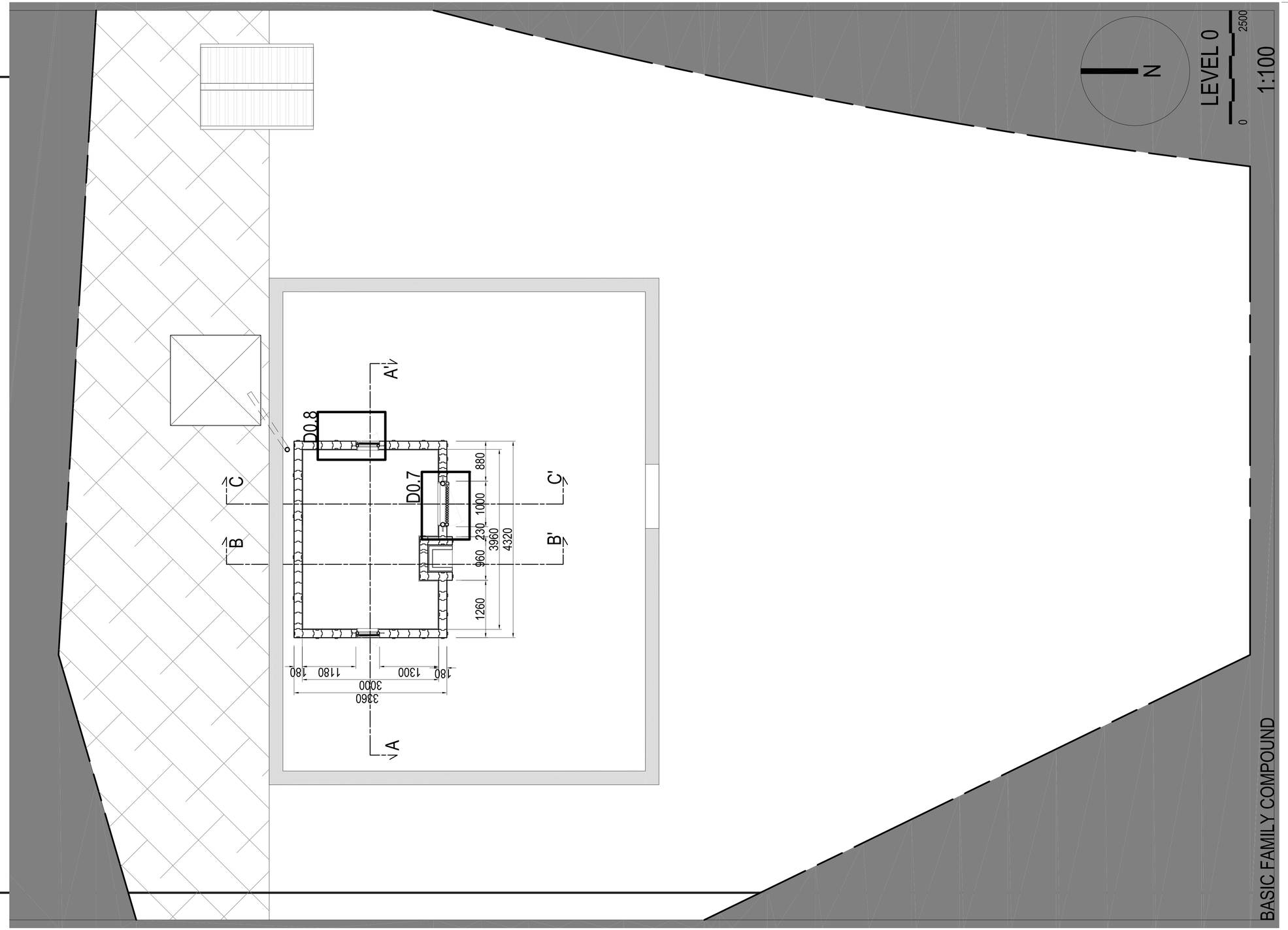
COMMUNITY PLAN 1:200

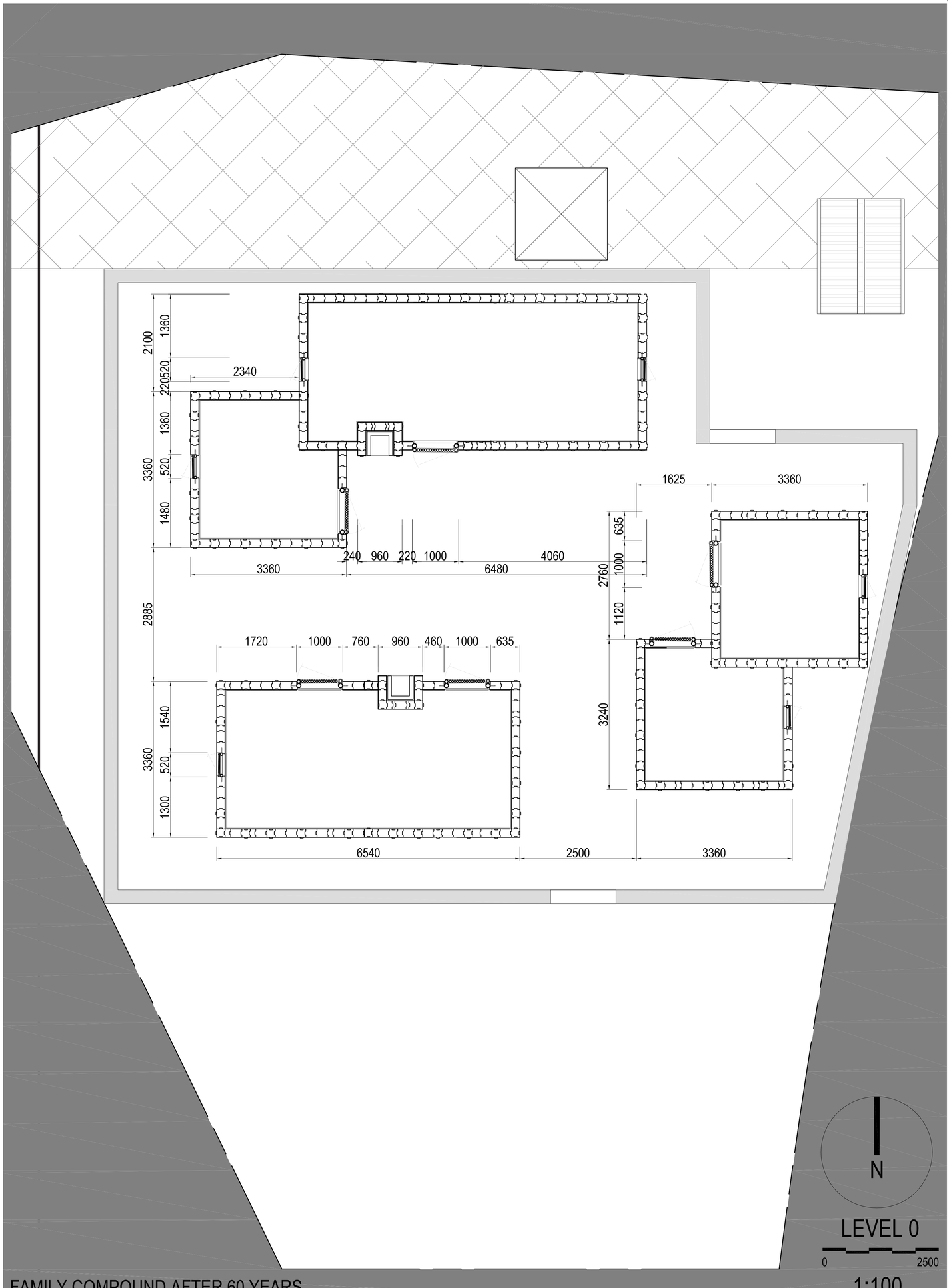
PLAN 1:100

FACADES 1:50

SECTION 1:20

DETAILS 1:5





LEVEL 0

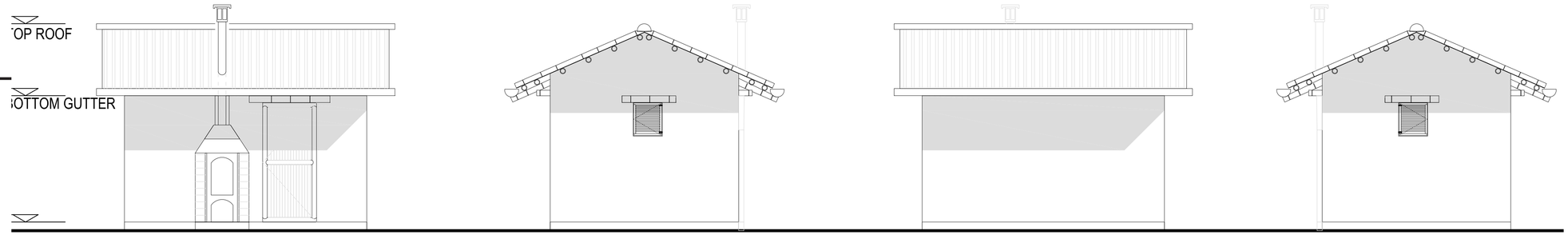
