title page

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Title: Masanga Dwelling
Subtitle: Environmental Architecture in an African Context

Thesis project by:
Rasmus Christensen Hamann (ma4-ark6)

Supervisor: Peter Lind Bonderup

Technical supervisor: Asger Hyldgård

In cooperation with: Architects Without Borders - Denmark

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Also including Appendix CD and Presentation folder

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Rasmus C. Hamann

synopsis

The project deals with an actual problem concerning lack of dwellings for the hospital staff in Masanga, Sierra Leone. The project is made in cooperation with the Danish department of Architects Without Borders.
The aim is to integrate parameters such as material technology, natural ventilation, daylight and cooling/heating in the project and due to the economic frame of the project low tech solutions are in focus. The design will be carried out as a prototype of staff dwellings and an overall master plan of the area wherein the dwellings are placed. The overall basis for the design is the climatic context being warm and humid.
As a point of departure for the project, field work is made in Masanga. Here the sociologic, cultural and topological context is investigated and registrations of the site are made.

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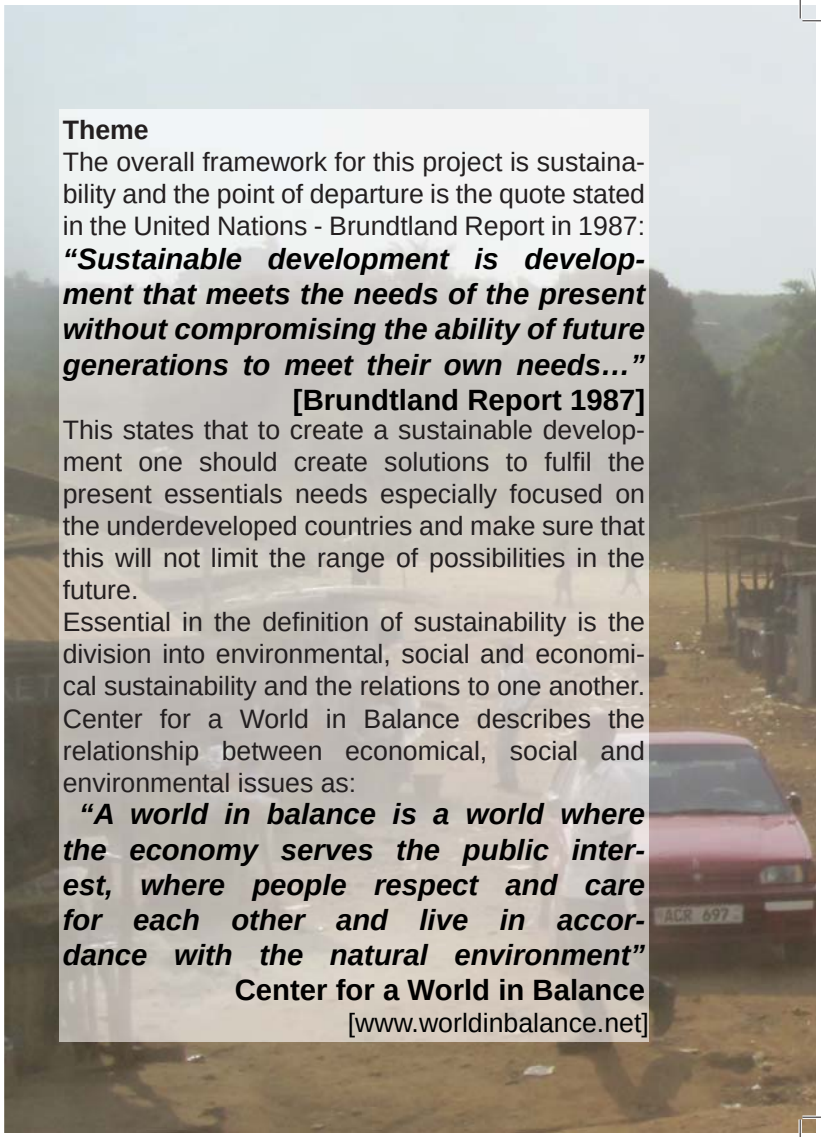
Introduction

This report contains the program and process of the master thesis project by Rasmus C. Hamann specialized in Architectural Design at the Department of Architecture and Design at Aalborg University.

The project deals with a sustainable solution for the design of staff housing for Masanga Hospital in Sierra Leone, Westafrica. The project is made in cooperation with the Danish department of the NGO Architects Without Borders (AWB), which aim is to develop the build environment and to support those who do not have access to the knowledge of an architect. The Danish department of AWB was introduces in 1998 (see app. 1).
[www.arkitekterudengraenser.dk]. As a starting point for the project a field trip to Masanga in Sierra Leone was made.



Theme

The overall framework for this project is sustainability and the point of departure is the quote stated in the United Nations - Brundtland Report in 1987:

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs…"

[Brundtland Report 1987]

This states that to create a sustainable development one should create solutions to fulfil the present essentials needs especially focused on the underdeveloped countries and make sure that this will not limit the range of possibilities in the future.

Essential in the definition of sustainability is the division into environmental, social and economical sustainability and the relations to one another. Center for a World in Balance describes the relationship between economical, social and environmental issues as:

"A world in balance is a world where the economy serves the public interest, where people respect and care for each other and live in accordance with the natural environment"

Center for a World in Balance

[www.worldinbalance.net]

ill. 5.1: informal settlement in Sierra Leone
ill. 5.2: diagram of the relation between ecology, society and economy

Design to improve life

One of the basic needs that are not fulfilled in various underdeveloped countries is the need for habitation and sanitation.

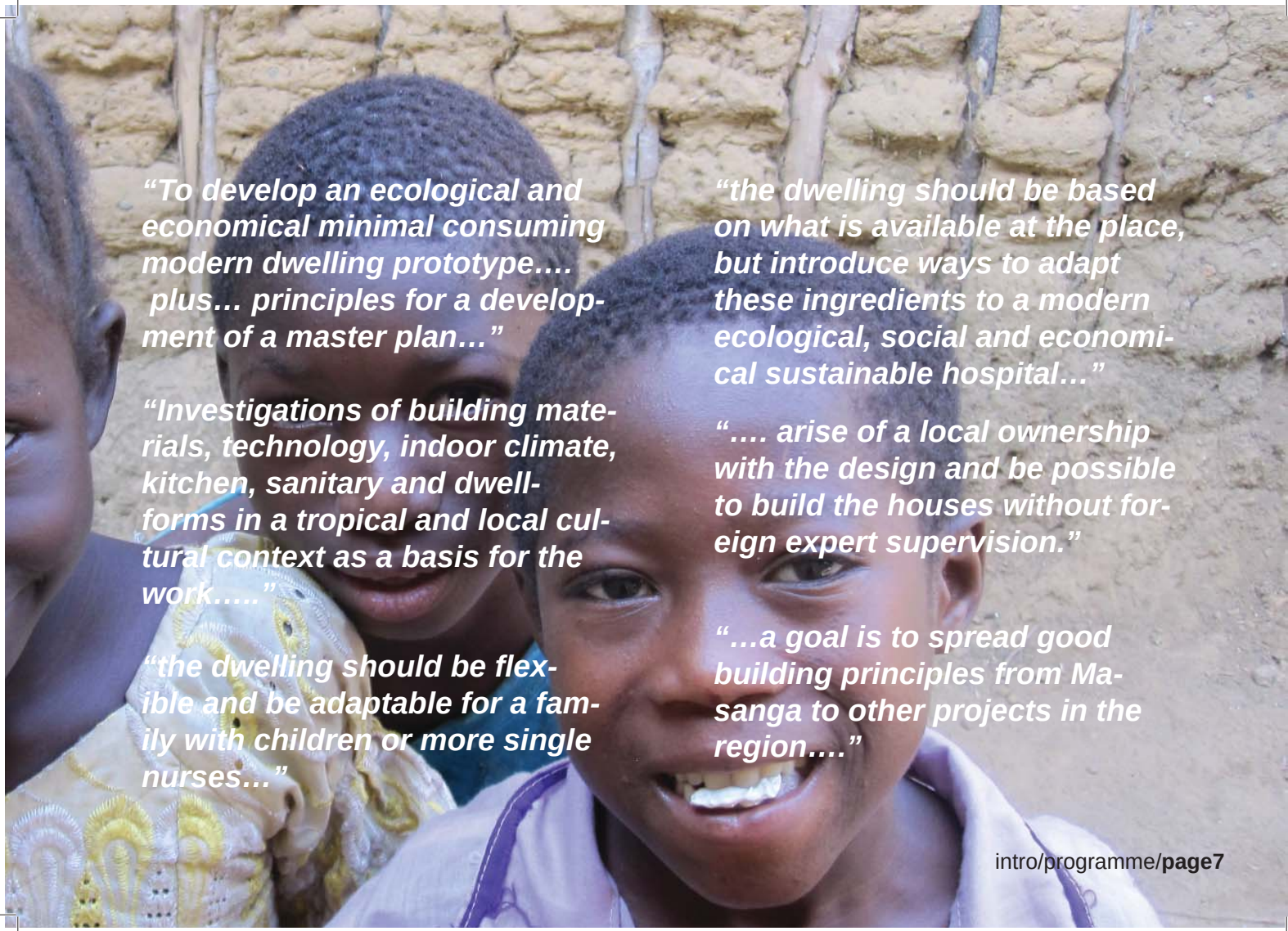
"600.000.000 urban dwellers and 100.000.000 people in rural areas live in overcrowded and poor-quality housing – slums and squatter settlements, old buses, shipping containers, and railway platforms"

[Architecture for Humanity, 2006]

Acting as a bottom-up principle the issue of proper habitation and sanitation is what is being dealt with in this project and hence supporting an agenda of helping people that really needs it.
Sierra Leone is one of the poorest countries in the world due to the civil war that ended in 2002. [www.um.dk] The Danish department of Architects Without Borders has together with other NGOs e.g Association of Friends of Masanga (AFOM) supported the Masanga hospital and the nearby area throughout years.
This project will be a contribution to the development of the area consisting of improvement of the living conditions for the local staff at the hospital.

The project will act as a starting point for the later construction of dwellings in the area.
The aim of the project is initially stated by Architects Without Borders and can in overall terms be summarized as the quotes on the following page (translated by author, see app. 2).[Sollien, 2009]
These statements will together with conclusions made of the analysis throughout the program act as a starting point for the creation of a vision for the project.

ill. 6.1: children in Masanga



"To develop an ecological and economical minimal consuming modern dwelling prototype…. plus… principles for a development of a master plan…"

"Investigations of building materials, technology, indoor climate, kitchen, sanitary and dwellforms in a tropical and local cultural context as a basis for the work….."

"the dwelling should be flexible and be adaptable for a family with children or more single nurses…"

"the dwelling should be based on what is available at the place, but introduce ways to adapt these ingredients to a modern ecological, social and economical sustainable hospital…"

"…. arise of a local ownership with the design and be possible to build the houses without foreign expert supervision."

"…a goal is to spread good building principles from Masanga to other projects in the region…."

method

In the following pages the method to the design is described. The overall design method is based on the Integrated Design Process (IDP), which characterizes projects which takes technical, functional and aesthetic parameters into consideration during the process. The IDP method is an iterative process, where different phases of the project interconnect and relate to each other forth and back. The program is for instance the foundation of the sketching phase, but the sketching phase can also affect the program and imply new or more elaborated analysis. The loops go on all through the process as the different phases affect each other and imply reconsiderations, new analysis followed by new sketching. The IDP can basically be divided into the following phases. Se ill. 9.1 on the following page.

The analyzing phase

Important aspects that is needed to start up the sketching phase is analyzed. This is for example the fieldwork done in Sierra Leone, where a context analysis was made. This process results in an architectural program, containing the aim for the project and a description of technical and architectural design parameters. The investigations made in the analyzing phase has an impact on the design of the staff dwellings.

The initial investigations/sketching phase

Through this process the architectural approach and the technical ideas are tested in relation to each other and evaluated according to the architectural program and design parameters. At the end, the best concept are selected for further elaboration and optimization.

The synthesis phase

In this phase the dwellings reach its final form and expression and detailing, adjustments and calculations are made based on an optimization of the considered parameters.

The presentation phase

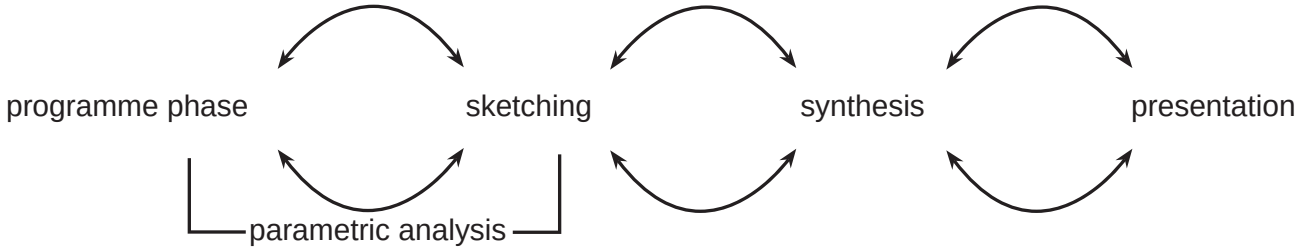
The final phase contains most of the visualization. It is presented in a way that focuses on the qualities of the project in relation to the aim stated in the analysis phase, and can be seen as a description of how the demands from the analysis phase has been achieved.

Architect/engineer

Especially when working with environmental sustainability in architecture it makes sense to integrate the disciplines that typically are managed by the engineer with those managed by the architect. Also the idea of working parallel in different scales can be included, this ensures that one scale is not the dominant and parameters on all levels will be considered.

Parameters

To create a symbiosis between design and analysis a set of parameters can be stated as the basic design features e.g. the orientation of a building or the size of openings. These parameters can be used in a design constellation, which afterwards can be evaluated by various building simulation software, e.g. Ecotect, Virtual Environment or BSIM and then create the basis for a new design constellation. This process in an ongoing process – an Integrated Design Process.(see ill. 9.1)
[Hansen & Knudstrup, 2004] [Hansen, 2007]



ill. 9.1: diagram showing the integrated design process

Field work - working contextual rather than conceptual

The project has its origin in a specific place – Masanga in Sierra Leone. A field trip to Masanga takes place in the beginning of the project period to experience and investigate the place. The aim is to write an architectural program and make investigations as the basis for the design project. It is seen as an important in this project to be able to make the project take off in and discuss the locale traditions and conditions. However statements and conclusions in this report are based on empirical data and experiences made in Masanga and in Sierra Leone.

The initial fieldwork is seen as essential for the project, and thus to be able to build in such a special context as the African bush without having experienced the place.
Furthermore a general theoretical approach throughout the project is critical regionalism (which will be explained in the theory section on page 12) that suggests a deeply understanding of the context to be able to make an implementation of a new design.
Through the fieldwork, the following points has to be considered.

a) A registration of the site through photos, measures and drawings.
b) Investigations of the context on a more overall level – containing topology, infrastructure, but also organizational and sociological issues. As an example what kind of tools is available for a building project?
c) The African dwelling – how do the locals live and dwell. What kind of spatial preferences do they have?
d) Collection of knowledge that can be used as inspiration for a later design – for example landscape structure, local building traditions or local materials.
The points can be interpreted as three major keywords – talking, measuring and exploring. Where the talking comprises interviews with potential users, chats with the local craftsmen, and talks with the architects and other volunteers in Masanga.
Measuring or registration is an ontological approach where the site has been measured and different registrations of existing houses has been made.
Exploring is being in the area and to experience the place and the surroundings, thus establishing an overall idea about the social, cultural and topological context. (see ill. 11.1)

ill. 11.1: illustration of the field work approach

theory

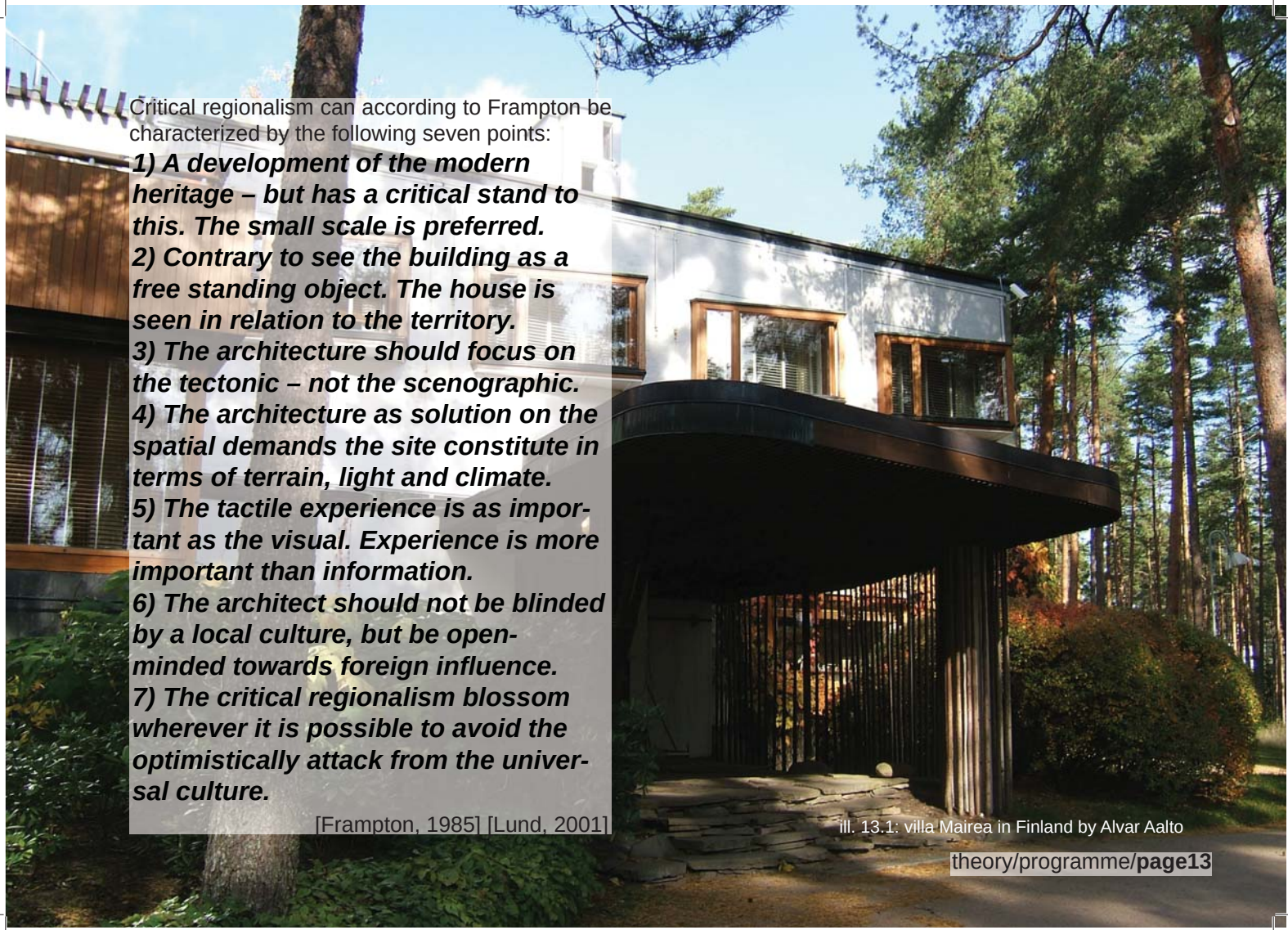
"Everywhere throughout the world, one finds the same bad movie, the same slot machines, the same plastic or aluminum atrocities, the same twisting of language by propaganda etc….." quote Paul Ricour [Frampton, 1985]

The main issue in the project concerns the implementation of a modern design in an underdeveloped area of the world. How does the design meet the place? Thus the design is what is brought to the place in terms of universal strategies, ideas and standards and the place is the cultural, social and topological conditions of the place.
To establish an architectural theoretical basic for how to approach this issue especially Kenneth Frampton's Towards a critical regionalism has been taken into consideration.

"...how to become modern and to return to sources; how to revive an old, dormant civilization and take part in universal civilization… " quote Paul Ricour [Frampton, 1985]

The paradox set up by Paul Ricour express the basic of what Frampton deals with in his critical regionalism. The aim for architecture is to create mediation between on the one hand the universal civilization and on the other the peculiarities of the specific site.
Through decades the globalization has created an international standard that destroys the ethic and mythological properties of a certain place. The discussion is about how to be modern in the globalized world, but still being regional with roots in the place and the culture. The two extremes are: a) the optimized building technology that creates a rather high-tech expression of the modern buildings or alternatively the modern technology is covered by a façade which hides all the units of the universal system. b) an unrealistic return to the preindustrial era, like a nostalgic and sentimental trip to the past which is often seen in regional architecture. [Frampton, 1985]

An example where the universal and the regional meet is seen in Alvar Aaltos Villa Mairea. It expresses how the white international functionalistic and cubistic morph into a more traditional Finish vernacular style. Another interesting viewpoint is the relation between the building and the landscape – between the culture and the nature. This is seen especially in the plan which is reaching out into the Finish forest with the use of columns which creates a relation to the surrounding trees. See ill. 13.1 [Lund, 2001]



Critical regionalism can according to Frampton be characterized by the following seven points:

1) A development of the modern heritage – but has a critical stand to this. The small scale is preferred.
2) Contrary to see the building as a free standing object. The house is seen in relation to the territory.
3) The architecture should focus on the tectonic – not the scenographic.
4) The architecture as solution on the spatial demands the site constitute in terms of terrain, light and climate.
5) The tactile experience is as important as the visual. Experience is more important than information.
6) The architect should not be blinded by a local culture, but be open-minded towards foreign influence.
7) The critical regionalism blossom wherever it is possible to avoid the optimistically attack from the universal culture.

[Frampton, 1985] [Lund, 2001]

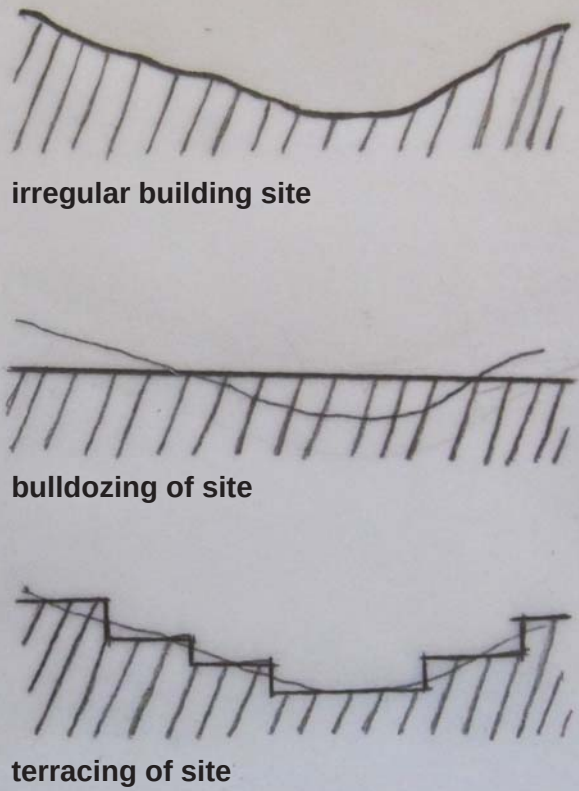
ill. 13.1: villa Mairea in Finland by Alvar Aalto

The architectural implementation

A synthesis between the global civilization and the elements derived from particularities of a place can be established by inspiration in the quality of local light, the tectonics of a unique local structure or the topography of a certain site.

The interplay between the nature and the architecture has a great importance. As an example Frampton mention how artificial light in a museum creates a non-place for the art, whereas an indirect light would change over time and create a place-conscious poetic derived from the interplay between nature and culture. The same goes for natural ventilation – it that gives an indirect relation to the nature.

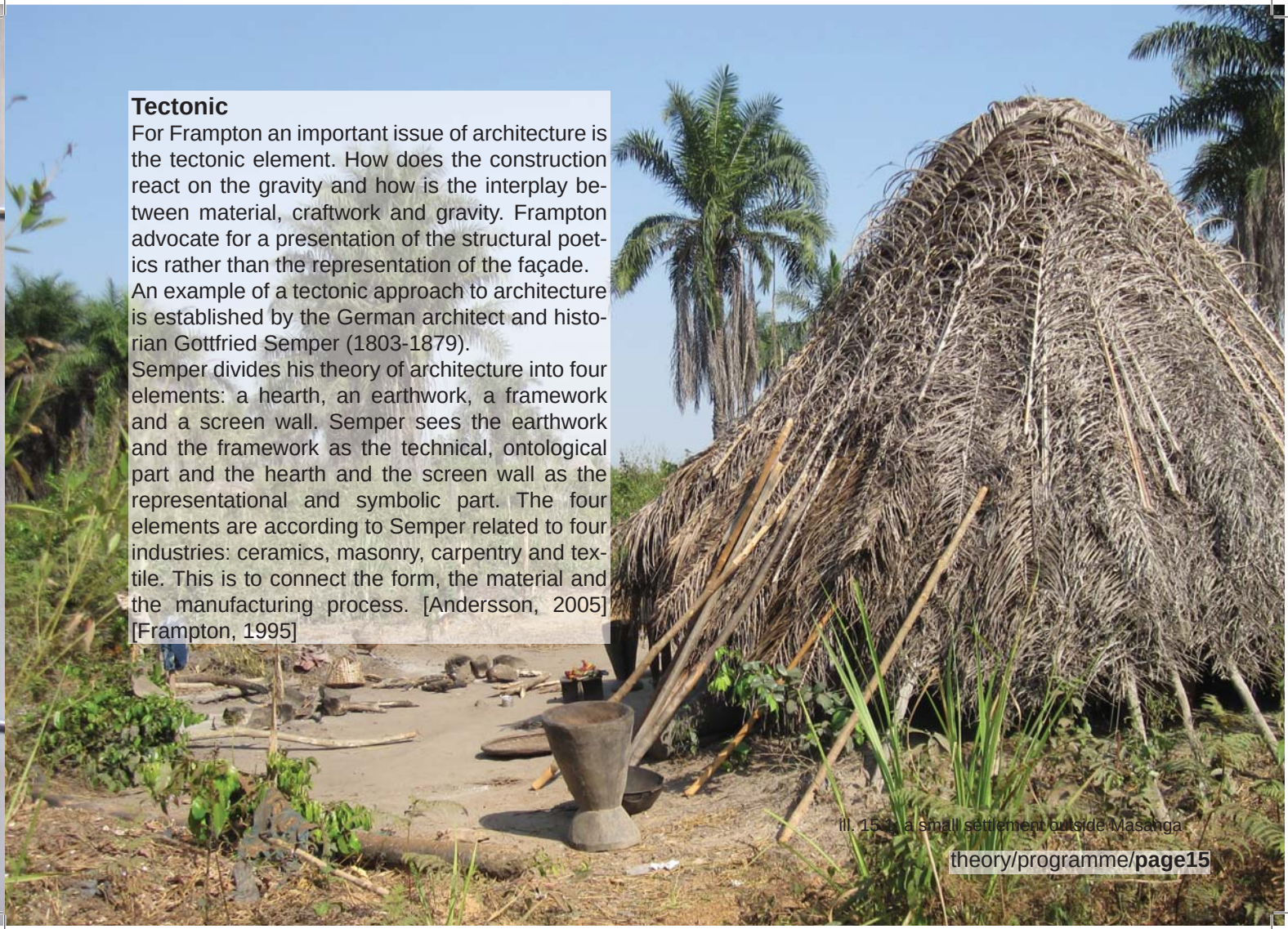
In modern architecture an irregular topography of a site is bulldozed to create a sort of empty spot – which will create placelessness, whereas a terracing of the terrain would create a simple cultivating of the site (see ill.14.1). [Frampton, 1985]



ill. 14.1: illustration of the site regulation princip that Frampton mention

Tectonic

For Frampton an important issue of architecture is the tectonic element. How does the construction react on the gravity and how is the interplay between material, craftwork and gravity. Frampton advocate for a presentation of the structural poetics rather than the representation of the façade.
An example of a tectonic approach to architecture is established by the German architect and historian Gottfried Semper (1803-1879).
Semper divides his theory of architecture into four elements: a hearth, an earthwork, a framework and a screen wall. Semper sees the earthwork and the framework as the technical, ontological part and the hearth and the screen wall as the representational and symbolic part. The four elements are according to Semper related to four industries: ceramics, masonry, carpentry and textile. This is to connect the form, the material and the manufacturing process. [Andersson, 2005] [Frampton, 1995]



ill. 15 - a small settlement outside Masanga

Important in Sempers theory is the socio-cultural relation, meaning that what creates and determines the architecture are not only the materials and the structure but also the context being the climate, the environment and the religious and social circumstances has a great influence. The architecture is always a consequence of the context in which is it placed and the socio-cultural frame of the observant.
Semper works with two concepts – tectonics and stereotomics. Tectonics is the fundamental structure – the lightweight frame. And stereotomics is the heavy construction – the base or earthwork. The role played by these concepts change according to the climate, tradition and materials available in the context.
Frampton also discuss these two concepts:

"..framework tends towards the aerial and dematerialization of mass, whereas the mass form is telluric, embedding itself deeper in the earth. One tends toward the light and the other toward dark. These gravitational opposites . . . may be said to symbolize the two cosmological opposites to which they aspire; the sky and the earth..."

[Frampton, 1995]

Summary

The reading of Frampton and Sempers theories creates a theoretical base for how to approach the design in the project.
Frampton's seven points can in the development of the project act as guidelines or point of interest to create a merge of the universal technology and standards and the place and the local culture - to create a contemporary design without neglecting the past.
Already by the planning of the fieldtrip to Masanga a positioning according to the context occurs. By actually going there a responsibility of involving the local culture seems obvious.
Semper mention a similar importance of the context of architecture – comprising the climate, the environment, the culture and so on. This corresponds to the idea in this project about a climatic, environmental and cultural relation to the context.
In addition Semper's division into tectonics and stereotomics seem appropriate in relation to a reflection of the site and the climate in the choice of material.

ill. 17.1: elevated goat house

context

History of Sierra Leone

Sierra Leone is placed in the western part of Africa. The population is divided into various ethnic groups – the two major groups are Mende and Temne. The official language is English, but the local communication is based on Krio. Despite of various religious and ethnic groups in Sierra Leone this has not been the motivation for any major conflicts.[Holmertz, 2008]

Sierra Leone was founded in 1787 and had before been an important area for the export of slaves. Initiated by Great Britain's campaign against the trade with slaves the capital of Sierra Leone was also founded in 1787 and named Freetown for the released and runaway slaves.

In 1896 the country was declared British protectorate and was so until 1951 where the first ordinary election took place. Sierra Leone was declared independent in 1961.

The civil war of Sierra Leone was ignited by the Liberian warlord Charles Taylor, who was seeking revenge for the Sierra Leonean military contribution to the international forces in the Liberian war. Charles Taylor was supporting the Revolutionary United Front (RUF) in Sierra Leone who was against the governmental regime. RUF financed their activities by smuggling diamonds and was known as having an aggressive attitude against the civil population. [Holmertz, 2008]

By the end of the civil war in 2002 approximately 50.000 people had been killed, 250.000 women had been raped, thousands had been mutilated and around 10.000 children had been kidnapped and used as child soldiers.

After the war Sierra Leone is at the bottom of UN's development index, which includes lifespan, child mortality, health, access to clean water, educational level etc. [www.um.dk]

"165 children of 1000 dies before the age of one and more than 200 children of 1000 never reach the age of 5"

UNICEF [www.um.dk]

"About four-fifths of the population lives in absolute poverty, forced to survive on less than 60 pence a day"

CARE [www.careinternational.org.uk]

"Sierra Leone rank as number 179 and at the bottom of UNDP's Human Development Index 2006"

Danish Ministry of Foreign Affairs

[www.um.dk]

ill. 18.1: house in Freetown

Sierra Leone
Area - 71.740km2
Population - 5,7mio.
Average lifespan - women 38 years, men 38 years
Analphabetism - women 79%, men 60%
Religion - Islam 50%, Christianity 40%, Traditional religions 10%

ill. 19.1: map showing Sierra Leone in Africa and Masanga in Sierra Leone

context/programme/**page19**

Masanga history

Masanga is placed in the northern part of Sierra Leone in the Tonkalili district. The Masanga hospital(see ill 20.1) was founded in 1948 to treat leprosy patients.

Previously the area was used by a logging company.

After the independence in 1961 the hospital was run by the Seventh day Adventist Church and became an acknowledged hospital all over Sierra Leone.

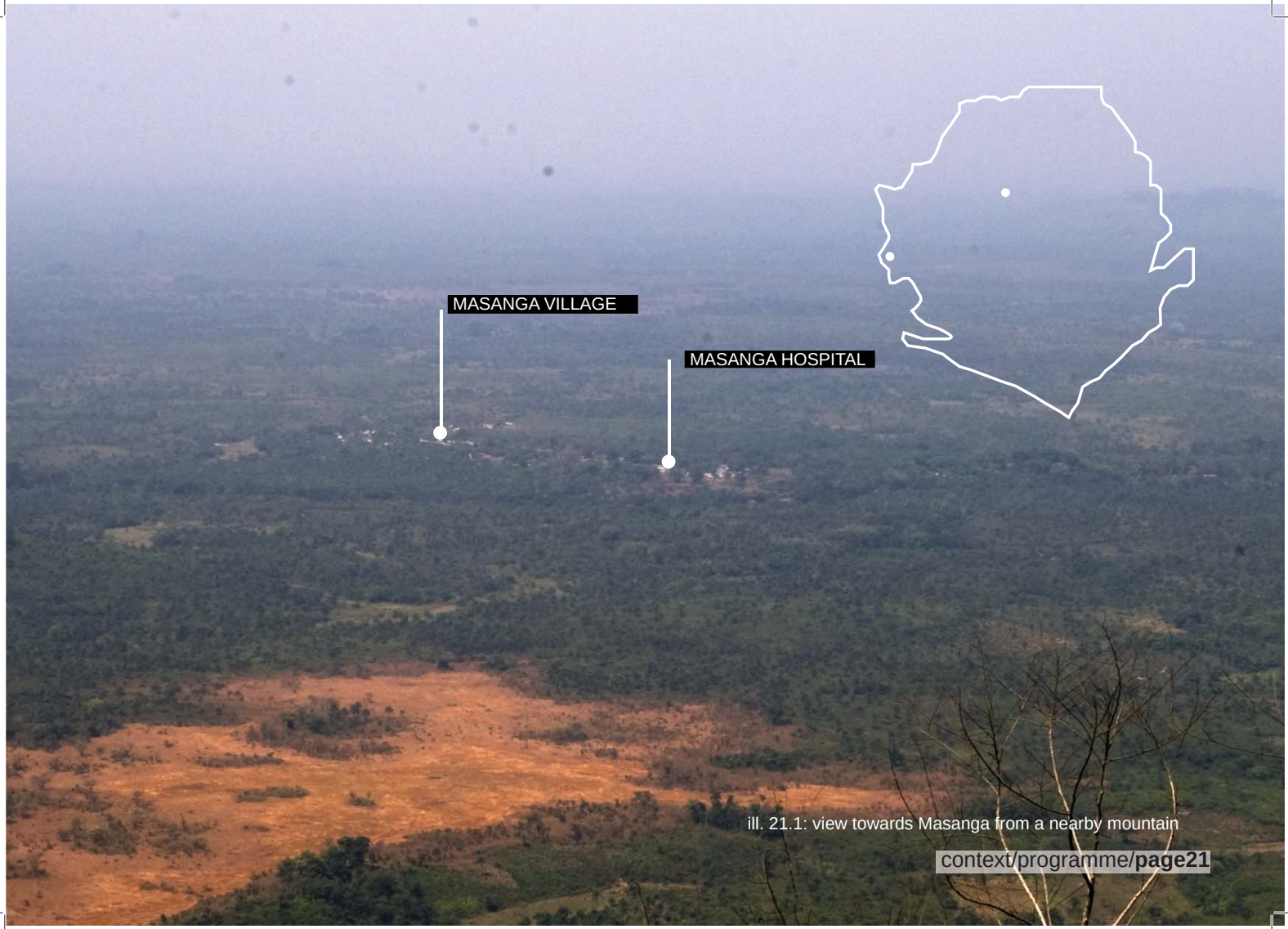
During the civil war the hospital area was used as a base for the rebels (RUF) and the staff and patients had to flee.

After the war the hospital was re-opened in 2006 by a Danish private initiative and is now run as a corporation between the local staff and various NGO's. [Architecture Sans Frontières]

Throughout years several volunteers from especially Denmark go to Masanga to help doing various projects. Association of Friends of Masanga (AFOM) is the organization that is organizing this volunteer work.

A great focus is on the hospital and having Danish medical students and nurses to help in the hospital, but also projects as business development is in focus to provide work for the locals and earn money to run the hospital. Examples of projects are a chicken farm, a tailor shop and a bike shop. [Architecture Sans Frontières, 2009].

ill. 20.1: The Masanga hospital



ill. 21.1: view towards Masanga from a nearby mountain

Mapping Masanga

In the following section a mapping of the Masanga area is made. A selection of layers investigated in terms of the program, the infrastructure and the landscape in and around Masanga (see ill 23.1).

Program

The program in and around Masanga can be divided into three main types - the village, the hospital compound and the former hospital staff housing area.

1)The village contains housing for the locals, a couple of schools and some smaller shops/kiosks and a small bar. The village consists of typically one-storey clay houses and it is quite dense. The few public programs as the school are made in concrete. In the periphery of the village a small enclave or separate village is placed where the leprosy patients are living.

2)The hospital compound contains various departments of the hospital, a garage, a workshop, an adult education centre and staff dwellings. All the buildings on the hospital compound are made of concrete.

3)The former hospital staff area contains a hostel for volunteers, houses for upper level staff, a renovation project of AWB, and a great amount of ruins of former hospital staff dwellings.

The infrastructure and the landscape

The two main structures in the area are the river and the dirt road. The road, which is a gravel road, runs through the village and the houses is placed adjacent to this.

Besides acting as a traffic spine through the village, although not that many vehicles pass daily, the road also acts as a multi-programmatic space where people dry their clothes and crops, keeping their hens and goats and a place for the children to play.

From the main road smaller non-motorized roads connects to the rest of the village.

The river is 5 minutes walk from the village and is where most of the inhabitants in the village do their laundry, but also where leisure activities like bathing and swimming takes place. Furthermore there is a place that is connecting to the opposite bank by canoe and by wading – this is the connection for workers and school children that live in the villages on the other side of the river. Across the river some gold mining also takes place.

A smaller branch of the river is dividing the hospital compound from the former hospital staff area.

The rural landscape around Masanga is mainly the result of the large amount of cutting of the trees in the former rain forest. A few places the existing forest is still present, but elsewhere the landscape is a constellation of lower bushes and some spread palm trees.

Around the area a small amount of agriculture takes place, comprises palm trees plantation, rise, cassava and maize fields.

ill. 23.1: three-layered map of Masanga

Pictures from the area

To give a general impression of the Masanga area some illustrations are shown according to the program and infrastructure in the area.

a small shop

the river

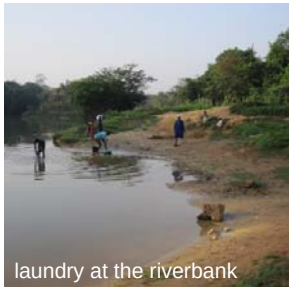
the old forest

the road

rise fields

ill. 24.1-24.5: pictures from Masanga

gold mining


laundry at the riverbank

the canoo for crossing

deforestation

the church

the well

the street in the village

the hospital

ill. 25.1-25.8: pictures from Masanga

Existing housing in the area

Walking through Masanga village and the surrounding area one finds certain types of housing. From the more traditional looking houses made out of clay or palm leaves over the wooden houses made by the logging company that was situated in the area more than an half century ago, to the concrete houses build by the Seventh day Adventist Church after the independence.

ill. 26.1: concrete house

Concrete houses

Primarily found in the area around the road between the hostel and Masanga 2 and build by the Seventh day Adventist Church for upper level staff.

ill. 26.2: clay/thatch house

Clay houses

Found in the village as a family dwelling. The houses are constructed from what material available in the bush. In this case clay bricks are used, but the walls can also be constructed as a wooden framework plastered with clay.

ill. 27.1: palm leaves house

Palm leaves house

Found in the outskirts of the village and in the rural district – used primarily for storage and for short term stay for example in connection with farming.

ill. 27.2: wood house

Wooden houses

Found in the area around the hostel and the hospital and was built by the logging firm. At the moment Architects Without Borders is working on the renovation of one of these houses.

