Study of a Two-Storey Family House in the Dar es Salaam Region, Tanzania

Studie av en tvåvåningsvilla i Dar es Salaam regionen, Tanzania

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This exam work has been carried out at the School of Engineering in Jonkoping in the subject area building technique. The work is a part of the three-year Bachelor of Science in Engineering programme. The authors take full responsibility for opinions, conclusions and findings presented.

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Preface

The organization SIDA, Swedish International Development Cooperation Agency, has a scholarship for a Minor Field study that is encouraging development projects in a developing country. This scholarship can be applied by everyone at a Swedish University. The scholarship made this final project about a two-storey family house in the Dar es Salaam region possible.

Building technology is a central part in developing countries, if the country should be able to get welfare to its inhabitants, they need to have decent housing. To be able to achieve this, the building technique needs to be developed, and this should include qualitative building to an affordable cost. Therefore this thesis will focus on a building project in the Dar es Salaam region in Tanzania.

The first idea with this final project was to study a family house that is made as a low cost project. Before the departure from Sweden a contact with the University of Dar es Salaam had been made. The University helped to establish a contact with a building company called National Housing Corporation, NHC. The request was to see and study a low cost project and NHC arranged an educational visit at the project Mbweni National Housing in Mbweni district in Dar es Salaam region. It turned out that the houses could not be classified as low cost, they were more luxury homes and the approach of the final report needed to be rethought.

The Mbweni district is placed about 50 km outside the city centre of Dar es Salaam. It is a new housing area that is made for the wealthy families in. The project consists of 49 houses and is a mix of bungalows and two storey houses. Since the area is bought by NHC from the government roads, drainage system, water, sanitary and electricity are planned to all houses.

The reason why no low cost project was shown is that the private building companies do not build those kinds of projects. If a house is classified as low cost it is often built by the owner of the house. The building companies always want to make a profit and then chose to build those kinds of buildings that can give as much profit as possible. When westerners come and visit, everyone wants to show the best they got and that can be a reason why the Mbweni National Housing was shown.

On this basis the purpose and the research question needed to be reformulated. From a Tanzanian perspective these houses can be seen as luxury houses but from a Swedish perspective these could be compared with a larger Swedish villa with basic standard. After the visit it became clear that a comparison between these houses and a Swedish house could be made. From the authors perspective it was most relevant to study and compare the structure, the climate and eco friendly constructions.
The communication with the University of Dar es Salaam did not work as planned. The University in Jönköping was contacted to try to get some help to solve the situation. The answer from Jönköping came after four weeks and the half of the time in Dar es Salaam had gone. Since no help was received neither from the University of Dar es Salaam nor in Jönköping a feeling of helplessness appeared. Most of the time in Dar es Salaam consisted of nagging for more information and no part of the report writing was made there. The general information about Tanzania is mainly taken from different websites. Since the internet connection only worked partially, and the times there were a connection it was slow, this information was collected afterwards. The University have a library that maybe could have been used but the University did not give access to this. If it would have been realized earlier that no more information could be found and a clearance from the University in Jönköping to start with the report the report writing could be started earlier.
Abstrakt

Detta examensarbete har gjorts som en Minor Field Study i Dar es Salaam, Tanzania. Tanzania är ett av de fattigaste länderna i världen och detta återspeglas i deras sätt att bo. Många människor bor i enkla hus gjorda av lera men huset som har studerats för detta examensarbete är ett lyxigt hus sätt ur ett tanzaniskt perspektiv. Företaget som bygger dessa hus är National Housing Corporation och är det bolag som har lämnat ritningar, information och ordnat studiebesök.

Syftet med detta projekt är att få kunskap om hur en tanzanisk tvåvåningsvilla byggs och utformas. Målet är att utvärdera om svenska kunskaper i byggnadsteknik kan implementeras på en tanzanisk tvåvåningsvilla med hänsyn till konstruktionen, klimatet och miljövänlig konstruktion.

För att kunna genomföra detta examensarbete har en Minor Field Study gjorts i Dar es Salaam, Tanzania. Under fältstudien har studiebesök, intervjuer och egna observationer gjorts.


Tanzanier tänker inte på ett miljövänligt sätt, och därför finns det en hel del förbättringar att göra på det här området.

Ur ett svenskt perspektiv finns det mycket som kan förbättras på det studerade huset för att få ett mer hållbart hus med hänsyn till konstruktionen, klimatet och miljövänlig konstruktion.
Summary

This final project is made as a Minor Field Study in Dar es Salaam, Tanzania. Tanzania is one of the poorest countries in the world and this is reflected in the way they live. Many people live in simple houses made out of mud, but the house that have been studied for this final project are a luxurious house from a Tanzanian perspective. The company that builds these houses are National Housing Corporation and it is this company that have provided drawings, information and educational visits.

The purpose of this project is to gain knowledge about how a Tanzanian two-storey family house is constructed and designed. The aim is to evaluate if Swedish knowledge in building technique can be implemented to a Tanzanian two-storey family house concerning the climate, building structure and eco friendly construction.

To be able to carry through with this final project a Minor Field Study has been executed in Dar es Salaam, Tanzania. During the field study educational visits, interviews and own observations has been made.

By studying the drawings, read the interviews and look at photographs that were taken at the site several conclusions have been made. The foundation is the thing that differ the most from a Swedish villa. The slab is cast on underground walls and has only a mould around. Since it does not have a mould underneath the concrete can mix with the limestones and the drainage function is destroyed. The concrete strip that is placed underneath the underground walls has a dam proof membrane underneath which should be placed over the entire foundation structure. The roof is constructed by trusses and rafters in small dimensions. The dimensions could be increased to enlarge the distance between them. The windows are equipped with grilles that should protect from break-ins but also makes it harder to get out in case of fire.

The upper slab is merged with the balconies and the balconies do not have an inclination out from the house. This could cause damages on the structure if water is stored there. The walls are made out of concrete which is the best material concerning the climate. To get an even better indoor climate the walls and the rest of the structure could be isolated so energy can be saved when the air conditioner is used.

Tanzanian do not think in an eco friendly way but in this question a lot of improvements could be made.

From a Swedish perspective there are a lot of things that can be improved on the studied house to get a more sustainable house concerning the structure, climate and eco friendly.

Keywords

building structure, climate, Dar es Salaam, eco friendly construction, Mbweni, National Housing Corporation, NHC, Tanzania, two-storey family house.
## Contents

6.3 CONCLUSIONS AND RECOMMENDATIONS ................................................................. 54

### 7 References ........................................................................................................... 55

7.1 PRINTED REFERENCES .......................................................................................... 55
7.2 UNPRINTED REFERENCES .................................................................................... 55
7.3 FIGURES ................................................................................................................ 56

### 8 Search Terms ...................................................................................................... 59

### 9 Appendices .......................................................................................................... 61
1 Introduction

This final project is a part of the programme Building Technique at the School of Engineering at Jönköping University. For this final project the authors applied for a SIDA-scholarship and made a Minor Field Study in Dar es Salaam, Tanzania. A two-storey family house has been studied in Mbweni district and compared with a basic Swedish private house concerning the structure, the climate and eco friendly construction.

1.1 Background

Tanzania is located just below the equator on the African east coast and it has eight bordering countries and one coastline, the Indian Ocean, which lies in the east. Tanzania is a country with a varied landscape. The midland consists of large steppes, big forests and rainforests, big lakes, a high mountain and long sand beaches along the Indian Ocean. There are several national parks in Tanzania with a lot of African animals. Because of the big areas and the differences in height the climate are very different in different places.

Tanzania is a country with 45 million inhabitants and the most of the population lives in the cities along the coastline where the biggest city, Dar es Salaam is situated. About half of the population is Christian, one third is Muslims and the rest is different kinds of minority groups. There are about 120 different ethnic groups like Maasais and Cushitic people. English and Swahili are the official languages but also Arabic and local languages are spoken.

Tanzania is one of the poorest countries in the world and the majority of the population lives below the extreme poverty line. The life expectancy are not higher than 57 years for women and 56 years for men. Tanzania is a country where a lot of the population suffers from serious diseases like HIV, aids and malaria.

Tanzania has been a German colony and later managed by Great Britain. But since the 1960s it has been an independent republic. Today’s president is President Kikwete and he was re-elected in October 2010.

Dar es Salaam is the biggest city in Tanzania and was the capital before the city Dodoma became the new capital in 1974. Because of the rapid growth of the city all the inhabitants can not be supplied with all the social services that are needed. In the city of Dar es Salaam the average living space is 4 m² per person, compared with 44.5 m² per person in Sweden. The majority of the population can not afford to buy their own house and therefore the luxury house that have been studied for this final project are not produced for the average inhabitants.

National Housing Corporation, NHC, that builds the house is a public enterprise governed under the Ministry of Lands and Human Settlements Developments, which is controlled by the Government of Tanzania.
For this final project something special wanted to be done and a Minor Field Study in Dar es Salaam, Tanzania was decided to be the ground for the project. The idea was that the University in Dar es Salaam should provide several relevant low-cost projects to study. After arrival only one educational visit at one building site was arranged. The building site was Mbweni Housing that consists of 49 luxury family houses. Since it was the only showed project, Mbweni Housing became the project to study.

1.2 Purpose, Aim and Research Questions

The purpose of this project is to gain knowledge about how a modern Tanzanian two-storey family house is constructed and designed. The aim is to evaluate if Swedish knowledge in building technique can be implemented to a Tanzanian two-storey family house concerning the building structure, climate and eco friendly construction.

The questions that will be answered with this report are:

- How can the structure and/or the design of a Tanzanian two-storey family house be improved concerning building structure from a Swedish perspective?

- How can the structure and/or the design of a Tanzanian two-storey family house be improved concerning the indoor climate from a Swedish perspective?

- How can the structure and/or the design of a Tanzanian two-storey family house be improved concerning eco friendly construction from a Swedish perspective?

1.3 Delimitations

This final project will focus on a study of a two-storey family house. The building site that have been visited consists of both bungalows and two-storey houses, but it is only one two-storey house that will be studied.

To keep this project within reasonable limits no calculations of the constructions durability will be made. There are no rules and regulations about how to build and design a family house, as there are for public buildings, and therefore nothing like that will be studied. No thoroughly economic calculations will be made but it will be considered during this project.

When the calculation of the insulation will be made it will be calculated that the wall consist of just concrete and insulation. It is obvious that the insulation needs to be fixed with joists and moisture barrier, but this will be neglected to make the calculation easier. The calculation will be basic just to get an indication if the insulation will make any difference and therefore will all volumes, surfaces and electrical costs be approximate numbers.

The purpose of this final project is not to create a new better solution for the whole structure of the house. The purpose is just to evaluate if Swedish knowledge can be implemented in this project.


title

1.4 Outline

The structure of this report follows the layout of the exam report template, which is given from the School of Engineering at Jönköping University.

The report will start with a theoretical background where overall information about Tanzania will be found. After that the methods that have been used are explained.

The result part will be divided into two parts. The first part will focus on the findings. The building structure, the indoor climate and how they work to get an eco friendly construction will also be explained. The second part will focus on the analysis. Problems from a Swedish perspective will be illuminated, concerning the building structure, the climate and eco friendly construction. Where better solutions can be find these are explained.

The result part will be followed by discussions of the methods and the findings. And to tie it up a conclusion will be made.
2 An Overview of Tanzania

Tanzania is one of the poorest countries in the world and is located in the middle east of Africa with a coast that boarders to the Indian Ocean. Africa’s highest mountain, Kilimanjaro, is situated in Tanzania, next to the border to Kenya. Both Africa’s biggest and deepest lakes are partly situated in Tanzania. Generally the weather is very hot and sunny. The flag (Figure 1) represents the green grass, the blue water, the bright sun and the black people.