0 2500

FAMILY COMPOUND AFTER 60 YEARS

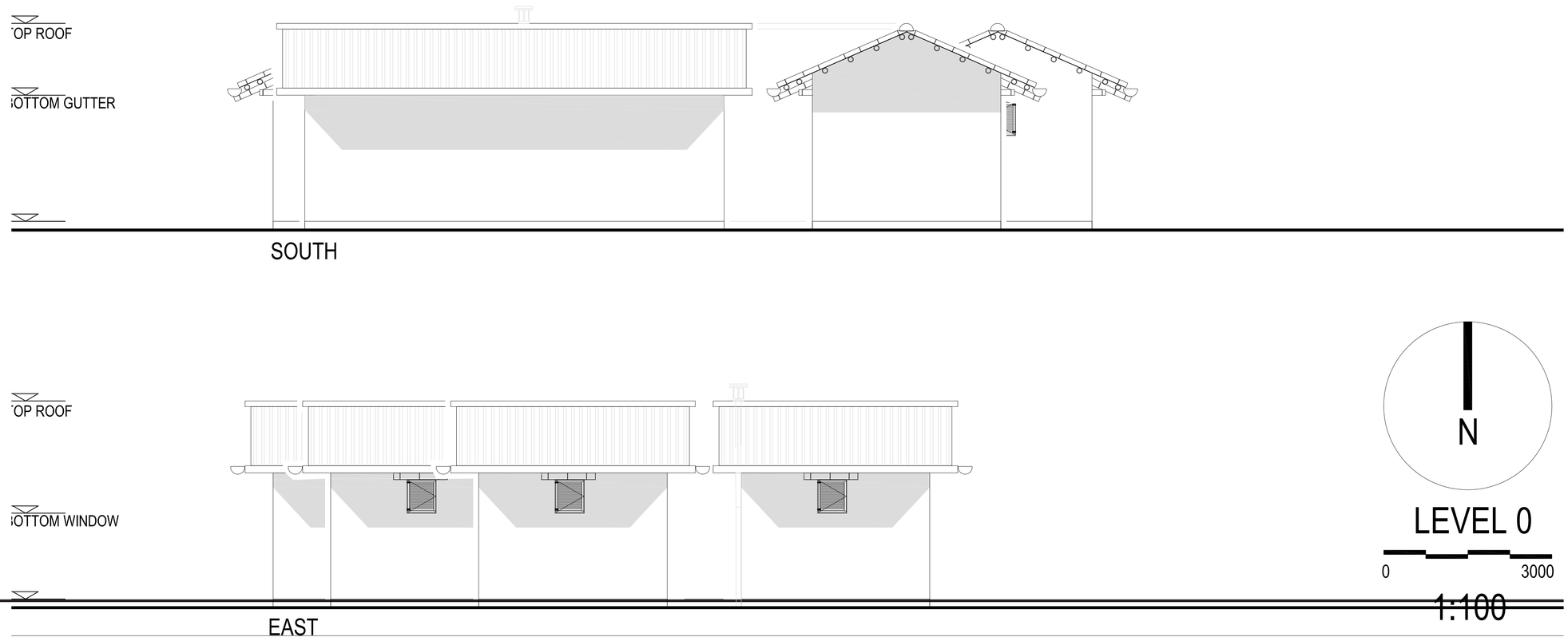
1:100

MASTERPLAN 1:1000
COMMUNITY PLAN 1:200
PLAN 1:100
FACADES 1:50
SECTION 1:20
DETAILS 1:5

C FAMILY UNIT



LY UNIT AFTER 60 YEARS