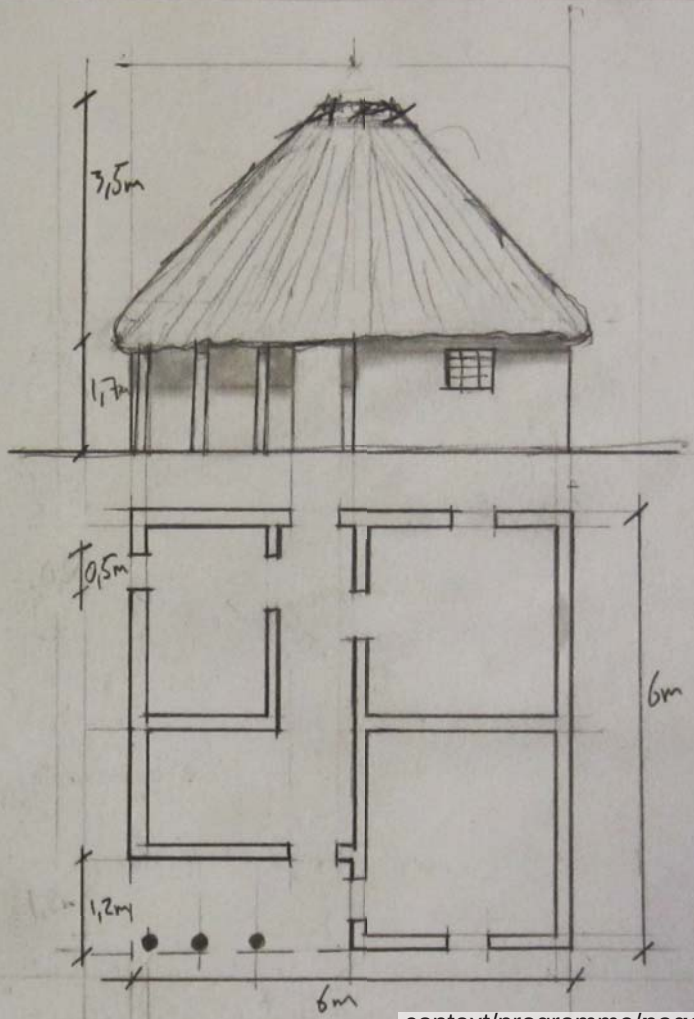
Case - traditional Masanga house

To understand the constellation of a traditional clay house, a visit to Albert Ramsu's house was made. He is a local, who are working as an assistant at the eye clinic at the Masanga hospital and a potential resident of the new staff housing.

The house was completed last year and Ramsu explained how he had built the house himself with help from other locals and with materials that was available in the bush to make it as low cost as possible. Before the war he was living in one of the concrete houses, that now is a ruin. Because a renovation of a concrete house would require materials that are more expensive, he chooses to build a new house with the materials that were available in the bush – which means materials for free. The only expense was for some rope to make the joins in the construction and a minimum of bolts.

ill. 28.1: roof of Ramsu's house

The basic construction of the house is made of various sizes of bush-sticks (young trees of for example teak) in a grid structure. This wall structure has clay as cladding and the roof is covered with thatch. The floor is made of clay as well.
The house consists of a covered outdoor entrance area. In this area there are two doors - one to a separated room and one to the rest of the house. The house contains a living room and to sleeping rooms connected with a corridor. The corridor leads to the backdoor. Cooking takes place outside.
Inside the house is experienced as chilled compared to outside, but because of the relatively small windows the house is dark and uncomfortable in addition the house seems quite moist.



ill. 29.1: measuring of Ramsu's house

Material/building technology

During the field work an important point of investigation was the materials available in the area. The investigations are made by talking with the craftsmen, architects and engineers working in the area and through the experience made during the fieldtrip. Thus the considerations are based on empiric data from the fieldtrip.

To create an overview of the potential materials for the building project a scheme has been made wherein the different materials are evaluated according to parameters as economy, availability and maintenance.

Thus this section is considering more pragmatic parameters, whereas the more aesthetic and tactile values will be considered during the design process. The point of departure is the context, thus the selection of materials are limited to a certain amount of materials.

typically formed as bricks and dried in the sun. Another technique is to apply clay as cladding on a wooden frame structure.

clay

economy
maintenance
availability

building with earth can be made in various ways. E.g. rammed earth meaning cast walls in a mould with a mixture of sand, gravel and clay and a stabilizer e.g. cement.

earth

economy
maintenance
availability

Is used in various ways typically as the wall or roof structure together with other sorts of bush-sticks.

bamboo

economy
maintenance
availability

ill. 30.1-30.3: material diagram

The parameters are rated on a scale from 1 to 3 steps. Where the amount of steps are equal to how good an economic solution it is, how good a material it is in terms of maintenance and how available it is in the area. A division into two categories can be made. The material that is to find directly in the context e.g. clay or leaves which creates a good economic solution, but it has a great amount of maintenance for instance during the rainy season. On the other side sandcrete or wood is not directly available in the near context and thus being a more expensive solution.
The intension in the project is to create a sustainable solution that is related to the materials in the context and create new ways of treating or applying the materials.

consists of a mixture of cement and sand. Is similar to concrete however the amount of cement used is smaller. Typically formed as bricks or slaps.

sandcrete

In the area the wood can be divided into two categories. The bush sticks or trees found in the bush which are used untreated or the constructional timber.

wood

Is typically used as roof covering or as part of walls covered with clay. The same use goes for thatch.

leaves

ill. 31.1-31.3: material diagram

Summary

The Masanga history has especially during the 1990's been a place for war and destruction. The present situation is still affected by the civil war, seen in the ruins around Masanga and in the poverty of the people living there.
Supported by foreign organizations the Masanga Hospital is getting a comeback as a highly appreciated hospital throughout Sierra Leone.
Through the mapping some potentials and weaknesses has been faced. Especially the idea of the road not only as a public space/square for various activities gives an impression of the informal structure the culture has especially to the spatial surroundings.
This relation is also seen in the constellation of the public and private where the only private is the indoor of the houses. They do not have a garden or outdoor space that cant be accessed by others. And whether the hens of one neighbor are staying on the plot or on the neighbor plot seems not to be important.
Contrary to the interesting in the main road is the dust created by the few vehicles passing by because the houses are placed relatively close to the road. Furthermore noise and a security issue should be noticed.

In and around Masanga a problem in the deforestation is present. On a global/national level this can course an increase in the Carbon dioxide concentration, and the arise of desert.
[www.climateminds.dk]
On a local level it can lead to erosion and especially change of the microclimate in terms of shading and humidity.
An integration of planting trees can be a solution where the architecture also can benefit from it.

The visit to Ramsu's house changed the sentimental idea of the traditional house of providing a good comfort. Although it was more chilled than outside, there was no air movement and no light which created a not that attractive atmosphere.

The material of construction is influenced by the economical situation of the user. Where the easier available and low tech material solution is cheaper.
However the cheap materials demand a lot of maintenance and might not provide the best living conditions. This is going to be further investigated in this project.

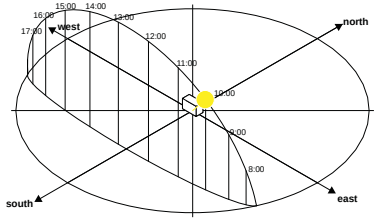
ill. 33.1: opening showing framestructure in Ramsu's house

macro climate

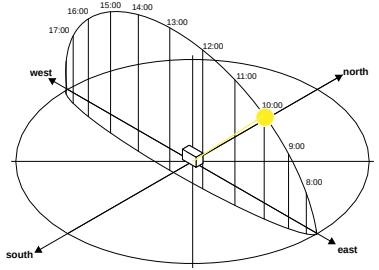
The climate in Sierra Leone is tropical, warm and humid and has a rainy season, which spans from May to October. The dry season begins when a dry wind reaches the country from the Sahara. [Holmertz, 2008]

Sun path

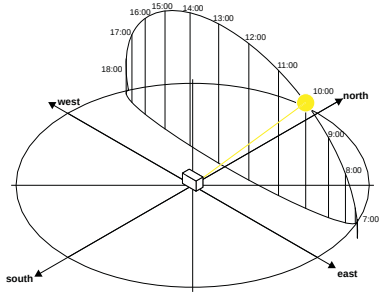
The location of Masanga at Longitude: 11° 50’ 0” West and Latitude: 8° 47’ 0” North means that it is placed close to equator and if you compare with the solar conditions in Denmark it is quite different. As seen in the sun path diagram at the right the sun will be not hit the northern facade of a certain building around winter solstice. However because the zenith position of the sun during the summer is placed north of the location the south façade will not have any solar radiation during the summer. (See sun path and solar altitudes in app. 5)



Winter solstice(December)



Equinox(March/September)



Summer solstice(June)

ill. 34.1: sun path diagrams for Masanga

Climate data

Caused by the lack of climate data from Masanga or Sierra Leone in general, data from www.energyplus.com concerning Accra in Ghana is used to have an idea about the general weather conditions. This goes for the wind, temperature and humidity data, but the data about the sun path is correct for the Masanga area.

It is possible to get data from Ghana or Senegal, but because Ghana is closer to the latitude of Masanga this is considered as been more representative for the weather in Masanga, since the climate belts of the earth is closer connected to the latitude.

Although the weather data from Ghana is used as the representative for the weather in Masanga, it is worth mention that the local climate conditions can vary from one another because Accra is placed by the sea at a south facing shore and Masanga is placed approximately 4 hours drive from a south-west facing shore. Factors as the wind and humidity will especially be affected by this, but also the temperature is varying depending on the distance to the sea.

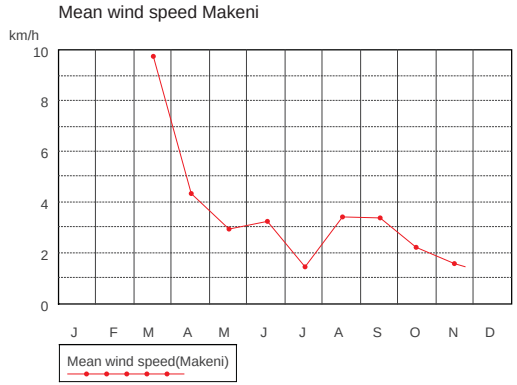
In the case of some kind of use of this project in reality it will be recommendable to verify with data collected for the specific site. The climate data is generated based on the building simulation program Ecotect.

Wind conditions

From very moderate data from the nearby city Makeni in Sierra Leone an idea about the very weak wind conditions in the area is seen.

In ill 45.1 the mean wind speed are illustrated for the year 1983. It does not extent 10km/h and the average is 3,6 km/h.

In app. 5 a wind rose for Accra is shown and this states that the dominant wind direction is from the south west. But this should again be considered in relation to that Accra in placed on a south facing shore and it might be difficult to transfer this data to Masanga. Based on the experiences in Masanga it seems to be wind from the east that is the dominant.

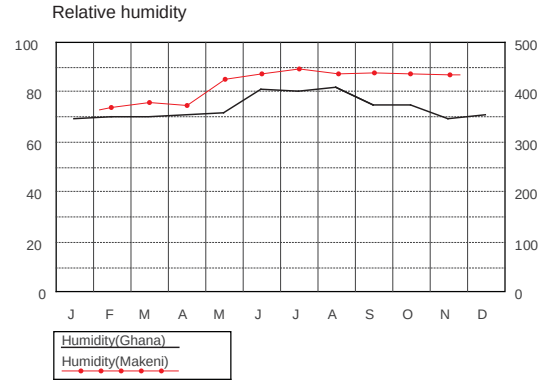


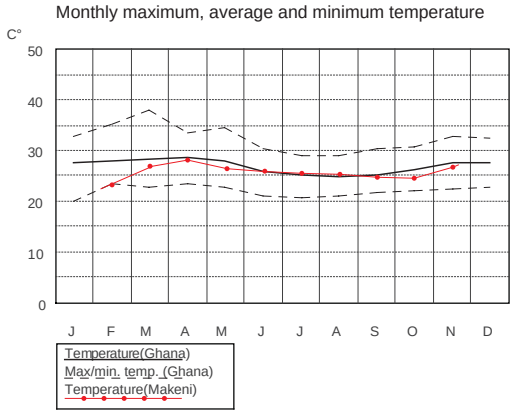
ill. 35.1: windrose for Accra

Humidity and temperature

Characterizing a warm humid climate is the relatively high relative humidity, often between 60 and 100% [Koch-Nielsen, 2002]. As seen in the ill. 46.1 the humidity is between 70 and 80% in Ghana. Another characteristic is the quite narrow range of temperature through the year. This can be seen in ill. 46.2 where the average temperature is between 25 degrees Celsius and 29 degrees Celsius all year around.

The mouth average maximum is highest in March where it reaches 38 degrees Celsius and the mouth average is never lower than 20 degrees.





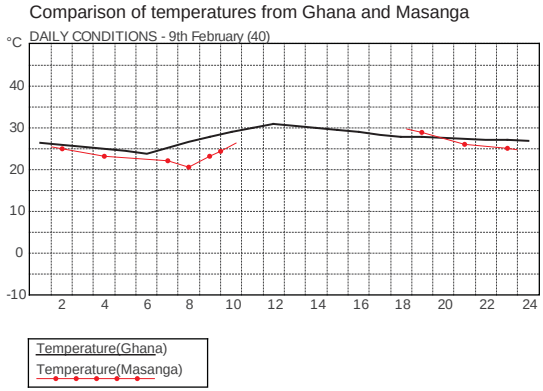
ill. 36.1, 36.2:humidity and temperatures of Accra/Makeni

Verification of weather data

Due to advocate for that the weather data from Ghana can be used as representing the weather data from Masanga, the Ghana data is compared with data from Makeni, a city near Masanga, where some weather data from the years 1983, 1984 and 1990 is available.

The red dots in ill. 46.2 show the available data from Makeni, that is very overall because it is only for a small amount of years. Compare the Makeni average temperature with the average temperature from Ghana there is obviously a coherency between the temperatures in the different months, although no data is available for Makeni in January and December.

A little more variation is seen in the humidity seen in ill. 46.1, but it still has some connection between the peaks and valleys of the curve.

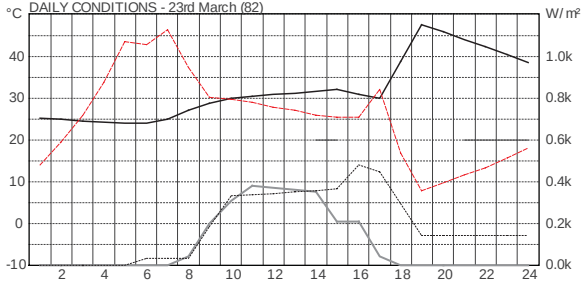


ill. 37.1: 24-hour climatic variations from Accra and Masanga

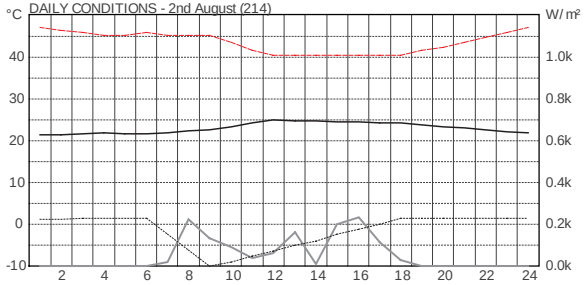
At the end of the fieldwork in Masanga a thermometer was located and it was possible to make a few temperature measurements during the last 24-hour. This is used to compare with the Ghana data from the same day – to see whether the 24hour temperature variations are similar. Although the temperature data from Masanga is limited and cannot be seen as representing the temperatures in Masanga it can still provide an impression about the coherency to the Ghana data and that the two curves can be interpreted in the same way.

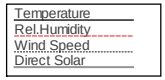
The hottest day is the 23rd of March where the temperature extends 45 degrees Celsius. This day has also a great range in the temperature dropping to around 25 degrees during the night.
The coldest average day is the 2nd of august where the temperature is between 20 and 25 degrees Celsius.
Thus the coldest day a year it is not less than 20 degrees Celsius.

Hottest day (average)



Coldest day (average)

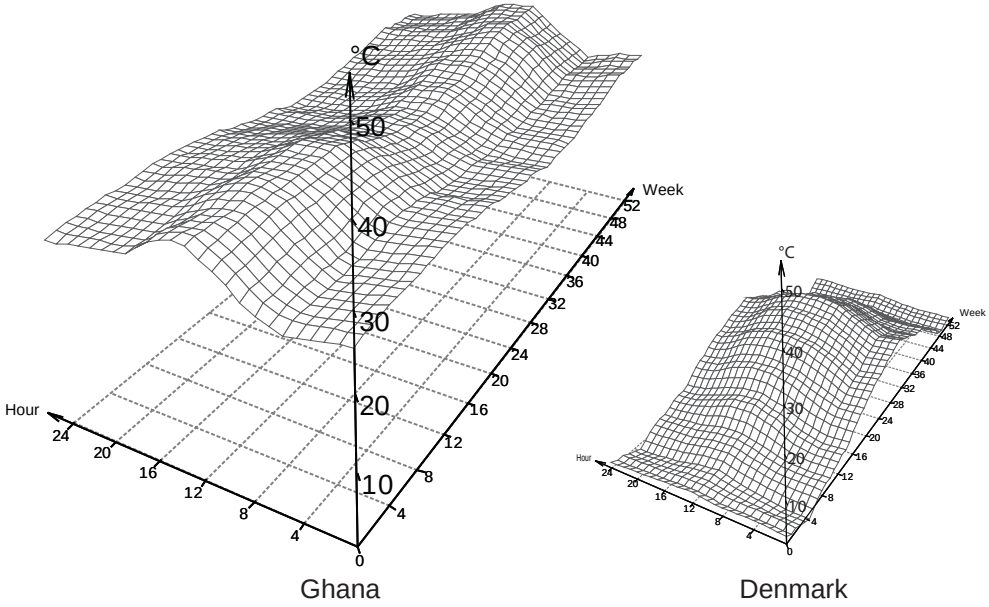




ill. 38.1: 24-hour climatic variations

The overall impression for the temperatures during the year and day can be collected in ill. 49.2 which shows the time a day at the left axis and the week during the year at the right. This shows clearly how little the temperature varies during the year, especially compared to Denmark.

Quite interesting is the fact that the 24hour temperature range is quite big, taken into consideration that a typically warm humid climate has a small 24hour temperature variation. [Koch-Nielsen, 2002]



ill. 39.1: 24-hour and annual temperature variation for Ghana(left) and Denmark(right)

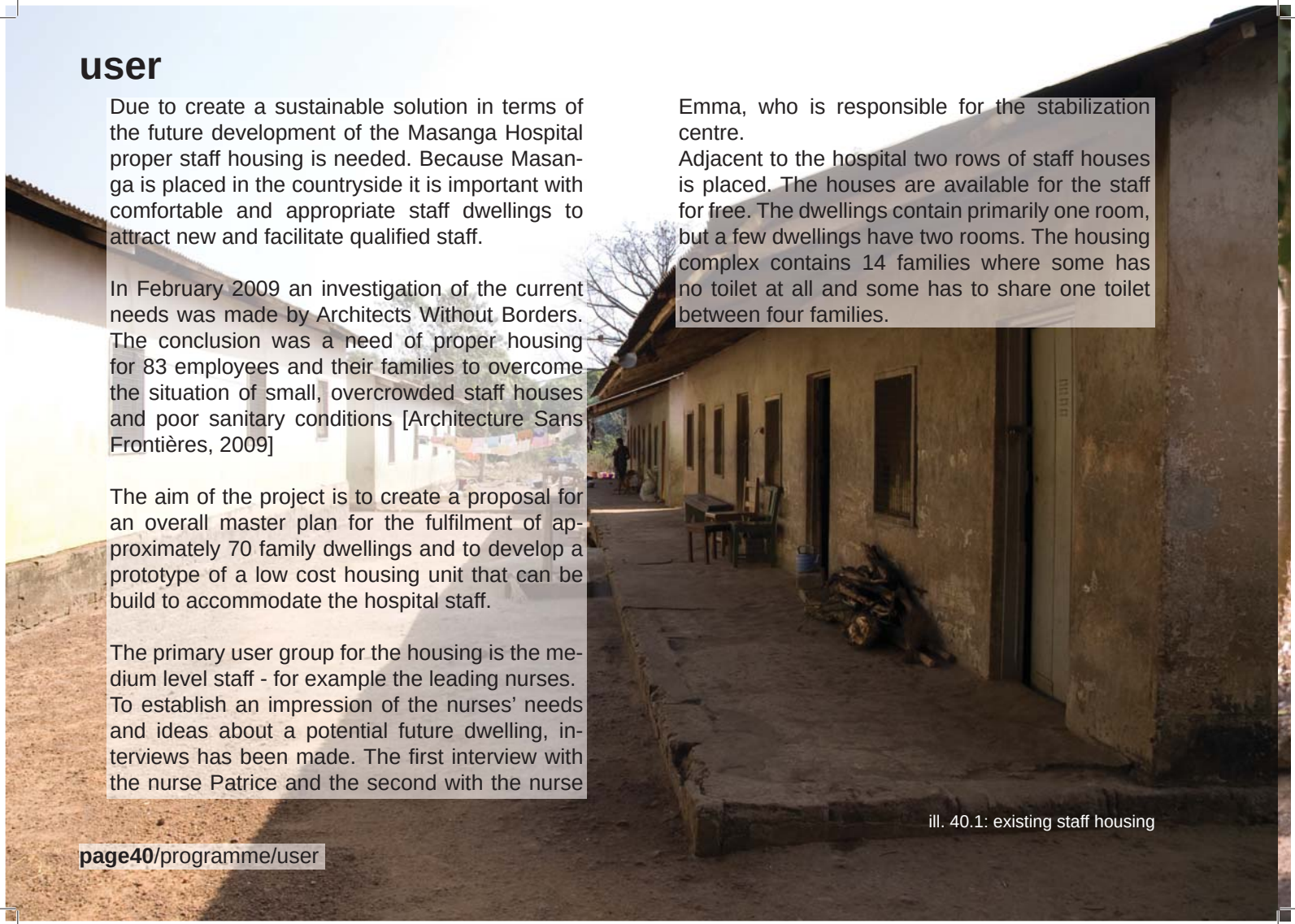
user

Due to create a sustainable solution in terms of the future development of the Masanga Hospital proper staff housing is needed. Because Masanga is placed in the countryside it is important with comfortable and appropriate staff dwellings to attract new and facilitate qualified staff.

In February 2009 an investigation of the current needs was made by Architects Without Borders. The conclusion was a need of proper housing for 83 employees and their families to overcome the situation of small, overcrowded staff houses and poor sanitary conditions [Architecture Sans Frontières, 2009]

The aim of the project is to create a proposal for an overall master plan for the fulfilment of approximately 70 family dwellings and to develop a prototype of a low cost housing unit that can be build to accommodate the hospital staff.

The primary user group for the housing is the medium level staff - for example the leading nurses.
To establish an impression of the nurses' needs and ideas about a potential future dwelling, interviews has been made. The first interview with the nurse Patrice and the second with the nurse Emma, who is responsible for the stabilization centre.
Adjacent to the hospital two rows of staff houses is placed. The houses are available for the staff for free. The dwellings contain primarily one room, but a few dwellings have two rooms. The housing complex contains 14 families where some has no toilet at all and some has to share one toilet between four families.



ill. 40.1: existing staff housing

ill. 41.1: staff housing toilets

Interview #1

The first interview was made with the nurse Patrice. The interview took place at the department of the hospital where he is working. (see app. 3)Patrice is living in a one-room dwelling with his wife and one of their children. The rest of his family lives elsewhere because of the small dwelling.
The interview was constructed to get an impression about what was bad about the present accommodation and what would be good in a future dwelling.
His primary concern about his present dwelling is the size of the room – approximately 10 square meters. And the fact that there is only one room – which means that everything should be in the same room.

His ideas can be summarized in following points:
- 3-4 rooms
- A sitting room, a bedroom for the boys, a bedroom for the girls and a bedroom for him and his wife
- a kitchen that contains water tabs, refrigerator, stove for gas and storage space
- an outdoor kitchen for making food on fire
- rooms separated by doors
- rooms size is approximately 10-15 square meters
- materials should be long lasting and low on maintenance like concrete or bricks.

After the interview we went to see his dwelling.
An interesting point in the talk was about the small house he had build for his chickens – it was placed on columns – the reason for that Patrice explained was to avoid the water in the rainy season, and to keep the chickens protected from bacteria and other threats.

ill. 42.1: The chickens' house of Patrice

Do you have some tips for us building in Masanga?
"It should be quick!!"

Patrice

Where do you prefer to eat?
"Some makes a separate room for dining. But this is Africa – we eat everywhere.
For example under the trees in the garden – where you can place a table."

Patrice

ill. 43.1: Patrice in his room

Interview #2

The second interview is made with the nurse Emma. (see app. 4) Like Patrice she also live in a single room staff dwelling. Her family lives in Freetown because there is no secondary school and college in the area.

Her concern about her dwelling is about the one-room problem. For her it is a big problem because whenever her sons or her uncle's visit her she have to borrow a room for them at one of neighbors because it is not normal in this culture for women and men to sleep in the same room. Another great concern is the bad toilet facilities and that she sometimes has to use the bush as toilet.

Her ideas about a good dwelling can be summarized in following points:

-a very simple dwelling, but with good toilet facilities.

- outdoor kitchen because of the fresh air. Rooms without ventilation is not good.
- possible to stay outdoor because it is to hot inside.
- two doors in the living room because of security.
- contain room for 4-5 people. Her and her fiancé and two sons (11 and 18) and a guest.
- 2 rooms would be okay. 3 rooms would be better. One for her and her fiancé, one for her two sons and a guest room.
- the dwelling should also have a sitting room and a living room.

After the interview walking towards her house, she says, that she likes to live and work in Masanga and she really wants to help Masanga - that is why she is here. But the housing is really too bad.

ill. 45.1: Emma in her room

Emma songlines

To give an impression of how people live in Masanga a mapping of Emmas every day is made - especially in relation to practical issues as toilet, working, cooking, working hours, laundry, pick up water at the well etc.

From the map on opposite page(ill. 41.1) the places are shown where she mainly is and the number on the map refers to the pictures of her actions(ill. 40.1-7).

3 bathing

5 work at the hospital

6 water from the well

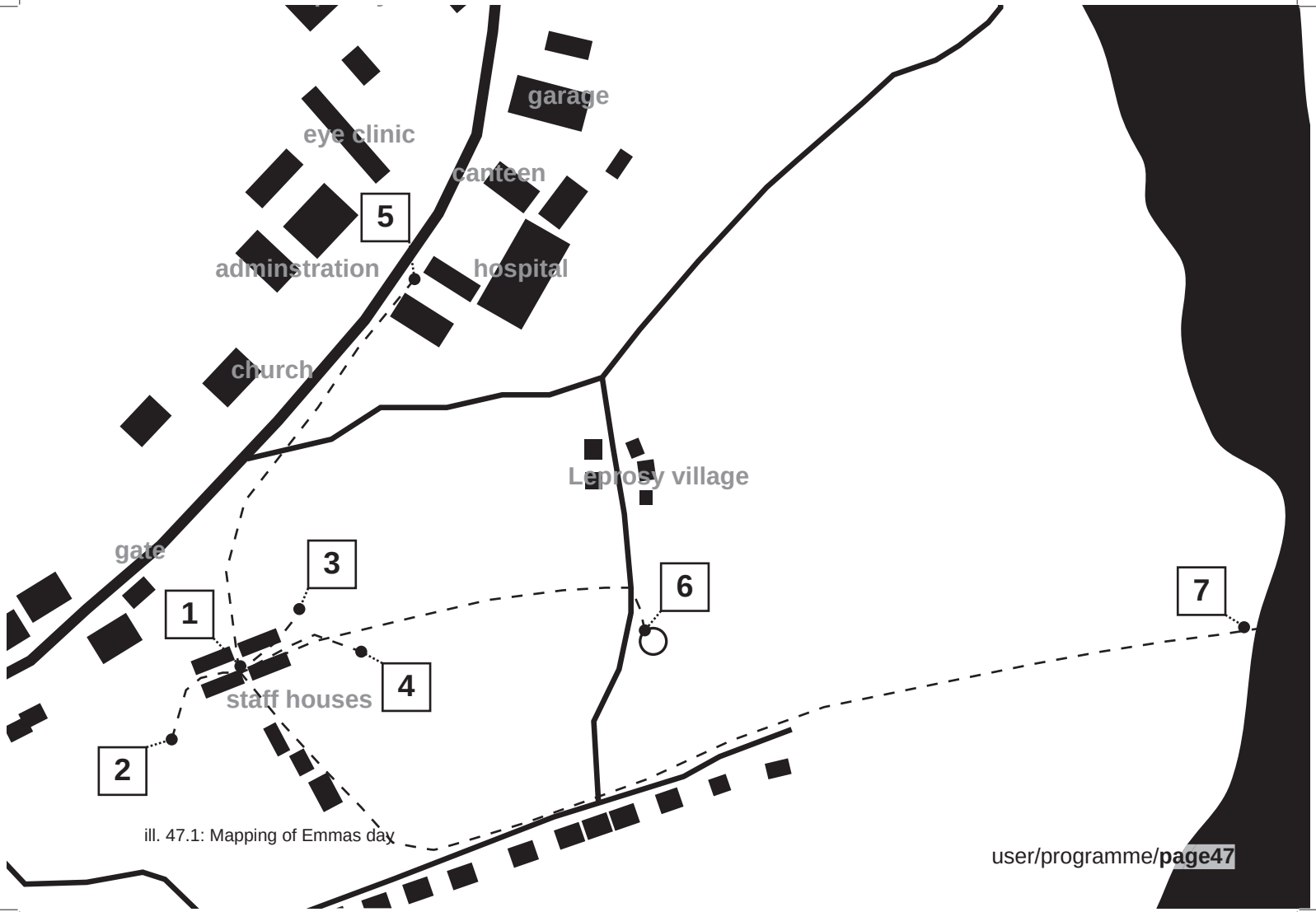
1 sleeping

2 toilet

4 cooking

7 laundry in the river

ill. 46.1-7: pictures from Emmas day



ill. 47.1: Mapping of Emmas day

Overview from the user interviews

During the interviews it was realized how bad the current housing situation is for the hospital staff, and how important it is for the hospital to provide good living conditions in order to keep their staff.
For the users, more space, compared to there current conditions, is essential in order to create good dwellings. Thus one room is not enough - but also how important the outdoor space is. Thus it can be a matter of providing good outdoor conditions as a factor just as important as the indoor conditions. It seems as a question about flexibility in the physical environment. A dwelling that provide space when it is needed e.g. when having guests and maybe used for other purposes when not having guests or when the children leave to go to schools in bigger cities.

Another important discussion is concerning the materials, where both of the interviewed persons are mentioning, that the materials should be long lasting. But maybe the preferred material does not reflect, what is optimal in terms of the environmental context, but rather, what is the optimal solution matching available amount of money, at a certain moment. Or is the difference between an exclusive material and a non exclusive material, only about using an expensive material which is not found in the bush just outside your door. In this way the focus on the material is not on the building technological properties but more about the symbolic value. The issues will be further discussed during the design process.

ill. 49.1: Emma in front of her dwelling

environmental design

The aim of the project is not only to create a social sustainable, but also environmental sustainable solution, according to the initial problem. This can be achieved by implementing the work with parameters as energy consumption for heating/cooling, natural ventilation and daylighting as a part of an integrated design process. By using various building simulation programs, these parameters can be evaluated and optimized according to the design. Furthermore the choice of material- and building technology will have a great impact on the process.

Climate adaptive architecture

Climate has a great impact on how the architecture of a certain area is expressed. For instance is there a difference in how buildings are articulated in Denmark and the buildings in a climate that is warm and arid or warm and humid.

In traditional houses of a certain area it is often possible to find an idea about how the locale has developed a building technology that is adapted to the climate. Thus the architecture corresponds to the climate and the environment and can be identified with the context.

		heating	cooling	lighting	ventilation
passive	basic design	conservation 1) Surface to volume ratio. 2) Insulation. 3) Infiltration.	heat avoidance 1) Shading. 2) Exterior colours. 3) Insulation	daylight 1) Windows. 2) Glazing. 3) Interior finishes.	natural ventilation 1) Building form. 2) Windows and openings. 3) Stacks.
	climatic design	passive solar 1) Direct gain. 2) Thermal storage wall. 3) Sunspace.	passive cooling 1) Evaporative cooling. 2) Convective cooling. 3) Radiant cooling.	daylighting 1) Skylights. 2) Light shelves. 3) Light wells.	natural ventilation 1) Single sided ventilation. 2) Cross or stack ventilation. 3) Air distribution. 4) Control strategy.
active	design of mechanical systems	heating system 1) Radiators. 2) Radiant panels. 3) Warm air strategy.	cooling system 1) Refrigeration machine. 2) Cooled ceiling. 3) Cold air system.	electric light 1) Lamps. 2) Fixtures. 3) Location of fixtures.	mechanical ventilation 1) Mechanical supply. 2) Mechanical exhaust. 3) Mixing or displacement principles.

ill. 50.1: diagram showing some parameters to be considered, divided into passive and active [Larsen, 2008]

In the warm climatic zones on earth more than half of the energy consumption used in the urban environments is used for air conditioning. In general various developing countries is placed in the warm climatic zones and if they will go through the same process as the western world with further urbanization and technological implementation the future energy demands will have a great impact. [Koch-Nielsen, 2002]

Active design – passive measure

In the book Stay cool by Holger Koch-Nielsen a guide for design in hot climates is presented. The basic idea is to work actively with passive measures. This means integrating the work with passive strategies as orientation, openings etc. in the design process(see ill.50.1).

An idea about integrating the work that was typically made by the engineer, e.g static calculations and environmental simulations, in the design process typically made by the architect. Furthermore a coherency between the urban design and the architectural design is essential. This has a great relation to the integrated design process stated under *Method* page 8.

To explain the term active design with passive measures, understanding the opposite: passive design with active measures is required.

The passive design means that there is no integration of technical or environmental strategies in the design process. The design is made by the architect and afterwards the engineer implement environment and technical necessities e.g. air conditioning.

The use of mechanical equipment creates a fully control of the internal environment and once inside the building the nature can be total ignored. This creates a exclusive environment that has no relation to the surroundings.

To utilize passive measures is to utilize the environment and listening to the nature. It will create an environment that is related to natural dynamics and will not always be controlled. When a fully controlled internal environment is needed e.g. in hospital design mechanical equipment is required. As this project deals with dwelling design active design can be implemented because the comfort conditions in your home is not that strict.

Although the point of departure for Koch-Nielsen is the context as the surrounding natural environment, he points out that the context also must be seen as global and present, containing economical and socio-cultural issues. [Koch-Nielsen, 2002]

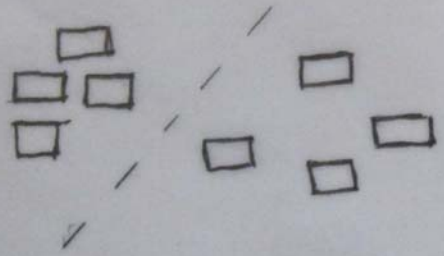
Masterplan level parameters

To create a general idea about how to implement different environmental strategies in the design some basic parameters a listed in the following. The parameters are what Koch-Nielsen refers to as passive measures.

The parameters are an initial set up and it is to be further detailed and documented in the initial design process.

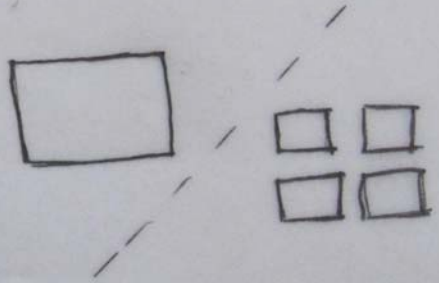
The parameters is to create a better overview divided into master plan level and building level corresponding to the two levels of which this project is distributed.

The parameters can be varied in terms of what is optimal in a certain region and climate. This demands further calculations.



Spacing between buildings

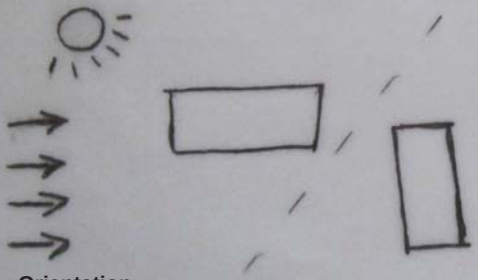
The spacing between buildings has influence on the air movement between the buildings. A dense building plan will restrict air movement and a widespread plan will create settings for a higher air movement. In addition the amount of shading from one building to the other or shading in the external environment will be affected similar the amount of solar radiation on the buildings will be affected.



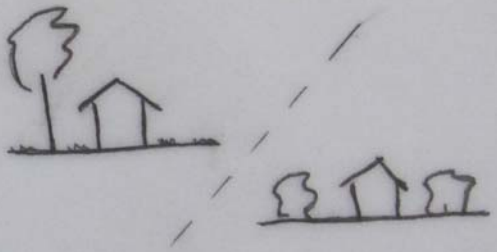
Compactness

This parameter indicates whether internal spatial demands are solved as a large volume or if it is divided into smaller volumes. The smaller volumes have a bigger surface area meaning a potential larger amount of daylight and ventilation. But it also means a bigger surface receiving solar radiation and a possible heating of the interior.

ill. 52.1,52.2: environmental strategy diagrams



Orientation
Orientation of the buildings relating to the position of the sun and the dominant wind direction has an influence of the solar radiation gains in terms of the size of the façade facing the sun. Analogous is the ventilation in the buildings caused by wind determent of the size of the façade facing the dominant wind direction.



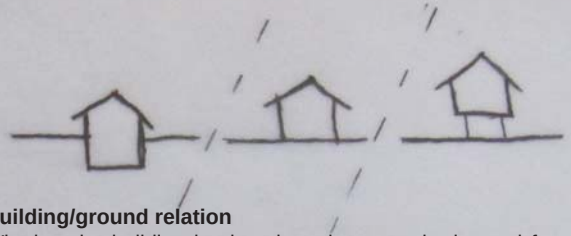
Vegetation
The placing of vegetation can have an impact on the wind conditions in the external and internal environment and create shading for buildings or people. Importance is the size of the vegetation – big trees will provide shade, whereas smaller trees or bushes will decrease air movement around the buildings.
Vegetation can in addition also create cooling by evaporative and filter the sunlight.

ill. 53.1,53.2: environmental strategy diagrams

Building level parameters

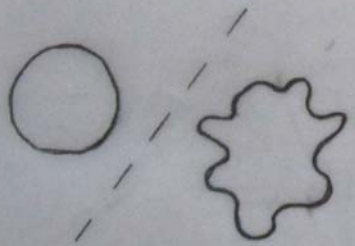
Some parameters has to be taken into consideration in the master plan level whereas some can be implemented in the building level. Of great importance is the interaction between the two levels and a changing focus forth and back.

ill. 54.1-54.3: environmental strategy diagrams



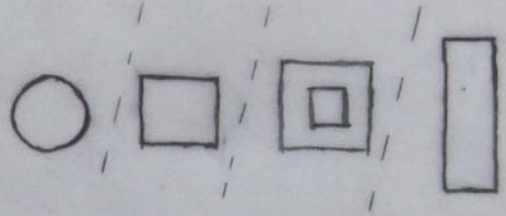
Building/ground relation

Whether the building is placed on the ground, elevated from ground or excavated into the ground will
have an impact on the utilization of air movement where the air movement increase by the height. Furthermore the amount of heat storage is related to the ground. If there is a great 24 hour change in temperature a closer relation to the ground can be preferable to avoid big changes in the interior.



Surface to volume ratio

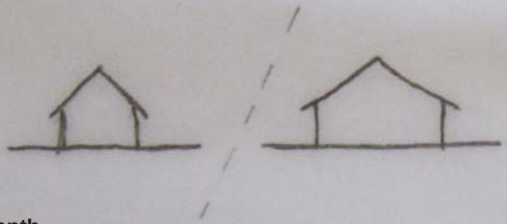
The surface to volume ratio is a factor that is defined as the surface divided by the volume. The surface to volume ratio has a great impact on heat loss and heat gains in a building. It can be compared to the term compactness, but in this interpretation it is seen as only containing one building and how articulated the façade is compared to the internal volume.