2.1 Geography and Climate

The United Republic of Tanzania is located on the east coast of Africa, (Figure 2) south of the equator and has an area of 945 090 km². Tanzania has eight bordering countries which are Kenya, Uganda, Rwanda, Burundi, Zambia, the Democratic Republic of Congo, Malawi and Mozambique. The country is also bordering to the Indian Ocean in east. Tanzania is a union between the mainland and the island Zanzibar (Figure 3).

1 http://flags.net/TANZ.htm [Quoted: 2011-05-02]
2 http://landguiden.se/Lander/Afrika/Tanzania.aspx, [Quoted: 2011-03-28]
Big areas in Tanzania’s mainland consist of plateau landscapes with large steppes. Tanzania also has large areas of forest and small areas of tropical rainforest and along the Indian Ocean coast there are several beautiful sand beaches. Lake Victoria is Africa’s biggest lake and is partly situated in the north of Tanzania. Tanzania also has Africa’s highest and lowest points. The peak of the mountain Kilimanjaro that is situated in the north east of Tanzania is 5895 meters above sea level and the bottom of Lake Tanganyika that is situated in the north west of Tanzania is 385 meter below sea level and has a maximum depth of 1435 meter.

Tanzania has several national parks like Serengeti National Park, the Ngorongoro crater and Lake Manyara where there is a lot of African animals such as lion (Figure 4), elephant, zebra, buffalo, leopard, rhino and giraffe.

The coastline in the east and the islands outside the coast, for example Zanzibar have a tropical monsoon climate while the midland has a dry and hot climate. The areas at the plateaus and around the mountains are more temperate and cooler and are therefore more pleasant to stay in. The coastline climate determines by the monsoon winds and the additional rains that comes with them. The long, heavy rains called masika falls during March to May and the short, lighter rains called mvuli falls during November and December. In the mountains it can rain any time of the year. The coolest months are from June to October and the warmest months from December to March, across the whole land.

2.2 People and Social Conditions

Tanzania has 45 million inhabitants and a high proportion lives in the cities along the coastline, especially in Dar es Salaam where more than three million inhabitants lives. The areas around Kilimanjaro, Lake Malawi and south of Lake Victoria are also areas that are densely populated. Dodoma is the capital of Tanzania and have 174 000 inhabitants. The inhabitant density in Tanzania is 48 inhabitants/ km².
Tanzania has 120 different ethnic groups where the largest groups are sukuma, nyamwezi, makonde, haya and chaga which belongs to the Bantu people, but none of these groups represent more than 10 % of the population. In the north of Tanzania there also lives Maasai (Figure 5) and Cushitic people which belong to the Nilotic people. There are also some minorities in Tanzania such as Arabs, Asians and Europeans.10

Figure 5 – Maasai women and their children.

(Private)

English and Swahili are the official languages in Tanzania. English is not spoken by many people in rural areas, it is mostly spoken in the big cities but even there many people do not speak English. The reason why English is more spoken in the cities is because it is the most common language in education, business and administration. At the islands Zanzibar and Pemba and along the coastline many people speak Arabic. In addition to these languages there are also approximately 130 other local languages.11

About half of Tanzania’s population is Christian and most of them are Catholics which is the consequence of that Tanzania was a German colony in the early 1900’s and missionaries where active in Tanzania. One third of the population is Muslims and most of them are Sunnites. In Zanzibar 95 % of the population is Muslims, which have been in Zanzibar since the 600’s. Traditional African beliefs

10 http://landguiden.se/Lander/Afrika/Tanzania.aspx, [Quoted: 2011-03-28]
are something that the majority of the Tanzanians believe in. It is believed that the spirits belonging to ancestors can bring luck and misfortune, health and disease. Traditional witch doctors were banned in 2009 because killing of albinos occurred since their body parts consider to have magical powers. Unfortunately this has not helped and witch doctors are still active around the country.12

There is compulsory school attendance for the grades one to seven, called primary school, in Tanzania but despite this it is not all children who attend to school. The school fees were removed in 2001 for the primary school but despite this there are still many families who can not afford to have their children in school. This is partly because school uniforms and books cost money, and partly because the children labour is needed at home. The goal of the government is that all children should attend in school in 2015. Before primary school, as the children start at the age of seven to nine years old, there is a pre-primary school for two years. After primary school there is an optional education divided into two periods of four and two years. Tanzania has three universities where the biggest is in Dar es Salaam. In Tanzania 72.6% of the inhabitants can read and write.13

In Tanzania 88.5% of the people lives below the extreme poverty line,14 that is 1.25 USD per day.15 Normally the population is not starving because most of them have their own agriculture and can then grow some crops and have some animals.16

The life expectancy in Tanzania is 57 years for women17 and 56 years for men.18 A reason for this is that so much as 6.5% of the population have HIV and aids. Another disease that also takes many lives is malaria, which kills about 300 000 Tanzanian people each year. Tuberculosis, diphtheria and amoebic dysentery are diseases that also are common in Tanzania. If medical care is needed a charge is taken out since the government’s ambition to free medical care is failing as a result of the country’s economic problems.19

The government offer pension, maternity benefit and insurances for accident and invalidity, unfortunately the benefit is very low. Since only formal employees and employers are entitled to pension many people are left without pension because they are working on the black market. Those who do not receive any pension needs to rely on their family for providing them. The retirement age is 55, which is just one or a couple of years below the life expectancy age. The most of the Tanzanian do not have a formal employment instead many works with their own small agriculture and/or in the informal black market.20

12 http://landguiden.se/Lander/Afrika/Tanzania.aspx, [Quoted: 2011-03-28]
13 http://landguiden.se/Lander/Afrika/Tanzania.aspx, [Quoted: 2011-03-28]
14 http://www.globalis.se/Laender/Afrika/Tanzania/(show)/indicators, [Quoted: 11-04-18]
16 http://landguiden.se/Lander/Afrika/Tanzania.aspx, [Quoted: 2011-03-28]
17 http://data.worldbank.org/indicator/SP.DYN.LE00.FE.IN, [Quoted: 11-04-18]
18 http://data.worldbank.org/indicator/SP.DYN.LE00.MA.IN, [Quoted: 11-04-18]
19 http://landguiden.se/Lander/Afrika/Tanzania.aspx, [Quoted: 2011-03-28]
20 http://landguiden.se/Lander/Afrika/Tanzania.aspx, [Quoted: 2011-03-28]
Only 54% of the inhabitants have access to clean water. Electricity is also in short supply and power failure and rationing of the power are common. The reason for this is that the electricity is produced by hydroelectric power and because it is often shortage of water depending on the drought, it is not enough water to supply the hydroelectric power station. Tanzania are using 82 kWh per person and year compared with Sweden that are using about 15 000 kWh per person and year.21

2.3 Politics, History and Economics

Tanzania is a republic and the president Jakaya Mrisho Kikwete (Figure 6) was re-elected in October 2010, he had then been the president since December 2005. The president can have the execution of power for maximum two five-year-periods. The united republic of Tanzania also includes Zanzibar, but Zanzibar has its own internal self-government. Laws are made by the National Assembly and applied to the mainland or for the whole union. Laws made for the whole Union are those related to foreign affairs, foreign trade and defence. Zanzibar has its own government and parliament which have the power of decision in questions relating to the islands of Zanzibar and Pemba.

Figure 6 – President Jakaya Mrisho Kikwete.22

Multi-party system was introduced in 1992 but despite this it is still the same party, Chama Cha Mapinduzi, CCM that dominates. Many smaller parties have tried to enter the National Assembly, but they have only got a few places. The judicial system is inefficient and exposed to corruption, although it has improved since the multi-party system was introduced.

In 1884 the Tanzanian mainland became German when the Great Powers of Europe divided Africa between themselves. In 1890 Zanzibar and Pemba becomes British protectorate. The British took over more and more of Zanzibar and Pemba’s functions, from that previously only manage the foreign policy, in 1913. Germany later lost Tanganyika, the Tanzanian mainland, after World War I.

21 http://landguiden.se/Lander/Afrika/Tanzania.aspx, [Quoted: 2011-03-28]
Instead the British became manager when Tanganyika became a mandate under the League of Nations (formerly United Nations). Already in the 1920’s the fight for an independent Tanganyika began and the Tanganyika African Association (TAA) established in 1929. It was not until 1954 that the TAA converted to a political party by Julius K Nyerere. This had effect and in 1961 Tanganyika became independent and two years later Zanzibar and Pemba became independent. After this, in 1964, Tanganyika and Zanzibar islands established the United Republic of Tanzania with Julius K Nyerere as president.

Tanzania is a poor developing country that is largely dependent on aid and loans from the rest of the world. The aid pays nearly half the government budget expenditures and for almost nine-tenths of the development projects. Great Britain, the Scandinavian countries, Japan and China are major donor countries. The aid Tanzania has got can be estimated to 55 USD per person.

The agriculture represents almost half of the GNP, but despite this it is primarily the agriculture as restraining the economical growth. This is because that the agriculture is old-fascinated and it is exposed to extreme climate changes and it is often hit by drought. Tanzania’s foreign debt in 1998 was the value of the entire country’s GNP. Between 2001 and 2003 around seven billion USD was removed which led to that the foreign dept in 2005 was less than a third of its GNP.

One thing that has given big revenues in recent years is tourism (Figure 7) and mining. The tourism is going better and better and tourists contribute with about 1.35 billion USD. The mining sector grew the years 2000 to 2005 with over 15 % per year, which has given a great boost to the Tanzanian economy.

Tanzania is rich in natural resources, gold is the biggest export product, but also other minerals are extracted. The reason that the mining industry have expanded is that Canadian, Australian and South African mining companies have invested in the country’s mining industry. Other essential products exported from Tanzania are industrial products, tobacco, coffee and cotton. Sisal (a kind of hemp), spices, tea and cashew nuts are also products that are exported (Figure 8). The most common imported products are machines, vehicles, building materials and fuel. China, India and South Africa are Tanzania’s largest trading partners.
In the 1970’s Tanzania became economy suffered when the country tried to increase the population’s reading and writing skills as well as reducing diseases and malnutrition. Meanwhile public health and knowledge was improved, the production of products was neglected which led to a severe economic crisis in the 1980’s. The crisis led to that Tanzania was forced into a recovery program in which the country had to devalue the currency, the Tanzanian shilling, removing subsidies on basic products and reducing the government budget deficits. Subsidies led to that food prices rose sharply, which meant that many had to have multiple jobs to manage the everyday life. This have made that the informal, black market has grown.

2.4 Dar es Salaam

Dar es Salaam means haven of peace and was founded in 1862 by Sultan Seyyid Majid of Zanzibar. The city was the capital of Tanzania to 1974 when Dodoma became the new capital. Despite this Dar es Salaam still remain the most important city for trade and industry and its here where the government is stationed.

Dar es Salaam is located in eastern Tanzania and has a long coastline along the Indian Ocean. The city is Tanzania’s largest city with more than three million inhabitants and is the third fastest growing city in Africa and the ninth fastest growing city in the world with an average annual growth of 4.39 %. Dar es Salaam City is 1800 km², in which 1393 km² are land, the rest are water. The city is divided in three municipalities and each municipality is divides into wards, which are several smaller areas. The municipalities are Ilala, which is the administrative area, Kinondoni, which is the most popular area to live in and here lives half of the cities inhabitants, most from the high and middle-class and Temeke is the industrial area where the largest proportion of low-income lives (Figure 9).
The rapid growth of the city has led to that many inhabitants have settled in unplanned, densely settled squatter areas where 70-75 % of the areas do not, fully or adequately, have social services such as streets, sewers, clean water, schools, police, fire brigade or hospitals that are affordable and reachable. The plots are obtained by informal acquire (Figure 10). 89 % of all plots are owned outside the legal system which means that they don’t have any land-title or building permit.