N

LEVEL 0

0 3000

1:100

OP ROOF

OP WINDOW

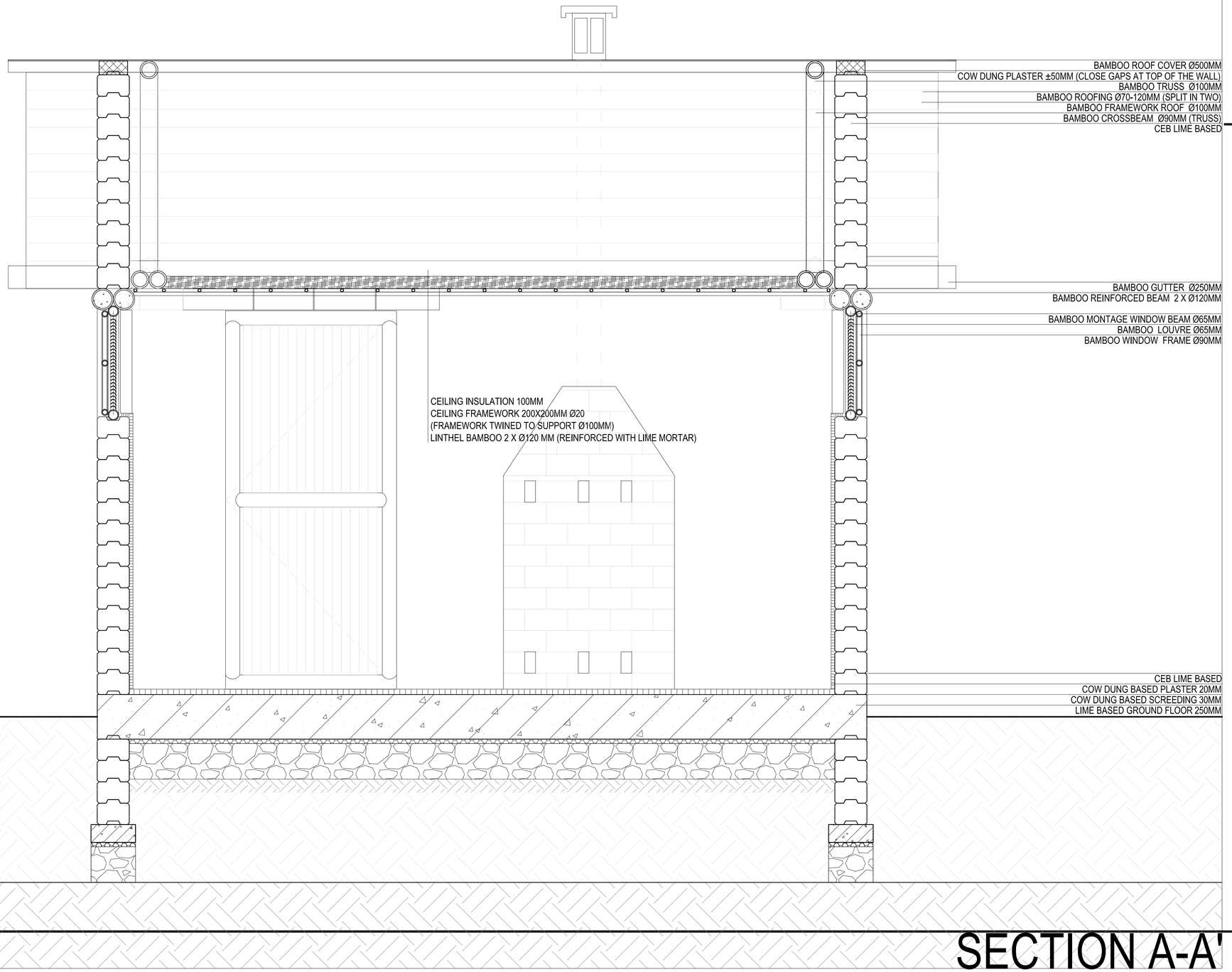
OP FLOOR

OTTOM FLOOR

OTTOM STABILIZATION

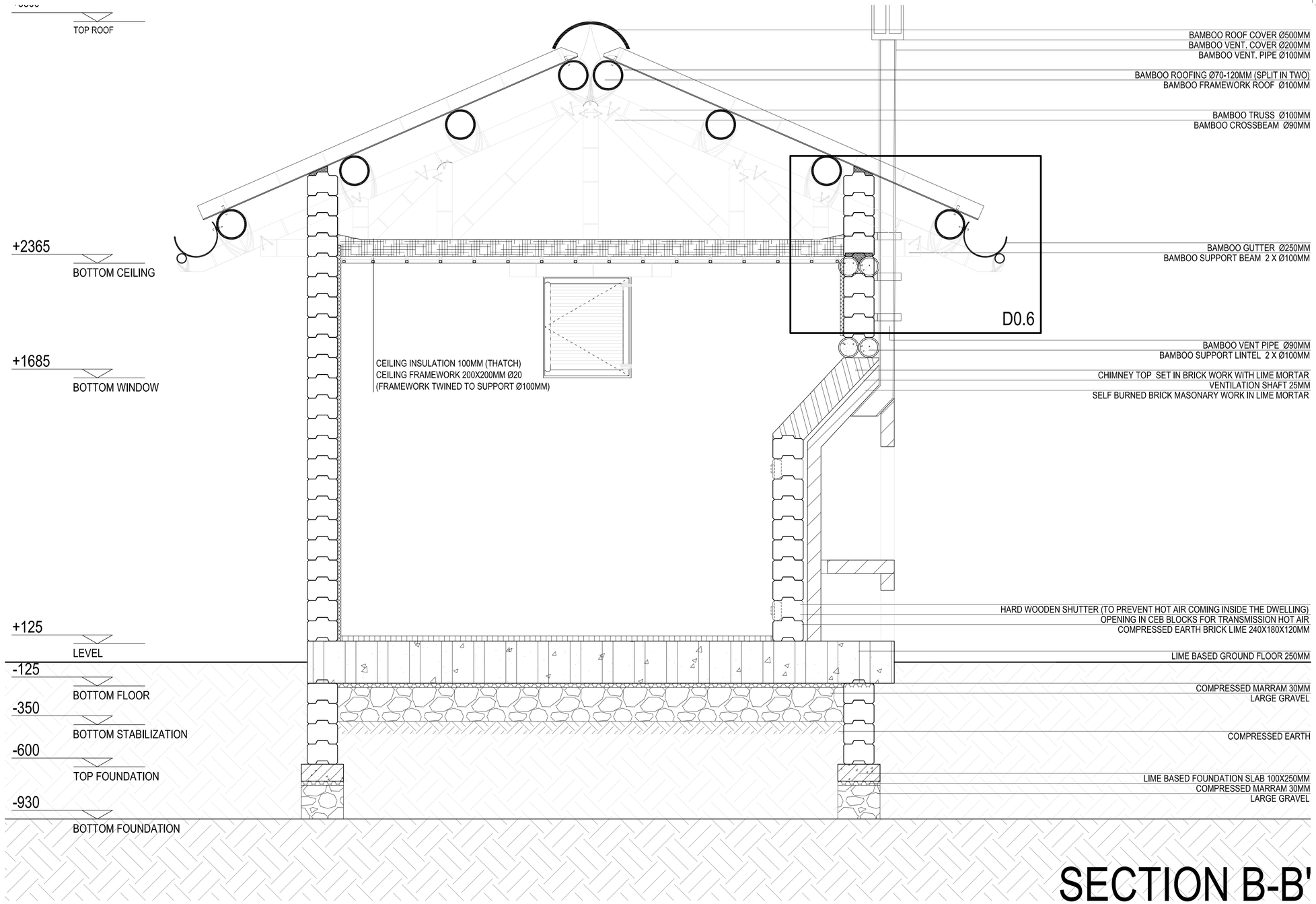
OP FOUNDATION

OTTOM FOUNDATION