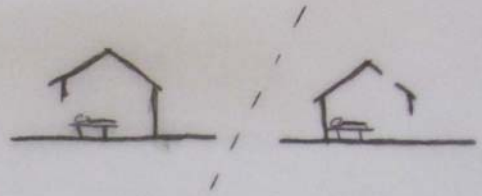
Typology

The utilization of different housing typologies is important in terms of solar gain, air movement and the comfort in the internal and external spaces. Where air movement is required a court yard typology will not be optimal because there will be no wind in the court yard. However a rectangular type will provide greater possibilities of implementing cross ventilation. The typology can also be connected to the surface to volume ratio and the same conditions are present.

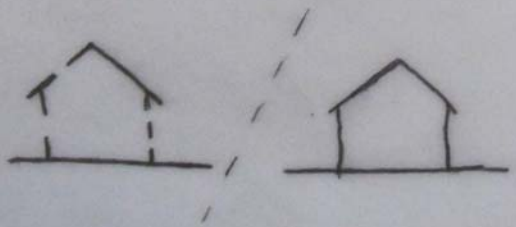
ill. 55.1-55.4: environmental strategy diagrams



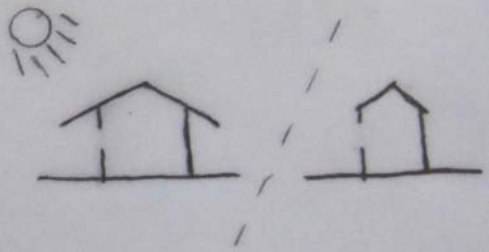
Space depth
The depth of the internal spaces is determining the properties for ventilation and daylight. Deep spaced will have a smaller amount of daylight and cross ventilation will have a lesser effect.



Placing of openings
The placing of openings can affect the amount of daylight penetrating the facade. In addition openings have a correspondence to the air movement – for instance can it be desirable for the utilization of the child factor but it can also be the reason for draught in relation to where you sleep.



Openness
The amount and size of openings in the design will especially have an impact on the air movement in the house. Furthermore the bigger openings the bigger coherency between in internal and external temperature.



Shading
Shading for the sun and thus the solar radiation can be provided by external factors as high trees or adjacent buildings or it can be created incorporated in the actual building in terms of eaves or different types of moveable shading devices. The shading can be placed and shaped in relation to the sun path to optimal use.

Indoor climate - Thermal and atmospheric comfort

An important issue in a dwelling is the human comfort. The comfort of humans can be divided into three types: the thermal, the atmospheric and the acoustic comfort.

In this project especially the thermal comfort will be of high priority in terms of implementing natural cooling strategies in the design of the dwelling. On the other hand the acoustic comfort will not be taken into consideration in the project.

Due to give an idea about the atmospheric and thermal comfort levels the European standard regulation will be used as a reference. Especially the report CR1752 will act as reference [CR1752]. CR1752 states that although human comfort requirements for the indoor climate are variable there will be a kind of coherency. An important factor is the PPD (Predicted percentage of dissatisfied) an index that illustrate the amount of people that will feel thermally dissatisfied.

Although the context is distant from the Danish climate and the Danish culture it is proven that the requirements for thermal comfort is similar.

"….Experiments have also been done to investigate other factors, such as sex, race, age, location, etc. which may affect the thermal comfort. None of these factors has been shown as a factor affecting thermal comfort beyond the accepted statistical significant level…."

[Manohar, 2003]

An interesting observation during the field work is the fact that the locals dress more warm during the winter, although the Europeans being there wear light summer cloth. This contradiction will be dealed with through the project by providing the possibility of reaching a colder indoor climate, but still be able to make a regulation.

It is decided to work with a category B for the indoor climate, according to the European standard to have a starting point for the design considerations in relation to the indoor climate. This is a medium category which state that PPD cannot extend 10% for the thermal environment (see app. 6).
In Europe the demands for air change can be calculated according to 4 categories:
Law demands
CO2-koncentration
Experienced air quality
thermal comfort

The demand for air change is calculated in the appendix (see app. 6) and the determining air change is for the experienced air quality and is calculated to 1,88h^{-1}.
The air change for thermal comfort is will be calculated during the design process to have a more detailed output. But it is supposed to be the air change that will be determining because of the demand for air flow for cooling the building.

Summary
In the previous section different parameters that can be broad into play during the design process have been listed.
The aim is to create an integrated solution that provides good physical conditions for the staff, in the light of that no high technological or power consuming devices are realistic in the context of the project. During the design process the different parameters are used in relation to aesthetic, functional and technical requirements and are evaluated through advanced building simulations or more simple estimation.
The indoor climate demands has its starting point in the European standards, but will be discussed and adapted during the process.

Program summary

In this summary the previous sections will be summarized to create an overview over the different elements which have been handled through the program.

In the introduction the overall frame of **sustainability** is set. Divided into **economic, social and environmental** sustainability. Furthermore the **initial aim** is being stated in terms of **Architects Without Borders** project assignment which briefly can be explained as: **to develop a master plan for the future staff dwellings and to design a prototype dwelling**.

The method is the **Integrated Design Process** where **parametric analysis** is going to be implementet.

The project takes off in the fieldwork which is connected to **Frampton** and his **critical regionalism**. Framptons **7 points** and **Sempers** concepts about **stereotomics and tectonics** will act as inspiration in the project and be a way to implement the **universal culture** in the specific **place**, comprising climate, topography and culture.

The context analysis spans the historical settings wherein the project takes place and give an idea about program, landscape and building typologies in the area. It also initiate a discussion about **use of material** in a more pragmatic way, but also through the experiences in Ramsu's house.

An important starting point for the design process is the **climatic data** – especially because it is a completely different climatic context, and thus new strategies for how to create a environmental sustainable solution is investigated based on **Koch-Nielsens** concept about **active design with passive measures**.

The use of the passive measures has the goal of creating ***good indoor climate*** and **good living conditions** for the staff without wasting resources or an unrealistic energy consumption.

Through **interviews with Patrice and Emma** a fundamental idea about what is essential for the staff and their potential future dwelling is reach.

ill. 59.1 VIew from water tower in Masanga

aim

The analysis phases leads to the aim for the project:

To create a social and environmental sustainable solution for the design of a prototype of staff housing and a master plan containing the staff housing, wherein elements as a symbiosis between universal culture and the place, local materials and the climate are taken into consideration.

ill. 61.1: goat house in Masanga Village

Inclusion

During the design process following issues, amoung other, are to be included. The issues are divided into technical parameters and more aesthetical or cultural parameters. The aesthetical parameters are set up as a set of notions which can be oppositions to one another. This will create a dualistic tension which spans a frame for the project to work in.

Aesthetics/cultural

- Exclusive/practical
- Tactile/visual
- Heavy/lightweight
- local/global
- inside/outside

….

Technical

- comfort conditions
- passive cooling/heating
- natural ventilation
- building and material technology
- daylight/shading

…..

Demarcation

Due to keep a focus in the project and because of the limited project period, following points will not be considered during the design process:

- whether it is correct or not to design and implement a design in a developing country, that fulfill or satisfy the life of people in the western world.

- economical calculations will not be made in the project, but economical considerations will be made due to create a solution that is realistic and can be accepted in terms of creating a cheap staff housing solution.

- detailing concerning acoustics in the dwelling will not be made.

- constructional issues will only be made on a conceptual level without detailed static calculations.

- local regulations, e.g. fire regulations, will not be considered in the project.

- because of the location of the project is distanced from any ocean and is 90meters above sea level precaution related to flooding and tornadoes will not be made. Furthermore Sierra Leone is not in an area of frequent earthquake, thus this will not be considered in the project. [Minke, 2009]

- whether the climate data from Ghana used in the project can be considered as representative for the climate in Masanga.

Design process strategy

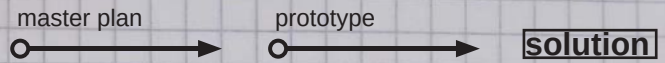
The project consists of two parts or two scales:
1) A master plan for how to place the dwellings for 70 of the hospital staff. The dwellings for the 70 staff members can be divided into renovation of 15 of the ruins of the former staff dwellings and approximately 40 new houses, assuming that some of the staff will live in the same house or some will presumably be relatives living together.
2) The other part of the project is the detailed design of a prototype of a dwelling being adaptable for a family or approximately 3 single nurses. The size of the dwelling will approximately be 60 square meters.

In a integrated design process these two parts can be approached in different ways. In addition their relationship or the priority plays an important role.
The master plan will be on a conceptual level, primarily arranged in the plan; however the prototype design is site specific and related to the adjacent context in terms of topography and climate.
Typically is the top down approach to the design starting with the master plan and then afterwards implementing the individual dwellings.
In this project a bottom up approach is also considered where the place specific relations play a big role.

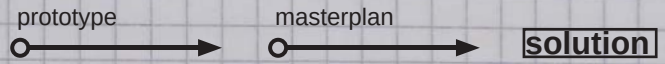
Following the integrated design process a combination will be optimal where the two scales are seen as two parallel processes with the change of focus from one scale to another.
The big scale has the advantage of the overview and the coherency between the dwellings internally and group of dwellings to the surroundings. But there is a risk of creating a too abstract plan that will create placelessness – to use a term from Frampton.
The small scale will work opposite – it will react to the specific place, but it can create a design that is too site specific that cannot be adapted other places in the master plan.
Thus an intermediate scale or abstraction level is introduced acting as an initial investigation and the point of departure for the master plan and the prototype. The goal of this level is to create a concept for a common dwelling type that can easily be adapted to a specific site with different properties, wherever it is placed in the master plan or regardless how the master plan is shaped. It is to set up the frames for the development of the dwellings, and the starting point is the design of a conceptual model, that makes investigations of climatic parameters and material technology. See ill. 65.1

The design process

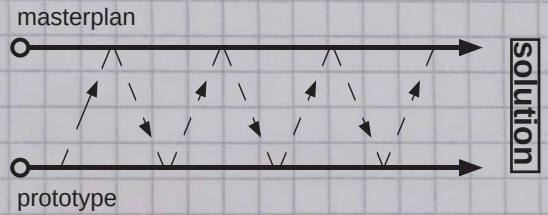
top down principle:



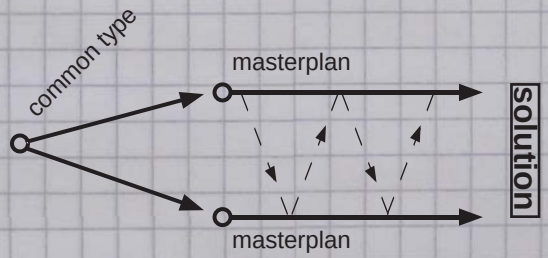
bottom up principle:



parallel process:



intermediate abstraction:



ill. 65.1: diagram showing the principles of the design process

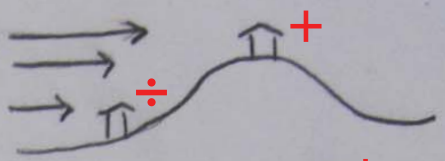
Site

Continuing the *Design process strategy* a site for the master plan is needed. Furthermore within this site a location for the prototype has to be found.

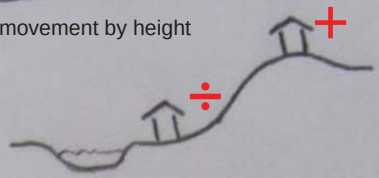
The master plan site is chosen according to some main parameters(see ill. 66.1). The height of the location which has a great influence on the air movement and can also be related to flooding from the river during the rainy season. Also the sort of vegetation has an impact on the microclimate. It is better to place buildings close to high trees because they do not decrease the air movement, but they do shade for the sun [Kock-Nielsen, 2002].

Based on experience made during the fieldwork a feeling of it being warmer in the village, than in the area around the hostel. This can be caused by the fact that the village is placed low and without any high trees, and the hostel area is placed higher and with a lot of high trees.

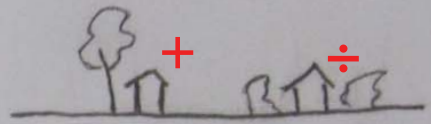
The road is another issue that has to be taken into consideration. Especially in terms of dust the road can be a problem, but also in terms of noise and safety. It is supposed that the road, will have an increase in traffic load in the future, thus the problem will not decrease over time. Therefore a site that is distanced from the road or makes it possible to create some kind of barrier will be appreciated.



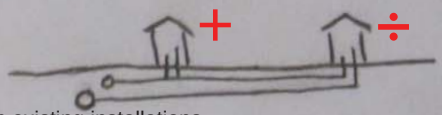
increase of air movement by height



distance from river in terms of flooding in the rainy season



height of vegetation influence air movement and shading



distance from existing installations

distance from main road in terms of dust, noise and security

ill. 66.1: diagrams with master plan considerations

ill. 67.1: map showing different master plan areas

Contrary a location close to the existing pipe lines can be an advantage, although the condition of these installations is not known. Especially in the start up phase it is supposed to be connected to the existing installations, whereas in the future new installations will be beneficial.

Different locations in and around Masanga has been considered, especially at the river bank next to the village or in the area north west of the hostel(see ill. 67.1). These two locations are considered because they contain the spatial constellation for a master plan of hospital staff dwellings.

Considering the parameters the site north west of the hostel is chosen. It has the qualities of being placed on a small hill. It is in an area with existing ruins of the staff housing, meaning there will be some installations. It is also placed close to the main road, meaning this can be a problem that has to be dealt with in the master plan.

An interesting point is that it is in the former area of the hospital staff, which gives it some kind of status to the locals - a status that can be an advantage of creating an attractive area for the hospital staff. The ruins can also be included in the master plan for the hospital dwellings.

Furthermore the area near the hostel has a great amount of old trees that can act as shading devices, and over time more trees can be planted.

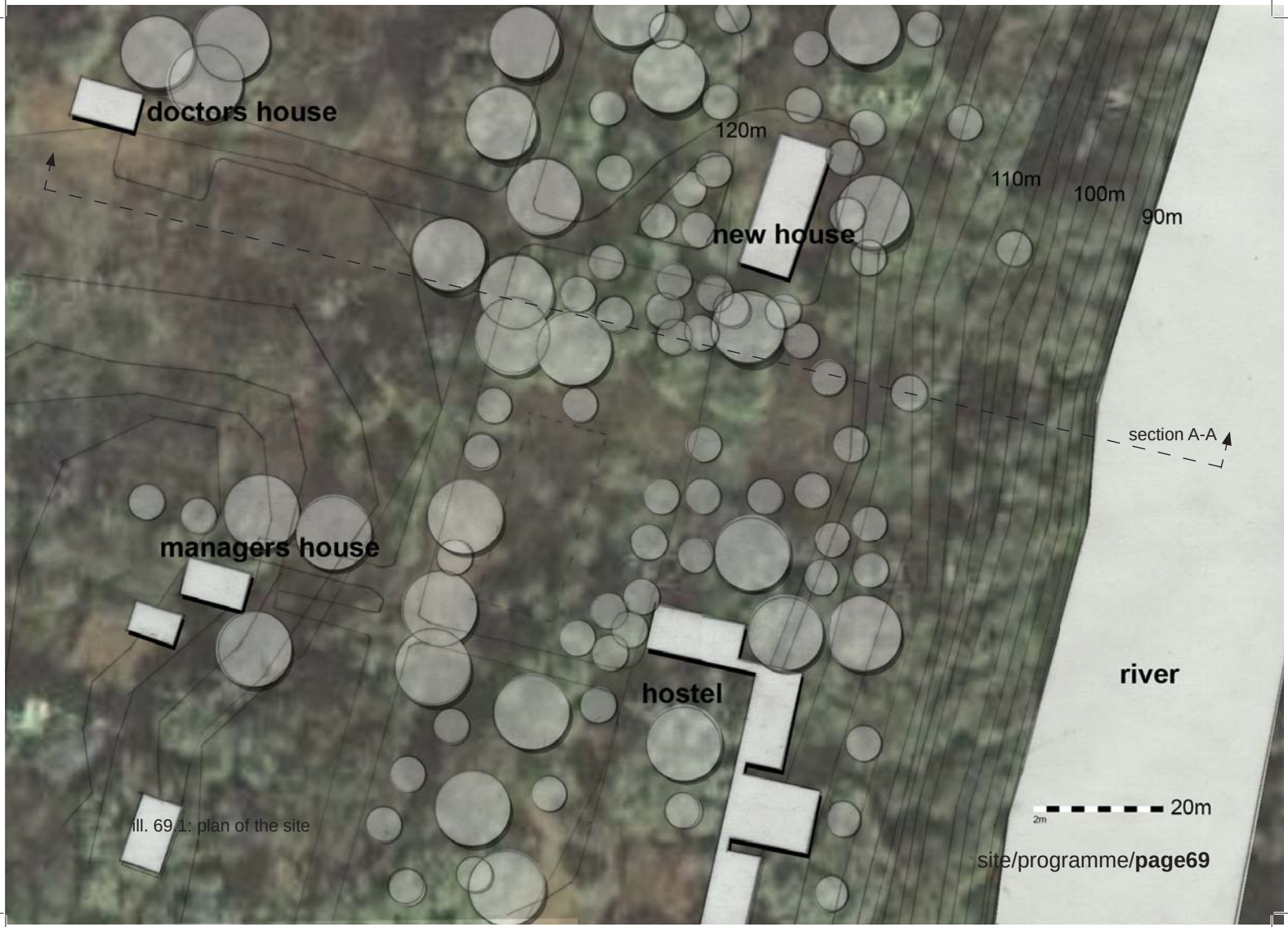
The prototype site

During the field work a specific site was chosen to have the opportunity to design a prototype in an actual context. This gives the advantage of investigating a house design in the near context, meaning the correspondence between the house and the context can be seen.

It is decided to place the prototype site between the hostel and New House. This is because it is in an area with tall trees, and relatively close to the infrastructure, which is an advantage when building a prototype in terms of supplies.

The site can be the starting point for all the dwellings, which over time can spread in the north and west direction from the site.

ill. 68.1: picture from the site



ill. 69.1: plan of the site

Section

Characteristic for the site is the section through. It explains the relation to the river and the surrounding woods and how the topography of the site is.

20m

2m

ill. 70.1: section A-A through the site

"new house"
120m
110m
100m
90m
above sea level

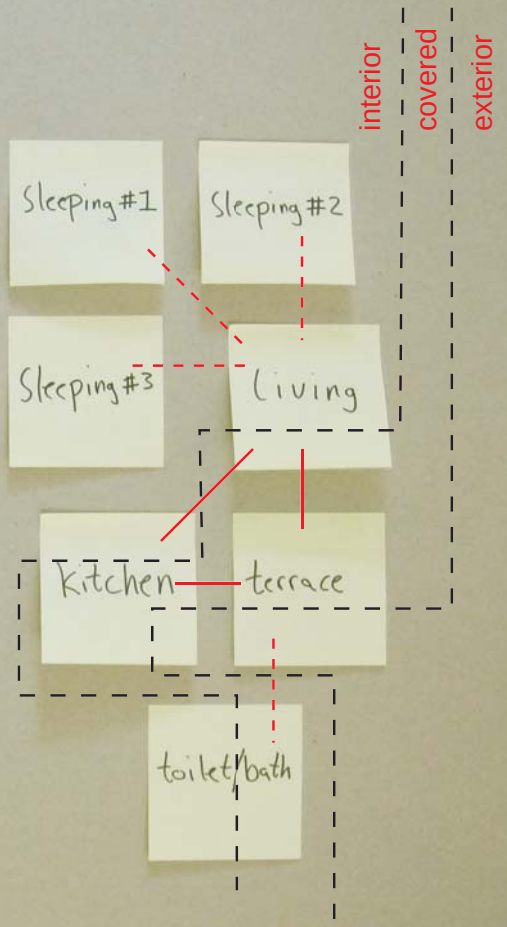
Spatial organisation

Based on the analysis and the fieldwork in Masanga, it is decided that the prototype dwelling should contain three sleeping rooms, which can be occupied by a family with children or three single nurses.

Occupied by a family one room is for the adults, one room for the girls and one for the boys. Because the demands for a dwelling are different than in the western world, it is considered to be realistic to create a dwelling, that is no more than 60 square meters. Also taken into consideration that most of the time the family will be outside. The sleeping rooms will not be used for anything accept sleeping and storage. To use a minimum of space is also preferable in terms of creating an economical solution.

Causes by the relatively small dwelling an important issue is to work with the comfort in the external surroundings of the dwelling. An approach to this is the implementation of an intermediate zone, between the interior and the exterior. As a starting point this is dealt with as a covered area.

Thus some of the main program e.g. the kitchen or living room, can also be seen as partly covered, partly outside.(see ill. 72.1)



ill. 72.1: diagram showing the spatial organization

Room program

The important concern in the design of the dwellings is the human comfort in and around the dwelling. To obtain this, different quantitative and qualitative parameters are set up for the different rooms, acting as a starting point and guidelines for the design (see ill. 73.1).

The parameters are based on various European standard regulations e.g. CR1752 and an interpretation of the empiric collections made in Masanga. The calculations for the indoor climate demands can be seen in app. 6.

	size	room height	persons	occupation hours	daylgiht	orientation	view out	view in	min. air change	temp summer	temp winter	clothing summer	clothing winter
sleeping #1	10spm	1,5-2m	1-2	22.00 - 07.00	+/÷	S	+/÷	÷	1,88h^{-1}	24°C +/-2°C	22°C +/-1,5°C	0,7clo	0,43clo
sleeping #2	10spm	1,5-2m	1-4	22.00 - 07.00	+/÷	S	+/÷	÷					
sleeping #3	10spm	1,5-2m	1-4	20.00 - 07.00	+/÷	S	+/÷	÷					
Living	10-15spm	2,3m	1-7	17.00 - 22.00	+	N	+	+					
Bath/toilet	5spm	2,3m	1	17.00 - 22.00	+/÷	S	+/÷	÷					
kitchen	5-10spm	2,3m	2-3	17.00 - 20.00	+	N	+	+					
Terrace	10-20spm	-	-	17.00 - 20.00	+	N/S	+	+					

ill. 73.1: diagram showing the demands for the different rooms

initial investigations

ill. 74.1: glass shutters at a window in the hostel in Masanga

initial investigations/page75

initial investigations

As stated in the section *Design process strategy* the project has a master plan and a prototype dwelling level. The design is to be initiated by the development of a common type of dwelling, which can be adapted to a certain site in the master plan.
In this section basic technical investigations of especially the thermal conditions of a dwelling are made. The main issue in the context of the project is to avoid overheating in the dwelling.
Although the investigations are basic and not that specific, they can create an understanding of how the climate affects the building and the indoor climate of the building, thus establishing a way to work deeper into the context.

Investigations of a common type are made according to:
- typology
- orientation
- thermal mass
- opening orientation
- building ground relation
- shading (eaves analysis and building shadows)

In general the different parameters cannot be isolated because they will always have an impact on each other, but in the frame of this project, it seems reasonable to focus on one parameter at the time, to clarify the impact it has on the indoor climate.

The investigations are made with a closed volume with standard infiltration/ventilation amount. Natural ventilation will be treated later in the process. The building constructions are set to be standard construction types and materials, except the investigation dealing with thermal mass. Furthermore the occupation is set to five persons with hours of occupation reflecting the room program.
In the different investigations the outdoor temperature is always represented, acting as a guideline for the temperature to be obtained. Because of the overall factors used, the output can be seen more as a relative value connected to the outdoor temperature than actual values.
The investigations are made in the two building simulation programs Autodesk Ecotect Analysis and IES Virtual Environment.

IES Virtual Environment

Virtual Environment is a building simulation software used as a tool in the integrated design process. The program can be compared to B-sim and has a simulation part with variable time step, which can be dropped to 1 minute. The simulation is based on principle models of heat transfer and includes real weather data. The software can be linked to a Sketch-up model.

At the moment the software is being used in Denmark at DTU and is being incorporated at the School of Architecture in Copenhagen. The software is used in the project for thermal performance analysis. [www.iesve.com]

Autodesk Ecotect Analysis

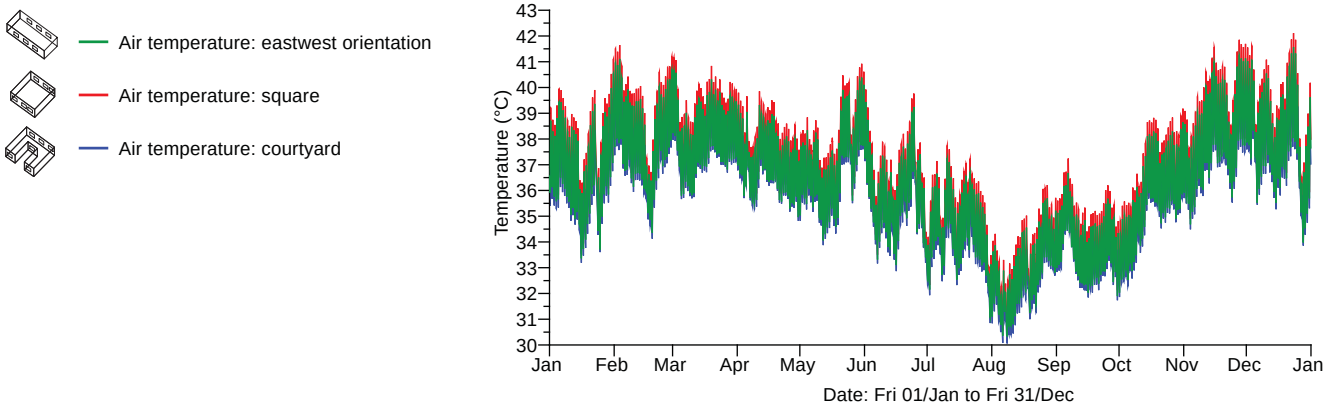
Ecotect Analysis is a building performance simulation software similar to Virtual Environment, although the thermal simulation is not that strong in this software. Therefore the software is used more overall for the treatment of weather data and solar conditions. [http://usa.autodesk.com/] [Thuesen, 2009]

Typology

The first investigation looks upon which building typology creates the best indoor thermal conditions. Three typologies are investigated, a rectangular, a square and a courtyard type to test typologies with different surface to volume ratios. Two types of graphs are presented – one illustrating the temperatures during the year(ill. 78.1) and one illustrating the temperature during 24 hour at the peak day(ill. 79.1-3).

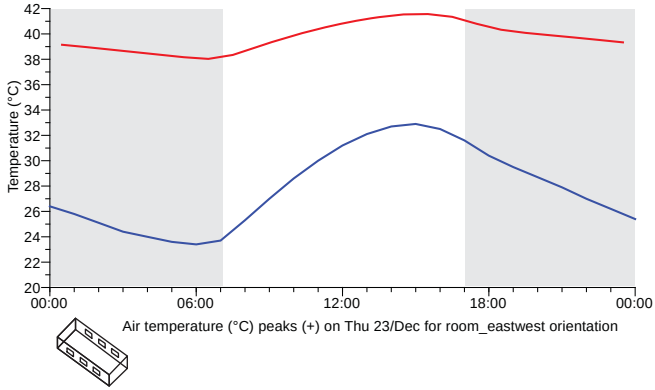
The conclusion is that the courtyard type creates the best conditions diurnal and annual.

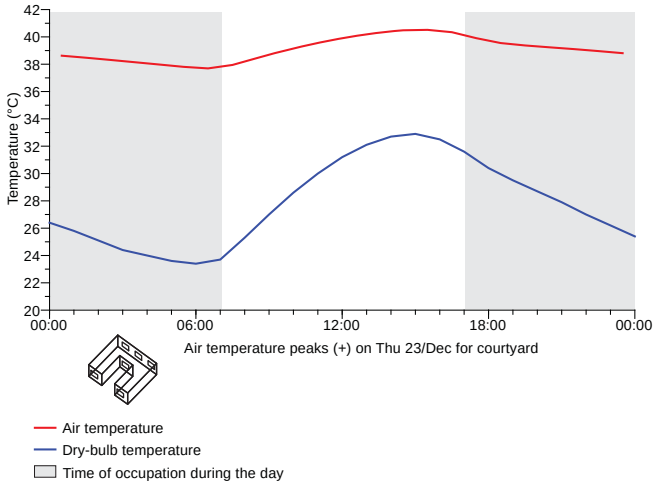
The rectangle and the square have approximately the same conditions at the peak day, but during the year the rectangles has the best performance. Although the courtyard typology created the best result, it is decided to work on with the rectangle type, because the dwelling has a limited size, and the courtyard in the middle will not create optimal use of the space. The courtyard type is performing best because of the high surface to volume ratio. This factor can be increased in the rectangular typology as well.

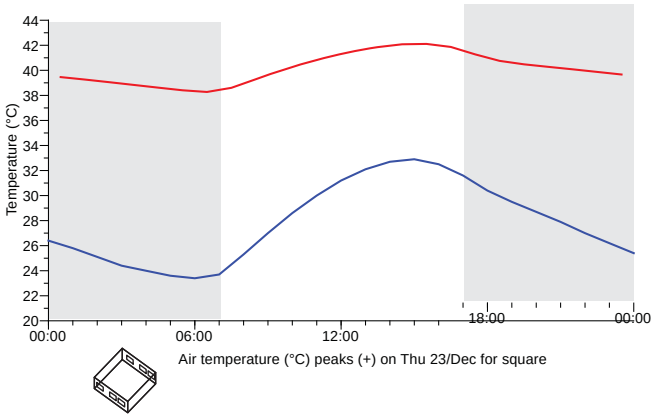


ill. 78.1: graf showing the annual temperature for the three building typologies

ill. 79.1-3: grafs showing the diurnal temperature for the three typologies

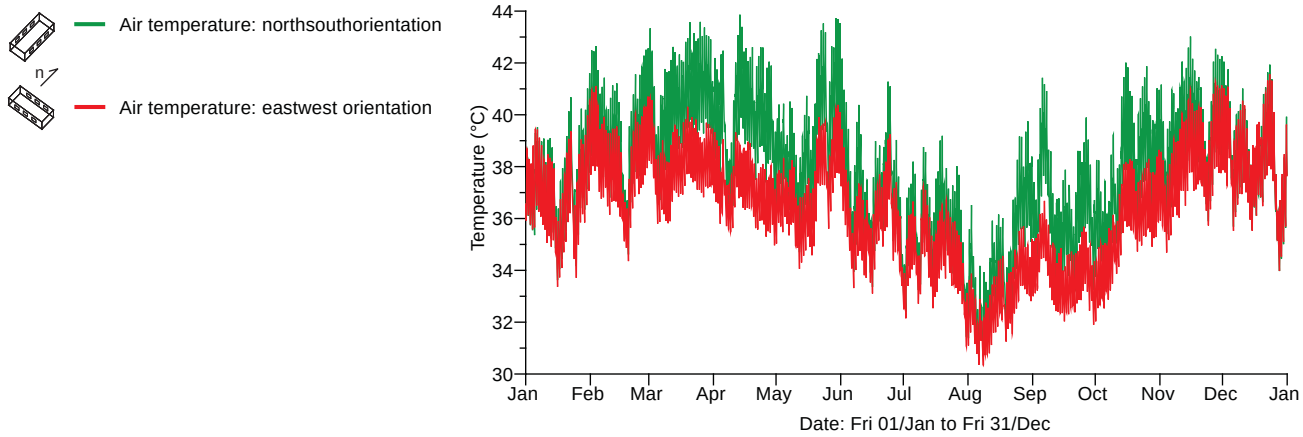






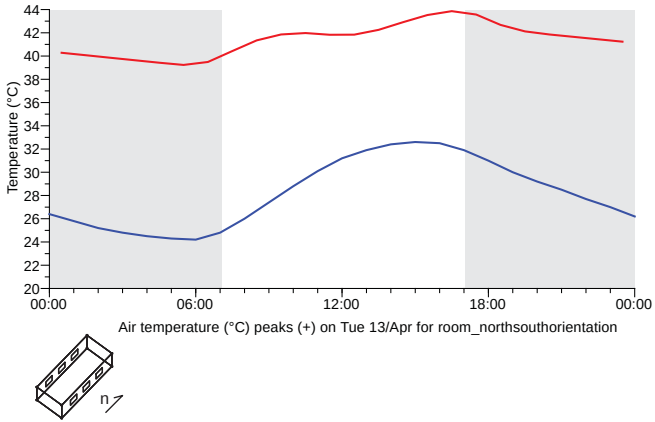
Orientation

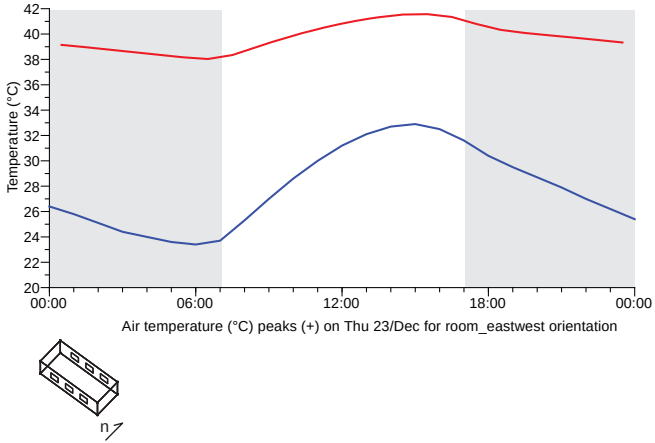
This investigation deals with the orientation of a rectangular volume. The orientation of the building east-west is optimal both annual (ill. 80.1)and diurnal(ill. 81.1-2) due to the path of the sun at the location. The high altitude of the sun at noon causes the north and south facades to be less exposed to the sun, whereas the east and west facades will be more exposed to the sun during the morning and the afternoon.



ill. 80.1: graf showing the annual temperature for the two orientations

ill. 81.1-2: grafs showing the diurnal temperature for the two orientations





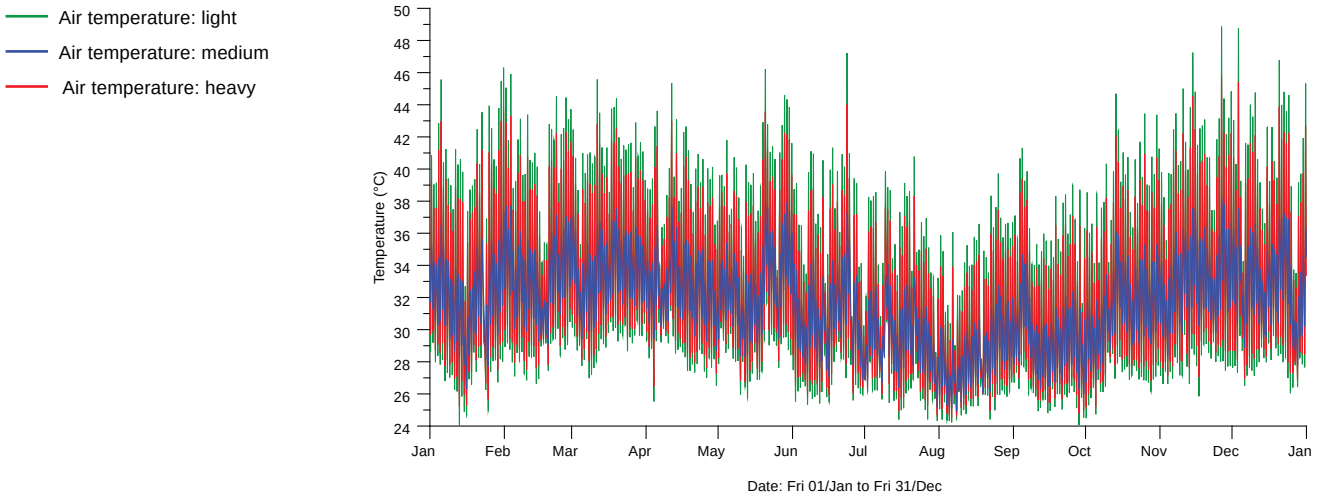
Air temperature
Dry-bulb temperature
Time of occupation during the day

Thermal mass

The thermal mass of a building has a great impact on the temperature; the more thermal mass, the more is the indoor temperature approaching the average outdoor temperature. The investigation looks upon three different thermal masses, a heavy weight, a medium and a lightweight. It is shown that the more thermal mass the lower is the temperature range. This means that the coldest time at night or during the year is kept warmer and the warmest time are kept colder.

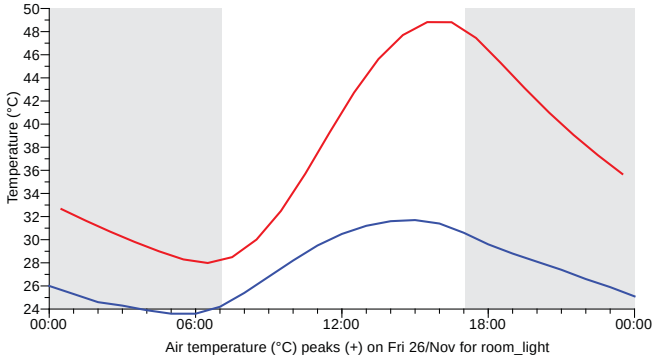
Considering the diurnal temperature ranges(ill. 83.1-3), is it obvious that the heavy building will make it colder during the hot day hours and contrary the lightweight building will be colder in the night when the heavy building still will be warm because of the thermal accumulation. In this investigation the ventilation amount is not taken into consideration, and thus is the advantage of the light building not being overheated during the day not revealed.

ill. 82.1: graf showing the annual temperature for the three amounts of thermal mass

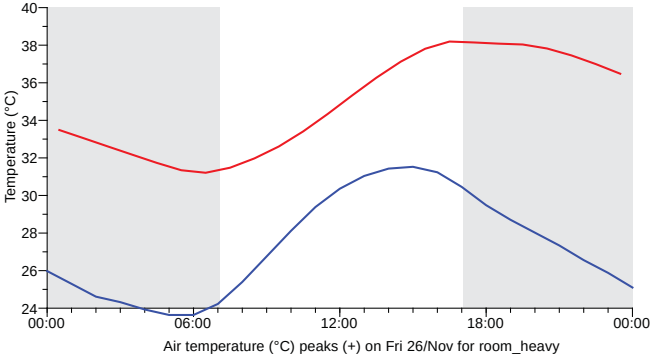


The reason for not considering the ventilation amount is to focus on one parameter at the time. An option in using thermal mass is in relation to zoning of the dwelling. The areas that are being used during the afternoon and evening can have the advantage of the thermal mass, whereas the areas used during the night, can be much colder when constructed in light materials.

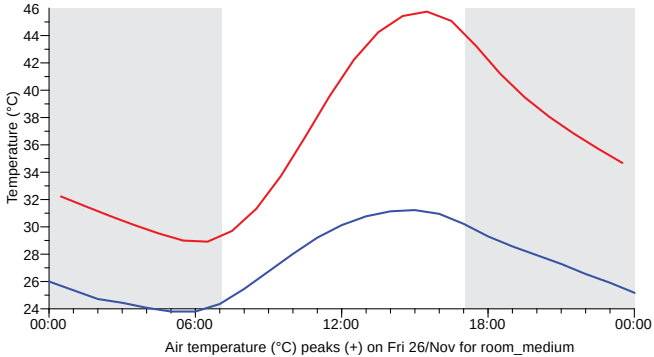
ill. 83.1-3: grafs showing the diurnal temperature for the three amounts of thermal mass



Light: lightweight walls, roof and ceiling and floor in wood



Heavy: heavyweight concrete walls, concrete roof and ceiling and heavyweight concrete floor.



Medium: lightweight concrete walls, roof and ceiling wood and standard concrete floor.