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29 City Director. (2004) *Dar es Salaam City Profile*. Dar es Salaam City Council, Dar es Salaam, ch. 11.4.2 Urban Design and Social Services
2.4.1 Family Houses

A majority of Dar es Salaam's population rent low-cost housing and over 70% of the population lives in households of one or two rooms where it in the average household lives 3.8 persons. A standard room is often 12 m² and can accommodate an average of three persons per room which gives the average space of 4 m² per person. The Swedish people lives on an average space of 44.5 m² per person.

According to Global Property Guide the average cost for renting a living area of 100 m² is 500 USD per month. This is approximately 750 000 Tanzanian shilling, Tsh, which is 7500 Tsh /m²/month. The same dwelling costs about 70 000 USD to buy which is 104 million Tsh. This cost relates to housing of better quality and on planned and serviced land in Tanzania. Of course, it is very many people that neither can afford those rents nor the buying price. The average income for 35% of Dar es Salaams population are 32 000 Tsh per month which is approximately 21 USD. People with a high income may be granted a house loan by either the company building the house or some banks, for example Commercial Bank of Africa, CBA. The repayment period is short, about two to three years at National Housing Corporation and maximum fifteen years at CBA and it is far from all who are entitled to receive a loan. According to figures from 1995 the price for renting a traditional mud house is about from 1000 Tsh per month and a “modern” cement block house cost about 5000 Tsh per month. Rental dwellings become more and more expensive when the distance to the city centre reduces. Although the figures are old and have increased in recent years they show the differences in costs between better dwellings and dwellings in the slum. The different options for accommodation consist solely of renting or owning and any form of condominium does not exist.

The most popular house to build and live in for the urban poor is the Swahili house. It is usually four, six or eight rooms along a corridor and at the bottom of the corridor is a door leading out to an enclosed backyard where the kitchen and toilet is (Figure 11). The Swahili houses are built in three different alternatives. The traditional Swahili houses are built of piles, grass and mud (Figure 12). These houses have problems resisting weather exposure and attacks by insects. Semi-modern house is essentially traditional, but improved. They have a foundation in coral-stone, a cement base around the houses where the piles are covered, the walls plastered with sand and cement mortar, also the floor is covered with sand and cement mortar and the palm leaf roof is replaced with sheet metal. The third option of the Swahili house is the best and most expensive. The foundation is made of concrete or sand and cement mortar, the walls are made of sand and cement blocks and timber is used for roof construction which is then covered with a tin roof.\(^{38}\)

\[\text{Figure 11 – Typical plan of a Swahili house.}\] \(^{39}\)


\(^{39}\) Housing and Building Materials in Low-Income Settlements in Dar es Salaam. Jill wells – South Bank University, UK, Sinda H. Sinda – University of Dar es Salaam, Tanzania and Fatiha Haddar – South Bank University, UK. P. 399
To be able to afford a house, the vast majority build their own houses instead of buying. This since the private construction sector does not build any low-cost housing because they make more money on more expensive houses. Instead the government working with a government-linked company, National Housing Corporation, NHC to produce low-cost housing. Unfortunately, NHC also have difficulties to manage to build cheap houses and the dwellings are often too expensive. It is estimated that 60-80 % of Dar es Salaam's population lives in unauthorized squatter housing as this is what can be afforded. Many inhabitants cannot afford a house even if it is built by themselves and then the solution is to rent a house from someone who already has a house. There are two reasons for constructing own houses. The first reason is that the owner of the house and his family should have a place to stay and the other is to lease out all or part of the house to earn an income. It is very common (70 % of all houses) that the owner and his family live in the house and that they at the

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same time rent out parts of it, 21 % of the houses are rented out completely, and where the owner lives somewhere else. There are therefore only 9 % of the houses where the owner lives with his family all by themselves.46

The building methods for a private house built by the owner compared to a house built by a building company do not differ considerably. When a non public or a family house is built no cranes or other large machines are used. All the material that are used is carried and put into place by hand. Modern tools are not used and no tools that require electricity or batteries such as drills, saws, nail guns etc. were seen at all at the Mbweni construction site and old pickaxes were used to excavate the land for pipelines. All concrete blocks used for the walls are made on site or purchased from nearby small businesses, often informal. The concrete used for the foundation and the slab is mixed in a tombola when a company is building, but private builders do not usually have this. The same method is used when the concrete is cast, workers carry buckets with the concrete on their heads, and are then poured into the mould in which the foundation or slab is cast (Figure 13). According to own observations no protective equipment such as helmets, gloves or special clothing and shoes was used in many cases. Some workers at the Mbweni construction site had ragged clothes and some were even barefoot, even though the site manager earlier had said that protective equipment was used.

Figure 13 - Picture showing the stair where workers go up and down with concrete buckets to cast the first floor slab.

(Private)

2.4.2 Luxury Homes

With the information above it is natural that the two-storey family-house in Mbweni is an expensive luxury home. The house is built with building permit, has formally employed workers and has good quality on building material. The house has a size of about 260 m² where the layout is not suitable for rental, which means that it is intended for high-income earners. At the same time, it is precisely these luxury homes that suits for a comparison with a Swedish villa because the builders of Swahili house has neither the ability of money, materials or knowledge to be able to implement Swedish changes. The luxury homes are designed by architects and engineers and built by employees who are supervised by an educated manager, which means that both the design and construction methods would be possible to change. In addition, the company has the ability to import new materials and the higher costs for the construction stage would only affect high income earners.

2.5 National Housing Corporation

National Housing Corporation (Figure 14), NHC is the company that is building the two-storey family-houses in Mbweni, Dar es Salaam. The company showed the construction site, provided drawings and two of the employees has been interviewed, both on site and by email afterwards.

Figure 14 – Logo of NHC.47

NHC is a public enterprise governed under the Ministry of Lands and Human Settlements Developments which is controlled by the Government of Tanzania. NHC was established in 1962 and was then reconstituted in its present form in 1990 to be the leading company in the housing sector in Tanzania.48 The vision of NHC is “to be a leading Real Estate Development and Management firm.”49 The mission of NHC is “to provide and facilitate the provision of quality housing and other buildings for use by the general public while operating on sound commercial principles.”50 To achieve this NHC provide and facilitate the provision of serviced land and buildings and also of building materials, components and other related articles. The land and buildings are used for residential, business and industry.51 NHC provides the market with both apartment buildings for renting and single family houses for buying. The cost and the quality of the buildings are very variously.

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2.6 Background to Research Questions

During the educational visit at Mbweni Housing some problems, from a Swedish perspective, were evident. As the Tanzanian structure of the building differs from a Swedish structure it was interesting to study the differences and maybe come up with better solutions. Since the climate is hot and humid, the indoor climate is negatively affected. To see if the indoor climate can be more comfortable this issue also was to be studied. A well discussed and always interesting topic is how to act in an eco-friendly way and that question also became a part of the study. These three topics became the ground to the research questions, since it was these topics that NHC could provide drawings for and information about.
3 **Method and Implementation**

To be able to answer the research questions and finalize this final project a field study has been made. Included in the field study were educational visits, interviews and collecting of drawings. Afterwards the collected information has been studied and modifications of the drawings have been made.

The Field Study included educational visits on a building site and interviews with the employees at the building company National Housing Corporation, NHC. During the educational visit own observations and interviews were made. During the field study drawings were collected that have been studied afterwards. Further interviews with the employees at NHC have been executed through e-mail after the field study. Different websites have also been studied to collect information.

The insulation calculations have been made with formulas that calculate the thermal transmission coefficient, U-values and energy consumption.

The educational visit started with an interview with the site manager. The site manager later showed the site and the studied house and answered to questions about the project. Own observations were made during this educational visit on the building, the workers and the material stored on site.

Before the interview questions were prepared to make a good structure on the interview. When the questions were asked a conversation with further questions arose. The collected drawings were studied after arrival to Sweden and more questions needed then to be answered. This was executed through e-mail. The questions were asked point by point to be able to get a concrete answer. To show the improvements made form a Swedish perspective one detail drawing is designed to show the improvements.

No part of the report writing was executed during the eight week visit in Tanzania. It was just the Minor Field Study that was made there. All the report writing has been made afterwards in Sweden.
4 Findings

The studied project is a project that consists of 49 new houses, both bungalows and two-storey houses. The area where the project is placed is called Mbweni and is located 50 km north of the city centre of Dar es Salaam. All the houses in the area are luxury homes and made for wealthy families. This type of area and houses are unusual and only exists in a couple of small areas in Dar es Salaam. The project started in 2005 with 15 houses. The second phase started in 2008 and consists of 34 houses. The Mbweni area is expected to expand further the next few years.

For this project a two-storey house was chosen to be studied. The topics that are going to be studied are the structure, the indoor climate and how to build in an eco friendly way.

The following texts are based on interviews (Appendix 1-3) and own observations and will only consist of facts. Drawings on one of the two-storey houses have been studied. The plan drawings (Appendix 4-5) show the type of house that has been studied. The detail drawing (Appendix 9-10) shows another house, but the connections are very similar according to Architect Solomon Zephania. The architect asserts that the construction of the connections looks the same on all houses of this type.

The Tanzanian way of building and designing a two-storey family house (Figure 15) differs from the Swedish methods. The following text will explain the building structure, the indoor climate and how it is built in an eco friendly way.

Figure 15 – The studied house.
(Private)
4.1 Building Structure

To minimize the cost and transportation local materials are used as much as possible. The local materials that are used in this project are wood, concrete and limestone for the structure. The imported materials are floor tiles, reinforcements, aluminium, Harvey tiles and other finishing materials.

Concrete is the most common material in the structure because it is a cheap material and it is easy to get hold of. On the outskirt of Dar es Salaam there is a big industry that manufactures cement and in the surrounding area there are stone-quarries, which mean that the costs can be minimized by short transports. Wood is hard to get hold of in the city area, which means that it has to be transported a long way and therefore is a more expensive material. A wooden structure is also more vulnerable to moisture. Damages like fungus and termites can easily appear in a wooden structure. Concrete is a better material because it is a slow material that stores the heat inside the material so the inside temperature can be as low as possible. A wooden structure would heat up the house quicker and the temperature inside would be higher. In this type of building wood is never used in the walls, just as a roof structure.

4.1.1 Foundation

The foundation consists of both walls and slabs (Appendix 9-10). The slab is elevated 450 mm from the ground level and lies on underground walls that have a minimum height of 1200 mm. Underneath the underground walls there is a 700 mm wide concrete strip foundation. Since there are walls under ground rooms are formed that are filled up with layers of soil. Between the soil and the concrete slab there is a layer of 150 mm well compacted limestones, which are crossed by hand in the nearby stone-quarries (Figure 16). The slab is cast directly on the limestones with a timber or steel frame around. The side of the foundation walls and underneath the slab is normally not protected against moisture damages but if there is heavy rain during the construction time some parts of the underground walls can be protected with a damp proof membrane. All concrete strip foundations has a damp proof membrane underneath. To get a smooth surface on the floor a 40 mm cement screen is made and floor tiles can be laid above that.

Figure 16 – Limestone.

(Private)

52 http://www.hrp.co.za/, [Quoted: 2011-03-29]
4.1.2 Walls

All the walls (Appendix 9-10) are made of concrete blocks (Figure 17) and are load-bearing. Most of them run from underground up to the ceiling on the first floor, even the inner walls. Some of the walls on the first floor do not have a wall just underneath, according to the drawings, but they are still a part of the bearing system.

Since there are no regulations concerning the quality of the concrete blocks when a private house is built the blocks are made on site by the workers. This is the cheapest and the easiest way of producing concrete blocks. If the concrete blocks should have special qualities, they are tested at the University of Dar es Salaam, which act as testing institute in Tanzania. It is only when public buildings are made that there are regulations concerning the quality of the blocks.