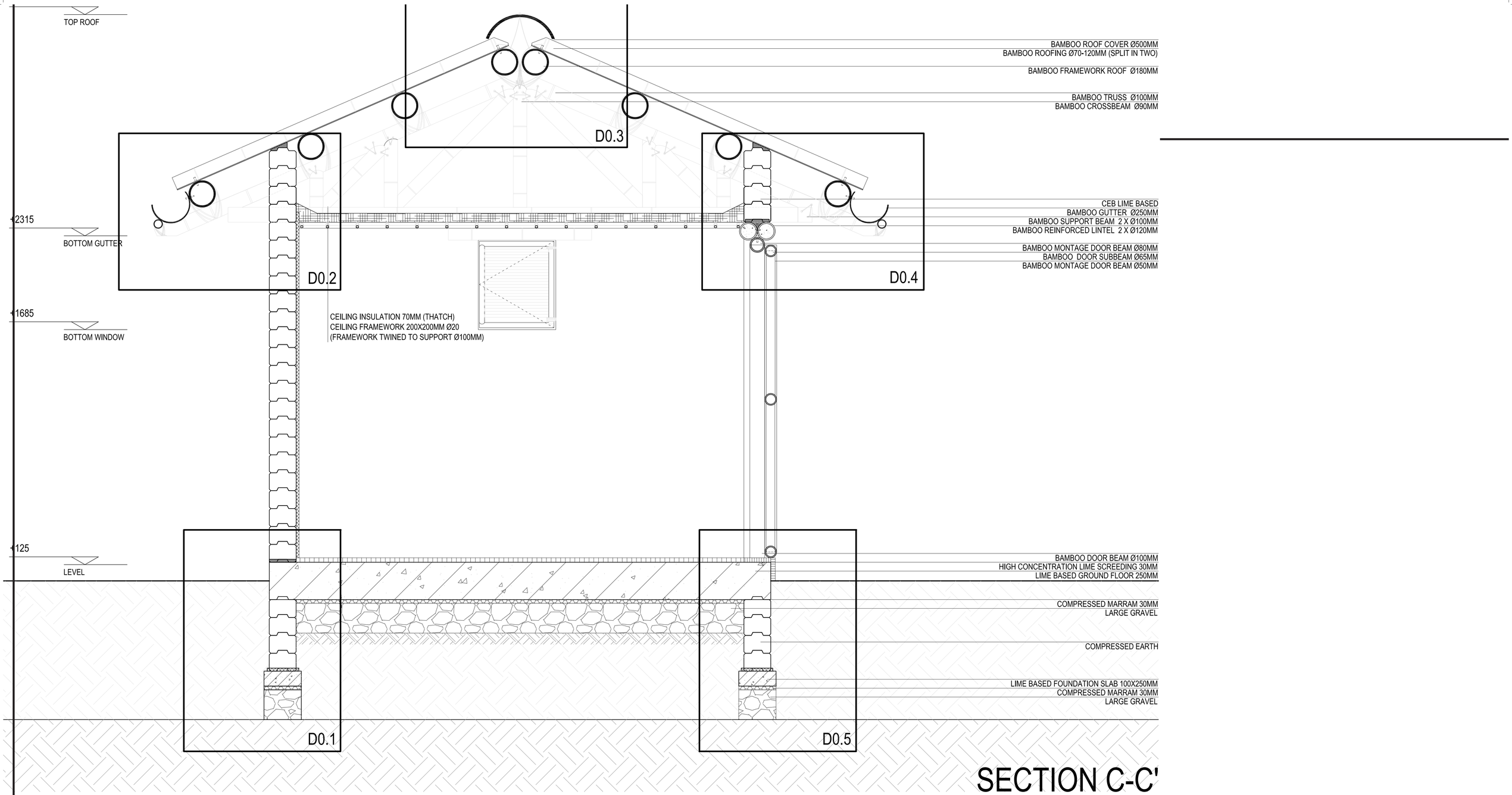


SECTION A-A'

MASTERPLAN 1:1000
COMMUNITY PLAN 1:200
PLAN 1:100
FACADES 1:50
SECTION 1:20
DETAILS 1:5



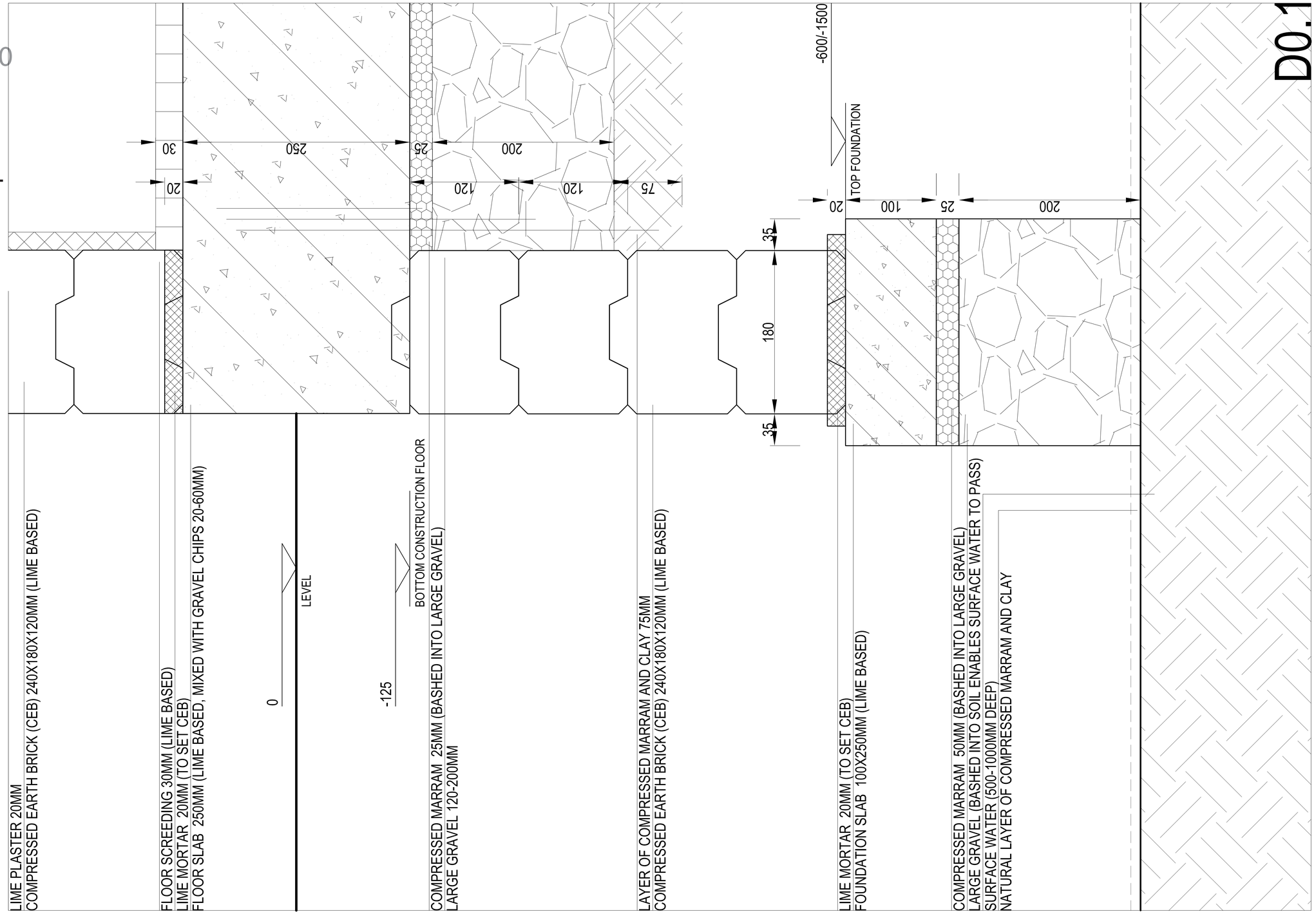
SECTION B-B'