Air temperature
Dry-bulb temperature
Time of occupation during the day

Opening orientation

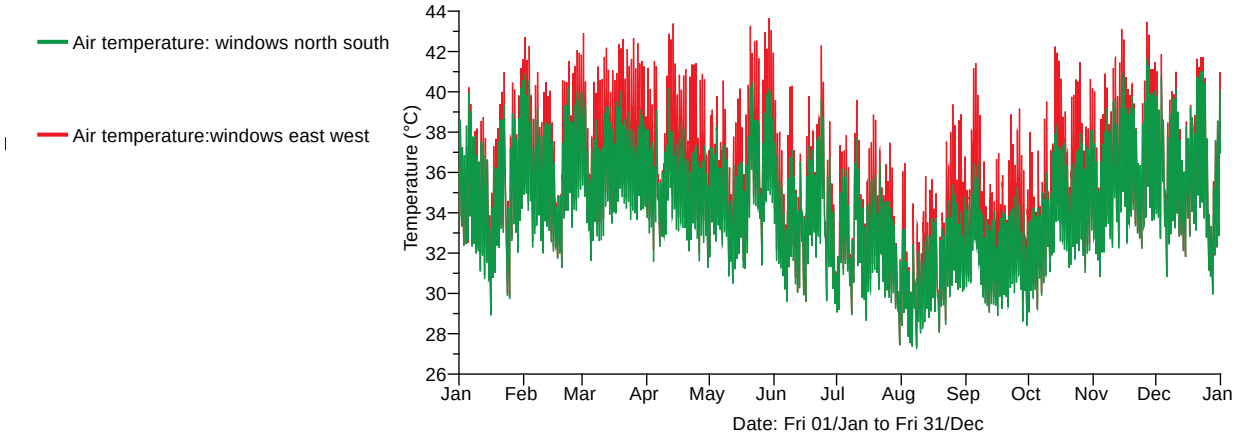
In the investigation of the orientation of openings an option is to place the openings in the north and south facade or in the east and west facade. The investigation is simplified to give an easier overview of the advantages and disadvantages. From ill. 84.1 it is seen that the windows placed at the north and south façade creates the lowest indoor temperature annually. This is also the case with the diurnal temperatures at the peak day of the year(ill. 85.1-2).

Thereby is it concluded that windows towards south and north are to be preferred.

A parallel to the investigation of building orientation is seen in terms of which facades being most exposed to the sun.

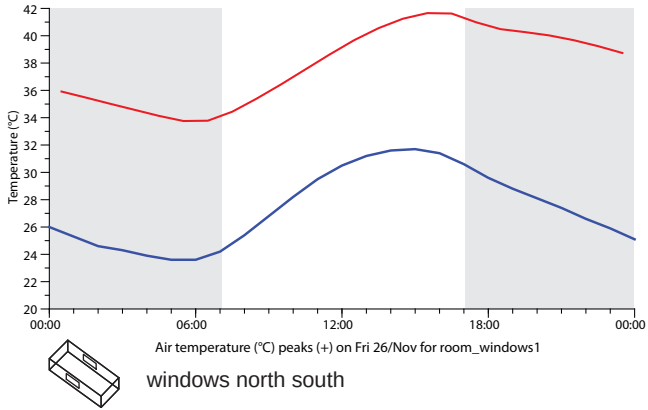
Although the best solution of the window orientation in relation to indoor temperature is north and south, it does not exclude windows towards east and west, but these demands a higher attention on shading devices.

Another issue which has to be further investigated is whether the windows are conventional windows with glass or more like openings or shutters.

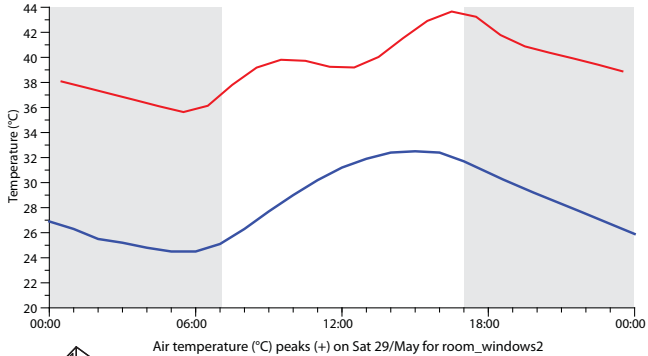


ill. 84.1: graf showing the annual temperature the two opening orientations

ill. 85.1-2: grafs showing the diurnal temperature for the two opening orientations



windows north south

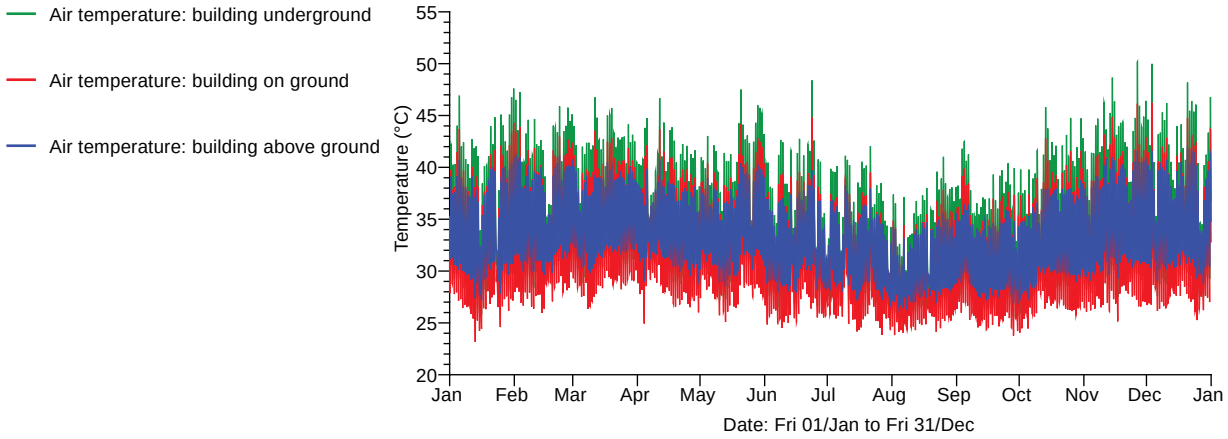


windows east west

Air temperature
Dry-bulb temperature
Time of occupation during the day

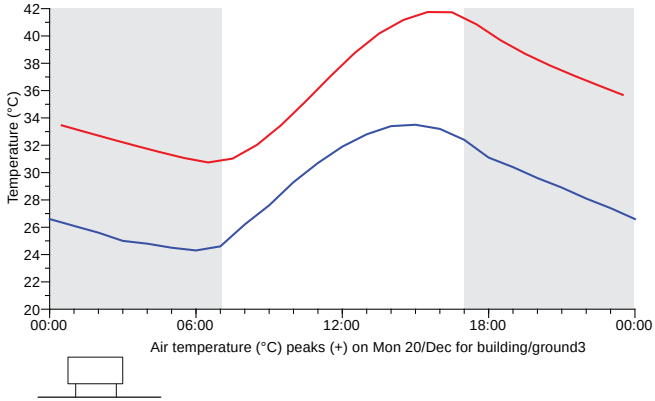
Building/ground relation

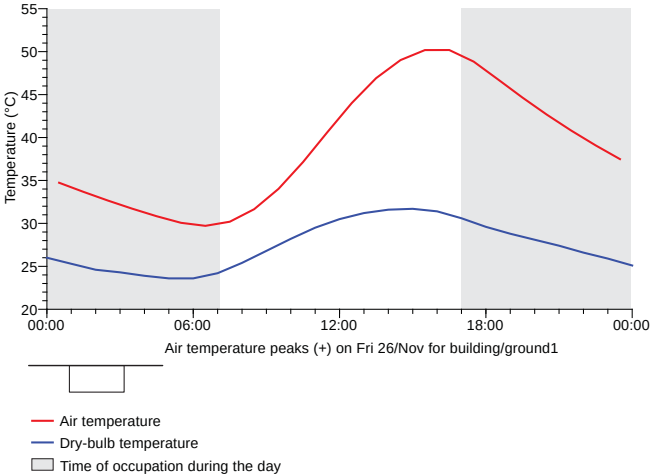
This section shows different possibilities of relations between a building and the ground, meaning whether the building should be under ground to some extent, if it should be placed on ground or if the building should be detached from the ground e.g. by placing the building on columns. In the annual analysis(ill.86.1) the building on ground is performing the best in relation to the indoor temperature, but also the building on columns are performing quite good. In the diurnal analysis(ill.87.1-3) the building on ground reaches the lowest temperature, but it also obtains a higher maximum temperature than the building above ground. Moreover the building above ground follows the outdoor temperature because there is no relation to the ground, which supplies the building with heat. It is a fact that air movement increases by height, but this is not taken into consideration in this analysis because it demands a dynamic calculation method. This will advocate for the building above ground.

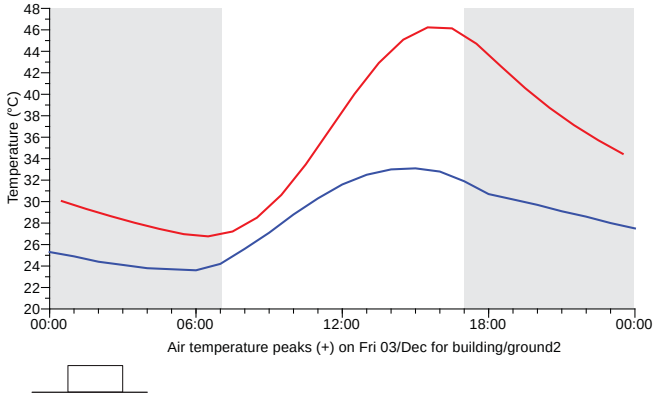


ill. 86.1: graf showing the annual temperature the three building ground relations

ill. 87.1-3: grafs showing the diurnal temperature for the three building ground relations





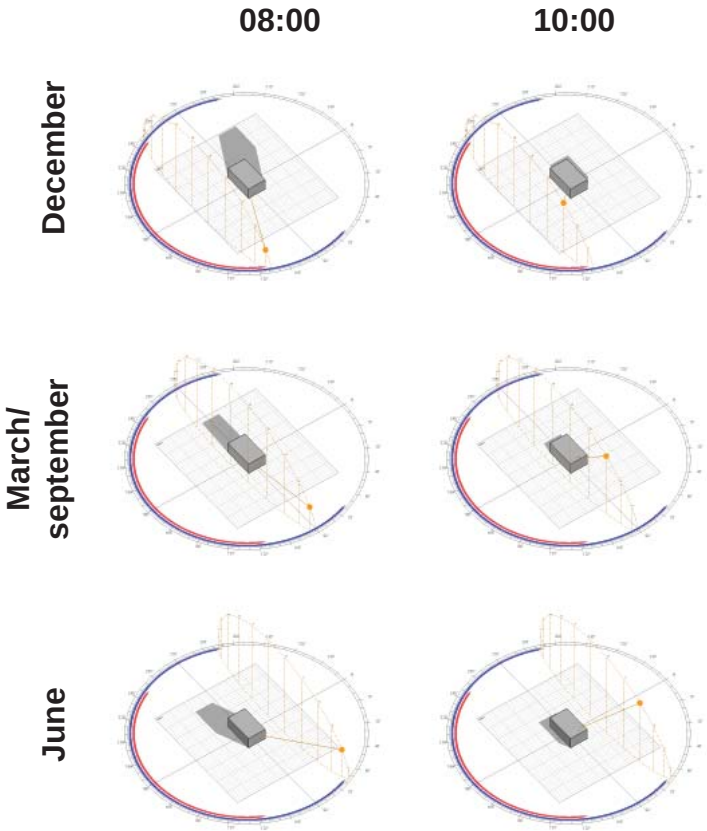


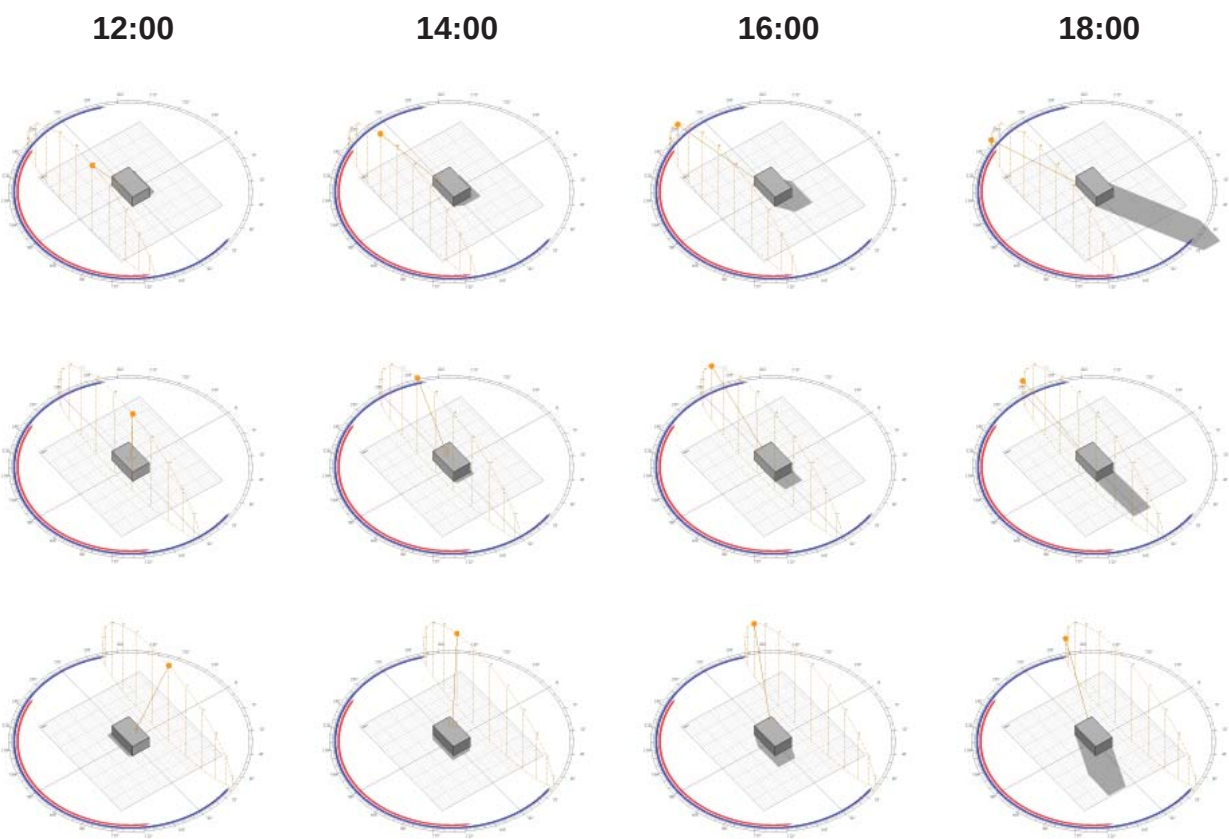
Shading analysis

This analysis is made in Ecotect where a simple rectangular shaped building is placed. The scheme(ill. 89.1) shows on one axis the time a day and on the other are the seasons. The reason for making this analysis is to determinate when the building shade and how much, but also to get a feeling of the sun path by investigating the shadows made from a building. The shading is especially interesting in relation to placing the program in the dwelling and the adjacent outdoor areas of the dwelling.

It is illustrated, that during the winter the sun will only be on the southern side of the building and thus creates shaded areas towards north. In the summer it is opposite – the sun is on the northern side of the building and the shaded areas are towards south. In the summer the sun altitude is higher revealed by the shorter shadow.

During spring/autumn the sun path is approximately straight east-west going, thereby has the east and west facades a high exposure to the sun.





ill. 89.1: diagrams showing the building shading during the year and day

Eaves analysis

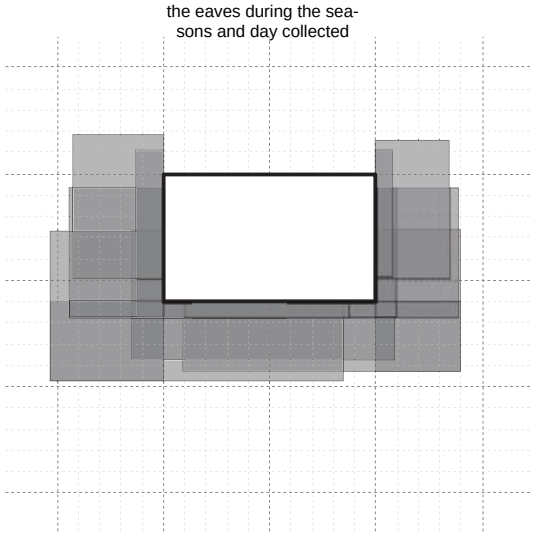
Analogue to the *Shading analysis* is the *Eaves analysis*. In this analysis a rectangular building volume is used. This illustrates the length of potential eaves for creating sufficient shading for the façade not being exposed to the sun(ill. 91.1).

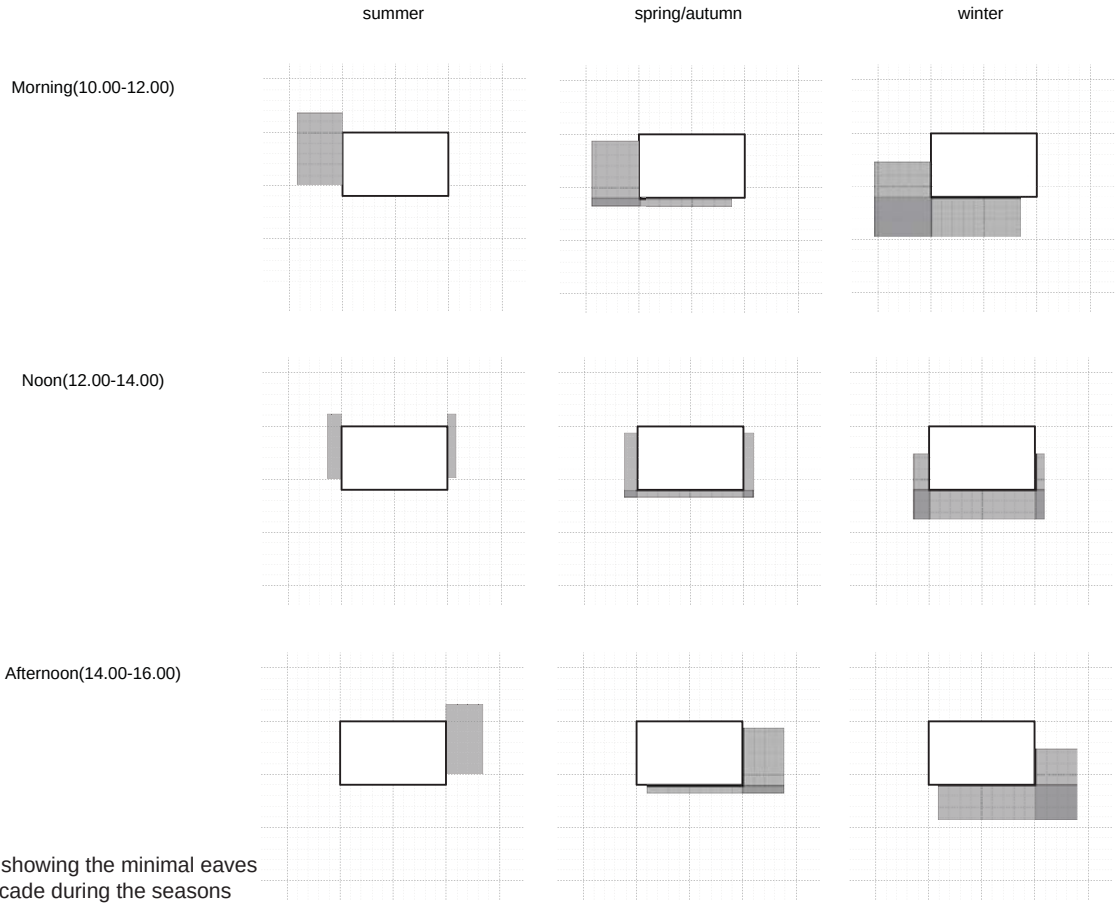
An example is the morning in spring/autumn where there will be a demand of an eave towards south of approximately 1 meter and 4,5 meters towards west.

In the overall model to the left it is clear that the shading/eaves has to be considered towards south, east and west, but there is no reason for shading towards north accept a small eave of approximately 20 cm(ill. 90.1).

Although the analysis is stylized by dividing the eaves into four rectangular pieces it still provides an idea about the potential shading. The eaves would be more optimal shaped by following the sun path and thereby being more curved.

ill. 90.1: diagrams showing the minimal eaves for shading the facade during the year.





ill. 91.1: diagrams showing the minimal eaves for shading the facade during the seasons and time a day

Conclusion

The aim of this section is to create a general understanding of the climatic context and how it influences on the build environment. The investigations create the basis for the stating of some general guidelines in the design of the common dwelling type.

The dwelling has a rectangular shaped layout with the long facades facing north and south.

Thermal mass can be used as removing the peak temperatures and will be optimal in terms of zoning the dwelling e.g. placing the areas that are occupied during the afternoon and evening in relation to thermal mass and the areas occupied during the night – sleeping areas – in a light construction.

The openings in the dwelling should mainly be placed towards north and south – which also correspond to the longest facades – otherwise shading devices will be more crucial.

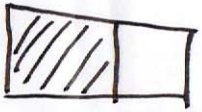
In terms of the relation between the building and ground it can be an advantage to level the dwelling from ground to avoid the constant high temperature in the ground, furthermore the air movement is supposed to increase by height. This issue will be discussed later in the project.

According to the sun path it is vital to work with shading especially towards south, east and west e.g. by extending the eaves. Towards north the altitude of the sun is so high that shading can be minimized.

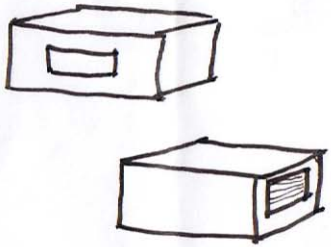
This points out a direction for placing more outdoor related program e.g. the cooking facilities.

The conclusion is summarized in the diagrams on following page (ill. 93.1). The diagrams are seen as guidelines for the design of the common dwelling.

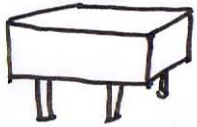
1) the building is shaped as a rectangle orientated east-west.



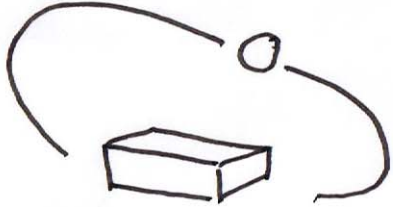
2) thermal mass can be used for reducing the peak temperatures and for zoning of the program.



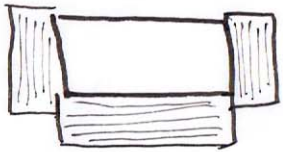
3) windows mainly orientated north and south, otherwise shading devices are required.



4) building on columns will reduce the internal temperatures



5) awareness of the solar path and the high altitude.



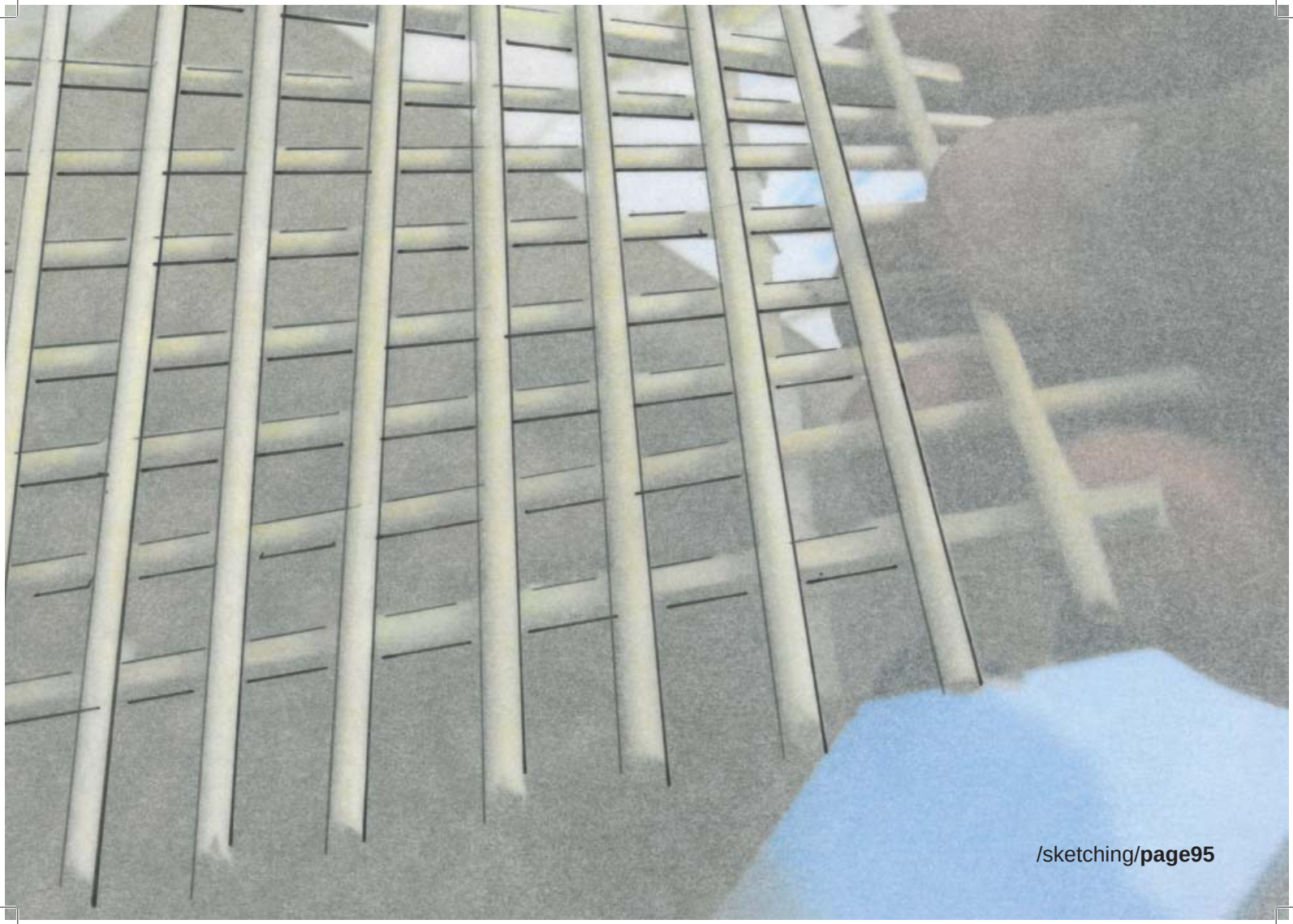
6) shading is especially required on the south, east and west facades.

ill. 93.1: sketches showing the conclusion of the intial investigations

sketching

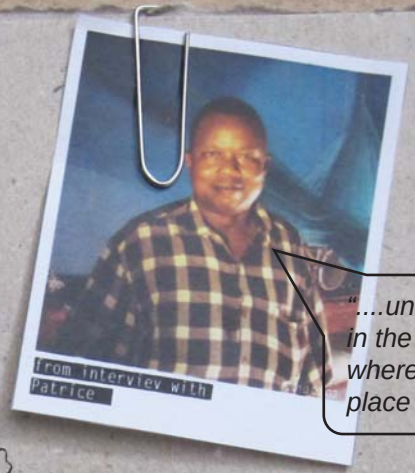
In this part of the process the conclusions from the program phase and the initial investigations act as the starting point for the design of the common type dwelling.
The sketching starts with the stating of the concept for the dwelling and afterwards different models and approaches will be presented.
Afterwards a zoom out will be made and the master plan will be discussed, leading to an implementation of the common dwelling type at the site specified in the program.

ill. 94.1: collage with mix of model photo and sketch



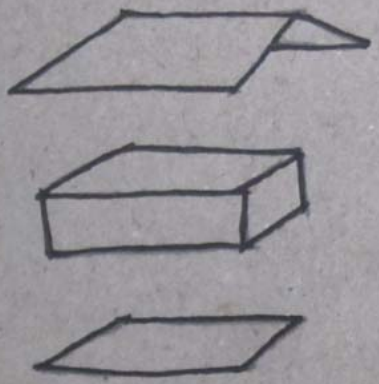
concept

The idea is to create an environment in and around the dwelling that is like being under a tree in the garden. Like a tree the dwelling should provide a place to stay, shelter from the rain, shade from the sun and safety. In the tree these qualities is provided by the three elements, the tree crown, tree trunk and the roots/ground.



"....under a tree in the garden - where you can place a table..."

ill. 96.1: inspiration sketch



cover
shading
utilizing the wind
shelter for rain
lightweight

frame
adapt to the program
flexibility
layers of shading
transparency
relate indoor and outdoor

base
create stability
thermal mass
fire proof
secure
status
relation to topography
heavy

The properties from the tree are translated into a building terminology manifested in the terms cover, frame and base. Further properties have been added to the terms to act as actual guidelines for the design.

ill. 97.1: concept sketch

design considerations

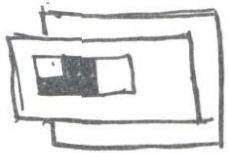
In continuation of the initial investigations and the concept some initial ideas of the design has been produced. See ill. 98.1. These ideas are to be implemented in the further design.

the mass in the building - as the secure, the thermal mass and the fire proof.

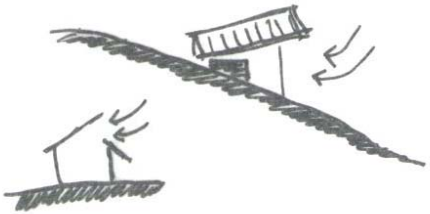
the relation between the topography, the road and the building - turning the hard material against the road to symbolize status

organisation of program in terms of thermal comfort:
- living towards north
- sleeping towards south

shading for the outdoor areas and the walls - as eaves or screen walls



house in house:
- a core of security and stability
- layers of transparency and shading



utilizing the wind with the roof

the division of roof and ceiling and a ventilated attic- to avoid heating of the interior

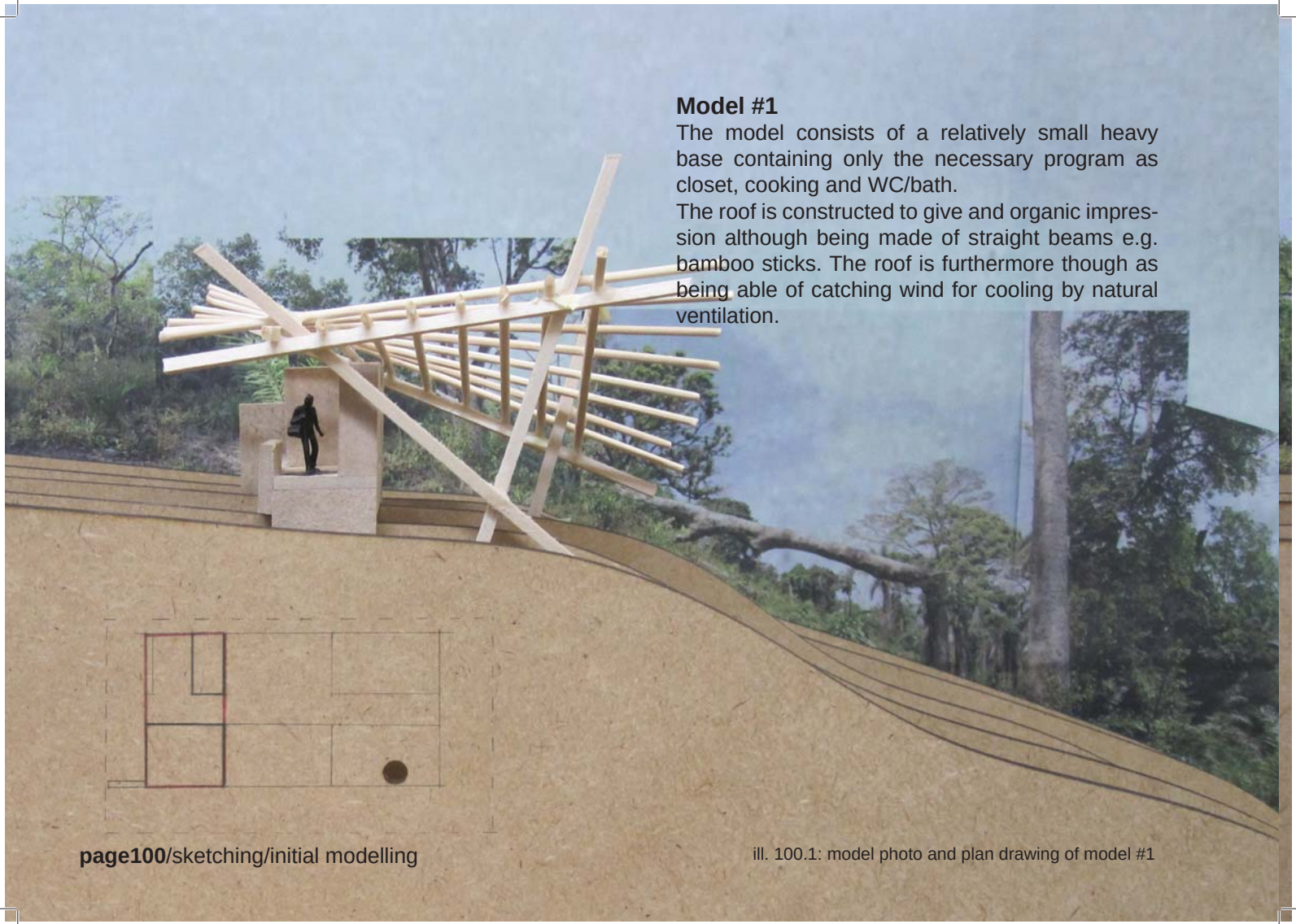
ill. 98.1: sketches of different design considerations

initial modelling

Throughout the next pages some initial models for the common dwelling type are illustrated. The idea is that from the beginning of the design process to work integrated with materials and structure. In the models the focus is on the “base” or the heavy construction – thought as being some kind of earthwork like rammed earth - and the light roof construction. These two parts of the dwelling reflect a dependency between the heavy construction providing stability to the roof and the roof as creating shelter from rain for the heavy construction. In the models the “frame” part is not implemented – this part is being incorporated later as an area where the living and sleeping takes place. E.g. as separate units being attached like an additive system.

The ideas from the previous page act as the starting point for the modelling and are as far as possible incorporated in the models.

In all the models the heavy part of the construction contains bath/toilet facilities, cooking facilities and a safety closet. This program are placed in the heavy part of the construction because of the moist and fireproof properties of the heavy construction, but also because of the symbolic value of something heavy as being secure.



Model #1

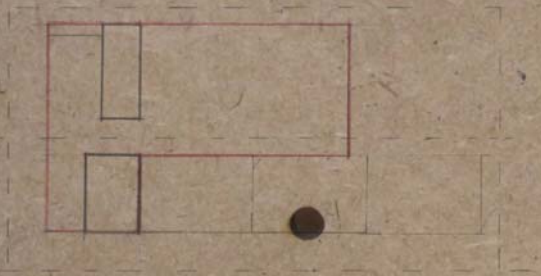
The model consists of a relatively small heavy base containing only the necessary program as closet, cooking and WC/bath.

The roof is constructed to give and organic impression although being made of straight beams e.g. bamboo sticks. The roof is furthermore though as being able of catching wind for cooling by natural ventilation.

ill. 100.1: model photo and plan drawing of model #1

Model #2

This model has a relatively bigger base where living activities can take place. The base is shaped as creating small plateaus for sitting and for storage. The base is inhabited by secondary program like carved out of a monolithic mass. The roof is a simple pitched roof with varying length of the rafters to create different shading properties.

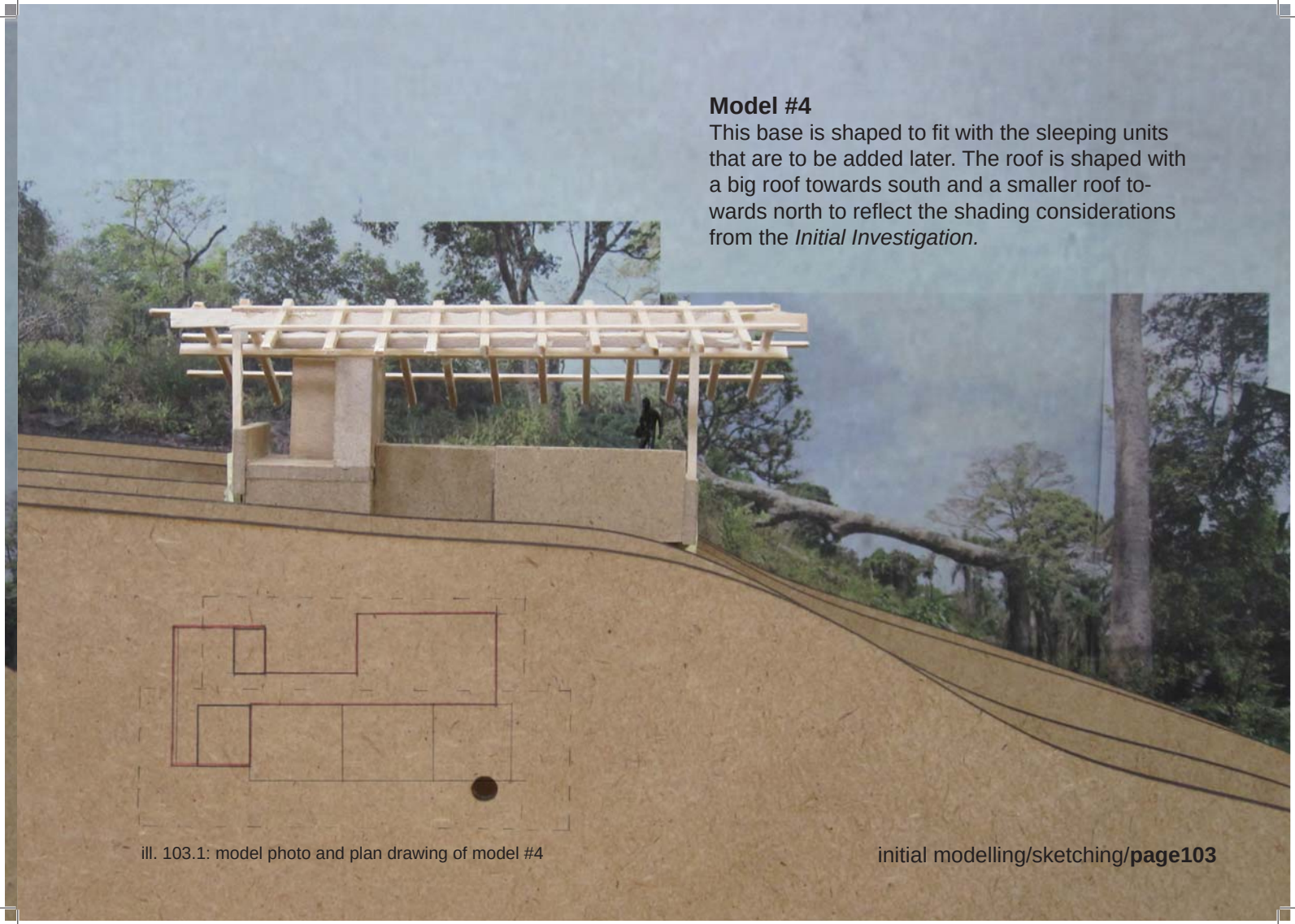


ill. 101.1: model photo and plan drawing of model #2

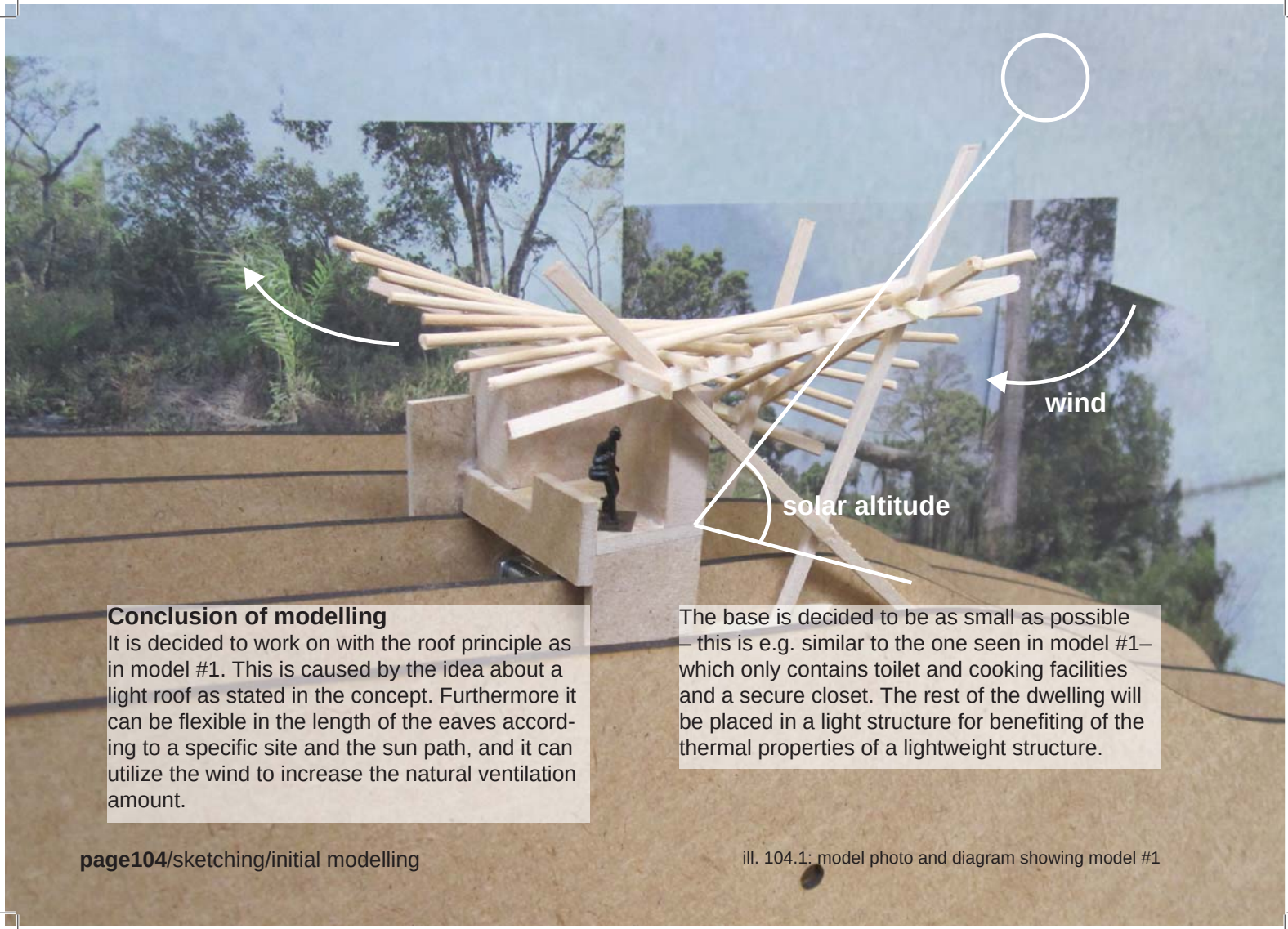
Model #3
This model has a simple base as well, with the basic program. The roof is a shed type where the highest site is facing north and the lowest side is facing south to provide shading in the building. The roof is seen as being extended from the building outline to provide a shaded area around the dwelling.

ill. 102.1: model photo and plan drawing of model #3

Model #4
This base is shaped to fit with the sleeping units that are to be added later. The roof is shaped with a big roof towards south and a smaller roof towards north to reflect the shading considerations from the *Initial Investigation.*



ill. 103.1: model photo and plan drawing of model #4



Conclusion of modelling
It is decided to work on with the roof principle as in model #1. This is caused by the idea about a light roof as stated in the concept. Furthermore it can be flexible in the length of the eaves according to a specific site and the sun path, and it can utilize the wind to increase the natural ventilation amount.