![Figure 17 – Outer wall made of concrete blocks. (Private)](image)

4.1.3 Roof

The roof construction is built up by 100 x 50 mm trusses and rafters in wood (Figure 18). Because of the small dimensions on the trusses and rafters and all the angles on the roof a lot of material is required. The many trusses make it impossible to furnish or use the floor as storage space.

A common coating material for the roofs in Tanzania is sheet metal. Since these houses that have been studied are produced for the more wealthy people a product called Harvey tiles are used as coat material. Harvey tiles are a kind of sheet metal that looks like ceramic tiles and they have a more exclusive look. The surface is treated with acrylic coating that can withstand high ultra-violet levels.53

To try to cool down the house the roof is equipped with louvers for natural ventilation. These are placed under the roof ridge. This is the highest place on the roof so the warm air that rises can come out easily.

The trusses work as battens and the rafters as counter battens. No tongued and grooved boards are used so the Harvey tiles can be seen from the inside. There is no insulation in the roof either.

**4.1.4 Windows**

The windows are single-glazed sliding windows with aluminium frames (Figure 19). Inside the windows a mosquito net is placed to stop the insects to come in.

In Tanzania brake-ins and stealing is very common. To prevent this, the houses are equipped with grilles. These are attached in the window frame, on the outside of the glass.

**4.1.5 Connections**

The following explanations are based on Appendix 9-10.

The top of the outer wall on the second floor is cut out on some places so that the trusses can lay there. How the trusses are attached further in the wall is not explained by the drawings.

The ceiling is attached to timber hangers that are attached in the rafters. Along the walls the ceiling is lowered 135 mm further to create an aesthetic effect. The lowered part of the ceiling is also attached against the walls through a timber hanger that is attached with big nails directly in the concrete walls.
The roof eave is closed by a board so that birds and other animals can not come in underneath the roof and this also gets a good looking bottom on the roof eave.

The slab for the balconies and the slab for the first floor are cast in one piece. The slab for the first floor goes out to the outer edge of the walls and separates the walls on the ground floor from the walls on the first floor.

In the same height as the balconies and the slab for the first floor there is an aesthetic board in concrete that runs around the house on the outside.

The slab on the ground floor goes to the outer edge of the outer walls and separates the walls from each other. The only thing that covers the end of the slab is 15 mm thick plaster.

### 4.2 Climate Issues

The climate in Tanzania is very hot and humid. The daily temperature is around 30 °C. This temperature is measured in the shadow so the perceived temperature is even higher. The perceived temperature is also increased by the humidity. A normal day the humidity is around 80 %.

#### 4.2.1 Moisture Damages

Since the climate is very humid moisture damages can easily appear in the construction. It is not only in the connections that these damages can appear, they can also appear in the middle of the ceiling (Figure 20). Booth concrete and wood structures take damage because of the damp. The Tanzanians are aware of that concrete is a better alternative concerning the humid climate and therefore houses made out of concrete are more common. Despite this it is not unusual that the ceiling is covered with wood, for the aesthetic reason, even if the rest of the structure is made of concrete.

![Figure 20 – Example of moisture damage, small mildew spots in a wooden ceiling. (Private)](image)

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54  http://www.climatetemp.info/tanzania/dar-es-salaam.html, [Quoted: 2011-03-29]

4.2.2 Heat and Cooling

The heat is a big problem in Tanzania, especially inside the houses. A lot of heat is produced and stored in the buildings. All this heat needs to be removed by fans and air conditioning to create a more comfortable indoor climate. Holes are made in the outer walls so the buyer can install their own air condition. Since the temperature usually does not fall below 15 °C during the year any reconsider to cold do not need to be taken (Figure 21).

<table>
<thead>
<tr>
<th>Average temperature over 17 years</th>
<th>Unit</th>
<th>Year</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>°C</td>
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<td>Average high temperature over 17 years</td>
<td>°C</td>
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<td>26</td>
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<td>27</td>
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<tr>
<td>Average low temperature over 17 years</td>
<td>°C</td>
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<td>25</td>
<td>24</td>
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<td>22</td>
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<td>21</td>
<td>22</td>
<td>24</td>
</tr>
<tr>
<td>Highest recorded temperature over 17 years</td>
<td>°C</td>
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<td>37</td>
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<td>15</td>
<td>12</td>
<td>17</td>
<td>17</td>
<td>20</td>
</tr>
</tbody>
</table>

Figure 21 – Temperature differences during the year, (http://www.weatherreports.com/Dar_Es_Salaam_Airport_Tanzania?units=c,)

4.3 Eco Friendly Construction

Eco friendly is a concept that does not exist in Tanzania in the way of recycling. Any recycling or reuse in an eco friendly perspective is made unconsciously. If material is reused, it is from an economic perspective, because the cost is more important than quality and eco friendliness. All the material to this project, and to most of the projects, is bought in the beginning of the project when the prices are known. The reason for this is to be able to calculate the budget right in the beginning so the budget not will change later if the prices are updated and changed. All the materials are stored on the site and are exposed for the rain and other things that can make damages on the materials. The materials can also cause contamination of the ground. For example the wood is impregnated with cristosome against pests and vermin’s. When the wood is stored unprotected on site the chemical can easily be transferred to the ground. In Tanzania the building companies cast their own concrete block on site which means that no unknown and dangerous substances are mixed in the concrete blocks.

The building site is in many ways more eco friendly than a Swedish building site, except for the material storage. Practically no machines are used, neither small such as drills, nor large such as cranes. This means that the building site in Tanzania is less polluted and consumes less energy than a Swedish building site. Not many trees are planted on the building site that can avoid soil erosion and create protection against the sun. The reason for this is that the trees do not survive anyway because of the drought, according to the site manager Albert Guruyedi. Building material such as Harvey tiles, reinforcements and floor tiles are
imported which mean long transportations that are energy-intensive and require a lot of diesel and oil that pollutes the environment.

Since this is a luxury home from a Tanzanian perspective, the people living here live a more luxurious life than the majority of the population. This means that the electricity consumption will be high, since the building will be cooled with air conditioning. It is also presumable that people will use televisions and computers and probably use the car a lot, since the area lies outside the city centre. These people will probably buy more things than the average Tanzanian which also affect the environment in a negative way.
5 Analysis

The following text will illuminate the problems that can occur in the construction of a Tanzanian two-storey family house and some suggestions for better solutions will be made from a Swedish perspective.

5.1 Building Structure

Most of the family houses in the Dar es Salaam region are made out of concrete because of the climate and the cost, likewise in this project. Concrete is a cheap material that is easy to work with and to get hold of in the city area and it can resist moisture damages much better than a wood construction. Wood is a material that is hard to get hold of in the city area.

5.1.1 Foundation

The foundation is the one thing that differ the most when a Tanzanian family house is compared with a Swedish family house. In Sweden the slab is cast directly on the ground with insulation under and around, that function as a mould, and draining material underneath. The houses that have been studied for this project have a slab that is lifted up from the ground with underground walls underneath. Underneath the slab there is a layer of limestone that should serve as a draining material. The slab is cast directly on the limestone with a mould around. That means that the concrete can be blended with the limestone and the stones drainage function is lost. Underneath the limestone the underground rooms are filled with soil. Because of the warm weather no insulation needs to be used to insulate against any cold. The layer of limestone is a good idea so that the moisture from the slab easily can be led out of the construction. But since there is no layer that breaks the capillarity the damp can easily go up from the soil to the slab and cause damage.

Mostly the weather in Dar es Salaam is very hot and the ground becomes very dry. It is considered that no moisture protection for the foundation is needed because of this. But when the rain seasons come it rains heavily and the ground becomes damp. If it rains heavily and for a long time, which it usually does from March to May, the moisture can penetrate through the structure and lowers the durability. An additional risk is that mould can appear which can both cause damages on the structure and harm the people living there. In some constructions a damp proof membrane can be used if the construction is made during the rain (Figure 22). Instead of putting up a damp proof membrane if it rains during construction time it should always be a part of the construction. This would be placed on the outside of the entire foundation. The foundation strip where the underground walls stand on always has a damp proof membrane, but the walls and the slab also need to be protected. No drainage system is made under and around the house, except the limestone, which also prevent moisture damages on the foundation and therefore this should be made.
5.1.2 Walls

All walls, both internal and external, are made out of concrete which is the best material for the walls in a Tanzanian family house. In Sweden it is more common to use wood to the structure of the walls in a family house of normal size. Because of the humid climate the risk of getting moisture damages in the construction is much bigger if wood is used instead of concrete. Concrete is also much easier to get hold of in the city centre than wood material. The concrete blocks that the walls are made of are moulded on site by the workers. Structurally the walls could be made in wood but the concrete can stand the strain better from the climate than a wooden structure can.

To get a nice finish on both the inside and the outside of the wall a layer of plaster is placed directly on the concrete. On the outside the plaster goes below the ground level and moisture from the ground can penetrate between the plaster and concrete wall. This can cause damages and the plaster can crack and fall off.

To help to reduce the heat inside a layer of insulation can be placed on the inside of the concrete blocks. The insulation is then covered with gypsum board that is attached with screws to joists which is attached to the concrete blocks (Figure 23).
5.1.3 Roof

To keep down the costs a kind of metal sheet called Harvey tiles is used as coating material for the roof instead of clay tiles. These are cheaper than clay tiles and are imported from South Africa. The Harvey tiles are also much lighter and can be put up easier and the trusses and rafters do not have to be as strong as it would have to be if clay tiles were used. With a lighter structure the cost can be reduced compared with a heavier structure. A disadvantage with Harvey tiles is the heat they generate. When the sun shines the sheet gets very warm and the heat radiates to the inside and the space underneath becomes heated up. To get the air to circulate underneath the roof and try to cool it down the roof is equipped with grids for natural ventilation. The grids are placed underneath the roof ridge so the warmest air can be ventilated.

To get a good circulation of the air in the entire house a connection between the rooms and the area underneath the roof should be made. Warm air rises and if the room is closed all warm air stays in the room. If the room have a connection to the roof area the warm air could rise to the top of the roof and ventilate out naturally.

When a layer of insulation is placed underneath the Harvey tiles the radiation heat is partly stopped by the insulation. The space underneath the roof do not get heated up that much and the climate in the entire house will be cooler. To keep the insulation in place tongued and grooved boards needs to be placed on the outside and a board on the inside (Figure 24).

Since the roof construction is built up by trusses and rafters with small dimensions lot of wood is required and the space can not be used or furnished. If the dimensions of the trusses and rafters are increased the number of trusses and rafters could be reduced and the space could be used.

![Figure 24 – Improvements from a Swedish perspective concerning roof insulation](image)
5.1.4 Windows

All Tanzanian houses and their windows are equipped with grilles to prevent things like brake-ins. In this house that has been studied the grilles are attached on the outside of the window frame. This way of attaching the grilles do not make it that difficult for the housebreaker to get inside. The window frame is not that hard to remove from the wall and if the frame is removed so are also the grilles. A better way to solve the problem is to mould in the grilles in the concrete walls. That will make it almost impossible to break in.

The grilles are a good way to keep unwanted visitors away but it also makes it hard to get out. In case of fire inside the house the people who are inside cannot get out. If the grilles are able to be opened and have padlocks that can be opened from the inside the chance of getting out in case of fire would be much higher. The risk of a brake-in is much bigger than the risk of a fire inside so therefore the grilles are needed and prioritized.

Because of the hot climate the windows are often open to try to cool down the rooms. This allows all the dirty air, which comes principally from the emissions from all old cars and daladalas (mini buses) in the city, to enter the rooms and pollute the inside climate. Dust and particles comes in and can cause health problems and destroy the interior. If the windows are closed and some kind of filter that purifies the air is placed in the air conditioner the inside climate could be much better.