TOP ROOF
+2315
BOTTOM GUTTER
+1685
BOTTOM WINDOW
+125
LEVEL
D0.1
D0.2
D0.3
D0.4
D0.5
BAMBOO ROOF COVER Ø500MM
BAMBOO ROOFING Ø70-120MM (SPLIT IN TWO)
BAMBOO FRAMEWORK ROOF Ø180MM
BAMBOO TRUSS Ø100MM
BAMBOO CROSSBEAM Ø90MM
CEB LIME BASED
BAMBOO GUTTER Ø250MM
BAMBOO SUPPORT BEAM 2 X Ø100MM
BAMBOO REINFORCED LINTEL 2 X Ø120MM
BAMBOO MONTAGE DOOR BEAM Ø80MM
BAMBOO DOOR SUBBEAM Ø65MM
BAMBOO MONTAGE DOOR BEAM Ø50MM
CEILING INSULATION 70MM (THATCH)
CEILING FRAMEWORK 200X200MM Ø20
(FRAMEWORK TWINED TO SUPPORT Ø100MM)
BAMBOO DOOR BEAM Ø100MM
HIGH CONCENTRATION LIME SCREEDING 30MM
LIME BASED GROUND FLOOR 250MM
COMPRESSED MARRAM 30MM
LARGE GRAVEL
COMPRESSED EARTH
LIME BASED FOUNDATION SLAB 100X250MM
COMPRESSED MARRAM 30MM
LARGE GRAVEL

SECTION C-C'

MASTERPLAN 1:1000
COMMUNITY PLAN 1:200
PLAN 1:100
FACADES 1:50
SECTION 1:20
DETAILS 1:5

D0.1



COW DUNG PLASTER ±50MM (TO CLOSE GAPS AT TOP OF THE WALL)
BAMBOO ROOFING Ø70-120MM (SPLIT IN TWO)
BAMBOO ROOF SUPPORT Ø100MM
HARDWOOD WEDGE Ø10MM (LOCKING ROOF TO ROOF SUPPORT)
HARDWOOD WEDGE Ø10MM (LOCKING GUTTER, BARK BRAIDING)
BAMBOO GUTTER Ø250MM
TRIM BAMBOO TRUSS Ø100MM TO FIT GUTTER

+2365

BOTTOM GUTTER

280

772

180

20

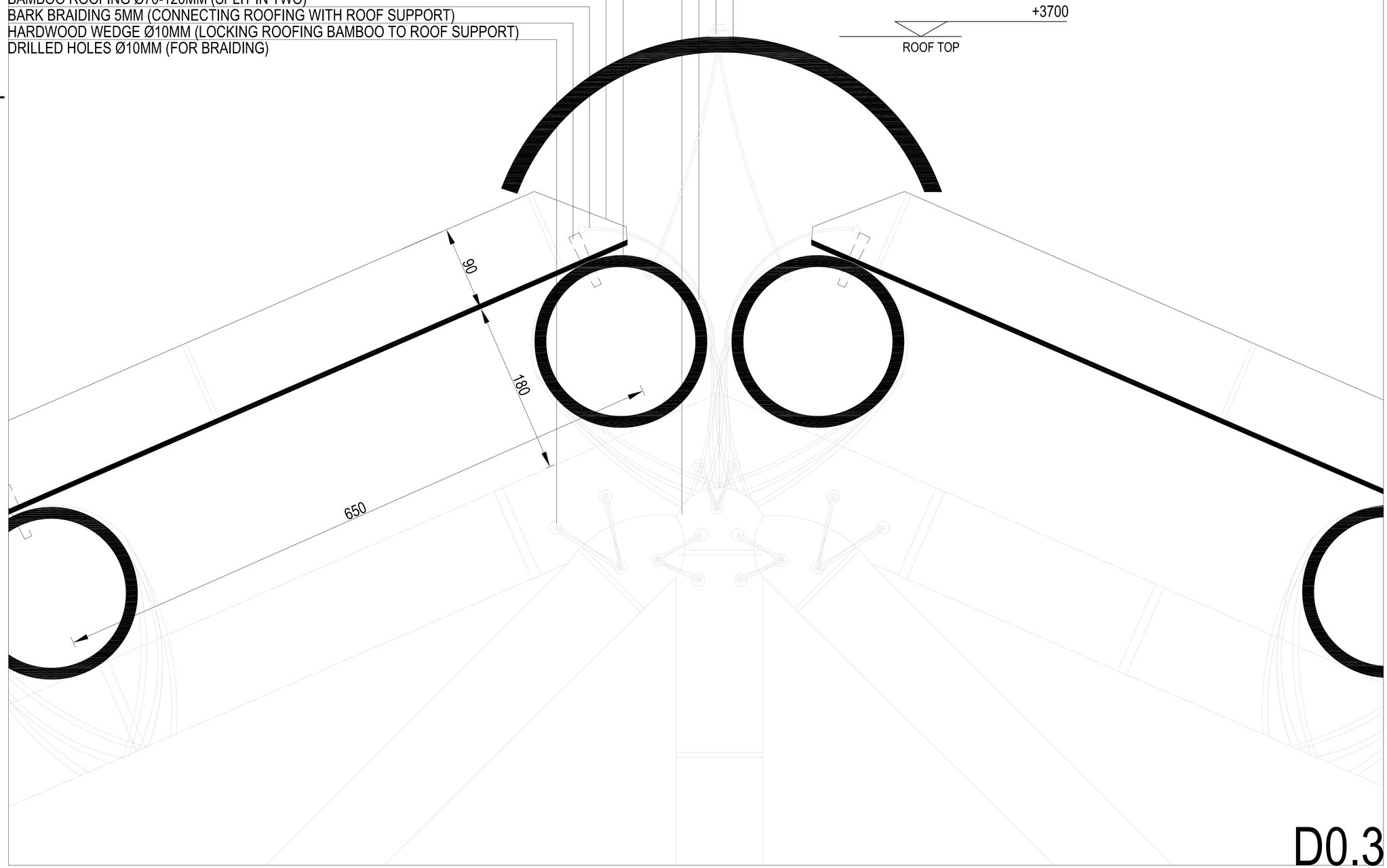
172

BAMBOO GUTTER SUPPORT Ø60MM
BARK BRAIDING 5MM
COMPRESSED EARTH BRICK 240X180X120MM (WITH HIGH PERCENTAGE LIME TO CARRY WEIGHT OF THE TRUSSES.)
COMPRESSED EARTH BRICK (CEB) 240X180X120MM (LIME BASED)
COW DUNG PLASTER 20MM (LIME INFORCED, NORTHERN FACADE)
BARK BRAIDING 5MM (CONNECTING TWO LAYERS OF FRAMEWORK)
BAMBOO CEILING FRAME 20MM (FRAME 200X200MM)
THATCH 70MM (ON TOP OF BAMBOO FRAMEWORK)