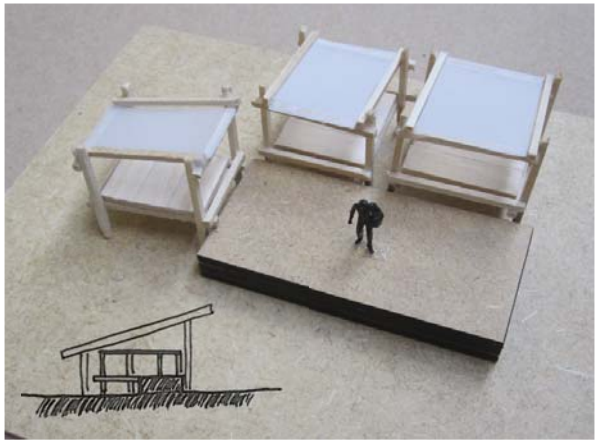
The base is decided to be as small as possible – this is e.g. similar to the one seen in model #1– which only contains toilet and cooking facilities and a secure closet. The rest of the dwelling will be placed in a light structure for benefiting of the thermal properties of a lightweight structure.

ill. 104.1: model photo and diagram showing model #1

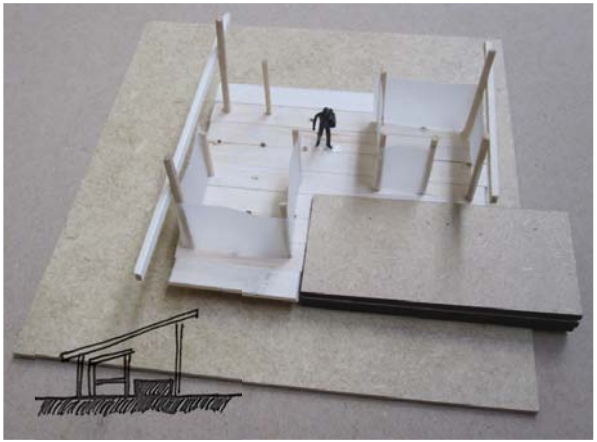
Frame modelling

The part in-between the base and the roof – called the *frame* are supposed to be flexible in terms of specific site conditions and the occupants. Two main principles have been tested. The first(ill. 105.1) is an additive system comprising small programmed units - e.g. a sleeping unit or a living unit - that are to be plugged in at the base. The idea is that you can “buy” the units you need and e.g. when the children are leaving the home, the parents can sell the unit to another family that needs a sleeping unit.

The other principle(ill. 105.2) are about a general terrace that is based on a grid system and if site specific or occupant specific attributes are needed - walls, doors and facades can be changed within the grid system. This principle adds more freedom in the way of arranging the dwelling and it is chosen to work on with this principle. The other principle can have a tendency of being too static, because the units are not easy to change or replace.



ill. 105.1: model photo and drawing of model where different units can be added - e.g. sleeping unit



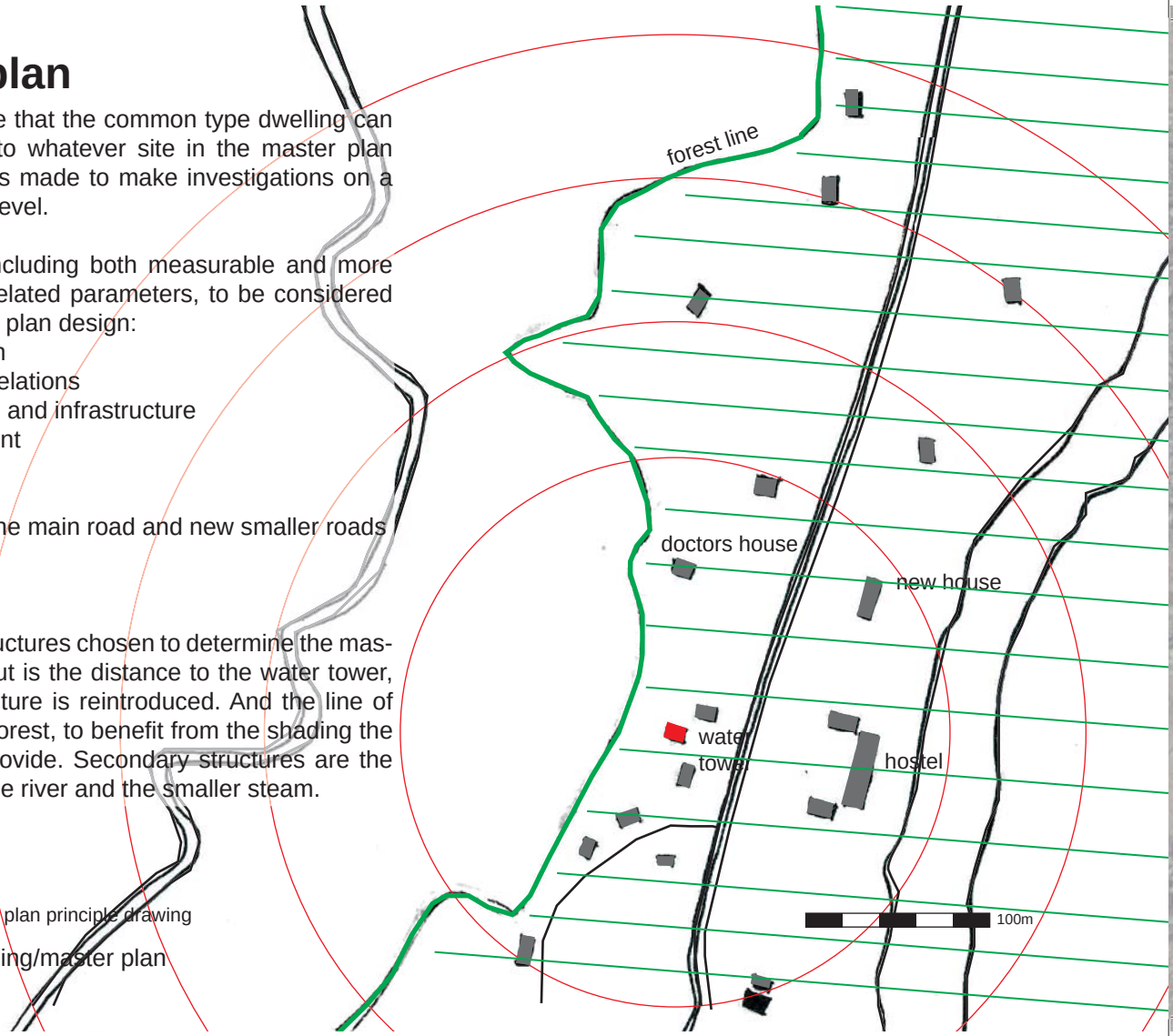
ill. 105.2: model photo and drawing of model where columns and walls can be changed in a grid system.

master plan

To make sure that the common type dwelling can be adapted to whatever site in the master plan a zoom out is made to make investigations on a master plan level.

Keywords, including both measurable and more experience related parameters, to be considered in the master plan design:
- organization
- neighbour relations
- installations and infrastructure
- air movement
- security
- status
- relation to the main road and new smaller roads
- arrival

The main structures chosen to determine the master plan layout is the distance to the water tower, that in the future is reintroduced. And the line of the existing forest, to benefit from the shading the high trees provide. Secondary structures are the main road, the river and the smaller steam.



ill. 106.1: master plan principle drawing

Through sketching different principles has been investigated, and the layout at the right is chosen(ill.107.1)(see app.7 for the different sketches). It is constellated as small clusters - as a village in village principle – which has a strong relationship inwards in the cluster.

It is related to the water tower and the forest line.

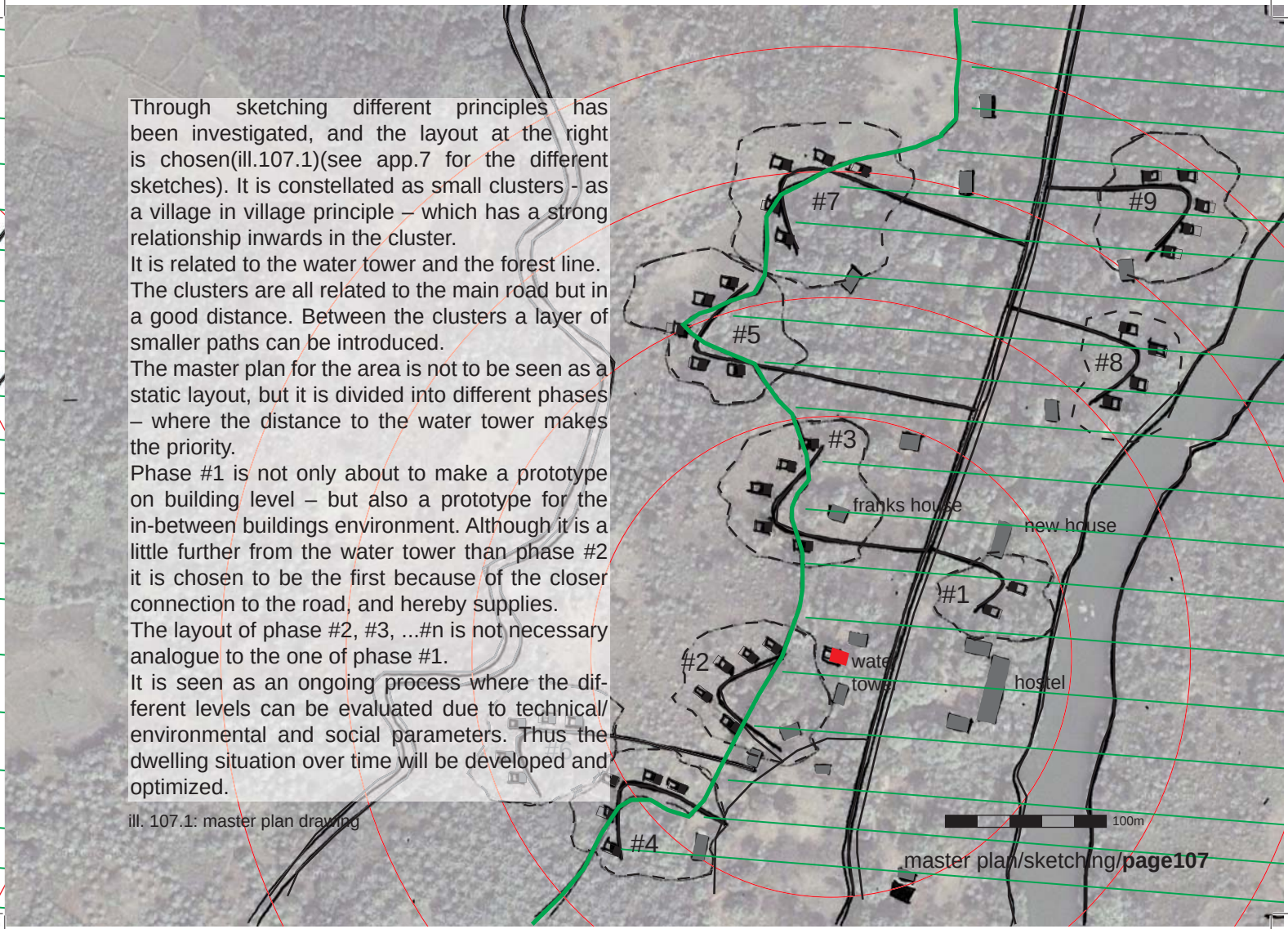
The clusters are all related to the main road but in a good distance. Between the clusters a layer of smaller paths can be introduced.

The master plan for the area is not to be seen as a static layout, but it is divided into different phases – where the distance to the water tower makes the priority.

Phase #1 is not only about to make a prototype on building level – but also a prototype for the in-between buildings environment. Although it is a little further from the water tower than phase #2 it is chosen to be the first because of the closer connection to the road, and hereby supplies.

The layout of phase #2, #3, ...#n is not necessary analogue to the one of phase #1.

It is seen as an ongoing process where the different levels can be evaluated due to technical/ environmental and social parameters. Thus the dwelling situation over time will be developed and optimized.



ill. 107.1: master plan drawing

the village (in the village)

The clusters are seen as having a strong internal relationship – between one building and another. A zoom is made to clarify these relations and how the layout of a single cluster is.

Issues to be aware of are:
- relation between the dwellings
- where to place the social spaces in the dwellings
- placing of dwellings in terms of cross ventilation

At the next page different organizations of the clusters are listed(ill 109.1). To make more freedom in the placing and the rotation of the different dwellings, some additional calculations are made to give an idea about, what will happen, if the dwellings are rotated 45 degrees (see app. 8).
The dwellings will have a decrease in the internal thermal comfort – but because the dwelling now can be rotated to increase cross ventilation this will be accepted.

The third organization principle is chosen as the starting point(ill. 109.1). It provides good conditions in terms of cross ventilation in the dwellings because the buildings does not block for each other.

Furthermore the dwellings have the same overall direction where the kitchen part of the dwellings are facing the same direction – facing the main road, and the dwellings will be as close to still create a kind of intimate relation.

ill. 108.1: photo from a village nearby Masanga

ill. 109.1: sketches showing cluster principles

1) The size of the cluster in relation to the sociel connection and air movement

2) Make the cluster more directional in terms of the direction the kitchen is facing.

3) Shape the cluster in terms of not restricting the air movement by the dwellings blocking for each other

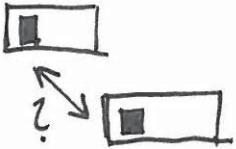
rotatation of the th
thatching roof

Relation between dwellings

Because of the outdoor kitchens in Masanga this connects the different dwellings and families. This connection is thought to be incorporated in the design. The idea is that through the cooking activities and related facilities it is possible to create a connection between the dwellings and create a community spirit known by the occupants from their present dwellings.

Different organizations have been considered, but the two main directions are a circular layout and a straighter layout, where the straighter seems to provide the same introvert relation around “the fireplace” than the other, but still keep the idea about having the heavy part of the dwelling facing the main road.

This has to be incorporated in the considerations from the previous page.



how to relate the buildings?

rotatation of the heavy part to create relation

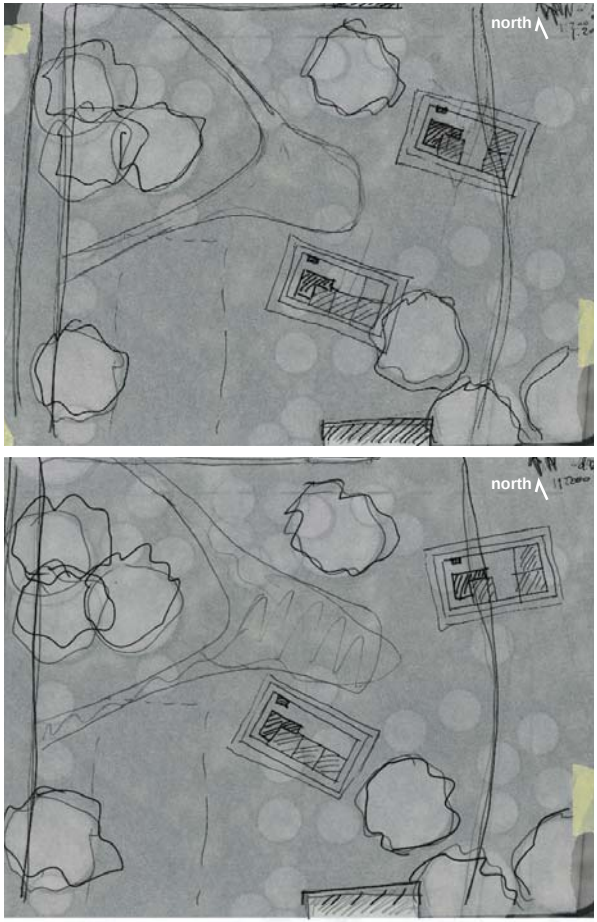
mirroring of the the building

ill. 110.1:sketches showing building relations

ill. 111.1: photocollage of some of the kitchens in Masanga

implementation at the site - phase #1

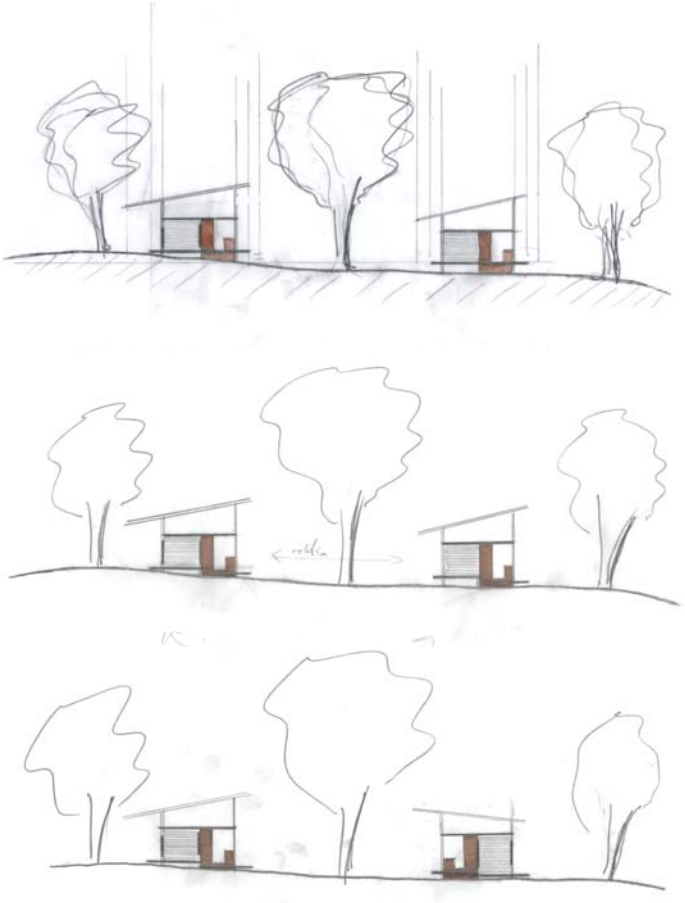
In the following pages the placement of two dwellings at the site between *new house* and the hostel is investigated.
As mention at the *Master plan* section phase #1 has two major points to examine.
Phase #1a: one dwelling and how it works functionally, technically and cultural.
Phase #1b: two dwellings and how they relate to each other.
At the illustrations at the right two plan sketches are shown(ill. 112.1-2). The first one show the two buildings being placed parallel and the kitchen part in the dwelling are facing north. A connection between the dwellings is created by the placement of the rooms - where the northern dwelling has an axis through the dwelling, which creates a relationship to the southern one.
The lower one works with a rotation to make the kitchen part have a relatively larger relation.



ill. 112.1-2: plan sketches showing buildings at the site

Sections

For examining the spatial properties of the dwellings and the in between relation, some sections are made. The illustration at the right shows three sections with the two dwellings. (ill.113.1)
The first one deals with a relatively simple section, where the kitchen in both dwelling is facing north.
In the next one a level in the dwellings are introduced to make the dwelling meet the landscape, and hereby create a relation to the surroundings and the other building.
Although different moves can be made to approach a better relation between the buildings, it is realized that a mirroring of one of the dwellings is the best. This causes that the kitchens of the two dwellings are facing each other, and strengthen the relation. The solution is shown in the bottom section of ill. 113.1. A disadvantage of this is that a higher roof towards south is needed, which can cause some problems in terms of solar radiation on the facade, but this has to be dealt with by using a larger roof eave.



ill. 113.1: diffrent sections showing the relation between two buildings

Summary

Throughout the sketching phase “the outline” of a common dwelling type has been found. Though still on a conceptual level that has to be further detailed in the *Synthesis* phase. The dwelling has an organic shaped roof that can utilize the wind for cooling the dwelling and that can be adapted to a specific site. The heavy part of the dwelling contains a secure closet, bath/toilet and cooking facilities and act as a part that are expressing status and security.
The light constructed part or the so called *frame* of the dwelling contains the living area and the sleeping areas.

The master plan is made with the distance to the water tower and the line of the high existing forest as the main determining factors, and the dwellings are placed in small clusters.
The different dwellings can be mirrored and rotated to fit into a specific context and in relation to the neighbouring buildings.

ill. 114.1: photo of a 1:100 process model

synthesis

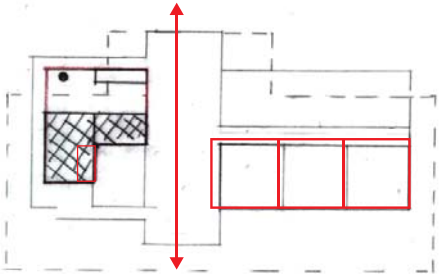
In this phase of the project the detailing of the common dwelling will take place and in this relation consideration of how it is placed on the specific site comprised in the phase #1 of the master plan (see page 107).
Furthermore natural ventilation, thermal analysis, material and construction will be treated.
Afterwards a final zoom out will be made to detail and clarify the overall master plan.
The different topics throughout this section will be quite divided although it has been a parallel process that from time to time has focus on different aspects of the design. The division in this report is only to provide a better overview to the reader.

ill. 116.1: photo of rammed earth mock up

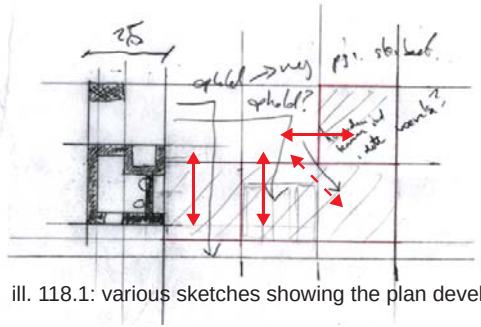
plan development and detailing

This chapter concerns the development of the plan of the dwelling from the initial sketches to the detailed plan. Although the plan/layout has been developing parallel to other issues throughout the design process, it is presented as a whole to clarify notions as organization of program, grid system, flexibility, relation to the surroundings, security etc. Some sketches of the plan development can be seen in the sketches at the right(ill. 118.1). The sketches are to be read from left to right.

The dwelling has its flexibility and extension possibility in the light construction part at the right.
There is an outward orientated axis across the dwelling. One room has a special character of being the permanent and the place where the safe closet is placed.

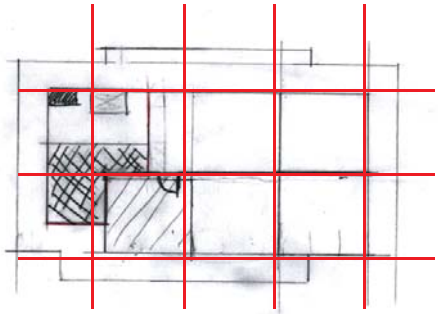


The dwelling can be arranged in different rooms according to the grid. But a problem occurs in the access to the rooms.

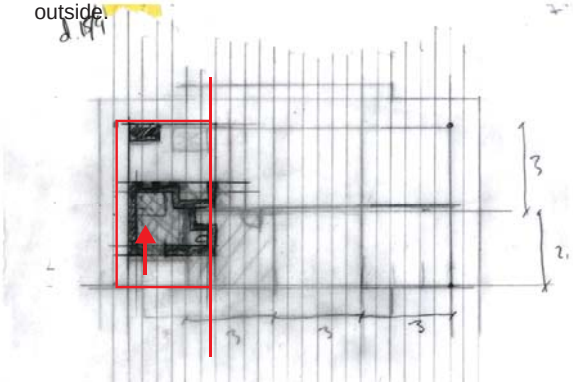


ill. 118.1: various sketches showing the plan development

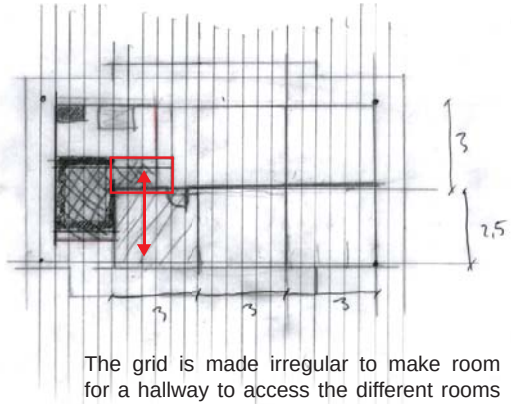
The dwelling is minimized and a grid system is introduced.



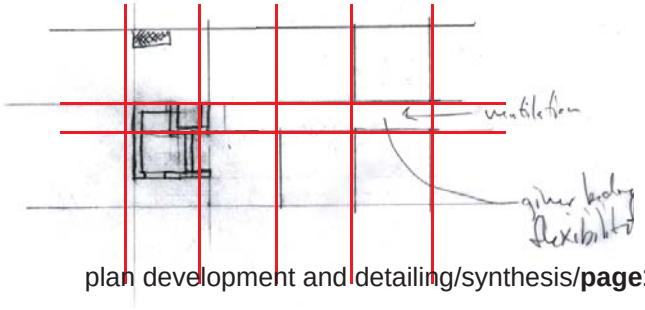
The heavy part is reduced to follow the grid and to not interrupt with the master sleeping room. The toilet/bath is accessed from the outside.



The relationship between the master sleeping room and the heavy part containing the secure closet is investigated.

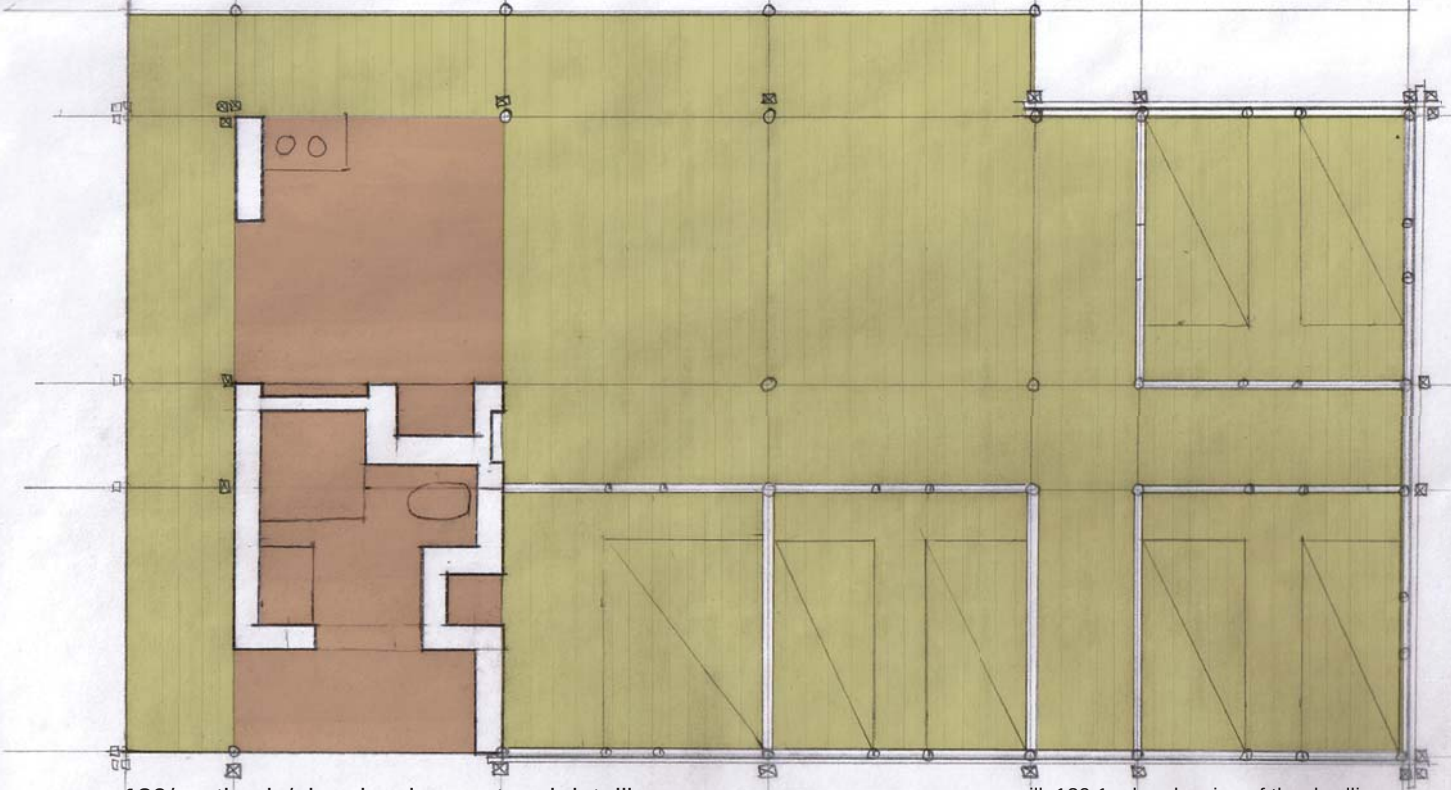


The grid is made irregular to make room for a hallway to access the different rooms independent of how they are arranged. Furthermore this provides an increased possibility for ventilation along the dwelling.



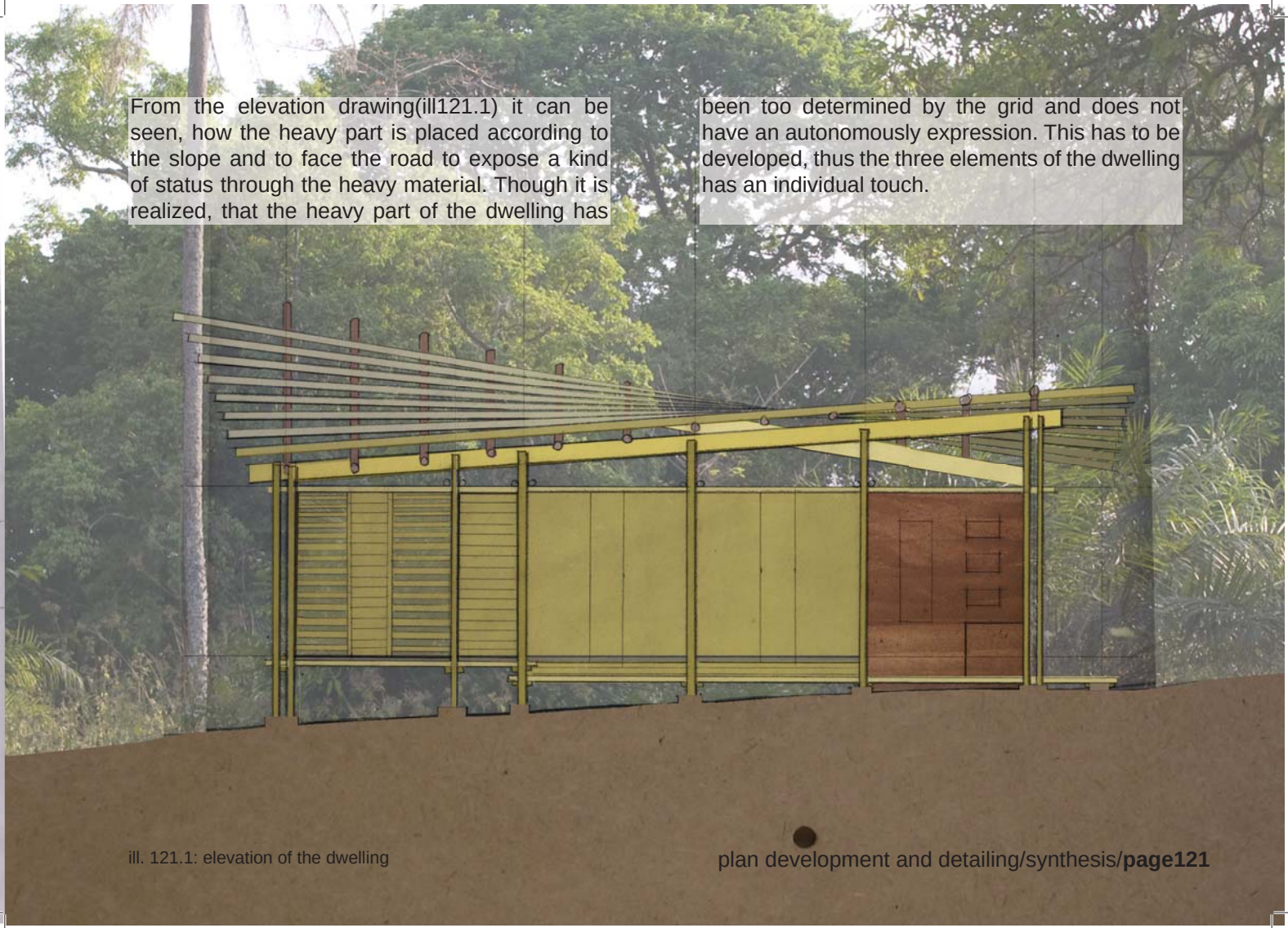
Plan and elevation

At ill. 120.1 and ill. 121.1 an intermediate plan and elevation is shown. The plan has a grid structure that is made irregular because of having two hallways in the longitudinal and transverse direction of the dwelling. This provides flexibility, but also some obvious emergency exits and cross ventilation ways.



ill. 120.1: plan drawing of the dwelling

From the elevation drawing(ill121.1) it can be seen, how the heavy part is placed according to the slope and to face the road to expose a kind of status through the heavy material. Though it is realized, that the heavy part of the dwelling has been too determined by the grid and does not have an autonomously expression. This has to be developed, thus the three elements of the dwelling has an individual touch.



ill. 121.1: elevation of the dwelling

ill. 122.1: photos of 1:20 model

The heavy part

To develop the heavy part of the dwelling in terms of providing an individual expression independent of the grid, models of the heavy part are made in 1:20.(ill. 122.1)

The importance of the individual expression of the heavy part is related to the concept (page 97) to have the three main parts that all have their attributes and expression.

The heavy part is organized to fit to the programme it contains and thus overruling the grid.

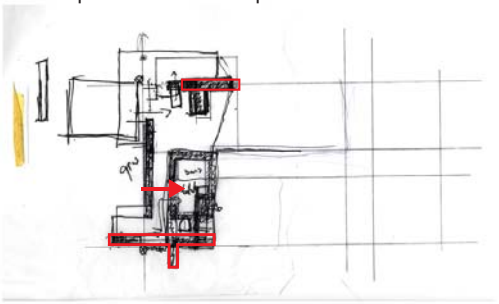
The development is also explained in the sketches at the right(ill. 123.1 - are to be read from the left to the right).

An important factor the heavy part has to express, is the secure and status, which are present to the user in having a heavy construction.

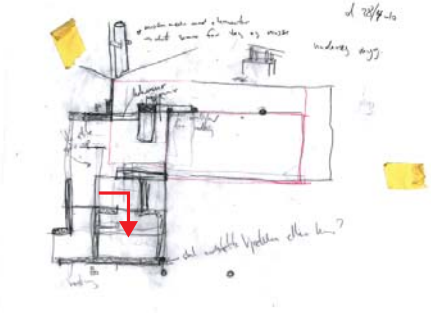
Derived from the interviews made with the potential users a concrete construction was preferred. This heavy expression is being transferred to a rammed earth wall construction that is cheaper and has a larger relation to the context.

This is also the reason for placing the heavy part of the dwelling in the “public“ end of the dwelling. And by making the rammed earth walls create overlaps an expression of having an entire heavy construction will occur from the road.

The heavy part is further developed to not being a part of the grid - and hereby getting an expression of its own. The access to the bath and toilet is moved to the west facade in terms of optimization of the space used.

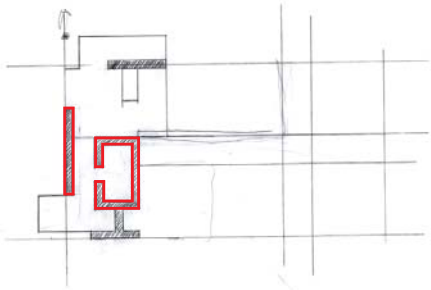


The bath/toilet entrance is moved again to provide an optimization of space and to relate it more to the interior, without creating direct access, which is seen as bad for hygiene reasons.

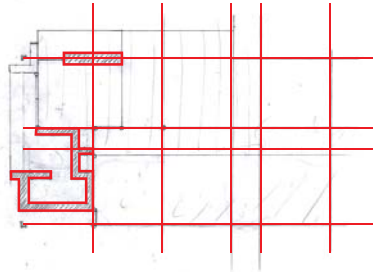


ill. 123.1: various sketches showing the plan development

The toilet/bath is seen as an outdoor part, only covered by the roof, but open without any ceiling. The bath/toilet is constellated as an open part with walls screening for insight.



The final plan comprises the lightweight structure in two levels and organized in an irregular grid and the heavy part that is more free and organized to fit to the containing program.

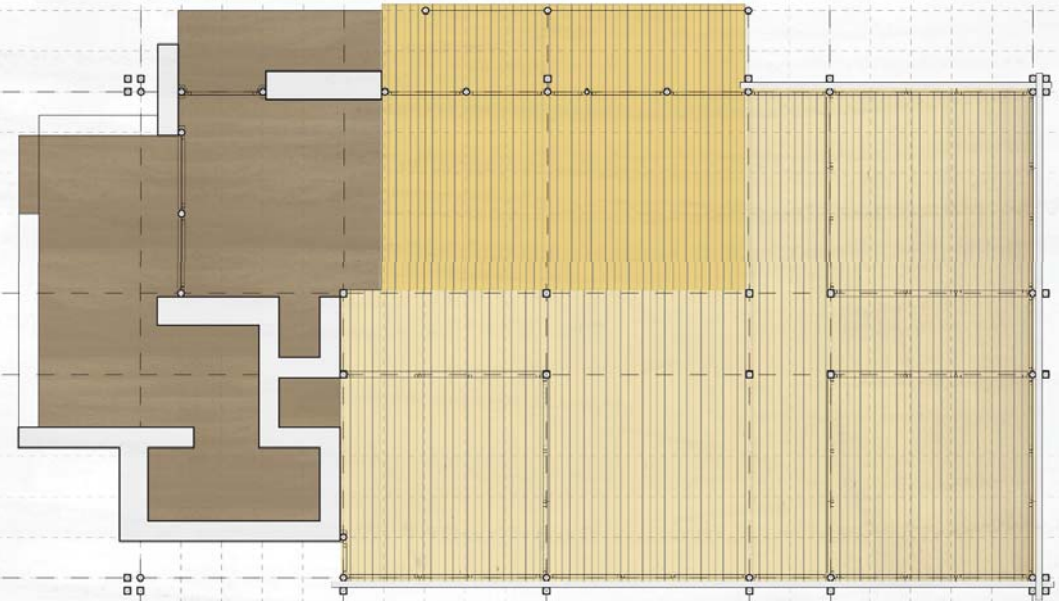


Plan and elevation

At ill. 124.1 and 125.1 the final plan and section of the dwelling is shown.