5.1.5 Connections

To get more circulation on the warm air underneath the roof the board that closes the roof eave could be replaced with a net or something that lets the air in. If the circulation is increased the climate could be a little bit cooler.

In Sweden the slab and the balconies would never be cast in one piece because of the cold thermal bridge that can appear. Problems with cold thermal bridges do not exist in Tanzania. The humid climate and the heavy rainfalls are a bigger problem concerning this connection. Water can easily be stored on the balcony and on the board around the house and cause a lot of moisture damages. Since the slab separates the walls the end of the walls and slabs are exposed for water that can be stored on the balcony and the board. The water can easily penetrate up in the wall. The damp can also come inside trough the slab and cause damages on the inside. If the balcony and the board would have a small inclination out from the house the water could drain and the damages would be minimized (Figure 25). The end of the balcony and the board can have a drip that avoids the water to trickle along the underside back to the wall.

The same problem can appear where the ground slab separates the walls. Since the outer plaster goes under ground moisture can wander from the ground and up to the connection trough the plaster.
5.2 Climate Issues

The hot and humid weather can make damages on the construction and cause inconvenience for the people that are living in the house. With a daily temperature of around 30 °C and a humidity of 97 % in the mornings damages on the structure are common.

5.2.1 Moisture Damages

Damp damages can appear easily and anywhere in the structure. They are as common in the connections as they are in the middle of a wall or the ceiling. The Tanzanians are aware of that concrete is a better material than wood concerning moisture damages. Therefore is wood material chosen as little as possible in the construction.

Damp damages can be avoided by making some small changes on the structure. Instead of just placing a damp proof membrane underneath the foundation strip the entire construction underneath the ground could be covered with a moisture barrier. Even if the limestones is supposed to function as a drainage material a damp proof membrane could be needed that can protect the slab. Since it rains heavily sometimes a drainage system could be installed so all the water can be lead away from the house. An easy way to lead away the water from the house is to have a plot that tilts away from the house. On serviced land drainage system is made along the roads and the water from the plot can easily be lead to these.

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56 http://www.weatherreports.com/Dar_Es_Salaam_Airport,_Tanzania?units=c, [Quoted: 2011-03-29]
The engineers at National Housing Corporation, NHC claim that the houses are protected from the rain. What they mean by that is that the roof eave is extended so that it protects the walls and the connection to the ground. This only works if the rain falls straight down. If it is windy the rain does not fall straight down and the walls can get wet and take damage. A lot of water can also be stored on the balconies and on the board around the house and cause big damages if it does not dry up quickly enough. If it has not rained for a long time the ground is very dry and hard and cannot absorb all the water directly which leads to that a lot of water can stand around the house and cause damages.

5.2.2 Diffusion

Diffusion is movement of a substance’s atoms of molecules into a different subject, usually from a place with high concentration of humidity to a place with low concentration. Diffusion always appears, more or less. When air condition is used indoor the temperature differences becomes large and the diffusion increases. When no insulation is used this is not a problem since it is only the concrete that becomes damp but when insulation is used the moisture can cause damages in form of mould on the insulation and joists. To avoid this, the house can be equipped with dehumidifiers. If no dehumidifiers are used condensation appears between the concrete and the insulation. This means that this type of structure can not be implemented without dehumidifiers. When dehumidifiers are used the relative humidity inside can be assumed to be 60 % and the structure is not affected in a negative way by the moisture. In these calculations the indoor temperature is estimated to 22 ° C and outdoor temperature 26 °. Included in the calculation is also an addition if moisture of 4 g/ m³. This occurs by the people that are living in the house, for example cooking and cleaning. When the relative humidity pass 100 % condense arise. The figure show relative humidity above 100 % but physical 100 % is the maximum value. When the line for humidity by volume (green line) and the line for saturated humidity by volume (blue line) crosses condense arise. Even if the lines crosses in the middle of the concrete condense can not arise there, condense will always arise in a between two materials (Figure 26 and Appendix 25-26).
Analysis

Humidity by volume (g/m³)
Saturated humidity by volume (g/m³)
Relative humidity, practical (%)
Relative humidity, theoretical (%)

Figure 26 – Moisture diffusion in the walls
5.2.3 Heat and Cooling

The climate in Dar es Salaam is often very hot, often around 30 °C. The warm air and the radiation from the sun heats up the buildings and a lot of heat are stored in the structure. The indoor climate becomes very warm and some adjustments on the construction can be done to lower the temperature as much as possible. In these houses that are made for the wealthy families, holes are made in the outer walls where the buyers can install their own air condition.

Big porches and balconies are made around the house to screen off the sun (Figure 27). The balconies converges trough a board that also helps to screen of the sun to the ground floor. The roof is also equipped with large overhang that screens off the sun to the first floor. These constructions are not consciously made, the construction is just made from the traditional way of building houses.

Figure 27 – The house with big porches and large roof overhang.

To try to get rid of the hot air inside, many people open up the windows to try to ventilate and get a cooler indoor climate. At the same time they run the air condition to cool down the house. When the warm air keeps coming in through the open windows the air conditioner needs to cool more air and this requires more energy and cost more money. If the windows were closed the air conditioner would have more effect.

Since the coating material on the roof is made out of Harvey tiles a lot of heat is produced there that radiates and heats up the rest of the house. If a thin layer of insulation would be placed underneath the Harvey tiles some of the heat radiation from the tiles can be stopped and the inside climate will be cooler.
All the walls and the foundation are made out of concrete which is a slow material in terms of thermal inertia. This helps the building to keep a more even temperature. The heat from the day stores in the structure and warms the rooms in the night. It is very rare that the temperature goes below 15 °C in the nights so no insulation is needed for the cold. Instead it would be possible to insulate the walls to keep the heat out.

5.2.4 Energy Consumption for Cooling

To see what the difference in energy consumption for cooling the house would be if the two-storey family-house is insulated compared to when it is not insulated, simple calculations have been made. The aim with these calculations is to see if the insulation could be a good alternative to reduce the heat and saving money in cooling costs just as insulation is used in cold climates to reduce heating costs. Four different thicknesses of the insulation in the walls and the roof will be calculated to see the different effects. The temperature of the soil underneath the house can be assumed to be 22 °C, to make a rough estimate since this is the lowest average air temperature.

The calculations are made with formulas from the Schools of Engineering Jönköping University and are made in five different stages to be able to see the differences. The comparison is made by calculations on the completely uninsulated structure and is then compared with structures with different thickness of insulation that is placed under the Harvey tile roof, on the inside of the outer wall and on the ground between the concrete slab and the limestone. When an air condition is used the estimated indoor temperature is 22 °C and the outside temperature is estimated to 26 °C. The temperature under the foundation is estimated to 22 °C. This means that the soil neither cause heating nor cooling of the structure. This means that insulation of the foundation is unnecessary. (Table 1). (See calculations in appendix 13-24).
Table 1. The table shows the result of energy consumption and the yearly cost for the energy consumption for different thickness of insulation.

<table>
<thead>
<tr>
<th>Construction</th>
<th>Energy consumption, kWh/year</th>
<th>Electricity cost, USD/kWh</th>
<th>Cost for energy consumption/year, USD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - Harvey tile roof, Concrete walls, Concrete foundation</td>
<td>92 449</td>
<td>0.25</td>
<td>23 112</td>
</tr>
<tr>
<td>2 – With 50 mm insulation on roof and walls</td>
<td>16 148</td>
<td>0.25</td>
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<td>3 - With 100 mm insulation on roof and walls</td>
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<td>4 - With 150 mm insulation on roof and walls</td>
<td>9 290</td>
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<td>5 - With 200 mm insulation on roof and walls</td>
<td>8 340</td>
<td>0.25</td>
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</tr>
</tbody>
</table>
The result shows that the vast saving of energy and money arises when the totally un-insulated house gets its walls and roof insulated, even if it is just a little part of insulation. When the insulation is increased, the energy consumption decrease even more and more money is saved. The house will cost more money to build if insulation is used but this will be paid off soon because the difference in energy consumption and cost would be big.

The result is based on that cooling is used day and night, and on all the square meters of the house, which is probably not going to be the real case. This means that the energy consumption per year will be lower which means lower costs and that it takes longer before the extra construction cost will be paid off. For example if the air condition is chosen to be used only 12 hours per day the energy consumption will be reduced by half. It should nevertheless not take very long time before the extra cost has paid itself in lower electricity consumption. The result is also based on that the house has natural ventilation that goes from the rooms to the roof space and then out and even in the opposite direction. Windows and doors need to be closed, otherwise the effect of the cooling from the air condition will be reduced and the energy consumption will be even higher.

The energy consumption is very high and this is because the building has a very big volume as the building area is big and the distance from floor to ceiling is high.

It is hard to know what the exact cost for the insulation would be. Probably the insulation needs to be imported, which costs extra money and it can be hard to get hold of. An alternative to the ordinary mineral wool is hemp. Hemp has recently started to be used increasingly as insulation in buildings, for example in Sweden. The hemp is a material that does not get mouldy because it transports moisture and it does not need any fire retardants since it has the same fire rating as wood. An alternative to the hemp may be the sisal that is a hemp likeness plant. The sisal is grown in large quantities in Tanzania because it is a large export product, and therefore it would be easy to get hold of and probably cost less than other insulation alternatives.

When the calculations were made it was assumed that the energy flow equally through the entire structure. This is not the real situation since the energy flows in various amounts depending on the part of the structure. Since the roof is heated by the sun the warm air underneath the roof press down the cooled air towards the floor. Because the space underneath the floor is completely filled up with soil, this layer will never have as high temperature as the air around the walls and roof. The cold has difficulties to penetrate through the foundation and soil since it is compact materials and already has around the same temperature. Therefore the cold will primarily penetrate the lower parts of the walls. To get a more accurate result, this is something that should be included in more advanced calculations.

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5.3 Eco Friendly Construction

There is no concept such as eco friendly construction in Tanzania. The main priority when a building is built is to build as cheap as possible. The cost is more prioritized than the quality of the building and how it affects the climate. A building's life-span is something that can affect the climate in a negative way but the Tanzanians do not have that in mind.

The building company mould their own concrete blocks on the site. Since there are no regulations that say how a family house should be built, the concrete blocks are not quality tested. Moulding their own concrete blocks is a cheap way to get the material to the structure but since the blocks are not quality tested the quality is unknown. There is no chemical additive in the concrete which is good concerning the nature but the quality maybe could be better with some additive. The reason why no chemical additives are used is because of the high cost. If some additives were used the quality could be better and the building's life-span could be lengthened and the climate would be less affected.

All the material is bought in the beginning of the building process. The reason is that the costs are known then and the company does not want to risk that the prices will rise. It is not a given fact that the prices will rise but the risk of that is high. When everything is bought in the beginning it needs to be stored somewhere during the building time. All material is being stored on the site and is exposed for the climate (Figure 28). Damp damages and vermin’s can attack the material and risk the durability and length of life of the material.

![Figure 28 – Building material stored on site.](Private)

Sometimes material can be reused and recycled, but it is not because they want to be eco friendly. The reason is because it is the cheapest way sometimes. Even here the durability can be a problem since it is not always known where the material or product comes from.
To save material, money and the environment the thicknesses of the walls could be reduced. All the walls, both inner and outer, are 230 mm and could be reduced. In a Swedish private house the load-bearing walls are around 150 mm thick. This thickness could also be used in Tanzania. But since they mould their own concrete blocks without any additive the durability probably is not that strong and the thickness maybe needs to be 230 mm to be able to function as a structure.