D0.2

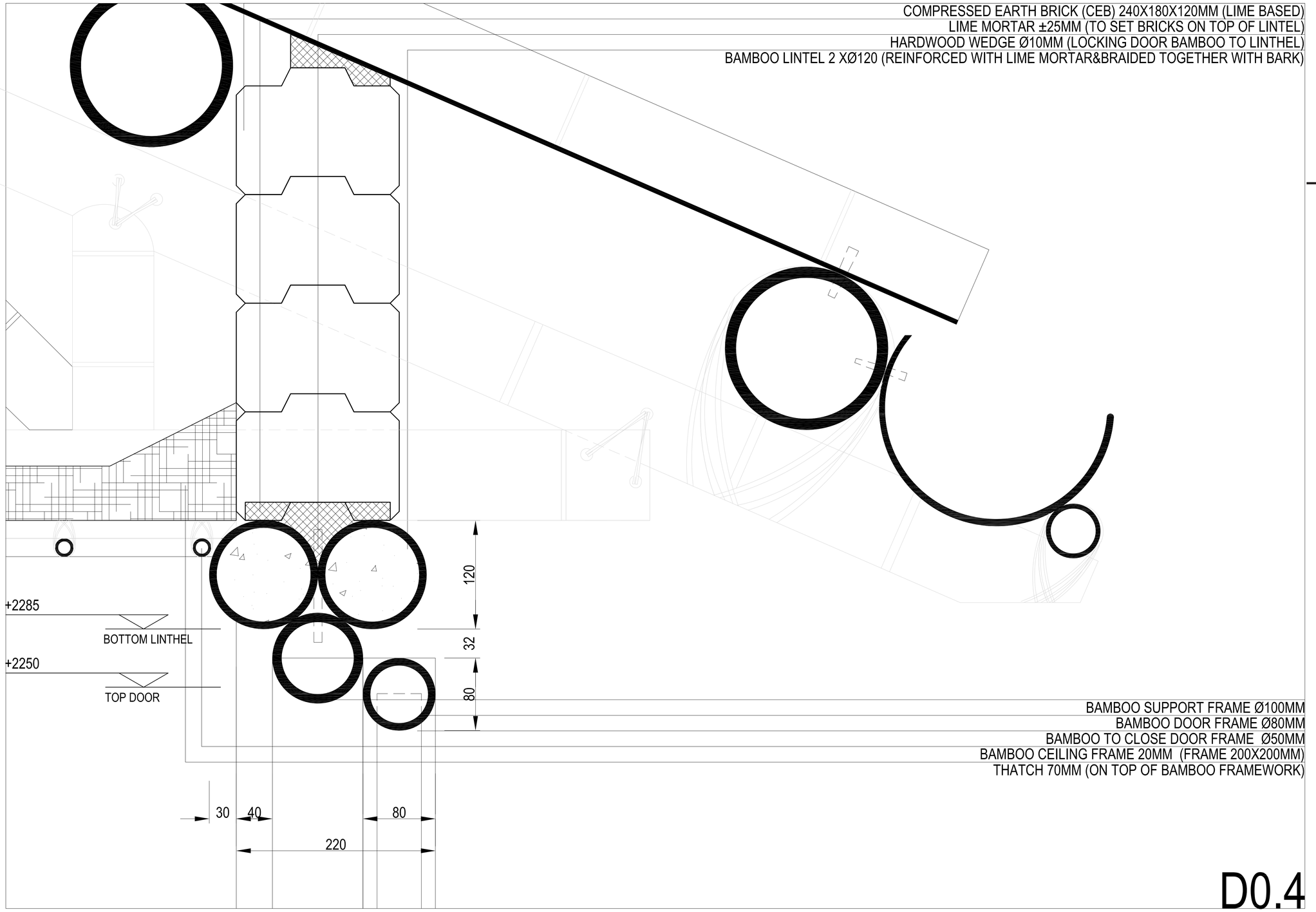
MASTERPLAN 1:1000
COMMUNITY PLAN 1:200
PLAN 1:100
FACADES 1:50
SECTION 1:20
DETAILS 1:5

BAMBOO ROOF COVER Ø500MM (SPLIT INTO TWO PIECES)
BARK BRAIDING 5MM (CONNECTING ROOF COVER WITH ROOF SUPPORT)
BARK BRAIDING 5MM (CONNECTING ROOF SUPPORT WITH TRUSSES)
TRUSS SUPPORT BEAM Ø90MM (VERTICAL)
BAMBOO ROOF SUPPORT Ø100MM
BAMBOO ROOFING Ø70-120MM (SPLIT IN TWO)
BARK BRAIDING 5MM (CONNECTING ROOFING WITH ROOF SUPPORT)
HARDWOOD WEDGE Ø10MM (LOCKING ROOFING BAMBOO TO ROOF SUPPORT)
DRILLED HOLES Ø10MM (FOR BRAIDING)



D0.3

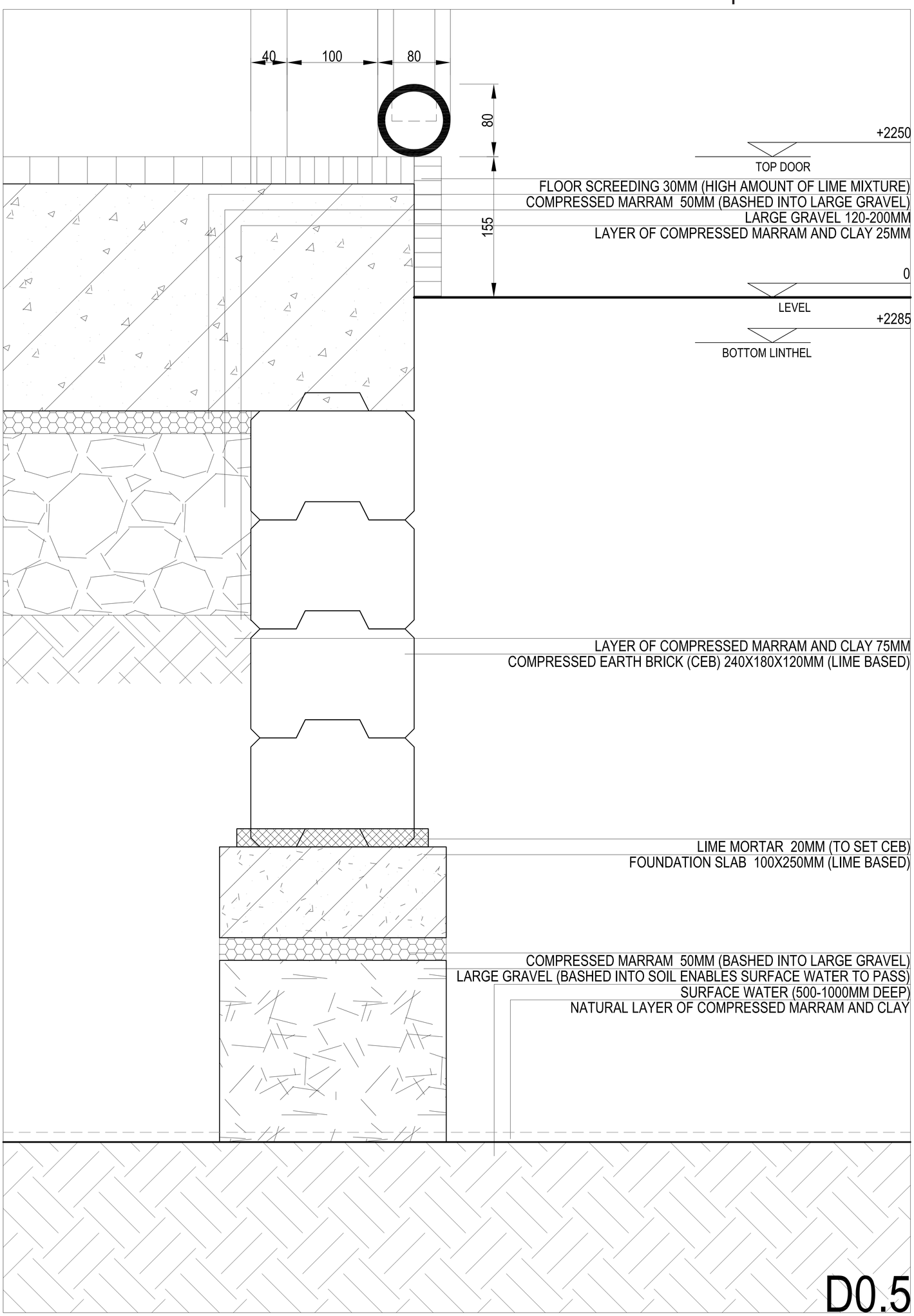
COMPRESSED EARTH BRICK (CEB) 240X180X120MM (LIME BASED)
LIME MORTAR ±25MM (TO SET BRICKS ON TOP OF LINTEL)
HARDWOOD WEDGE Ø10MM (LOCKING DOOR BAMBOO TO LINTHEL)
BAMBOO LINTEL 2 XØ120 (REINFORCED WITH LIME MORTAR&BRAIDED TOGETHER WITH BARK)