There is an overlap between the heavy and the light constructed parts and they merge together because of the level and the program.

Furthermore the heavy part is reduces where the roof columns are places to make the division clearer, thus only touching the roof structure at the two walls stabilizing the roof.



ill. 124.1: plan drawing of the dwelling

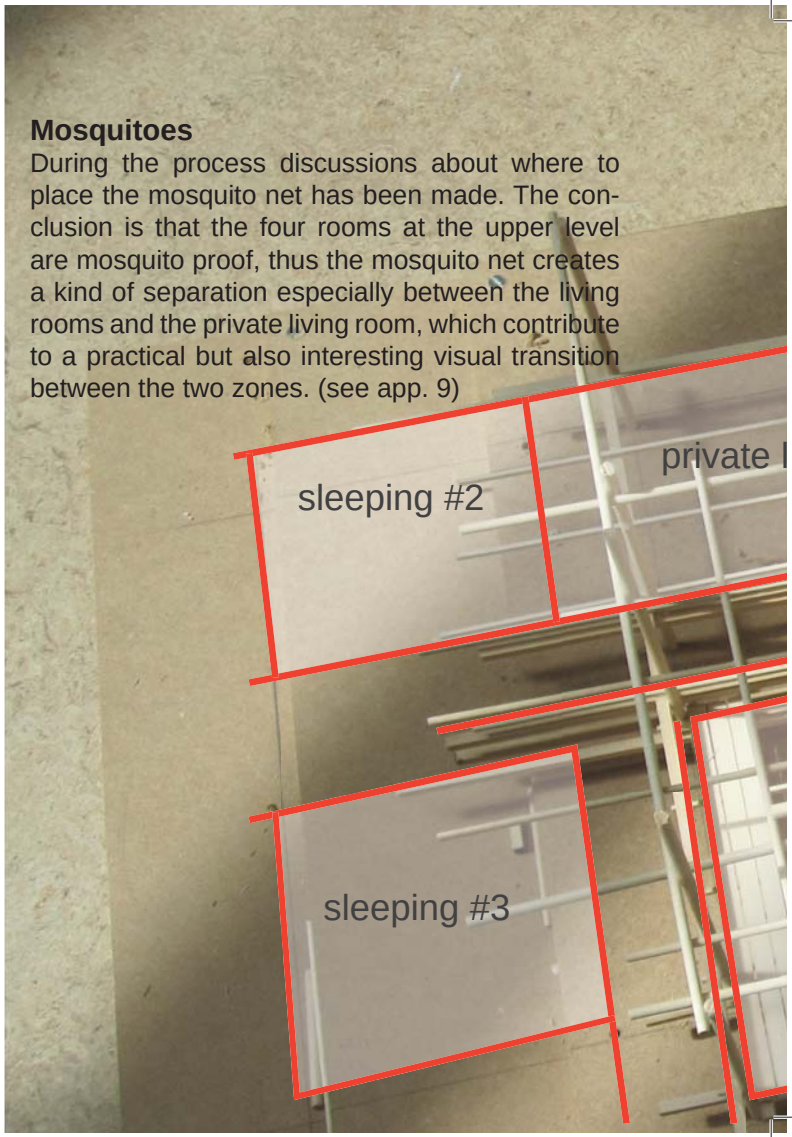
ill. 125.1: elevation of the dwelling

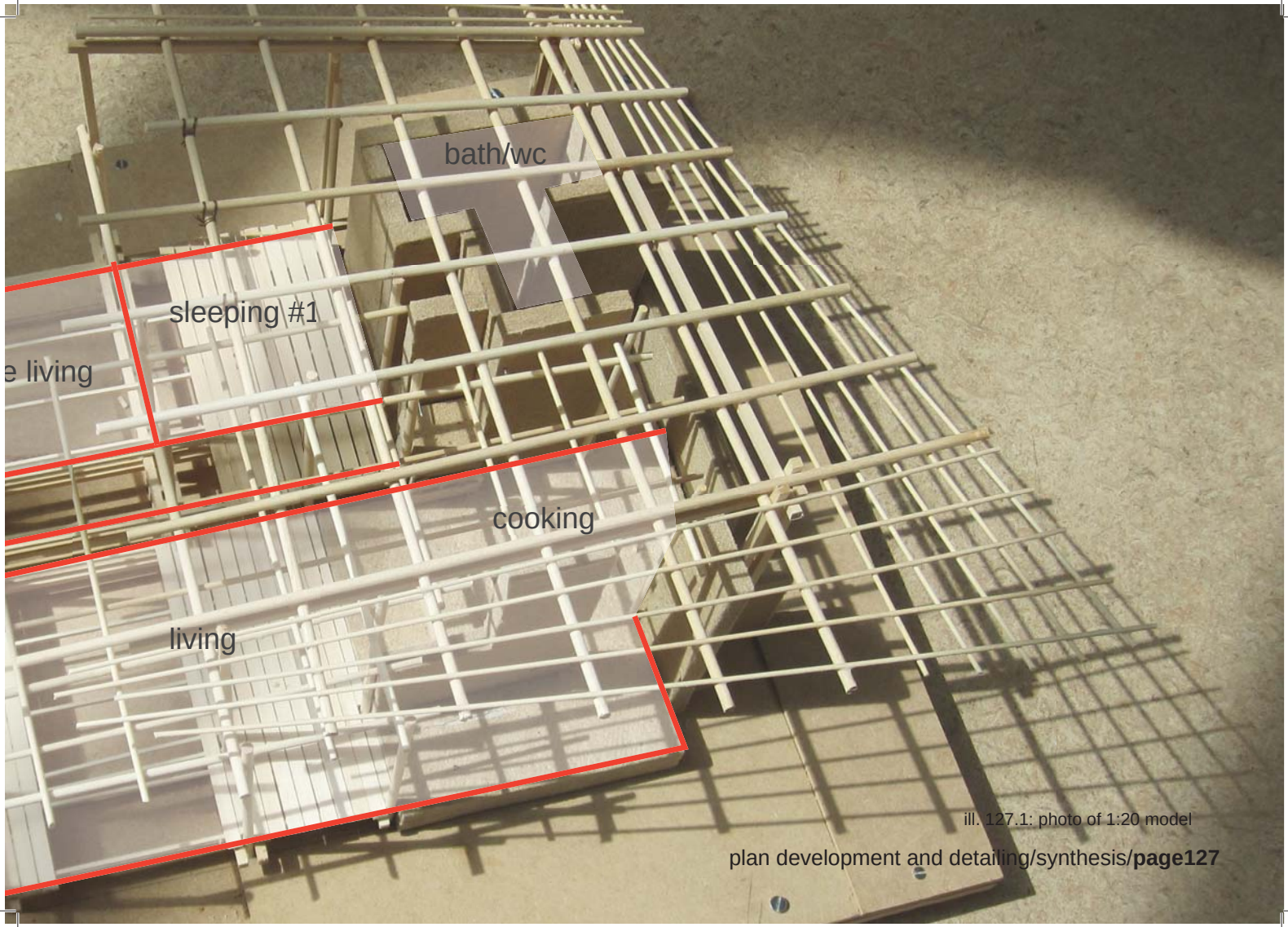
Zoning

In the illustration at the right the zones and rooms of a dwelling is visualized(ill. 127.1).
The dwelling consists of two levels - one containing the heavy part with bath, closet and cooking and the living/dining room.
The upper level contains the sleeping areas and a more private living room. This part is the flexible, where the order of the private living room and the sleeping rooms can be changed. Furthermore the hallway space can be included in a sleeping room, when it is used by more children, or the private living room can be extended. The only permanent rooms is the sleeping#1 because it has the access to the secure closet, and thus seems optimal always to place the master sleeping room next to this.
The edge between the two levels is seen as a place for sitting e.g. in the absence of furniture. The level creates a lower part that relate to the outdoor and an upper part that is more private and intimate.

Mosquitoes

During the process discussions about where to place the mosquito net has been made. The conclusion is that the four rooms at the upper level are mosquito proof, thus the mosquito net creates a kind of separation especially between the living rooms and the private living room, which contribute to a practical but also interesting visual transition between the two zones. (see app. 9)





ill. 127.1: photo of 1:20 model

natural ventilation

With natural ventilation it is worth considering the worst case of temperatures and thus the important is to provide cooling by natural ventilation when the sun is shining, it is hot and there is no wind. Hence it is not optimal to only focus on a natural ventilation strategy based on wind. From the limited weather data from Makeni the wind is strongest during Marts. But because the wind is so weak – 3,6km/h in average according to weather data from Makeni (see Climate, page 34) it will not be considered in terms of the overall natural ventilation calculations, but only act as an extra bonus in terms of increasing the natural ventilation.

Because no active cooling is being used in terms of mechanical air conditioning, because of the economical situation of the project and the fact that there is no reliable electricity supply, the optimum is to reach the outdoor temperature. It will not be possible to provide a lower actual temperature than the outdoor, but of cause the experienced temperature can be lower in terms of an increase in air movement, the so called chill factor.

In the following section the natural ventilation in the dwelling will be considered and following points are to be taken into consideration:

-Openings and the placement of the openings

-Hours of occupation in the different zones of the dwelling

-Security – when can the dwelling be open and when should it be closed in relation to theft.

-Openings in relation to mosquitoes – when does the mosquitoes bite and when do they enter the dwelling (see app. 9)

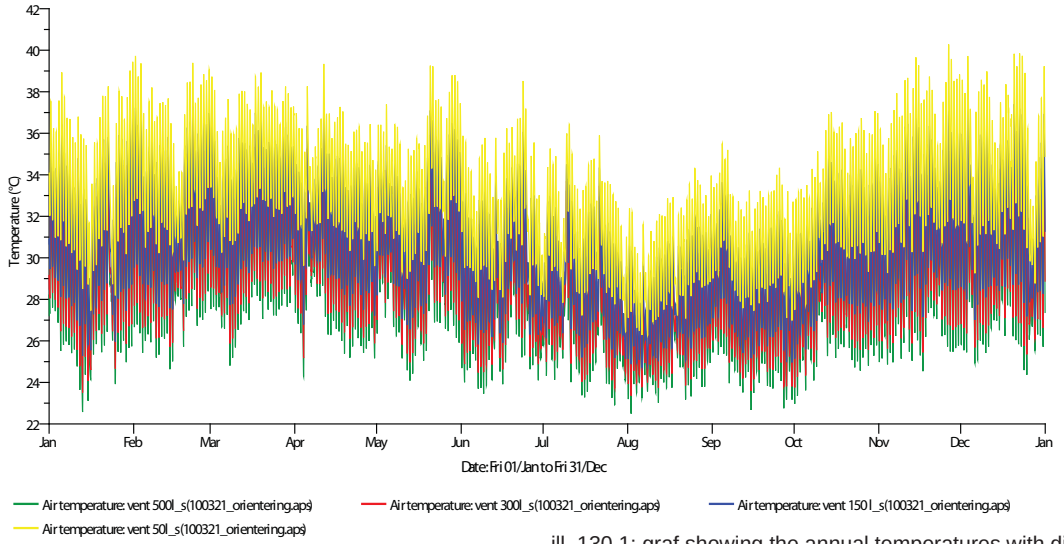
-Blocking of openings by furniture and storage

ill. 129.1: wind catchers for driving natural ventilation

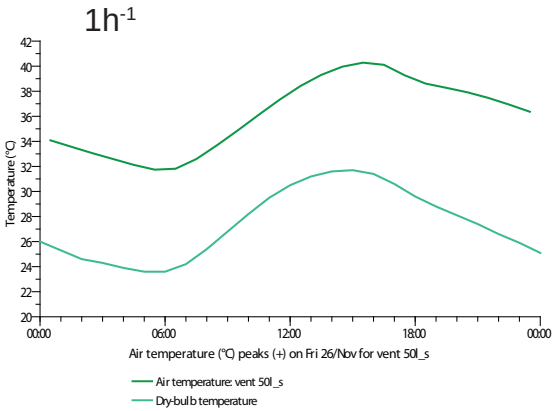
Air change and temperature

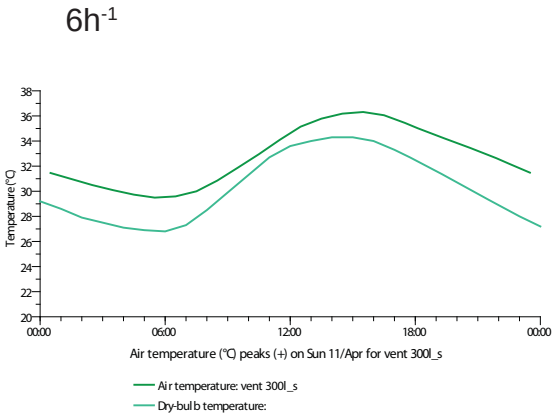
As a starting point an investigation is made about how the air change can affect the indoor temperature. From ill. 130.1 below it can be seen that higher air change result in lower temperature.
From the illustrations on opposite page the same pattern is seen for the diurnal temperature at a specific peak day(ill. 131.1-4).

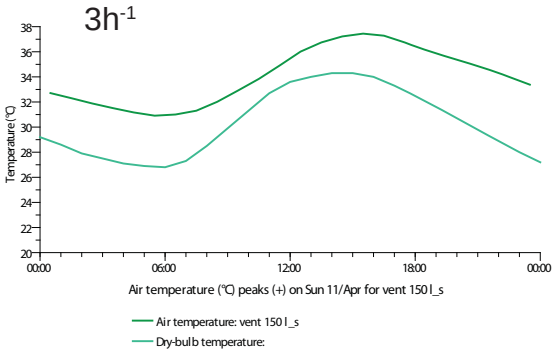
Interesting to notice is that the case with the smallest change of air is not peaking at the same day as the other cases. This can be because it is not that influenced by the outdoor temperature.
A logic conclusion is that an increase in air change will approximate the indoor temperature to the outdoor temperature. And thus a high change of air is beneficial, but still considering the possibility of regulation by the user in terms of draught.

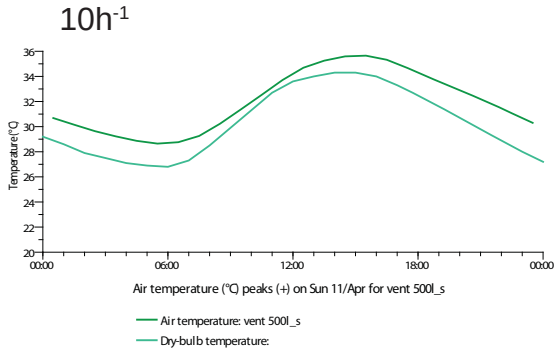


ill. 130.1: graf showing the annual temperatures with different air change









ill. 131.1-4: grafs showing the relation between diurnal temperature and air change

Natural ventilation - a tool box

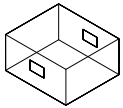
An important factor in relation to natural ventilation is thermal buoyancy, which is the air flow caused by temperature differences. The starting point for this investigation is the building with an air change on $3h^{-1}$ from the previous investigation(page 130), where the openings differ in size and in the height difference from the window on the one side of the building to the other.

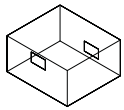
The investigation has to be seen superior, because the starting point of the investigation is an outdoor temperature on 34,4°C and an indoor temperature on 37,4°C based on the temperatures from the previous investigation(page130), where the building with an air change on three times per hour is used as case. See natural ventilation app.10 for the thermal buoyancy calculations made.

The reason for not being too strict about the results is that the calculation is based on a temperature difference between indoor and outdoor, but it does not take into account that with the increase in air change the indoor and outdoor temperature equalizes.

From ill. 133.1 on opposite page it can be seen that the larger an opening you have, the higher air change. The same goes for the increase in height difference between the openings on one facade to the other.

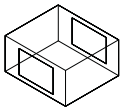
In relation to the opening size and height it has to be considered, how open a dwelling can be in terms of security, and the possibilities to get daylight through the openings, or have the possibility to see out of the window. These issues will be further treated under *Daylight*(page 150) and *The element system*(page 166).





	0,2m	1,0m	2,3m
			height difference →
0,4m²	0,39h⁻¹	0,86h⁻¹	1,31h⁻¹
4m²	3,8h⁻¹	8,6 h⁻¹	13,1h⁻¹
8m²	7,7h⁻¹	17,2h⁻¹	26,1h⁻¹

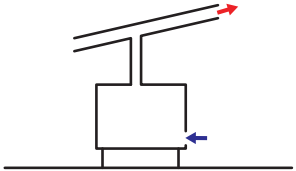
opening area ↓



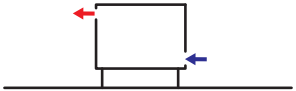
ill. 133.1: diagram showing the relation between thermal buoyancy, opening area and height difference

Natural ventilation strategies

In this project the focus on a natural ventilation solution will be limited to a sleeping room; this is to have a defined volume as the frame for calculations, and hereby limit the extent of the parameters taken into consideration.
Different ventilation strategies have been considered. See ill 134.1.
The first one illustrates the idea of using a double roof membrane to create a stack effect, which can run the ventilation.
The second one illustrates how the thermal buoyancy can be forces by a difference in opening heights, and thereby the openings do not have to be that large.
The third one has a quite open facade to provide the necessary air flow.
In the last one the inlet is placed in the floor providing relatively cooler air and the outlet is placed in the ceiling.

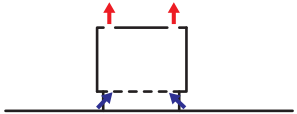


1) double membrane heat the outlet air and runs the ventilation



2) cross ventilation with inlet in the bottom and outlet in the top

3) cross ventilation provided by relatively large opening in both sides.



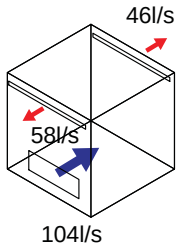
4)inlet openings in the floor and outlet openings in the ceiling

ill. 134.1: diagrams showing different ventilation strategies

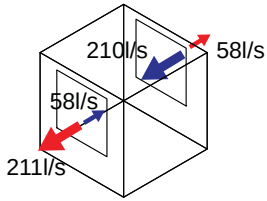
In the building simulation programme Virtual Environment (see page 77) some models for ventilation solutions has been made to give an idea about how the different solutions act.
From ill. 135.1 it can be seen, that the highest air flow is obtained in the solution with relatively large windows in the facade, and the smaller windows, the smaller air flow.
This does not necessarily mean that the largest windows are the best solution, because in this investigation the air flow caused by wind is also present. And thus the large windows in equal height is depending more on the wind. Furthermore a solution with inlet at floor height and outlet at the ceiling also provides a relatively large air flow.

Conclusion

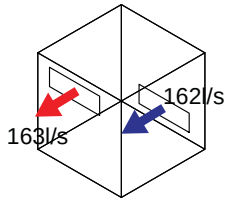
The idea of using the roof membrane as a part of the ventilation strategy seems in this project to complex in terms of construction, and the idea of having an entirely open facade would not be sufficient in terms of security. It also seems to depend a lot on the wind, but a facade with high infiltration, can be considered although the possibility of regulation is not realistic.
A realistic solution can be a combination to have an opening at the floor and an opening in relation to the ceiling. The opening at the floor has to be placed in the lower part of the wall, not in the floor in terms of the regulation possibility.
This will act as the starting point for further thermal investigations.



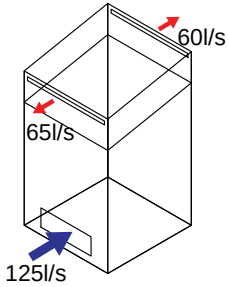
1) One large inlet at floor height and two smaller outlets at the ceiling



2) Two large openings covering more or less the entire facade



3) Two openings - one at floor level and one at ceiling level



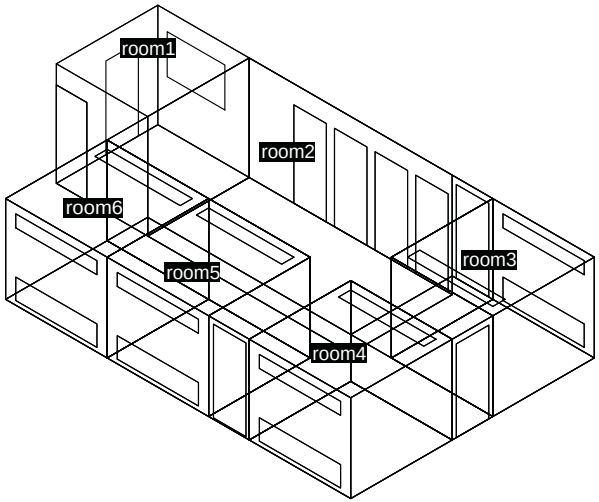
4) A solution where the rooms is being extended to under the roof.

ill. 135.1: diagrams showing air flow for different opening constellations

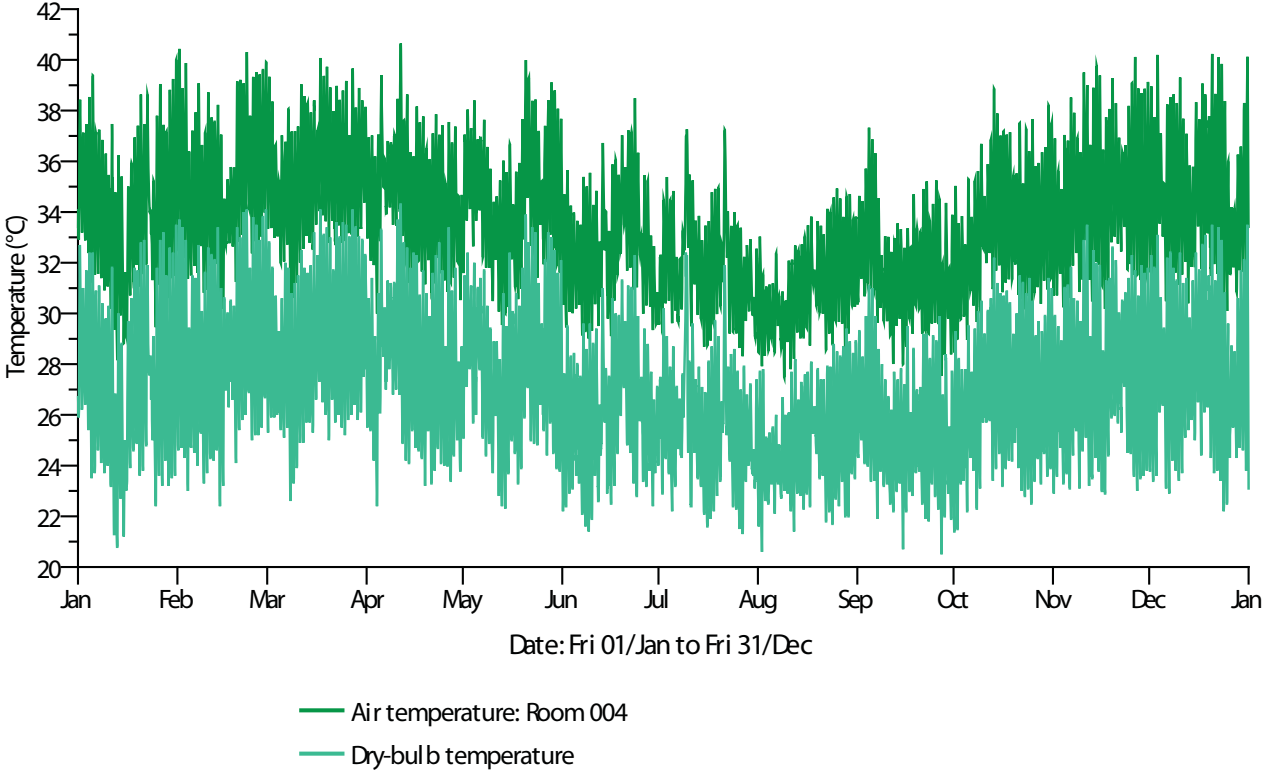
thermal analysis

As a continuation of the experiences made during the initial investigations and the design process a model is build in Virtual Environment for doing thermal analysis. The model is built as a simplification of the actual design.
The model contains of six rooms where the one (room 1 in ill 136.1) is assigned heavy construction to reflect the idea about making it in rammed earth, and the rest of the materials are assigned lightweight materials. Furthermore the sleeping rooms have been levelled by changing the transition coefficient of the floor.
The people load is set to 5 people at all times to reflect a worst case scenario.
The openings in the sleeping rooms are placed at floor level, at ceiling level and in the ceiling, as a development of the experiences made during the *Natural ventilation* section(page 128-135). Initially the openings are set to be 10% open at all times. This will later be changed to see the effect of cooling by natural ventilation.
In the first model the roof is not implemented as a shading device - just to clarify the effect of the shading from the roof.

The temperature from the first analysis can be seen in ill.137.1 and ill. 138.1 at the two following pages.
The room used as a case is room number 4 and from the ill. 137.1 at page 137 it can be seen that there is quite a difference between the outdoor temperature and the indoor temperature.



ill. 136.1: diagrams showing the different rooms in the building

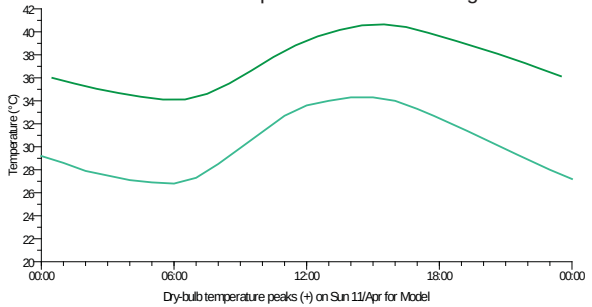


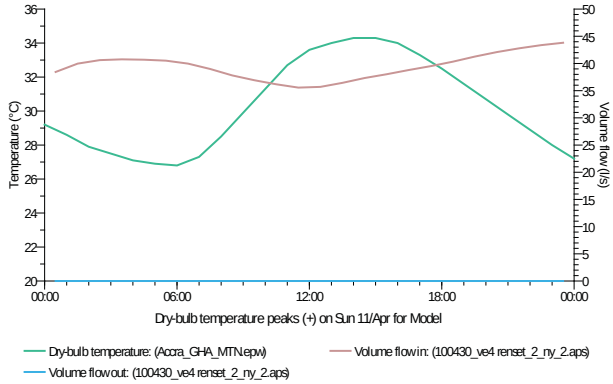
ill. 137.1: graf showing the annual temperature in the building without a roof

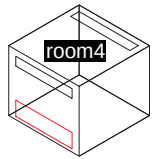
From the diurnal temperature at the peak day (see ill. 138.1) the temperature is approximately seven degrees above the outdoor temperature. This can be caused by the relatively low air flow rate. This is illustrated in the ill. 138.2 below, which state an airflow rate on approximately 35l/s, which is equal to an air change on 8 times an hour. Another important factor is that the ceiling is not covered with a roof in this case.

In illustration 139.1 on opposite page the result of the implementation of the roof is shown. The left columns is the model without roof, the middle has a roof that fits exactly to the outline of the building and the right one has a cantilever part on app. 1,5 meters.
As seen in the illustration the temperature drops around 1 degree in the afternoon at the peak day of the 11th of April, when applying a larger roof.

ill. 138.1: graf showing the diurnal temperature of the building without roof

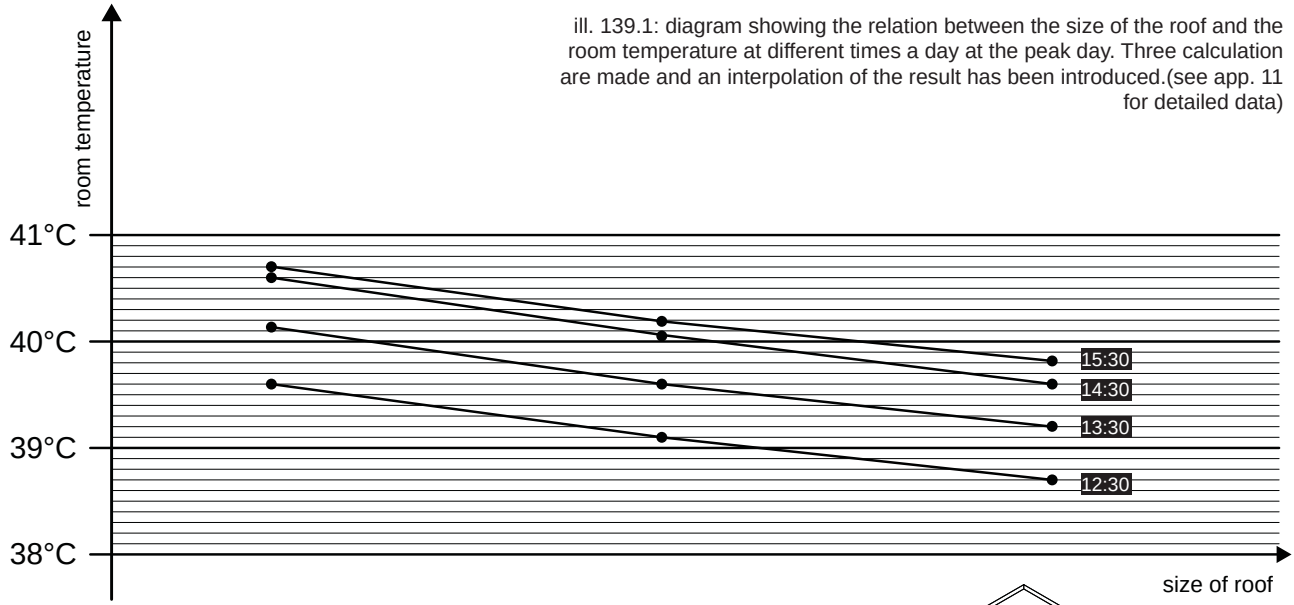


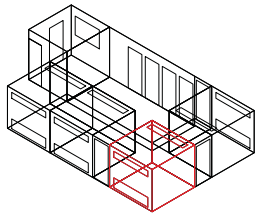


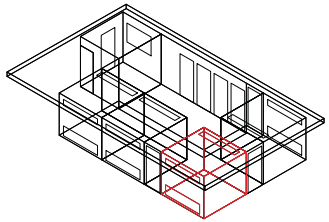


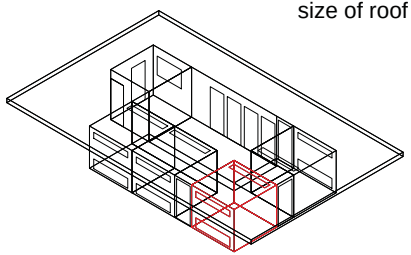
ill. 138.2: graf showing the diurnal temperature in relation to the ventilation amount

ill. 139.1: diagram showing the relation between the size of the roof and the room temperature at different times a day at the peak day. Three calculation are made and an interpolation of the result has been introduced.(see app. 11 for detailed data)









peak temperature	40.65°C	40.22°C	39.80°C
annual mean temperature	33.68°C	33.52°C	33.21°C

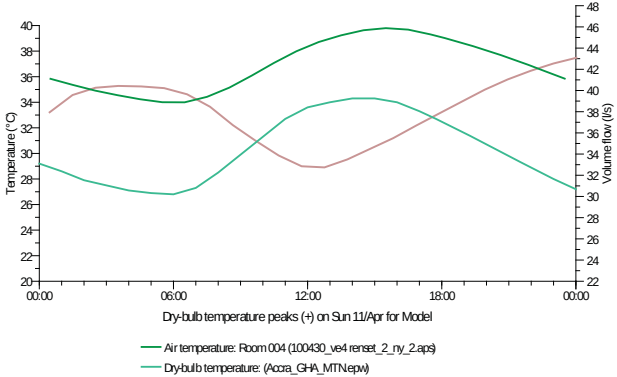
Opening area

To reduce the indoor temperature at the peak day (11th of April) different sizes of opening areas are tested. The peak day is used, because if the indoor temperatures can be reduced this day, it is assumed that the improvements will have the same effect the rest of the year. The same goes for the implementation of the roof at the previous pages.
In ill. 140.1 on this page and ill. 141.1-2 on the next page room number 4 is treated. In the first case the opening area is 10% of the possible opening area. The possible opening area is for room 4 approximately 2,2 m2.

The illustrations on this and opposite page show the room temperature for room 4, the outside temperature and the air flow passing in at the inlet opening in the bottom of the exterior wall. The air flow through this opening is seen as representing the sum of air flow from the three openings in the room, since this will in general be the only inlet, and hereby the air change can be calculated from this.

From the illustrations(ill. 140.1, ill. 141.1-2) it is realized that by increasing the opening area from 10% to 70% the air change is increased by a factor 4,5. And the internal peak temperature drops from 40 degrees to 36 degrees.
The reason for not increasing the opening area even more is based on an awareness that the mosquito net will create a pressure lost of assumedly 30% - and this is being dealt with by reducing the opening.

10%opening - 8h^{-1}



ill. 140.1: graf showing the diurnal temperature in relation to the ventilation amount for room 4

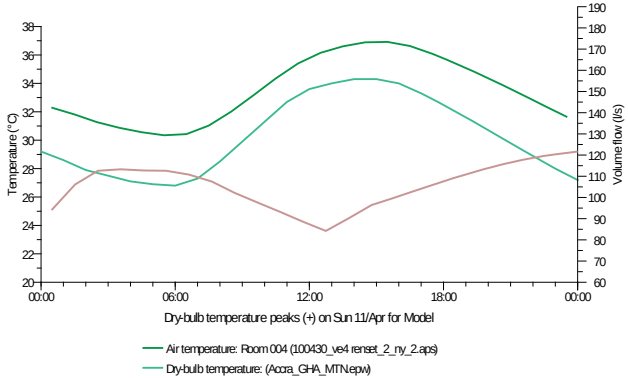
Conclusion

The openings are placed with an inlet at floor level in the outer wall and the outlet is placed in the upper facade part and in the back of the room in the ceiling.

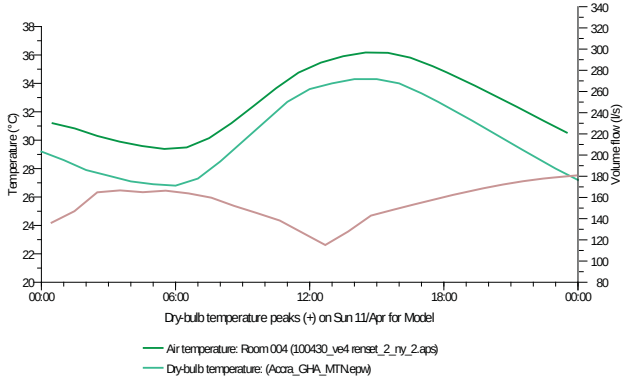
By providing possibilities of regulate the opening area an acceptable temperature can be obtained. Although it may not be possible to obtain an air change at 37h-1, which at least in a Danish perspective seems quite high.

A possibility is to make CFD (Computational Fluid Dynamics) calculation of the air flow through the room to make sure that furniture and storage is not placed to block the openings and to make sure that draught is not a problem.

40%opening - 26 h^{-1}



70%opening - 37h^{-1}



ill. 141-2: graf showing the diurnal temperature in relation to the ventilation amount for room 4

the roof

In the design process the Rhino-plugin Grasshopper has been used as the main tool in designing the overall structure of the roof. Grasshopper is an explicit history tool, which makes it possible to parameterize a design. This is to divide a design assignment into different parameters and factors which is possible to change independently during the process. The tool makes it easier to deal with complex design assignments, as long as is has some kind of rhythm or system.

During the sketching of the roof it was decided that the roof should be able to react on changes in orientation and the placing of the programme, thus the solar path was set up as a controlling factor in the shape of the roof and the size of the eaves.

The site adaptable roof

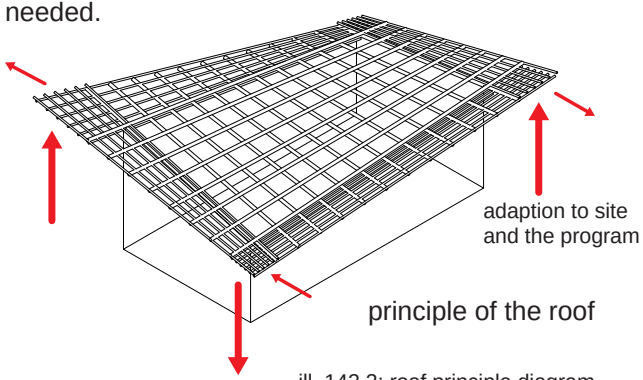
The idea is that according to e.g. the worst case of indoor temperature, the sun of this time a day and year will provide the solar altitude being determining for how the eaves are shaped, in terms of not having sun rays hitting the facade. A direct correspondence between the site, the orientation, and the shape of the roof are hereby created.

From the previous investigation the day with peak temperature was found to be in the afternoon at the 11th of April. This will act as the starting point and as stated previously if this day is treated, it is assumed to have a similar effect on the rest of the year.

The roof will be exact related to the specific place and not look like the neighbour building. Hereby the climate related design will be exposed and show how important the integration of the sun path is. In this way the roof acts as “the good example” of how to relate a design to the climate.

Another advantage is to avoid giving an impression like a standard house - instead the roof is systemized to fit the specific site – is there a tree that is going to be preserved, the roof can react to it or where the neighbours are placed in relation to the building and so on.

The project may be more costly in terms of time to spend on the construction in the different length of the roof beams, but in this way the material use is optimized in terms of shading when it is most needed.



ill. 142.2: roof principle diagram

Development of the shape

The idea is to use bamboo sticks for the roof beams, because it is a cheap and lightweight material.

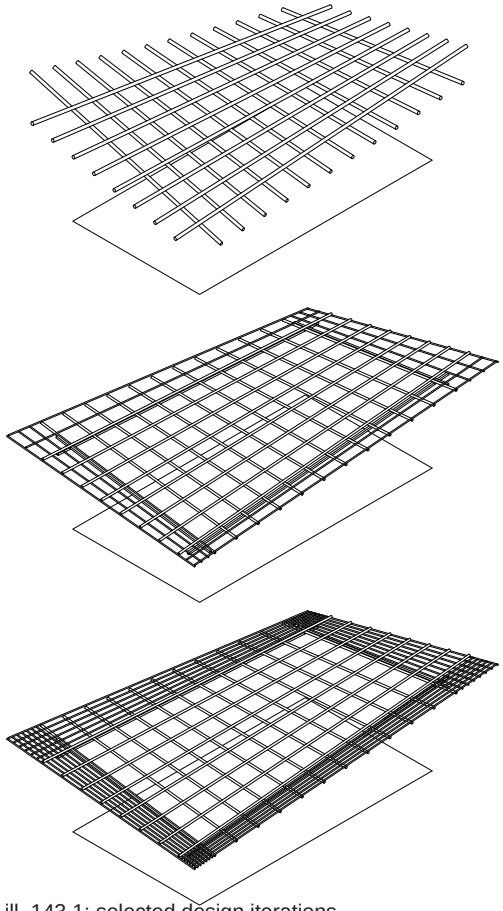
In the illustration at the right(ill. 143.1) some iterations in the development of the model and the grasshopper script is shown.

The model started without having bamboo sticks at the eaves - this was later developed to provide more shading although still using the same material and keeping the structural idea.

Furthermore the illustration shows the consideration of having a number of sticks in the different directions and how many sticks that will be appropriate to provide a decent shading for the dwelling and the outdoor areas.

Also more aesthetic considerations have been made in terms of creating a light roof that covers the dwelling but still has an expression of its own.

The idea is that the foot print of the “dwelling“ will be covered with a roofing membrane as a standard sized tarpaulin and the rest of the eaves will be covered with a higher density of bamboo sticks.



ill. 143.1: selected design iterations

The Grasshopper roof

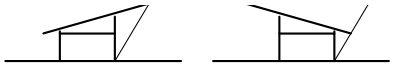
In the following two pages the Grasshopper-file is explained, to give an image of how the roof is constructed and which parameters has an influence on one another.