To save energy and money the structure could be insulated. As a Swedish house can be insulated against the cold a Tanzanian house could be insulated against the heat. If the roof and the walls are insulated the inside climate would not be heated up that much and the energy cost for the air condition could be reduced.

If insulation is used in a building the most eco-friendly alternative is hemp or maybe sisal, if tests show that sisal would be possible to use. The hemp contains no additives and is therefore a very eco friendly alternative to mineral wool.
6 Discussion and Conclusions

During the process with this project some resemblances between Swedish and Tanzanian building have been seen. But the most evident are the differences. In this chapter the methods and the findings of this final project will be discussed. To tie up the sack the main points will be summarised and suggestions for how the work could be developed will be made.

6.1 Discussion of Method

To be able to execute this project a study with educational visits and interview was necessary. The educational visit gave a lot of own impressions and was very giving for this final project. The interviews were a little bit harder to execute because of the communication difficulties. A lot of the questions where misunderstood and therefore the answers could be completely wrong. Sometimes they did not know the answer but answered it anyway just to please. To be able to get the right answer the questions were developed and sent by e-mail to try to get a better answer. Instead of taking the conversation trough e-mail afterwards the employees at NHC could have been pushed harder during the interviews to get the right answer from the beginning.

The drawings that were collected were studied mostly after the arrival back to Sweden. There were a lot of questions about the drawings that also had to be taken trough e-mail. If the drawings had been studied carefully during the visit in Tanzania the questions could have been asked face to face with the constructor and architect and the e-mail conversation could be avoided.

To give a general introduction of Tanzania and Dar es Salaam different websites have been used to collect the information. Information in book form about Tanzania and Tanzanian building methods is hard to find and therefore different websites have been used. It is fairly hard to get information about a country like Tanzania, the most information to find is tourist guides. Therefore own observations have been considered. To be able to find out more information about the country, literature could have been searched for during the stay in Tanzania, maybe some more information could have been found.

Early in the working process it was realized that the purpose and research question needed to be reformulated. After it had been done the work has gone forward and considering the circumstances the work has gone well.

6.2 Discussion of Findings

The purpose of this project is to gain knowledge about a Tanzanian two-storey family house and to evaluate if Swedish knowledge in building technique can be implemented to a Tanzanian two-storey family house concerning the climate, building structure and eco friendly construction.
Discussion and Conclusions

The one thing that strikes the most is all the differences and the kind of methods that are used when a family house is built. A lot of the solutions for the construction are made in the particular way because of tradition and economical limitations. Most of the solutions are there for a reason but the employees at NHC and the common man do not know the specific reason, according to the employees the structure and the design are that way just because of tradition.

6.2.1 How can the Structure and/or the Design of a Tanzanian Two-Storey Family House be Improved Concerning Building Structure?

The one thing that differs the most and can be improved in many ways is the foundation. If the concrete and the limestones are mixed the drainage function at the limestones disappear and they are superfluous. To prevent this, a mould should be placed around and under the slab.

The whole structure underground needs to be protected against moisture damages with a moisture barrier, not just the concrete strips as it is now.

The choice of making the walls out of concrete blocks is probably the best way to do in this area. It is the best material concerning the moisture and the risk of vermin’s. Since it resists moisture and vermin’s better than a wood construction the durability will also be better than a wood construction. The concrete is cheaper and easier to get hold of than wood, which make concrete a better material to use.

The dimensions of the trusses and rafters could be increased to get a lower number of pieces and be better organized so that the area underneath the roof could be used as for example a storage area. The trusses and rafters are attached to beam hangers that are directly attached in the concrete walls with big nails. A solution with plugs and screws that are properly attached would be a better solution. To get a better indoor climate the coating material of the roof could be reconsidered. The Harvey tiles produce a lot of heat to the building. Instead of changing the coat material to better but a more expensive material a layer of insulation can be put on the inside of the Harvey tiles to reduce the heat inside the house.

A connection between the rooms and the roof area could be made to get a better circulation of the air, which would mean better and cooler air inside.

In this house the window grilles are attached in the window frame. That makes it easier for housebreakers to break in. If the grilles instead were moulded in the wall it would be almost impossible to break in.

The balconies and the board around the house can cause problems to the structure. It has no inclination out from the house and if it rains the water can be stored there and cause damages. An inclination of 1:50 would be a good way to solve the problem.
6.2.2 How can the Structure and/or the Design of a Tanzanian Two-Storey Family House be Improved Concerning the Indoor Climate?

The complete structure under ground should always be protected with a damp proof membrane. A complete drainage system around and under the house should also be arranged to protect the foundation from moisture damages.

The heat is a more difficult problem to solve. Of course air conditioners are going to be installed but the construction and the design could also be changed to create a better indoor climate. To try to reduce the heat inside the house the roof and walls could be insulated. This is not used in Tanzania today and has probably never been used before and therefore it can be hard to implement this in the Tanzanian building structure. The easiest way to implement this is probably by informing architects and building engineers so that they understand that costs, energy consumption and environment have benefits from this. The architects and engineers can then convince the buyers of the houses that this solution will save money even if the cost of the house will be higher.

The alternative to conventional insulation could maybe be hemp or sisal. It is possible that this alternative would be easier to implement in the Tanzanian construction tradition because hemp and sisal are natural materials compared with the mineral wool that is inorganic.

As the calculations show it really makes a difference to insulate and therefore this should be analysed more and tested in Tanzania. Many of the buildings that are built are never intended for air condition. If air condition will not be used in the building, insulation should not be used because the building will not only become cooler during the day but also warmer in the night.

6.2.3 How can the Structure and/or the Design of a Tanzanian Two-Storey Family House be Improved Concerning Eco Friendly Construction?

The material for the concrete blocks is collected locally and no additives are used. That means that the transportation is minimized and that there are no chemicals that can damage the environment. Of course it is a good thing that no additives are used but that can also lower the durability. If some additives are added the durability can be increased and the building will last longer.

The fact that all of the material is bought in the beginning of project can be a problem. If the material is damaged they need to buy new material and money is wasted. If it is ignored that the material is damaged and used anyway the durability is lowered and the building won’t last as long. If the material is bought gradually the risk of damages can be minimized and the cost will probably not be that much higher.
If the buildings that use a lot of energy, like office buildings and big houses that use air conditioning, would be insulated a lot of energy would be saved. Tanzania is a country that has big problems with energy supply because the energy is not sufficient and power failure occurs often, furthermore the electricity is quite expensive. If less energy can be used by insulating the building money can be saved, the environment becomes less affective and power failure would occur less frequently.

6.3 Conclusions and Recommendations

To sum up this report it is obvious that there are a lot of things that can be improved at the Tanzanian house from a Swedish perspective. If the suggested changes are made there is a lot of money, energy and environment to be saved.

To develop this final project there are a few points that can be further continued. No extensive calculations have been made but further calculations can be made on the load-bearing parts of the structure and the cost of the project. The calculations of the insulation and the moisture are very brief and can be developed and deepened.
7 References

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7.3 Figures


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8 Search Terms

B
building structure, 5, 10, 11, 28, 48, 50

C
climate, 1, 5, 9, 10, 11, 13, 14, 18, 28, 33, 36, 37, 38, 39, 41, 42, 44, 45, 48, 49, 50, 53

D
damp, 5, 37
Dar es Salaam, 1, 2, 3, 5, 9, 10, 14, 16, 19, 20, 21, 22, 23, 24, 25, 36, 41, 48, 52, 54

E
eco friendly construction, 5, 9, 10, 11, 44, 48

J
Jonkoping, 2, 5

M
Mbweni, 1, 5, 9, 24, 25

N
National Housing Corporation, 1, 3, 5, 9, 21, 23, 25, 27
NHC, 1, 5, 9, 23, 25, 27, 41, 48, 49

T
Tanzania, 1, 3, 5, 9, 10, 11, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 25, 27, 31, 32, 33, 34, 39, 40, 44, 45, 48, 50, 51, 52, 53, 54
two-storey family house, 5, 9, 10, 28, 36, 42, 48
## Appendices

<table>
<thead>
<tr>
<th>Appendix</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appendix 1</td>
<td>Interview with Albert Guruyedi</td>
</tr>
<tr>
<td>Appendix 2</td>
<td>Interview with Eng. Morgan Nyonyi</td>
</tr>
<tr>
<td>Appendix 3</td>
<td>Interview with Albert Guruyedi</td>
</tr>
<tr>
<td>Appendix 4</td>
<td>Drawing of Ground Floor</td>
</tr>
<tr>
<td>Appendix 5</td>
<td>Drawing of First Floor</td>
</tr>
<tr>
<td>Appendix 6</td>
<td>Drawing of Section</td>
</tr>
<tr>
<td>Appendix 7</td>
<td>Drawings of Right Hand Side and Rear Elevation</td>
</tr>
<tr>
<td>Appendix 8</td>
<td>Drawings of Front and Left Hand Side Elevation</td>
</tr>
<tr>
<td>Appendix 9</td>
<td>Drawing of Typical Wall/Roof Section Detail</td>
</tr>
<tr>
<td>Appendix 10</td>
<td>Drawings of Typical Internal Wall Detail and Typical External Step Detail</td>
</tr>
<tr>
<td>Appendix 11</td>
<td>Drawing of Improvements from a Swedish Perspective</td>
</tr>
<tr>
<td>Appendix 12</td>
<td>Term explanation</td>
</tr>
<tr>
<td>Appendix 13</td>
<td>U-value, Roof – Stainless Steel</td>
</tr>
<tr>
<td>Appendix 14</td>
<td>U-value, Roof – 50 mm Insulation</td>
</tr>
<tr>
<td>Appendix 15</td>
<td>U-value, Roof – 100 mm Insulation</td>
</tr>
<tr>
<td>Appendix 16</td>
<td>U-value, Roof – 150 mm Insulation</td>
</tr>
<tr>
<td>Appendix 17</td>
<td>U-value, Roof – 200 mm Insulation</td>
</tr>
<tr>
<td>Appendix 18</td>
<td>U-value, Wall – Concrete</td>
</tr>
<tr>
<td>Appendix 19</td>
<td>U-value, Wall – 50 mm Insulation</td>
</tr>
<tr>
<td>Appendix 20</td>
<td>U-value, Wall – 100 mm Insulation</td>
</tr>
<tr>
<td>Appendix 21</td>
<td>U-value, Wall – 150 mm Insulation</td>
</tr>
<tr>
<td>Appendix 22</td>
<td>U-value, Wall – 200 mm Insulation</td>
</tr>
<tr>
<td>Appendix 23</td>
<td>Calculation of U-value x Area</td>
</tr>
<tr>
<td>Appendix 24</td>
<td>Total Energy Needs and Costs</td>
</tr>
<tr>
<td>Appendix 25</td>
<td>Assessments of Risk of Condensation and Moisture Damages in Building Structure, Without Dehumidifiers</td>
</tr>
<tr>
<td>Appendix 26</td>
<td>Assessments of Risk of Condensation and Moisture Damages in Building Structure, With Dehumidifiers</td>
</tr>
</tbody>
</table>
Appendix 1 – Interview with Albert Guruyedi

Interview performed on the 25th of January 2011, Mbweni district Dar es Salaam, Tanzania.
Attending persons: Liza Andersson (S), Malin Krantz (S), Tina Svensson (S), Emma Valtersson (S), Albert Guruyedi (A) and Dr Ladislaus Lwambuka.

Liza and Malin are two other students that also are doing their final project in Tanzania but they are not involved in this project. Albert Guruyedi is the site manager of building project "Mbweni National Housing". Dr Ladislaus Lwambuka is our supervisor from the University of Dar es Salaam and he did not participate actively in the interview.