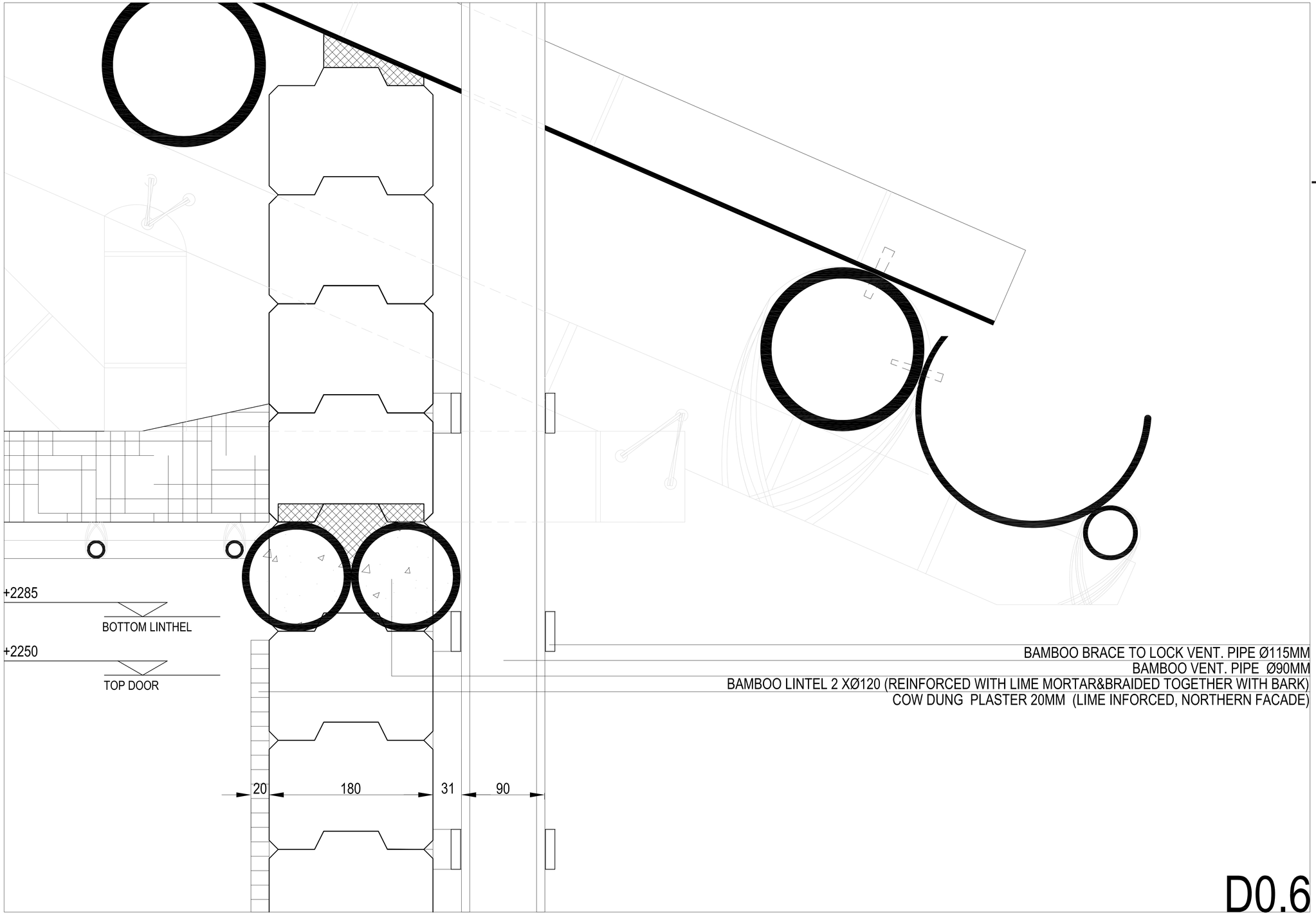
BAMBOO SUPPORT FRAME Ø100MM
BAMBOO DOOR FRAME Ø80MM
BAMBOO TO CLOSE DOOR FRAME Ø50MM
BAMBOO CEILING FRAME 20MM (FRAME 200X200MM)
THATCH 70MM (ON TOP OF BAMBOO FRAMEWORK)