The primary parameters are:
- the placement of the corners of the roof
- height of the “corners” of the roof

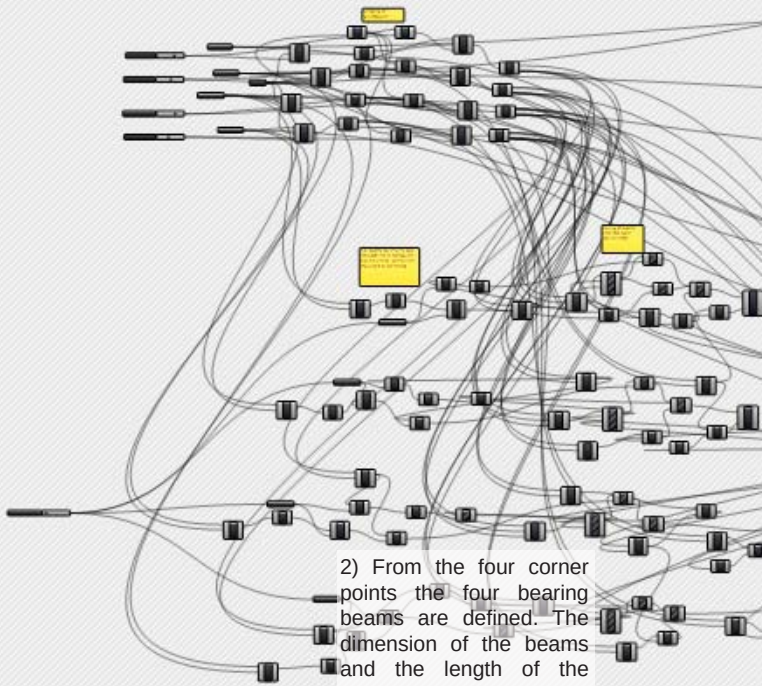
Which is determined by the shape of the building layout, the neighbours and the placement of the program in the dwelling (especially the placement of the stove)

The secondary parameters are:
- bamboo beam diameter
- number of bamboo beam in each direction
- the length of the bamboo beams
- the dimension of the under laying beam structure

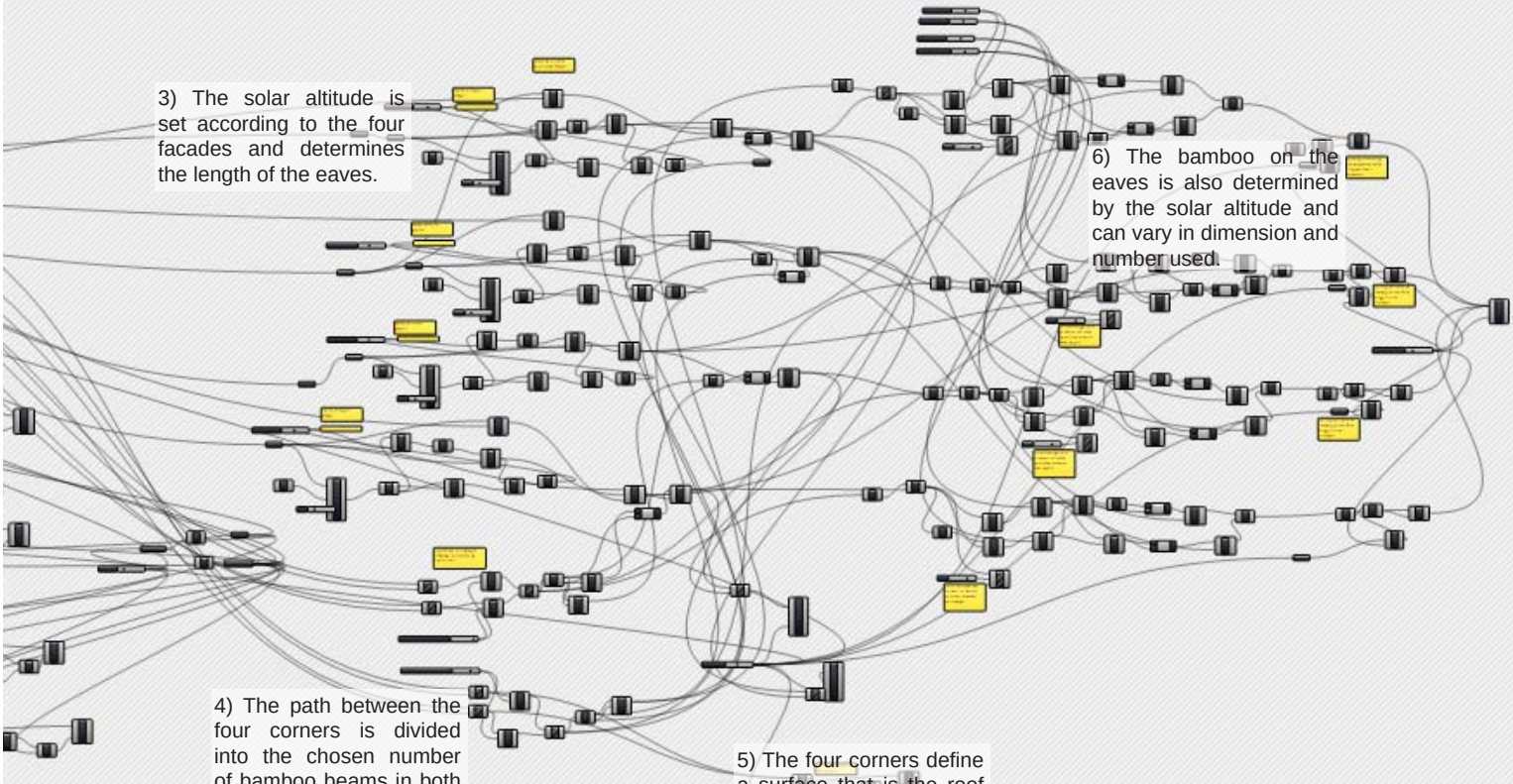
The external determining factor is the altitude of the sun, which also can be changed according to when the temperature peak experiences from the thermal analysis.



ill. 144.1: diagram showing how the lenght of the eaves provide shading for the facade



ill. 144.2: screen shot of the grashopper model



3) The solar altitude is set according to the four facades and determines the length of the eaves.

6) The bamboo on the eaves is also determined by the solar altitude and can vary in dimension and number used.

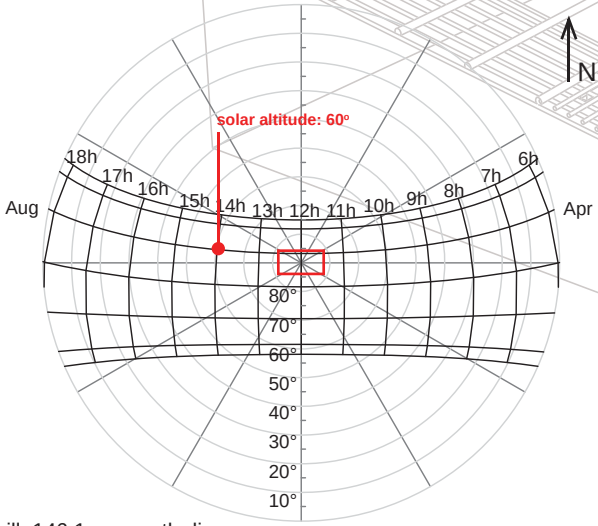
4) The path between the four corners is divided into the chosen number of bamboo beams in both directions. The length of the cantilever is set by the solar altitude.

5) The four corners define a surface that is the roof membrane.

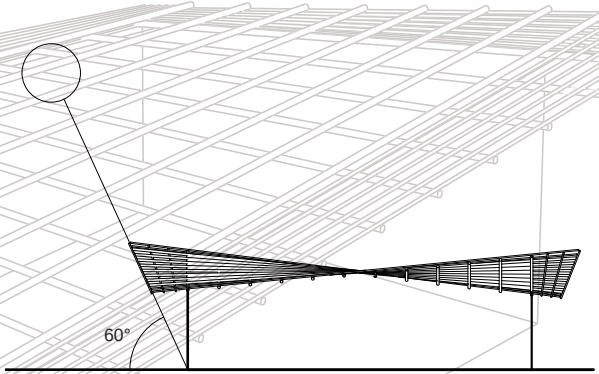
Implementation of the solar altitude

The peak temperature is on the 11th of April at around 15:30 (see page 138 in *Thermal analysis*). It is assumed that the solar altitude before this time at day is providing the overheating. This is why the solar altitude used as determining factor is at around 14:00, which has a value of app. 60° towards west.

This is an example of how the roof eaves can be dimensioned. But by rotating or mirroring the design another angle will give the dimension.



ill. 146.1: sun path diagram



ill. 146.2: the relation between the rood and the solar altitude

An important issue is that the parametric model only states some minimum eaves - as a kind of guidelines - but of course it can be overruled by the wanted expression, the outdoor spaces and in terms of protection from rain. These factors are what have determined the other facade eaves in this case.

Conclusion

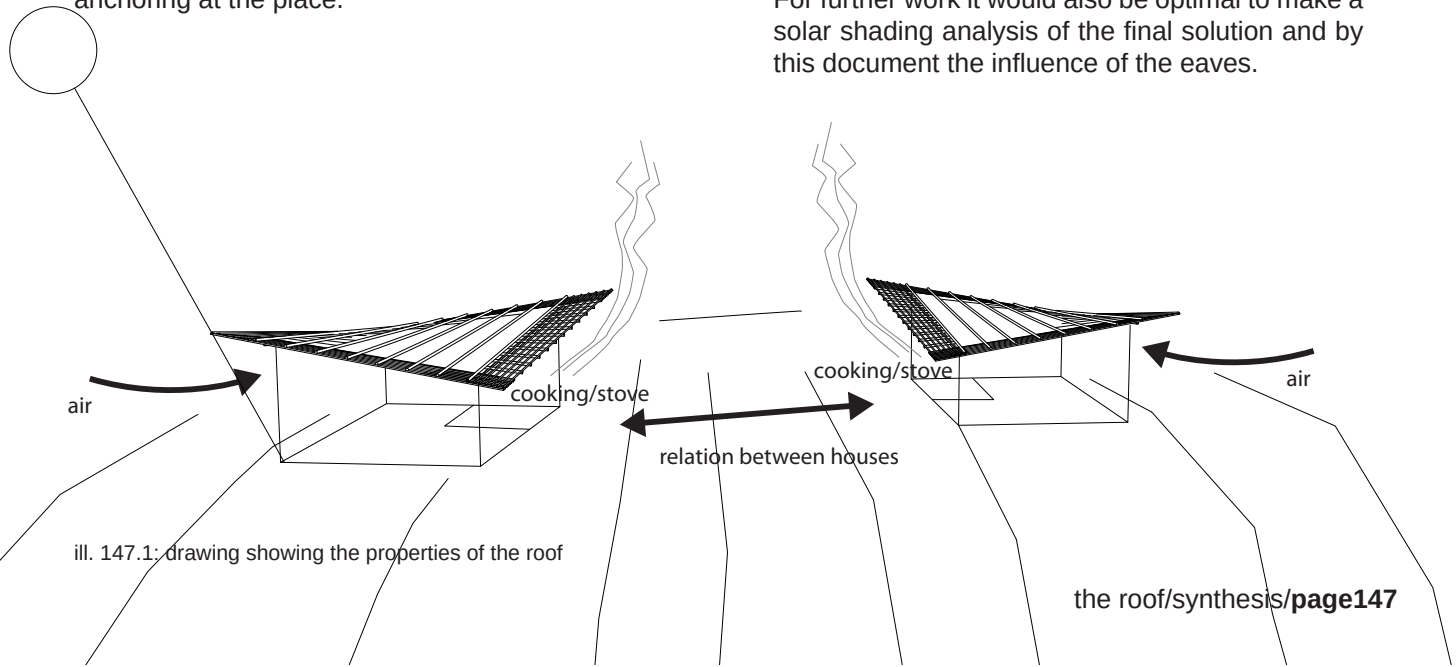
Below is a diagram(ill. 147.1) showing a kind of summary of the properties of the roof. The height of the roof is determined by the program - especially the placing of the stove - and to create a ventilated attic. Furthermore the shape of the roof can contribute to create a connection between neighbour buildings. The length of the eaves will then be determined by the solar path, cover for the rain and the outdoor area, thus creating an anchoring at the place.

Addition

In the grasshopper model another rule that could have been applied are, that it is always the same length of sticks, and it is then displaced to the side that need the shading. In principle this is also what happens in this case although it is not included as a parameter.

Another thing to include in the development of the roof could be the sloop of the roofing membrane in relation to get rid of rain water.

For further work it would also be optimal to make a solar shading analysis of the final solution and by this document the influence of the eaves.



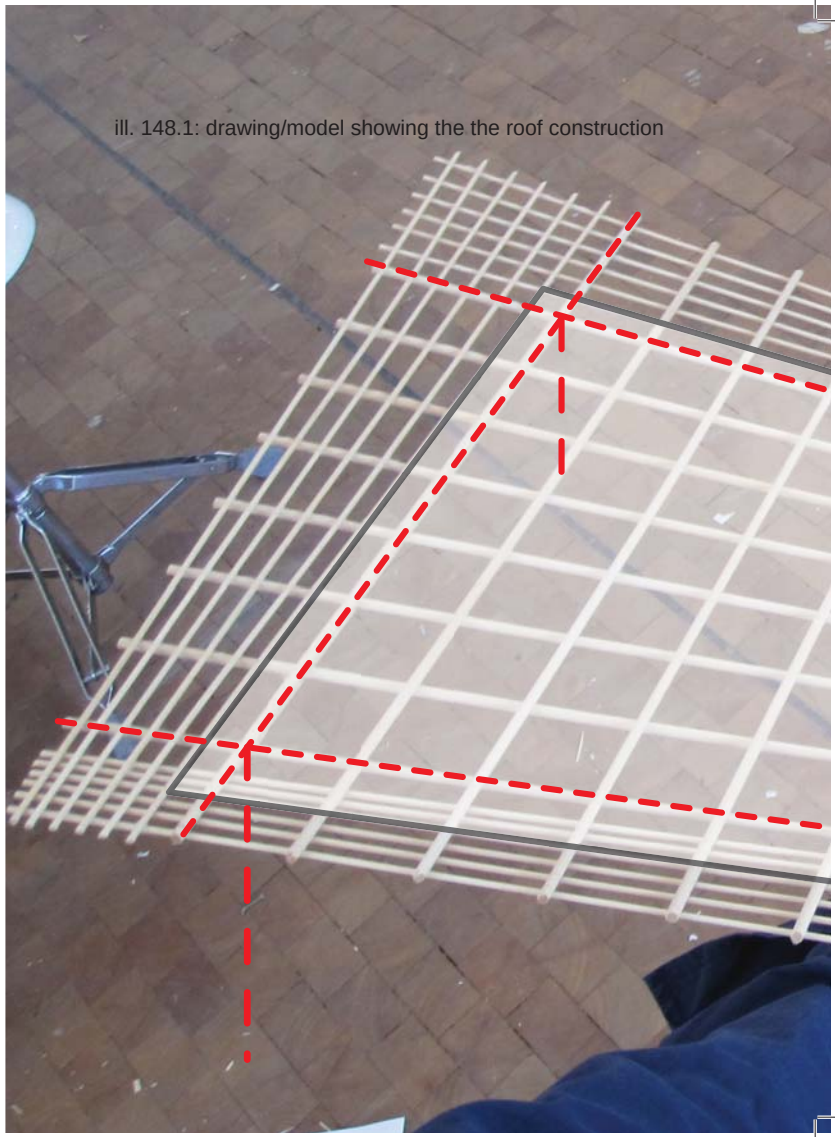
ill. 147.1: drawing showing the properties of the roof

The construction of the roof

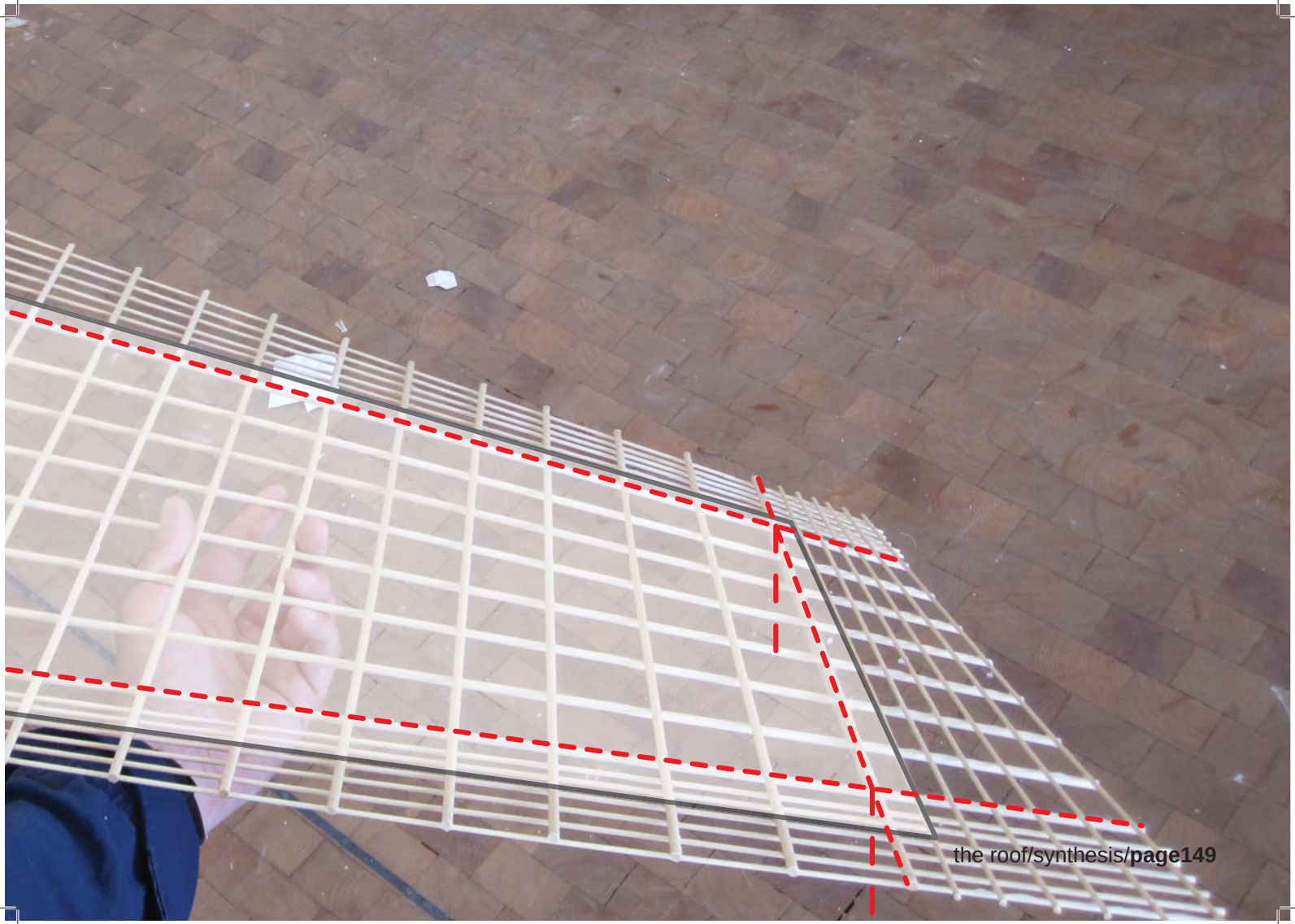
The roof can be constructed when the length of the four corner columns and the length of the four bamboo sticks shown in ill. 148.1 are known.

When the four bamboo sticks are placed at the construction site, the length of the remaining bamboo sticks can be measured from this, which makes the construction phase easier.

The roofing membrane such as a tarpaulin will be placed as marked with the black line in the illustration. It will be fixed between the two layers of bamboo sticks to avoid the membrane to flap in the wind. The edges will be tied to a bamboo stick in the eave.

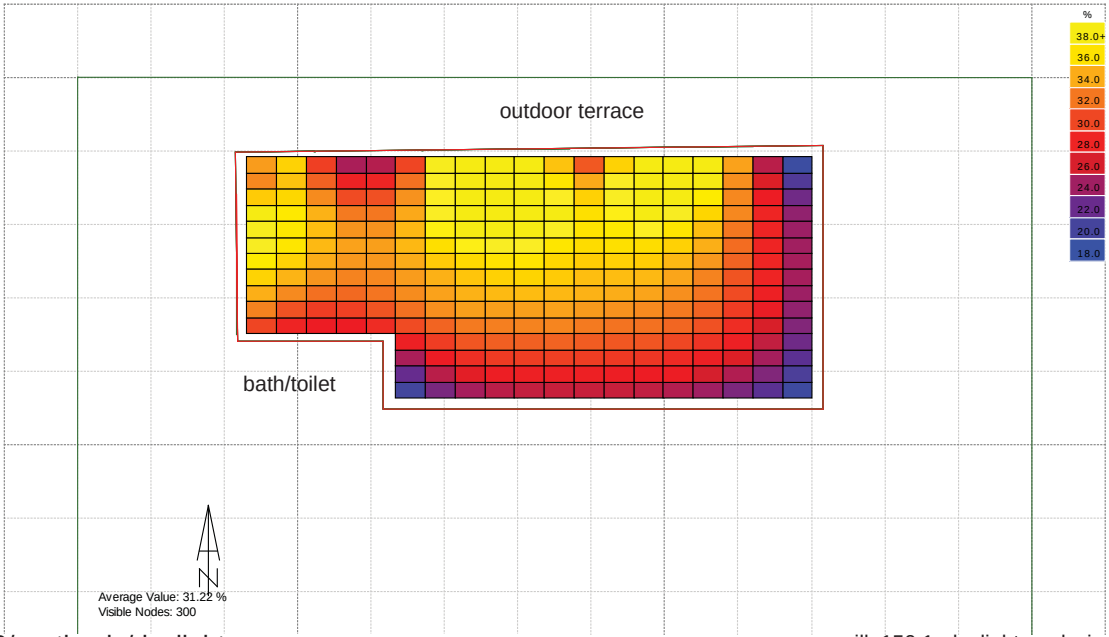


ill. 148.1: drawing/model showing the the roof construction



daylight

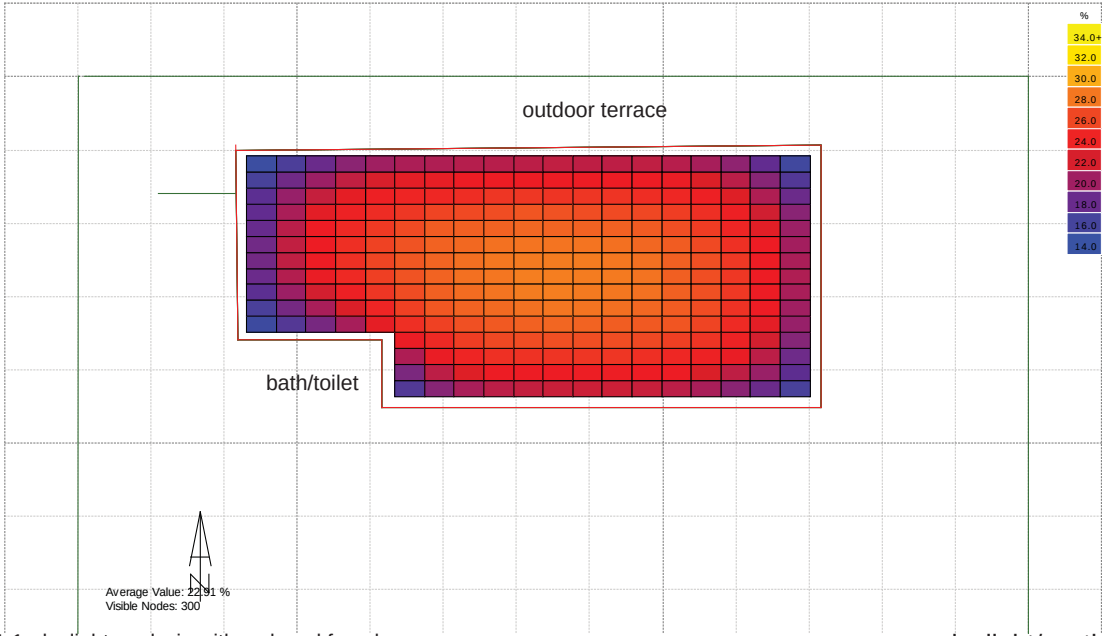
During the field work in Masanga one of the local houses was visited and a measurement of the house was made. See *Program* page 28. The experience of the house was that is was very moist and dark. Although not primarily, a goal for the dwelling in this project, is to create a dwelling that is more light and open. To verify that the lighting level is acceptable and the consideration through the process has an effect, the daylight factor for the living room is calculated in Ecotect. The reason for focusing on the living room is that the sleeping rooms are not supposed to be used during the daytime, thus daylight is not essential.
From the ill. 150.1 and ill. 151.1 the result of the analysis from Ecotect is shown.



ill. 150.1: daylight analysis with an open facade

In the first analysis(ill. 150.1) of the daylight factor the living room is open towards the outdoor terrace area. The dayligth factor is 31,2% in average - which means good dayligt conditions. In comparison the Danish building regulations says 2% as a minimum in an office building. The daylight range from 38% at the highest to 19% at the lowest, which is a quite big difference caused by the large openings towards the outdoor terrace area.

The next analysis(ill. 151.1) is where the shutters are in place towards the outdoor terrace, without any openings except the one in the ceiling of the room. This result has an average of approximately 23% daylight factor, which again is good in comparison to the Danish building standards. Hereby the daylight level in the dwelling is acceptable.



ill. 151.1: daylight analysis with a closed facade

rammed earth

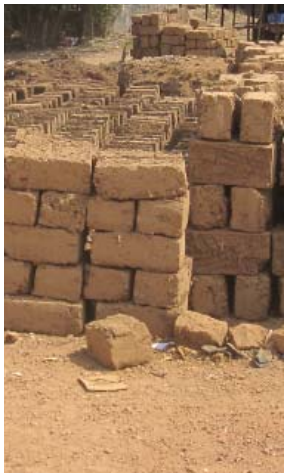
When considering the heavy construction or the base of the building important factors to include are: the use of cements and hereby the economy of the project, the relation to the site, the stability and the visual and tactile properties of the material.

Because of the limited range of possibilities in regard to economy in the project and the availability it is decided to focus on the technique of rammed earth. Rammed earth is an earth building technique where layers of soil are cast and rammed in a mould. The rammed earth technique is chosen because it creates a monolithic mass that will contrast the roof and the *frame* which is a structure, and thus support the idea about the three elements of the dwelling that has their own identity and properties. Furthermore the rammed earth part is being the stabilizer of the construction by absorbing the lateral forces.

This chapter deals with the rammed earth technique and is divided into three sections. The first is a theoretical part stating static properties, building technique and material use, the second comprises empirical material experiments and the third are dealing with the implementation in the project.

General introduction

Working with earth constructions there is generally two approaches – adobe bricks and rammed earth(see ill. 152.1 and ill.152.2). Where adobe bricks are used in areas with limited rainfall because of the possibility of drying the bricks in the sun and rammed earth is used in more humid areas where drying is not possible, and the walls can be built under a roof construction. To obtain an impression of a monolithic mass the rammed earth solution seems obvious and is chosen for further detailing.



ill. 152.1: adobe bricks

ill. 152.2: rammed earth

Typical rammed earth walls are between 300 and 600mm and have a compressive strength of 1,3MPa.
The soil being used consists of sand, gravel and clay in the ratio 6-1-3 respectively.
When collecting the soil for use in the rammed earth walls it should be avoided to use organic matter and to avoid large sized gravel.

Furthermore earth walls have good hygroscopic properties, which mean it has an ability to absorb and de-absorb moisture.

A critical point of rammed earth construction can be the durability of withstand the destructive action of weathering. Especially rain and frost are the most destructive natural actions. And it can cause erosion of the earth walls.
This issues can be dealt with through the design e.g. in terms of an overhang roof to protect from rain or a plinth for avoiding splashing rain.

Rammed earth can in terms of the content of clay swell with contact with water and it will shrink when drying, which goes for many other natural materials. As a consequence shrinkage cracks can and will occur.

Stabilization

Cement as a stabilizer can be introduced to improve the strength and the erosion resistance especially in exposed wall parts. The typically cement amount is between 5-15% and by using cement the content of clay can be decreased.
But using cement has especially two disadvantages: the ability of moisture passage will be reduced, the environmental impact of the cement production and the following recycling of the earth walls containing cement.
Alternatives to cement are lime and natural fibres.
Furthermore different plasters and coating can be used to make a more resistant surface.
[Minke, 2009]

Material experiment

"Of all our senses, touch and smell affect us more profoundly than sound and vision, as they engage our brain at a very primitive and profoundly emotional level" **[Pallasmaa, 1996]**

To get in touch with the material physically - some experiments with a mock up of a rammed earth wall has been made. With an awareness of the soil found in Denmark may not be similar to the one found in Sierra Leone it still make sense to experience the layering, the compactness, structure, colours, feeling etc. of an earth construction.
Iterations have been made in terms of trying different combinations of sand, clay and gravel(ill. 154.1).

ill. 154.1: different mock up iterations

ill. 154.2: mould for mock up

Furthermore experiments with using cement as stabilizer has been made. The experiences made by the material experiment can be collected in following points:

- avoid using top soil because it contains too much organic mould.

- smaller layers to make sure that it can be rammed and compressed properly.

- letting the wall construction dry for a while between applying the layers.

- cement can be used as reinforcement at the top of the wall and strengthen the edges.

- when using cement in certain layers e.g. the top one, a kind of transition from a layer not containing cement to a layer containing cement has to be introduced.

ill. 155.1: rammed earth mock up

Implementation

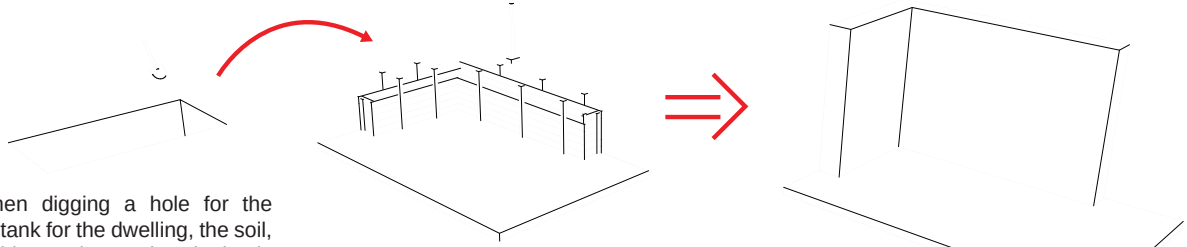
As earlier mentioned the rammed earth is used for making the heavy walls.

The process of making the rammed earth is though as explained in the illustrations below(ill. 156.2) and is based on manual work without mechanical devices, to activate as many labours as possible and to avoid using expensive equipment.

Using the soil from the septic tank hole for the rammed earth wall ensures that there is no uncovered hole nearby the dwelling where, when flooded, the mosquitoes can breed.

The rammed earth wall is placed on a concrete foundation and a plinth to prevent erosion and ensure stability.

ill. 156.1: inspiration pictures from Masanga related to earth

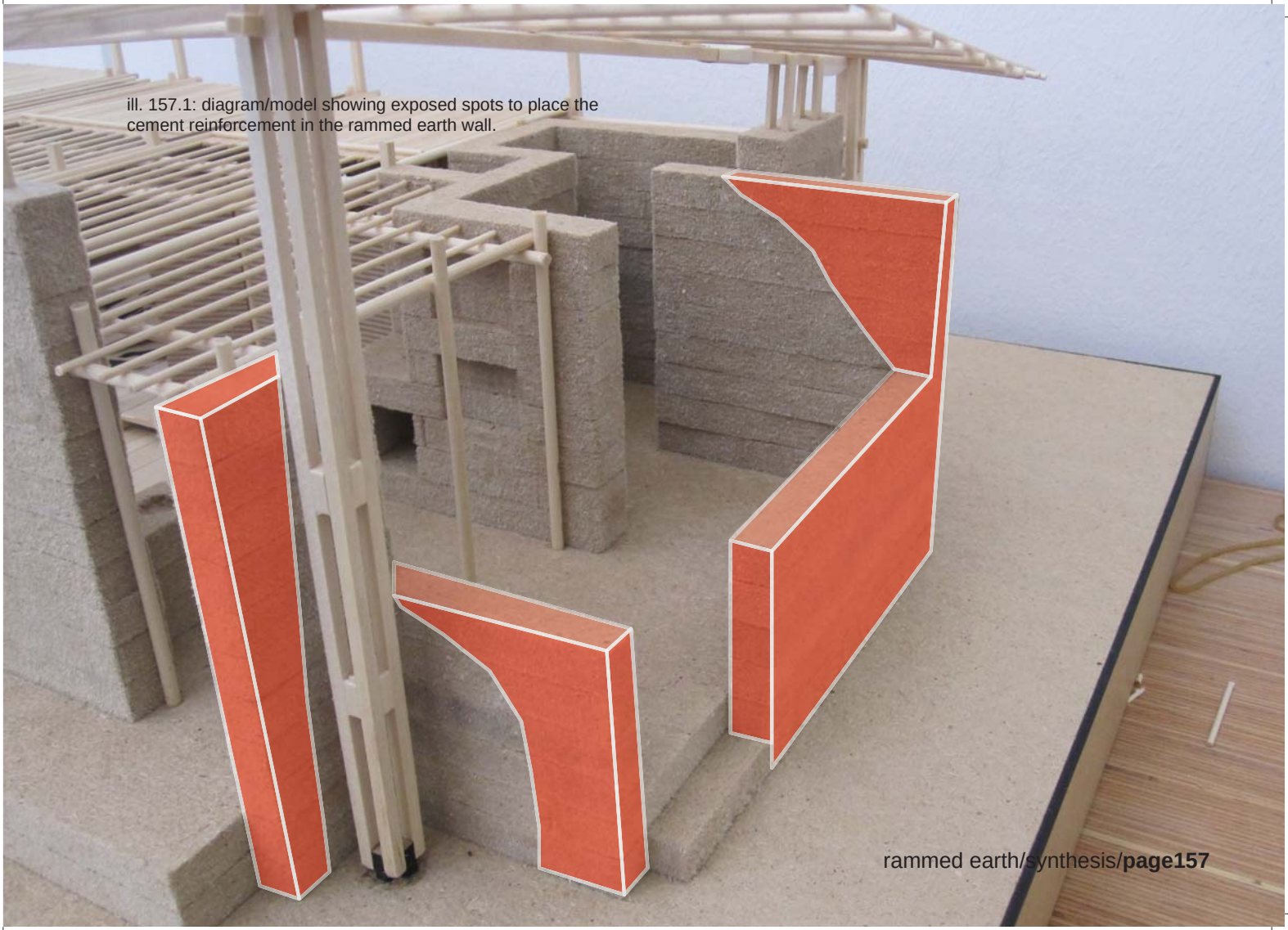


1) When digging a hole for the septic tank for the dwelling, the soil, if suitable, can be used as the basic in the rammed earth wall.

2) A mould is made of wood and layers of soil is filled in and rammed with a manual rammer.

3) The mould is removed and the wall is finished and additional surface coating can be made.

ill. 156.2: diagram of the rammed earth process



ill. 157.1: diagram/model showing exposed spots to place the cement reinforcement in the rammed earth wall.

structural system

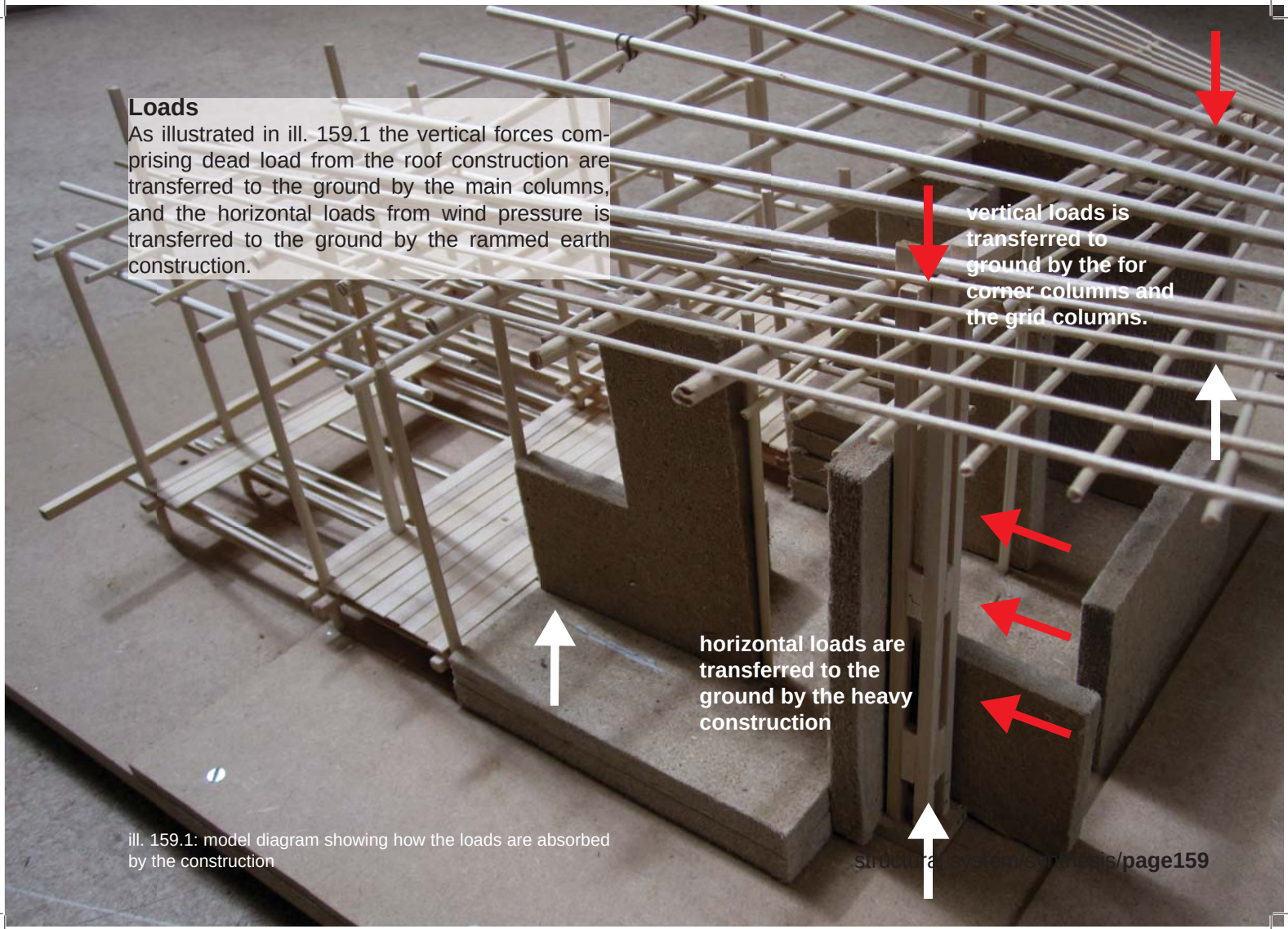
In the following section the structural system of the dwelling will be considered.
The construction is divided into three types of materials - rammed earth, constructional wood and bamboo(ill.158.1).
The division and use of materials are made according to their properties. The rammed earth can provide stability in the construction. The constructional wood can carry the overall structure, because of its well known load bearing properties, and the bamboo can be used for the lighter construction with a wider diversity in strength and dimensions.

ill. 158.1: material photos showing constructional wood from Masanga, rammed earth and bamboo

ill. 158.2: model in 1:20 showing how the rammed earth wall are connected to the roof beam and how it is connected to the bamboo frame structure.