(S) - Can you tell us about this building project?
(A) - The project started in 2005 with the first phase that contains 15 houses. The second phase that contains 34 houses started in 2008 and is expected to be finished in May 2011. There are two kinds of houses that are being built, bungalows and two-storey houses. The bungalows are sold for approximately 90 000 USD and the two-storey houses are sold for approximately 180 000 USD.

(S) - How are the projects financed and by whom?
(A) - By the National Housing Cooperation. NHC make investments by building these houses. By selling the houses for a larger amount of money that it cost to build them NHC make a profit.

(S) - What is the budget for this project?
(A) - The estimated budget for the second phase, 34 houses, is 3.5 million USD.

(S) - How do you keep the budget?
(A) - To build as fast as possible we can keep down the costs. And we buy all the materials in the beginning when the price is known. We can’t afford to risk that the prices will rise.

(S) - Is there any overall plan for Dar es Salaam?
(A) - There is a master plan that you can get from the Ministry of land or the city council. But the plan only controls the planning of streets and public buildings. The Ministry of land have decided where the streets should go in this area but don’t decide anything about the houses.
Are there any existing national rules and regulations in Tanzania?

The ministry of land controls the usage of land in Tanzania. The land is owned by the government as well as the National Housing Cooperation. The company makes a request to the registration board at the Ministry of land to receive/buy a particular piece of land. But before they can start building they must get a building permission from the Ministry or city council. The permission does not cost anything but it takes time.

Are there any regards taken to disturbing noise and accessibility?

No

Are there any demands for fire evacuation?

Only for multiple story buildings.

Are there any regulations concerning the working environment? Security?

The workers need to wear helmets, boots, gloves, scaffolds

How long does an average planning process take?

2-3 months (for this project)

Who are involved in the actual planning process?

The planning takes place at the head office by architects, constructors, consults for electricity and sanitary, counter surveyors.

Where does the focus lie in the planning process? What is prior?

We try to minimize the costs and design the houses so that the building time gets as short as possible. We make sure that the material is on site at the right time. The major problems that we face are the electrical black downs that are quite common. Sometimes a whole day can go to waste when these incidents occur.

Which types of accommodations are prioritized?

The priority lies in building simple villas and two story buildings, which are the most profitable for the company.

Who are the target groups?

The middleclass families and they who can afford to pay. No mortgages are given from the bank but the buyers can get instalments from the National Housing Cooperation, which they can pay off within 2-3 years.

Which types of documents and drawings are produced?

Architectural drawings, constructional drawings, electrical drawings, landscape drawings and drawings for ventilation, water and sewage.
(S) - Is there any supervising authority concerning buildings in Tanzania?
(A) - The Ministry of land. Inspectors from the Ministry of land make unannounced visits to the building sites to control the production.

(S) - Can you tell us a little bit about the houses?
(A) - There are two types of houses, bungalows and two-storey houses. The bungalows are almost 200 m² and the two-story houses are around 250 m². Every bedroom has its own bathroom. The ceiling height is 2.8 - 3 m which gives a nice spaciousness. The structure is made of concrete and the roof structure is made of wood. The roofs finish material is made of Harvey tiles and has steep slopes to make it easier for the rain to run off. The ventilation goes through grids in the roof and creates natural ventilation. The windows are sliding windows with aluminium frame. Outside the windows there are permanent grids. We prepare spaces in the outer walls so the buyers can buy and install their own air condition. All of the houses are supplied with electricity and water. Every house has its own system for drainage and solid waste. The liquid waste is separated from the solid waste and the two types of waste are collected in two different wells. Lorries comes and pick up the wastes.

(S) - Where does the material used in the production come from? National or imported?
(A) - National: wood, concrete and limestone. Imported: floor tiles, reinforcements, finishing material and aluminium.

(S) - Are there any prefabricated solutions used in the projects?
(A) - No.

(S) - Do you recycle the material?
(A) - No

(S) - How are the buildings adjusted to the existing climate, both regarding building technique and installations?
(A) - Harvey tiles are used instead of sheet metal to reduce the heat within the buildings. Trees are being planted for shadowing. We also use prolonged roofs to protect the house from the rainfall.

(S) - Which types of adjustments are made to create a sustainable society?
(A) - They plant trees.

(S) - Do you take notice to green areas in the planning?
(A) - They plant trees but they usually die due to the drought

(S) - What types of energy sources are used for heating, cooling, electricity and water supply?
(A) - Hydro energy (however not very reliable due to the droughts).

(S) - How does the building site look during the construction?
(A) - There is a guard that is watching the building site 24 hours a day since all equipment and all the construction material is stored on the site. Instead of portable sheds we
build up temporary buildings where we have offices and storage space.

(S) - How is the planning carried out in relation to service and communication?
(A) - The communications and services come to the building area instead of the opposite.

(S) - Have the projects fulfilled their purposes?
(A) - We try to keep the budget.

(S) - What is the purpose of this project and has it been fulfilled?
(A) - The purpose is to keep the budget and make a profit. We try our best to do this.
Appendix 2 – Interview with Eng. Morgan Nyonyi

Interview performed by e-mail on the 4th of April 2011.
Attending persons: Tina Svensson (S), Emma Valtersson (S), and eng. Morgan Nyonyi (M).

Morgan Nyonyi is an engineer at the National Housing Corporation that is the company that is building the houses in Mbweni district Dar es Salaam, Tanzania.

(S) - On the drawing with the details it says ”Note: All timberworks to be treated against pests and vermin”. What kind of chemical is used?
(M) - Frequently used chemical is Cristosome, whereby pieces of timber are deepened in a drum containing chemical and rotated in a certain pressure so as to impregnate chemicals deep inside timber cell.

(S) - It also says ”Note: Site to be treated before pouring the ground floor slab”. What is it treated and how?
(M) - The site is treated against termites by pouring anti-termite around the foundation walls and on hardcore.

(S) - What is the timber hanger attached to and with what?
(M) - Timber hanger is used to store timber in a way that they cannot be affected by change of weather.

(S) - What does ”Selected earthfill in 150mm layers” mean? Are the rooms underground totally filled with earth or just 150mm?
(M) - ”Selected Earth fill” means, imported earth materials(soil) from a borrow pit used to backfill the foundation to a thickness of 150mm after compaction prior to laying hardcore.

(S) - What happens when it rains and the walls and the foundation gets wet? Do they take damage or do they have time to dry before any damages appear?
(M) - During construction stage when there is normal rain, it is not possible the foundation to be damaged, if it is severe rain we cover the part in question by a Dump Proof Membrane like Nylon etc.

(S) - Why is the minimum depth 1200mm on the plinth wall?
(M) - The minimum depth is determined by the design, not always 120mm it depends with the height of the building.
(S) - On the drawing with the plans we see two shafts, one by each toilet area. Is shafts? And why are they there? As we can see there are no exterior walls around them, why?
(M) - The shaft you saw in the drawings are service ducts, either for plumbing and sewerage system or for electrical cables, the ducts has no exterior wall because they are going to be covered by timber doors like in cupboard/wardrobes.

(S) - The smaller bedrooms on the second floor each have a toilet. One has just a shower and a water closet and the other has just a water closet and a hand basin. Where is the first person supposed to wash his hands and the second one supposed to take his shower?
- Why is it a window between the toilets on the second floor? Are you supposed to look at each other when you are at the toilet?
- In the smaller bedrooms on the second floor there is a short wall (410mm), what are they for?
(M) - I’m not sure with the design, but I think the architect kept on consideration.

(S) - The roof on the Mbweni houses has holes for ventilation. Is this only for the air inside the roof or can the air from the rooms below circulate up and out through the ventilation as well?
(M) - The ventilation on the roof is there to help the roof to inhale i.e. for circulation of air in the ceiling.

(S) - On the detail drawing it says that the foundation consist of “compacted hardcore”, what is the name of the stone?
(M) - The compacted hardcore normally use hard limestone’s or granite stones.

(S) - When we visited the site they told us about the septic tanks. There are two tanks, one for solid waste (septic tank) and the other one for liquid waste, what is the second one called? And how many houses are connected on the same tanks?
(M) - The second tank is called “Soak away pit “, each house has both the septic and the soak away pit connected.

(S) - Where are the Harvey Tiles made? Are they made in Tanzania or imported?
(M) - Harvey tiles are from South Africa and New Zeeland.
Appendix 3 – Interview with Albert Guruyedi

Interview performed by e-mail on the 20th of April 2011.
Attending persons: Tina Svensson (S), Emma Valtersson (S), and eng. Albert Guruyedi (A).

Eng. Albert Guruyedi is the site manager at the Mbweni National Housing that is the building site that was visited during the field study.

(S) - Why are blocks used in the walls on the ground floor and reinforced concrete on the second floor? Why isn't the same material used on both floors?
(A) - Blocks are always used in the construction of walls of the same materials both ground and first floor and not differently.

(S) - What is the timber hanger attached to and with what?
(A) - The timber hanger are attached to trusses with nails.

(S) - What does "Selected earthfill in 150mm layers” mean? Are the rooms underground totally filled with earth or just 150mm?
(A) - Selected earth fill in 150 mm mean is the fill in order to fill the vacuum part of the under ground to raise the level of the building, and is filled in layers of 150 mm thick each. And are filled totally.

(S) - What happens when it rains and the walls and the foundation gets wet? Do they take damage or do they have time to dry before any damages appear?
(A) - When it rains and the foundation get wet there is no damage since there is an eave or hanger on top of the roof and sometimes it dries up before damage appear. The eave over hang is about 60mm to 80 mm.

(S) - Why is the minimum depth 1200mm on the plinth wall?
(A) - The minimum depth of 1200 mm on the plinth wall comes from the structural Engineer and depends on the result of design also type of the soil at the site concerned.

(S) - The roof on the houses has holes for ventilation. Is this only for the air inside the roof or can the air from the rooms below circulate up and out through the ventilation as well?
(A) - The roof on the house has the holes for ventilation inside the roof and not below the roof.

(S) - If it rains very much can the water go up through the outlet that goes through the walls?
(A) - If it rains very much the water cannot go up through the walls because it is treated by water proof materials like asphalt with bituminous material.

(S) - The detail drawings that we have got show doors and windows, but how are they attached to the wall?
(A) - Doors and windows are attached to the walls by fixing after plastering and rendering is complete are fixed by bolts and nails with cement also.

(S) - How is the concrete floor slab on the ground floor made? Does it have a mould around and under? And how do you in that case remove the one under after? If it doesn’t have a mould how does it react with the compacted hardcore underneath? Does it mix?
(A) - The concrete in the ground floor are made by casting after laying hard core to raise the level and make a mould by using timber or any other materials like steel form work.

(S) - When we look at our notes the numbers don’t match so we wonder how much you sell one house for? And what the total budget for the whole project is?
(A) - The whole project consist of 49 houses and we arranged this in two phases one with 15 houses and the second with 34 houses. The price per house depends on the area covered by the respected house. Ranging from Tshs 117million for bungalows and Tshs 263 million for two storey building. The total budget for the whole project is estimated as Tshs 3.5 billions.

(S) - How far up goes the concrete blocks on the ground floor? To the bottom of the window, the top of the window or somewhere in between? Is it the same construction on the first floor?
(A) - The concrete block goes up to the height of 2.7 m, to the bottom of the window is 90mm. And is the same to the first floor.
NOTE:
ALL TIMBERWORKS TO BE TREATED AGAINST PESTS AND VERMINE

roof pitch 31°

interlocking 'Decra' roofing tile laid to Manufacturer's instructions on 50X50mm timber battens on

150X50mm trusses/rafters bolted to reinforced concrete beam refer to Structural Engineers drawing No. S07

50X50mm timber hangers 12mm gypsum ceiling

+5.700 50X50mm timber hangers
door to shedule

+5.900 50X50mm timber hangers 12mm gypsum ceiling

50X50mm timber hangers

reinforced concrete lintel to Structural Engineers details

window to schedule

precast concrete window cill to Architects approval

230mm block walling plastered both ways and finished to schedule

100x200mm timber skirting to architects approval

floor finish on 40mm cement screed on 100mm thick concrete floor slab 1:2:4.