D0.4

DETAILS 1:5



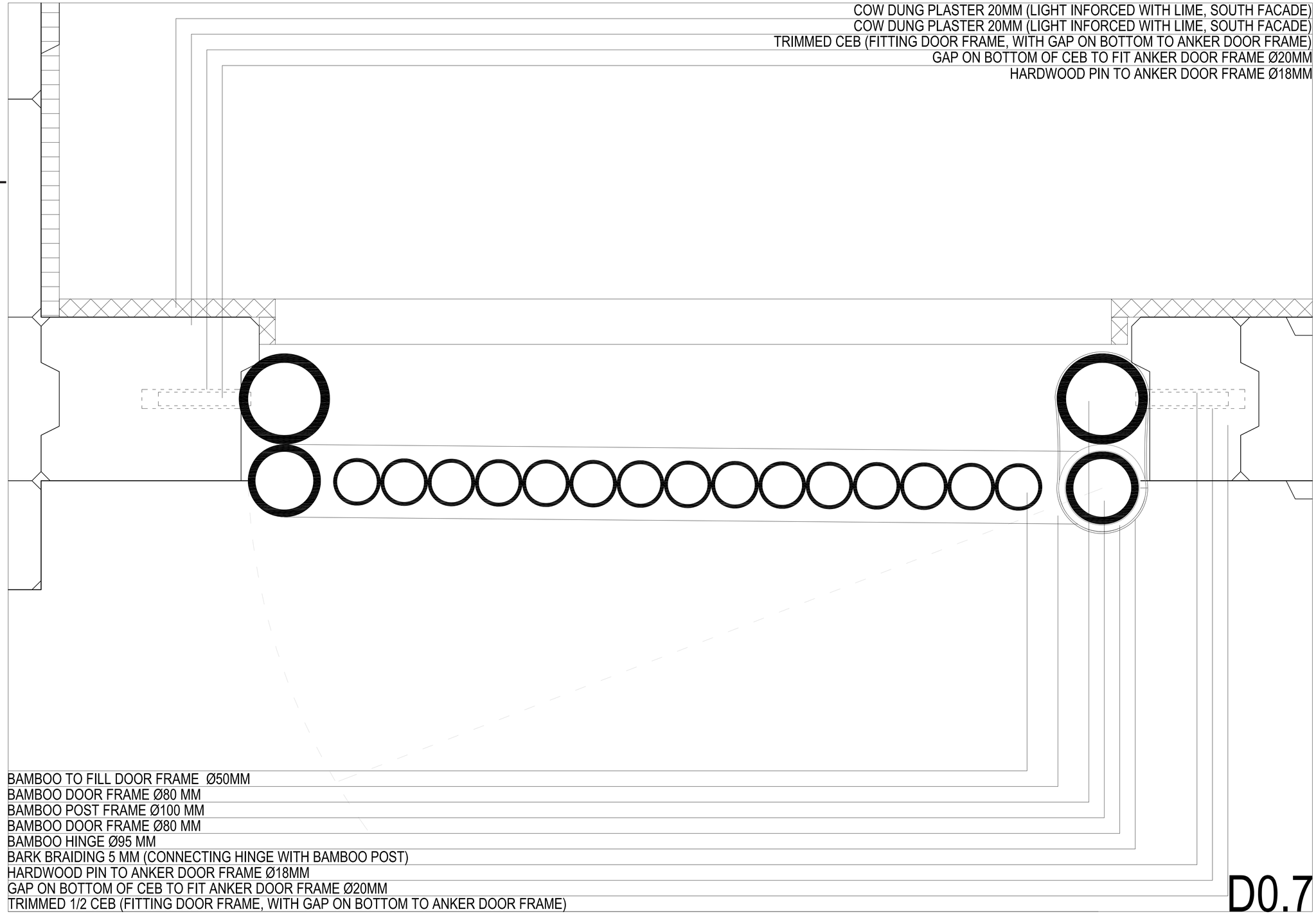
D0.5



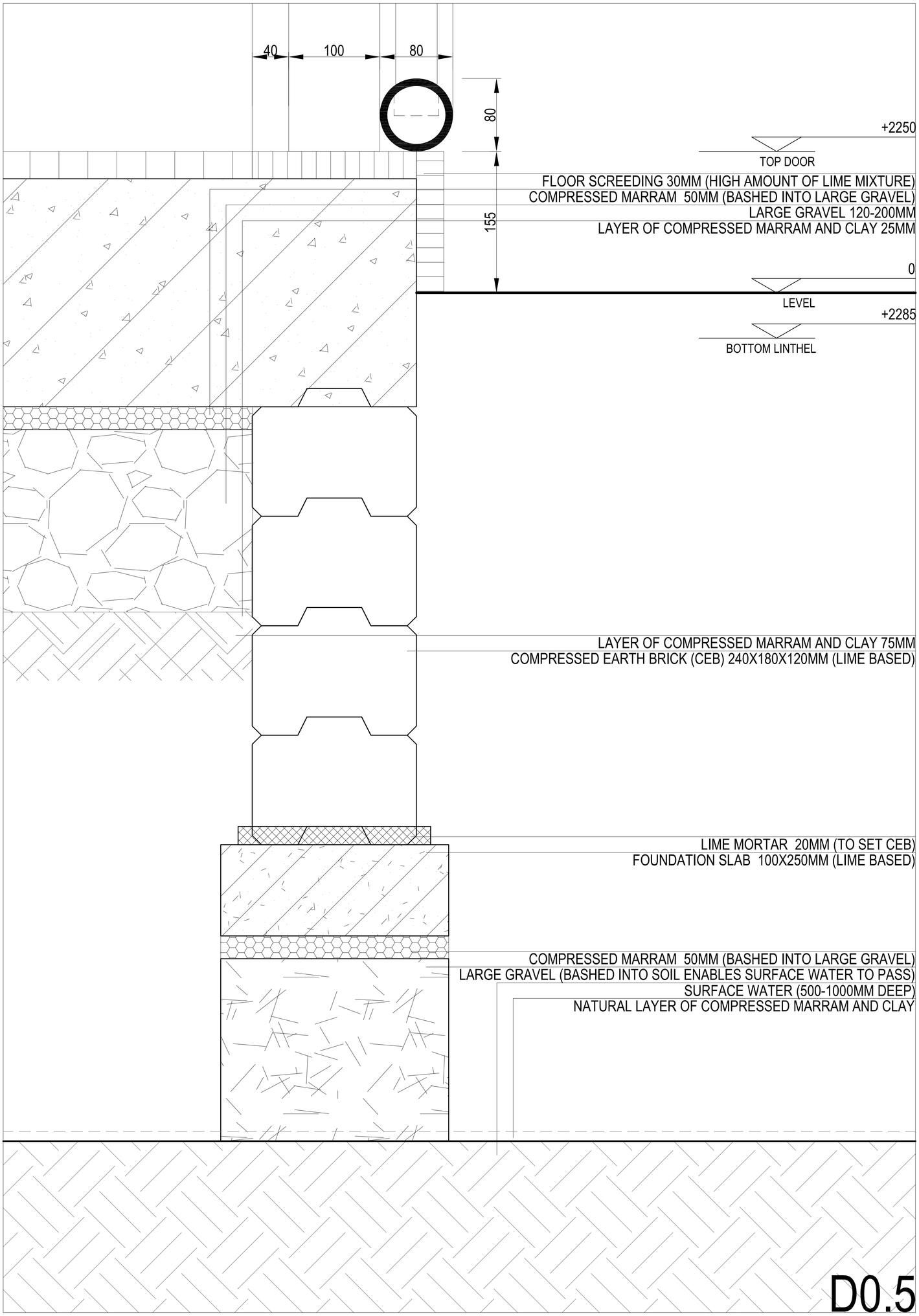
BAMBOO BRACE TO LOCK VENT. PIPE Ø115MM
BAMBOO VENT. PIPE Ø90MM
BAMBOO LINTEL 2 XØ120 (REINFORCED WITH LIME MORTAR&BRAIDED TOGETHER WITH BARK)
COW DUNG PLASTER 20MM (LIME INFORCED, NORTHERN FACADE)

D0.6

DETAILS 1:5



D0.7


40
100
80
80
155
+2250
TOP DOOR
FLOOR SCREEDING 30MM (HIGH AMOUNT OF LIME MIXTURE)
COMPRESSED MARRAM 50MM (BASHED INTO LARGE GRAVEL)
LARGE GRAVEL 120-200MM
LAYER OF COMPRESSED MARRAM AND CLAY 25MM
0
LEVEL
+2285
BOTTOM LINTHEL
LAYER OF COMPRESSED MARRAM AND CLAY 75MM
COMPRESSED EARTH BRICK (CEB) 240X180X120MM (LIME BASED)
LIME MORTAR 20MM (TO SET CEB)
FOUNDATION SLAB 100X250MM (LIME BASED)
COMPRESSED MARRAM 50MM (BASHED INTO LARGE GRAVEL)
LARGE GRAVEL (BASHED INTO SOIL ENABLES SURFACE WATER TO PASS)
SURFACE WATER (500-1000MM DEEP)
NATURAL LAYER OF COMPRESSED MARRAM AND CLAY

D0.5

DETAILS 1:5