Loads

As illustrated in ill. 159.1 the vertical forces comprising dead load from the roof construction are transferred to the ground by the main columns, and the horizontal loads from wind pressure is transferred to the ground by the rammed earth construction.



ill. 159.1: model diagram showing how the loads are absorbed by the construction

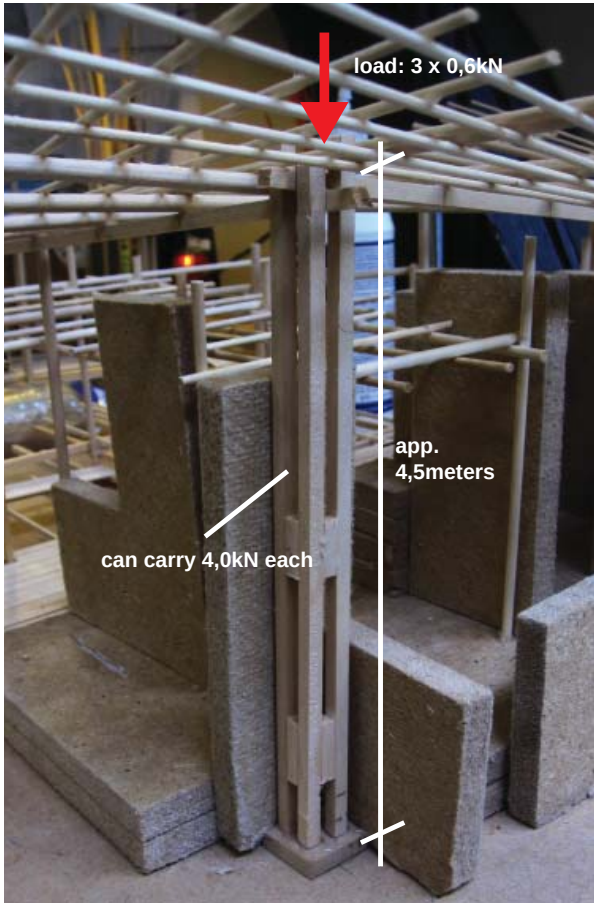
Construction and statics

In terms of the statics of the construction - the main columns are considered to give an idea about the dimensions of the construction. It should be underlined that these calculations are estimations and not that detailed, thus the dimensions may be over-dimensioned just to be sure, also in terms of not being sure of the quality of the wood in Sierra Leone.

In the spread sheet on the appendix CD the calculation of the dead load for the roof construction are calculated to be 0,6 kN, taking into consideration the weight of the beams, the bamboo structure and the tarpaulin - in the case where there is 22 main columns.

Because the wind is not that powerful and is supposed to be absorbed by the heavy part of the construction, this is not considered here.

The column length of the longest columns without having horizontal supports, are the one at the kitchen - approximately 4,5 meters. From ill.161.1, a page from the Danish Standard(Teknisk Ståbi) is shown - which state that a column having the dimensions 75x75mm and a length of 4,5 meters can carry 4,0 kN. This means that the construction can stand. As an addition the strength of the columns can be added by 30%, because it is fixed at the bottom. [Teknisk Ståbi, p.308]



ill. 160.1: model diagram of the loads and load bearing properties of a column

ill. 161.1: scan of page 310 in Teknsik Ståbi

7.4.3.2 Bæreevne

Regningsmæssig bæreevne i kN for centralt belastet, simpelt understøttet søjle. Bestemmende lasttilfælde med K-last, anvendelsesklasse 1 eller 2, normal sikkerhedsklasse. For andet bestemmende lasttilfælde eller anvendelsesklasse multipliceres med faktorerne i tabel 7.1.4.2.

tværsnit	fri søjlelængde i m								
mm × mm	2,0	2,5	3,0	3,5	4,0	4,5	5,0	5,5	6,0
konstruktionstræ, K 18									
75 × 75	18,6	12,4	8,8	6,5	5,0	4,0	3,3	2,7	2,3
100 × 100	53,0	37,1	26,7	20,1	15,6	12,4	10,1	8,4	7,1
125 × 125	106	82,8	62,2	47,4	37,1	29,7	24,3	20,3	17,2
150 × 150	169	147	119	93,8	74,5	60,2	49,5	41,4	35,1
175 × 175	242	224	195	162	132	108	89,6	75,2	63,9
200 × 200	325	308	284	250	212	177	148	125	107
225 × 225	417	403	381	351	311	268	229	195	168
Limtræ, L 40									
90[1] × 100	79,4	52,2	36,7	27,1	20,9	16,6	13,5	11,2	9,4
115 × 133	204	141	100	74,4	57,4	45,6	37,1	30,7	25,9
140 × 167	384	300	220	166	128	102	83,3	69,1	58,3
160 × 167	467	407	317	243	189	151	123	103	86,5
185 × 200	669	627	541	433	343	276	226	188	159

[1] *Det forudsættes, at tværsnittet er oplimet af mindst 4 lameller, ellers skal tværsnittets bæreevne multipliceres med faktoren 0,70.*

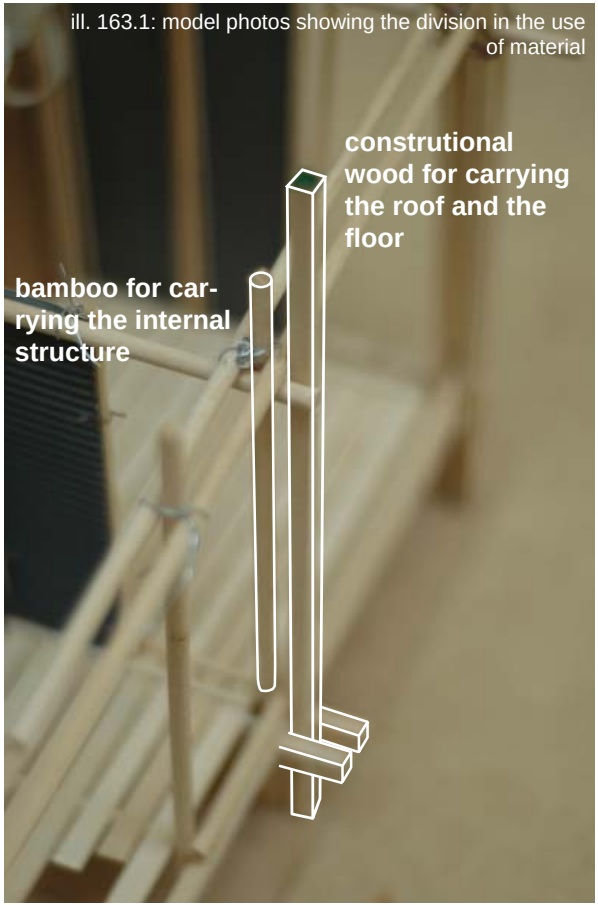
structural system/synthesis/page161

details

In the light construction there is a division of the material in the construction.
Constructional wood is used for the primary structure to carry the roof and the terrace where the sleeping rooms and living room are placed. This structure in joint by bolts to make sure it can absorb forces in longitudinal direction(ill. 162.1). The lighter interior structure framing is made by cheaper bamboo, that is supposed to be found in the nearby area of Masanga and is joint by rope or similar – this is because it will be harder to use bolts or nails in bamboo. But this means that a bamboo joint will not be that efficient to take forces in the longitudinal direction(ill. 162.2).

ill. 162.1-2: model photos showing a joint between two constructional wood beams and two bamboo sticks.

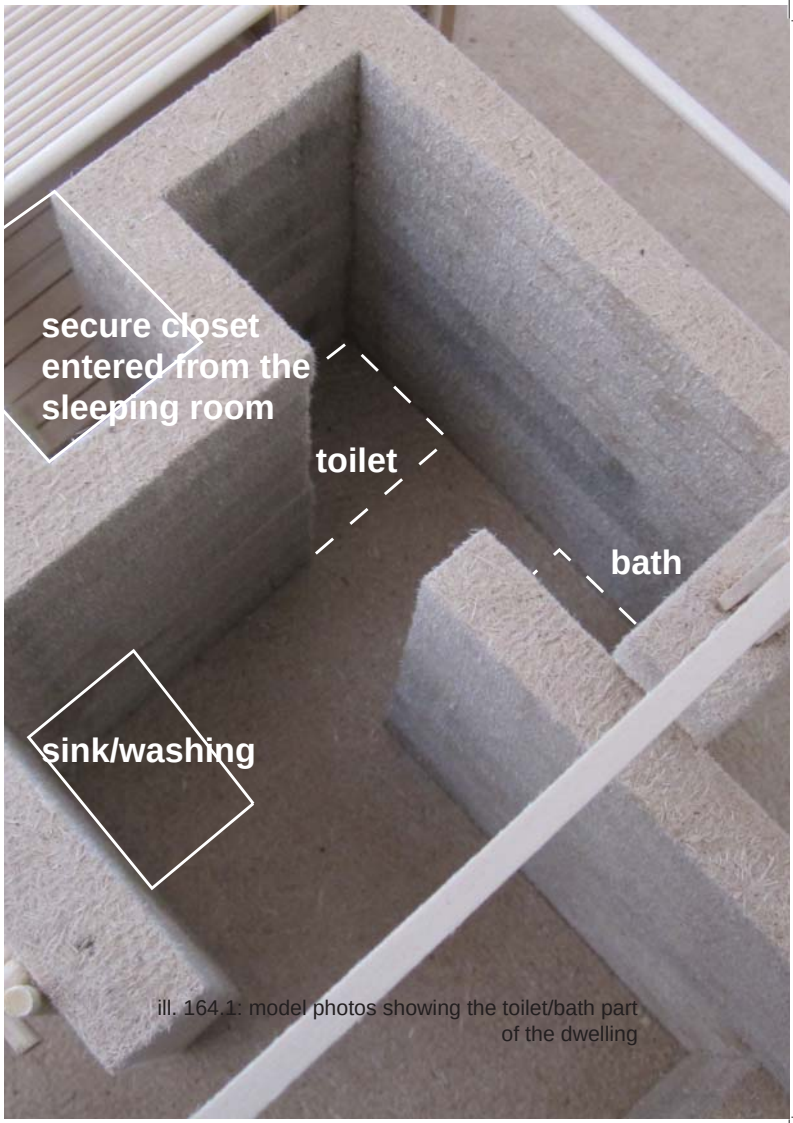
At the illustration at the right(ill. 163.1) a model photo is shown to explain the idea about the division of the material.
The idea is that the interior bamboo structure will be tied to the overall constructional wood construction. The details will be explained in drawing in the technical drawings in the *Presentation report*.



ill. 163.1: model photos showing the division in the use of material

the heavy part

The heavy part of the dwelling contain as mentioned cooking and kitchen facilities, toilet, bath and washing facilities, and a secure closet that can be entered from the master sleeping room.
The reason for placing this part of the program in the heavy part is mainly for security, in terms of fire proofing, but also that the secure closet is placed in the heavy part will make it seem more secure and static. The reason for placing the bath in the heavy part is to avoid rod in the wooden part of the building.
Although the use of cement is being minimized a proper foundation of concrete has to be made. In addition the floor in the heavy part of the dwelling is also being constructed in concrete.



ill. 164.1: model photos showing the toilet/bath part of the dwelling

Cooking

The cooking facility is thought as incorporated in the rammed earth construction - to keep the monolithic expression.

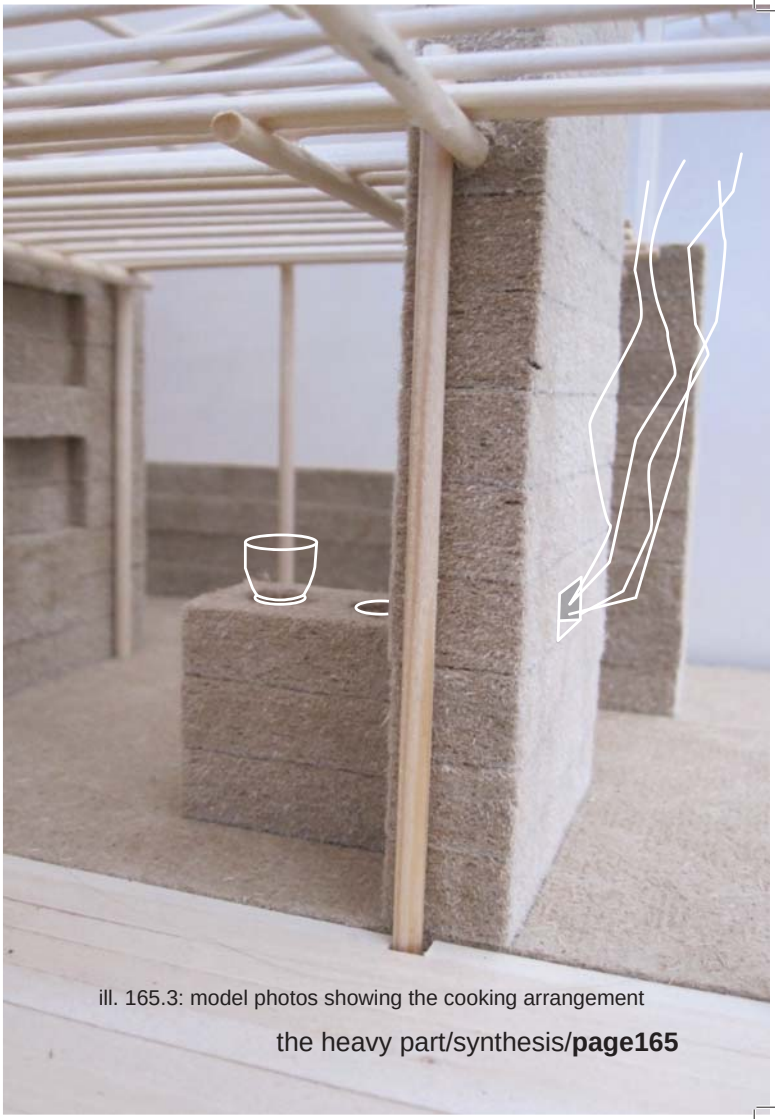
Below a reference photo is shown of how the cooking stove is made in rammed earth(ill.165.1-2).

The idea is that the smoke from the stove is led through a chimney in the wall to avoid smoke inside the building(ill. 165.3). An issue that is important with a health point of view and which is not present in the existing kitchens in Masanga.

Whether the chimney outlet can be placed higher in the wall to also get rid of the smoke in the area outside the kitchen, has not been further investigated.

Furthermore the shape of the roof is supposed to lead the smoke away from the house.

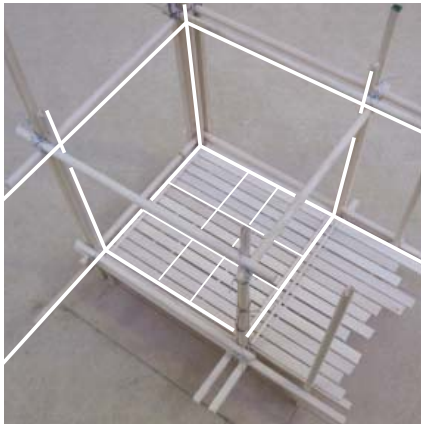
ill. 165.1-2: a stove made in rammed earth



ill. 165.3: model photos showing the cooking arrangement

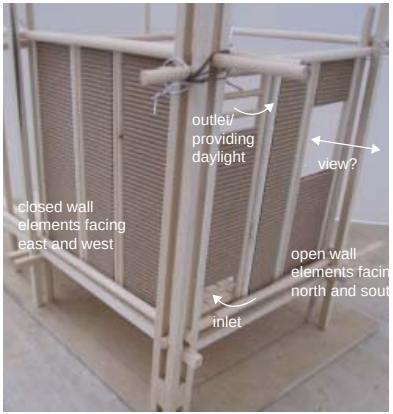
the element system

In the following pages the rooms in the lightweight part of the dwelling(the *frame*) and especially the process of the wall elements will be explained.
The idea about making a standard module of the dwelling is to make a flexible use of the space and elements. Furthermore the elements can be made at the workshop at the hospital in Masanga – approximately 10 minutes walk from the construction site.
Of course there will be some corrections at the site and some elements of the dwelling will have to be made unique.
The sleeping rooms and the more private living room are to be mosquito proof - thus mosquito net has to be placed in all openings.

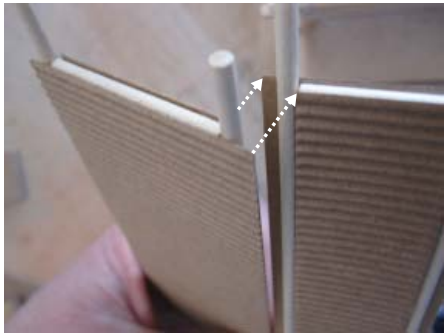


ill. 166.1: A standard room is 2,5 times 2,5 meters equals 6,25 sqm. It is divided into a element grid system of 1,0-0,5-1,0 meters times 1-0,5.1,0meters. It is supposed to be the sleeping room for up to 4-5 children or one nurse.

ill. 166.2: The wall elements are divided into two categories that are used for the facade and for the internal partitioning.
1) An open one facing north and south for providing cross ventilation
2) A closed one for preventing the sun to head the dwelling and to create a closed screen

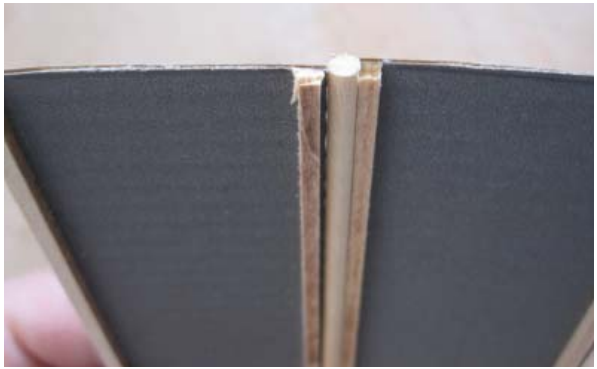


ill. 166.3-4: Two types of wall elements that has been tried. The one at the left is made from wood and has a bamboo stick as a buffer between the elements.
The one at the right has a frame made of bamboo and is clad with bamboo.
The wall elements have to be placed and fixed between the bamboo beams.



ill. 167.1: The elements are constructed to have an overlap to create a tolerance.

ill. 167.2: The element is constructed by constructional wood and is clad with e.g. splitted bamboo sticks. The elements are but together with a bamboo stick that acts as a buffer between the elements to deal with inaccuracy



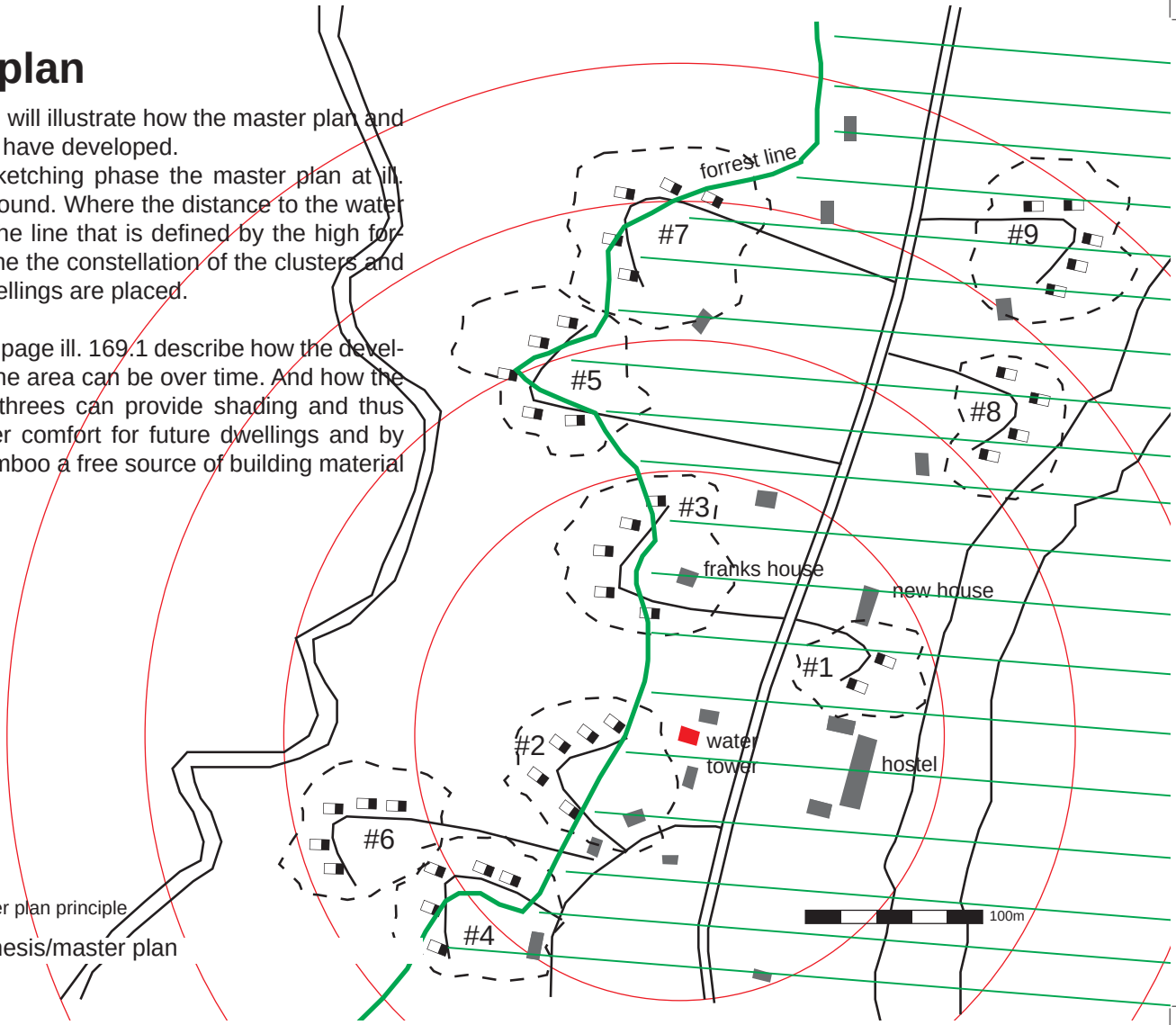
ill. 167.3: This overlap will be exposed in the exterior and create a subdivision of the facade.

ill. 167.4: A special door element has to be constructed and the rotation of the door can be made by a bamboo stick with a metal fitting at the floor and ceiling.

master plan

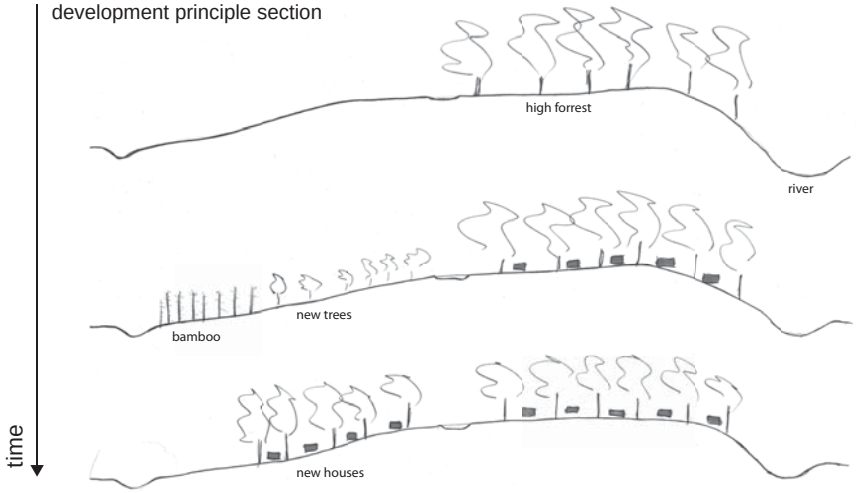
This section will illustrate how the master plan and the clusters have developed.
From the sketching phase the master plan at ill. 168.1 was found. Where the distance to the water tower and the line that is defined by the high forest determine the constellation of the clusters and how the dwellings are placed.

On the next page ill. 169.1 describe how the development of the area can be over time. And how the planting of threes can provide shading and thus create better comfort for future dwellings and by planting bamboo a free source of building material occur.



ill. 168.1:master plan principle

ill. 169.1:development sketch



- existing

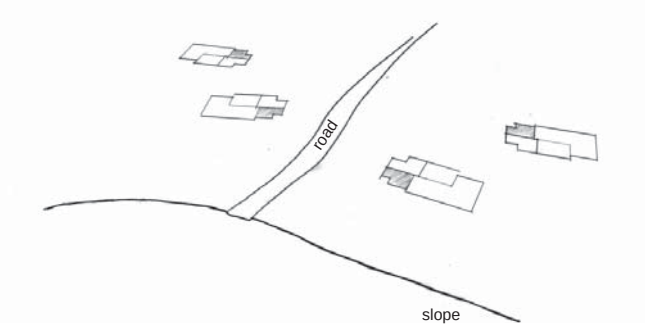
- building of houses in the high forrest.
- planting of trees in the new areas
for shadowing the future houses
- planting of bamboo for building material

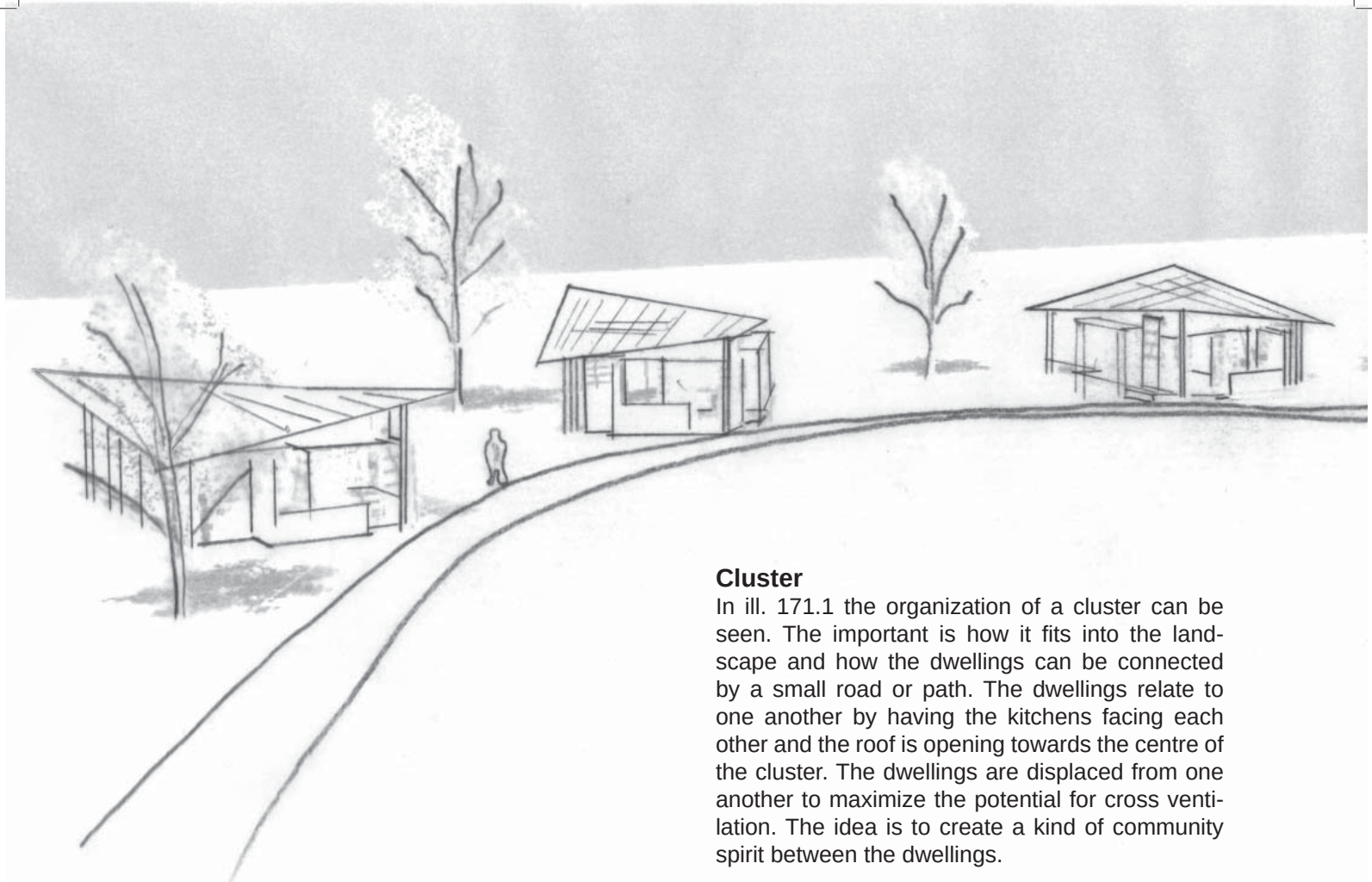
- building og houses in the new area
- the bamboo are used for the new buildings

Mirrorring according to the slope

Primarily the master plan consists of four mirrored dwelling types(ill.169,2). This is to always relate the dwelling to the slope in terms of having the heavy part of the dwelling at the highest point at the slope and to make sure that the kitchens are facing each other in a cluster. Another important issue is to make the heavy part of the dwelling face the road or “the public” to expose a kind of status. Derived from this there can be secondary rotations of the dwelling in relation to the near context and the adjacent buildings. This is also what will determine the roof height and eave length.

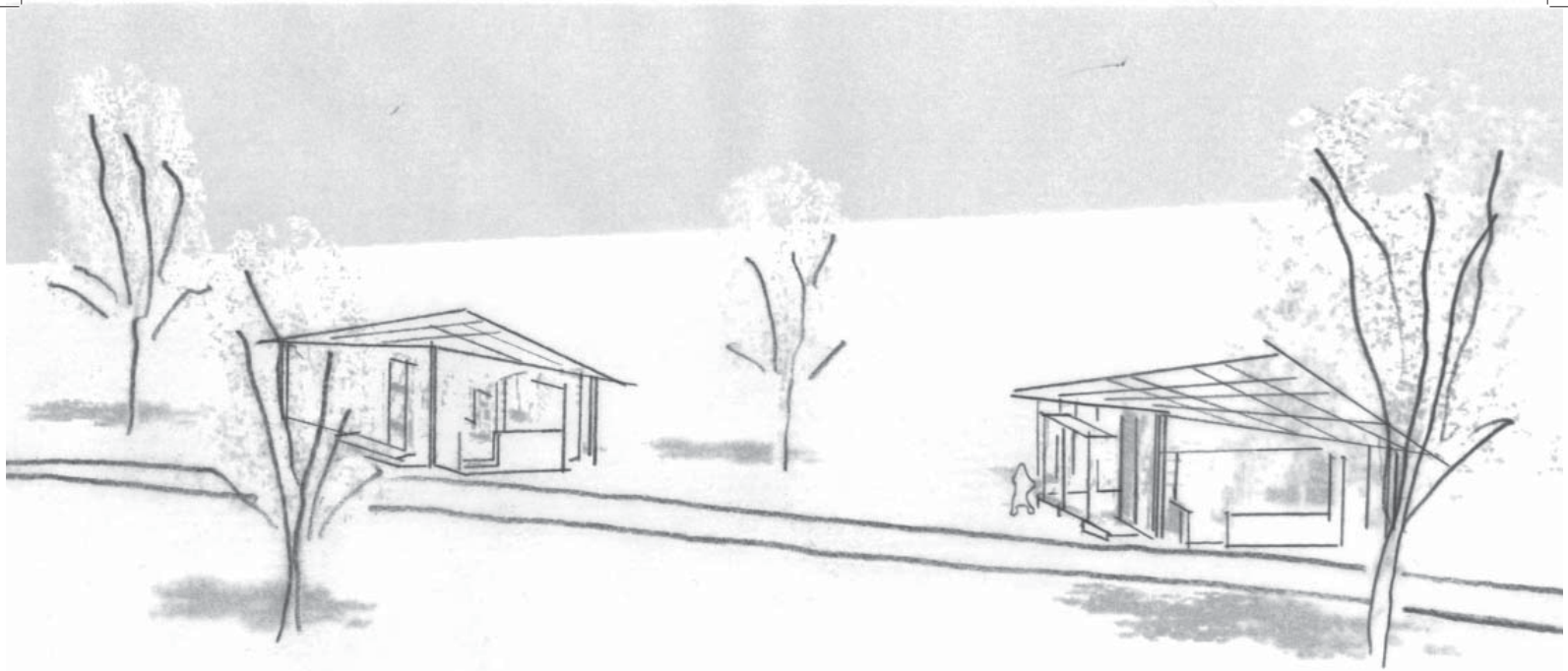
ill. 169.2: relation between the road, the slope and the dwellings





Cluster

In ill. 171.1 the organization of a cluster can be seen. The important is how it fits into the landscape and how the dwellings can be connected by a small road or path. The dwellings relate to one another by having the kitchens facing each other and the roof is opening towards the centre of the cluster. The dwellings are displaced from one another to maximize the potential for cross ventilation. The idea is to create a kind of community spirit between the dwellings.



ill. 171.1: sketch showing the relation between the buildings in a cluster

Phase #1 - placement at the site

The idea is to build two dwellings at the site between *new house* and the hostel(phase#1 at ill. 168.1). These dwellings will act as prototypes for all the future dwellings in the area. Of course there will be issues to reconsider after building it and things that has to be changed in terms of building construction.

An interesting issue is how the relation between the buildings in terms of their rotation to one another will have the effect of creating a small village in the village.

From the plan drawing at opposite page the placement is shown(ill.173.1). The dwellings have the heavy part facing the road and the kitchens and hereby the more public part of the dwellings is connected to each other.

ill. 172.1: sketch showing the relation between two buildings.

ill. 173.1: plan sketch showing the relation between two buildings at the site

conclusion

The aim of the project is to create a social and environmental sustainable solution for the design of a prototype of staff housing and a master plan, containing the staff housing, wherein elements as a symbiosis between universal culture, and the place, local materials and the climate is taken into consideration.
The project initiates in making a program which unfolds topics concerning the creation of the master plan and a prototype dwelling for the hospital in Masanga in Sierra Leone.
The starting point for the project, is field work made in Masanga where empirical data has been collected. The fieldwork comprises interviews with potential users, measurement of the building site and investigations of the potentials in the area, which is made to ensure an insight in the conditions in Masanga, especially and Sierra Leone in general.
Throughout the program phase a theoretical background knowledge has been established concerning critical regionalism and tectonic design. Topics that acts as the theoretical basis for the design task.
Furthermore investigations in relation to environmental design has been made, where a great part is dealing with the climate conditions in Masanga, to be able to include the climate as an important part of the design.
As a starting point for the design of a common dwelling type for the Masanga hospital, some initial investigations has been made comprising issues as typology, orientation, thermal mass, solar radiation and openings. These investigation lead to some general guidelines for designing in the warm humid climate of Sierra Leone and is essential to incorporate the climate in the design.

The sketching initiates in stating a concept for a common dwelling, which is inspired by the conditions one finds under a tree, in terms of e.g. shading, shelter and safety. This inspiration is transformed into three building elements a roof, a frame and a base. The roof for creating shading, utilizing the wind and shelter for the rain, the frame for adapt to the program, and create the flexible space for living and finally the base for creating stability, security and a relation to the topography.
Through the sketching phase these elements has been developed and at the end of the sketching a zoom out is made to view the dwelling in relation to the master plan.

In the synthesis phase the dwelling and the master

plan has been treated individually and together. In addition technical issues have been treated comprising indoor climate taking into account shading and natural ventilation. Furthermore construction, material and details have been considered.

The master plan is constructed with the idea of reintroducing the water tower in Masanga, and thus acts as the center point for the development of the housing. Furthermore the existing forest is chosen for the place where the first dwellings can be placed to benefit from the shading the trees provide. Over time, the areas now being bush, is planned to be planted with trees for providing shading for future dwellings and with bamboo for having a free source of building materials.
The master plan contains smaller clusters where 2-6 dwellings are placed. The idea is to create a village in village principle where the dwellings in a cluster have a strong relationship to each other as seen in Masanga village now.
As mentioned, the dwellings are divided into a roof, a heavy part and a light part. These elements has their own expression and qualities and together they form a balanced whole.
The roof or the cover is made as a parametric model that can be changed according to the specific dwelling in relation to orientation and is shaped to utilize the wind for ventilating and cooling the attic. Although the complex expression of the roof, it is simple to construct.
The heavy part or the base is made in rammed earth, which mainly is local materials with a minimum amount of cement used. The heavy part contains the cooking facility, bath/toilet and a secure closet, which the potential users that was interviewed, sees as essential for a dwelling. Furthermore the heavy part is used as expressing a kind of status, because the local see a heavy construction e.g. concrete as related to status, because it is expensive and cannot be found just outside the door in the bush. The idea is that the rammed earth part can give the same impression, although being much cheaper.
The frame or the light part of the building contains two levels. The upper level contains the sleeping rooms and a private living room, that can be rearranged to fit the specific needs of the user, and a lower part that contains the more public living area, that has a close connection to the outside. Thus creating various zones and transitions between the indoor and most private and the outdoor and public. This part of the building is constructed in a grid system with wall elements that fit into this system. This is what provides the flexibility in the building.

reflection

The process of creating a master plan and dwellings for the Masanga hospital in this project, has been done through an integrated design process, thus it has been necessary to consider and investigate various new aspects early in the process, in order to gain sufficient knowledge about which parameters affect each other and how they relate to environmental design.
Furthermore the African context and the fieldwork have been challenging issues that has played a major role throughout the project, and a design in this context demands an understanding that is beyond conventional thinking, and thus demands more initial investigation in terms of climatic calculations to get a feeling with the environment.

Critical regionalism has created the theoretical base for the project which deals with how to join the universal culture and the local culture. The universal culture are seen in the technological way of dealing with weather data, construction and the indoor climate and the local culture are more inherent in the use of material and the fact that the dwellings are organized as a interpretation of what the potential users find necessary in a future dwelling. Furthermore a quite low tech solution has been made which incorporate natural ventilation and cooling without any use of air conditioning, and constructional solutions that can be made by the locals without advanced machinery or equipment. The use of man power in the project is seen as an important factor in terms of providing employment in the area, thus better to use more labor than importing more high tech and expensive building materials e.g. cement.

During the design process an important factor has been the context, this being the cultural but also environmental. Cultural aspects that have been included are based on the interviews and the visit to Masanga, where factors as status in terms of building material is important, the security in terms of theft and fire, which has been met in the use of materials and the organization of the building layout. The materials used in the western world, e.g. concrete, seems to have a kind of status for the locals, thus a potential for this project is to make the locals understand that something just as good can be made with materials found in the near context used in the right way.

In a more aesthetical perspective the building meet the environment through the heavy part of the building at the highest part of the slope, and the heavy part can be seen as a continuation of the landscape in which the lighter part of the

building is placed. The lighter part of the dwelling is placed on columns just as goat and hens houses are seen in the area. Who knows why the locals build architecture for their animals like that – but not for themselves? Furthermore the natural ventilation strategies can create a coherency between the building and the environment, and the shading of outdoor areas creates an intermediate zone between the nature and the architecture. The tactile experience has played a large role in the project, which is seen in the different representations of the dwelling in models throughout the project.

In the project various building simulation programs and different equations has been made to create an image of the thermal conditions in and around the building. In this content it has to be mentioned that these programs are quite conventional and deals with closed building volumes, and is not that simple to incorporate in a context with a completely different climate – thus the calculations made, has to be seen superior, without saying that they point in a wrong direction. In addition some of the weather data used for this project is from a neighbour country, because only limited weather data is available for Sierra Leone.
Is it at all possible to talk about indoor climate in a house that is as open and diffuse and thus have a high infiltration, as the one created in this project? This also affects the indoor climate demands that were stated in the *Program* phase, where the demands are based on European standards. And although research has been made about that all human beings regardless race, sex and cultural background has the same thermal conditions – a major difference can be seen in Masanga. During the winter the white people living there dress in little cloth because it is hot in their terms, but the locals dress with big jackets and hats because they find it cold.
An issue that has to be further developed are the master plan for the area. The master plan made in this project points out some ideas of how a development can take place. But due to limited knowledge of the further plans for the area and how the technological development will run the master plan is not that detailed. But in the scope of this project, the idea about building a prototype dwelling, can act as a bottom up principle of dealing with the problems in the area – stating, maybe all problems cannot be solved on an overall level at the moment, but the development can be started from below with one dwelling as the good example. Maybe the future is to uncertain to create an overall plan that will solve all problems.

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All other illustrations are own illustrations.

appendix list

The appendices are to be found on the CD in the back of the *Program and Process* folder.
The appendices are as follows:

app.1: Description of Architects Without Borders
app.2: Assignment from AUG
app.3: Interview with Patrice
app.4: Interview with Emma
app.5: Sun path diagram and wind rose
app.6: Indoor climate
app.7: Appendix 7 -master plan sketching
app.8: nev orientation of building
app.9: mosquitoes
app.10: natural ventilation
app.11: temperatures depending on the roof type

Furthermore the CD contains additional pictures from the field work in Masanga and the files used for the various calculations made throughout the project.