150mm thick well compacted hardcore

Selected earthfill in 150mm layers.

230mm thick plinth wall

1:3:6 mass concrete strip FOUNDATION

TYPICAL WALL/ROOF SECTION DETAIL
ORIGINAL DRAWING
SCALE 1:30 (FOR A4)
Appendix 10

Note: All dimensions are structural.

Typical Internal Wall Detail

Note: Site to be treated to be treated before pouring the ground floor slab.

Typical External Step Detail

Original Drawing

Scale 1:30 (for A4)
17 mm board
trusses/rafters with 50-200 mm insulation
13 mm board

roof pitch 31°

+5,900
+5,700
+2,800
1:50

balcony

13 mm board
50-200 mm insulation

+0,000
+0,600
1:20

Damp proof membrane, that covers the underground foundation

230
700

TYPICAL WALL/ROOF SECTION DETAIL

IMPROVEMENTS FROM A SWEDISH PERSPECTIVE
SCALE 1:30 (FOR A4)
Appendix 12 – Term explanation

$E_{\text{trans}}$ – Energy consumption, transmission
$E_{\text{ll}}$ – Energy consumption, air leakage
$E_{\text{vent}}$ – Energy consumption, ventilation
$E_{\text{rv}}$ – Energy consumption, hot water
$E_{\text{free}}$ – free energy
$G_{\text{gradim}}$ – Degree hours
$T_i$ – Inside temperature $= 22 \, ^\circ\text{C}$
$T_o$ – Outside temperature $= 26 \, ^\circ\text{C}$ (http://www.climatetemp.info/tanzania/dar-es-salaam.html)

$R_{\text{si}}$ – Internal surface resistance
$R_{\text{se}}$ – External surface resistance
$U$-value – Thermal transmittance

1 kWh is estimated to cost 0.25 USD according to local inhabitants

All the formulas and values are taken from the formulary ”Energi 2010-11-15” from the department of building technique at Jonkoping’s school of Engineering.
## Calculation of $U_{corr}$-value

### Roof Harvey tiles

#### Homogeneous structures

<table>
<thead>
<tr>
<th>Layer</th>
<th>Material</th>
<th>$d$</th>
<th>$\lambda_{deki}$</th>
<th>$\Delta\lambda_w$</th>
<th>$\lambda_{ber}$</th>
<th>$R = d/\lambda_{ber}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 1</td>
<td>Rsi</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.10</td>
</tr>
<tr>
<td>1 - 2</td>
<td>Stainless steel</td>
<td>0.003</td>
<td>20,000</td>
<td>0.00015</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 - 4</td>
<td>Rse</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.04</td>
</tr>
</tbody>
</table>

$$R_T = \frac{\Delta R_w}{R_T} = 0.140$$

$$U_{ber} = \frac{1}{R_T} = 7.143$$

$$\Sigma\Delta U = U_{korr} = \frac{W/m^2\cdot°C}{7.143}$$
## APPENDIX 14

Calculation of $U_{corr}$-value  
Roof 50 mm insulation

Homogeneous structures

<table>
<thead>
<tr>
<th>Layer</th>
<th>Material</th>
<th>$d$</th>
<th>$\lambda_{dikl}$</th>
<th>$\Delta \lambda_w$</th>
<th>$\lambda_{ber}$</th>
<th>$R = d / \lambda_{ber}$</th>
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<td>0.10</td>
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<td>1 - 2</td>
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<td>0.036</td>
<td>1.389</td>
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<tr>
<td>2 - 3</td>
<td>Stainless steel</td>
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<td></td>
<td>0.00015</td>
<td></td>
</tr>
<tr>
<td>3 - 4</td>
<td>Rse</td>
<td></td>
<td>0.04</td>
<td></td>
<td>0.04</td>
<td></td>
</tr>
</tbody>
</table>

$$R_T = 1.529$$

$$\Delta R_w =$$

$$R_T = 1.529$$

$$U_{ber} = \frac{1}{R_T}$$

$$\Sigma \Delta U = 0.654$$

$$U_{corr} = \frac{1}{W/m^2 \cdot °C} 0.654$$
## APPENDIX 15

### Calculation of $U_{corr}$-value

#### Roof 100 mm insulation

**Homogeneous structures**

<table>
<thead>
<tr>
<th>Layer</th>
<th>Material</th>
<th>$d$</th>
<th>$\lambda_{dekil}$</th>
<th>$\Delta\lambda_w$</th>
<th>$\lambda_{ber}$</th>
<th>$R = d/\lambda_{ber}$</th>
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<td>Rsi</td>
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<td></td>
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<td>Insulation</td>
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<td>0.036</td>
<td>20,000</td>
<td>0.00015</td>
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<td>2 - 3</td>
<td>Stainless steel</td>
<td>0.003</td>
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</tr>
<tr>
<td>3 - 4</td>
<td>Rse</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.04</td>
</tr>
</tbody>
</table>

\[
R_T = 2.918
\]

\[
\Delta R_w = 
\]

\[
R_T = 2.918
\]

\[
U_{ber} = \frac{1}{R_T}
\]

\[
\sum \Delta U = 0.343
\]

\[
U_{corr} = 
\]

\[
W/m^2 \cdot ^\circ C \quad 0.343
\]
Calculation of $U_{corr}$-value  
Roof 150 mm insulation

Homogeneous structures

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<th>Layer</th>
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<th>$d$</th>
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<th>$\Delta\lambda_w$</th>
<th>$\lambda_{ber}$</th>
<th>$R = d/\lambda_{ber}$</th>
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</thead>
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<tr>
<td>0 - 1</td>
<td>Rsi</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.10</td>
</tr>
<tr>
<td>1 - 2</td>
<td>Insulation</td>
<td>0.15</td>
<td>0.036</td>
<td>4.167</td>
<td></td>
<td>4.167</td>
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<tr>
<td>2 - 3</td>
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<td>20,000</td>
<td>0.00015</td>
<td></td>
<td>0.04</td>
</tr>
</tbody>
</table>

\[
\begin{align*}
R_T &= 4.307 \\
\Delta R_w &= \\
R_T &= 4.307 \\
U_{ber} &= 1/R_T \\
\Sigma\Delta U &= 0.232 \\
U_{korr} &= \frac{1}{R_T} \\
&= \frac{1}{W/m^2\cdot{C}} \\
&= 0.232 \\
\end{align*}
\]
Calculation of $U_{\text{corr}}$-value

**Roof 200 mm insulation**

Homogeneous structures

<table>
<thead>
<tr>
<th>Layer</th>
<th>Material</th>
<th>d</th>
<th>$\lambda_{\text{dek}}$</th>
<th>$\Delta \lambda_w$</th>
<th>$\lambda_{\text{ber}}$</th>
<th>$R = \frac{d}{\lambda_{\text{ber}}}$</th>
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<tr>
<td>0 - 1</td>
<td>Rsi</td>
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<td></td>
<td></td>
<td></td>
<td>0.10</td>
</tr>
<tr>
<td>1 - 2</td>
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<td>0.036</td>
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<td>5.556</td>
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<td>2 - 3</td>
<td>Stainless steel</td>
<td>0.003</td>
<td></td>
<td>20,000</td>
<td></td>
<td>0.00015</td>
</tr>
<tr>
<td>3 - 4</td>
<td>Rse</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.04</td>
</tr>
</tbody>
</table>

\[
R_T = 5.696
\]

\[
\Delta R_w =
\]

\[
R_T = 5.696
\]

\[
U_{\text{ber}} = \frac{1}{R_T}
\]

\[
\Sigma \Delta U = 0.176
\]

\[
U_{\text{corr}} = \frac{W}{m^2 \cdot ^\circ C}
\]

\[
0.176
\]
## APPENDIX 18

### Calculation of $U_{corr}$-value Wall Concrete

**Homogeneous structures**

<table>
<thead>
<tr>
<th>Layer</th>
<th>Material</th>
<th>$d$</th>
<th>$\lambda_{dekl}$</th>
<th>$\Delta\lambda_w$</th>
<th>$\lambda_{ber}$</th>
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<td>0 - 1</td>
<td>Rsi</td>
<td></td>
<td>0.13</td>
<td></td>
<td>0.13</td>
<td>0.13</td>
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<tr>
<td>1 - 2</td>
<td>Concrete</td>
<td>0.23</td>
<td>1.7</td>
<td></td>
<td>0.135</td>
<td>0.135</td>
</tr>
<tr>
<td>2 - 3</td>
<td>Rse</td>
<td></td>
<td>0.04</td>
<td></td>
<td>0.04</td>
<td>0.04</td>
</tr>
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</table>

**Formulas**

- $R_T = 0.305$
- $\Delta R_W =$
- $R_T = 0.305$
- $U_{ber} = 1 / R_T$
- $\Sigma \Delta U = 3.279$
- $U_{corr} = W/m^2\cdot ^\circ C$
- $U_{corr} = 3.279$
APPENDIX 19

Calculation of $U_{corr}$-value  
Wall 50 mm insulation

Homogeneous structures

<table>
<thead>
<tr>
<th>Layer</th>
<th>Material</th>
<th>d</th>
<th>$\lambda_{deki}$</th>
<th>$\Delta \lambda_w$</th>
<th>$\lambda_{ber}$</th>
<th>$R = d/\lambda_{ber}$</th>
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</thead>
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<tr>
<td>0 - 1</td>
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<td>0.13</td>
<td>0.13</td>
</tr>
<tr>
<td>1 - 2</td>
<td>Insulation</td>
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<td>0.033</td>
<td>1.515</td>
<td></td>
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<tr>
<td>2 - 3</td>
<td>Concrete</td>
<td>0.23</td>
<td></td>
<td>1.7</td>
<td>0.135</td>
<td></td>
</tr>
<tr>
<td>3 - 4</td>
<td>Rse</td>
<td></td>
<td></td>
<td></td>
<td>0.04</td>
<td>0.04</td>
</tr>
</tbody>
</table>

\[
R_T = \frac{1}{1.820}
\]
\[
\Delta R_w = 
\]
\[
R_T = \frac{1}{1.820}
\]
\[
U_{ber} = \frac{1}{R_T}
\]
\[
\Sigma \Delta U = 0.549
\]
\[
U_{corr} = \frac{W/m^2\cdot ^\circ C}{0.549}
\]
## Calculation of $U_{\text{corr}}$-value

### Wall 100 mm insulation

#### Homogeneous structures

<table>
<thead>
<tr>
<th>Layer</th>
<th>Material</th>
<th>$d$ (m)</th>
<th>$\lambda_{\text{deki}}$ (W/m°C)</th>
<th>$\Delta \lambda_w$ (W/m°C)</th>
<th>$\lambda_{\text{ber}}$ (W/m°C)</th>
<th>$R = d/\lambda_{\text{ber}}$ (m²°C/W)</th>
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<td>0 - 1</td>
<td>Rsi</td>
<td></td>
<td>0.13</td>
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<td>0.13</td>
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<tr>
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<td>3.030</td>
<td>3.030</td>
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<td>0.135</td>
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<td>Rse</td>
<td></td>
<td>0.04</td>
<td></td>
<td>0.04</td>
<td>0.04</td>
</tr>
</tbody>
</table>

$$R_T = \frac{3.335}{R_{\text{ber}}}$$

$$\Delta R_w =$$

$$R_T = \frac{3.335}{R_{\text{ber}}}$$

$$U_{\text{ber}} = \frac{1}{R_T}$$

$$0.300$$

$$\Sigma \Delta U =$$

$$U_{\text{corr}} = \frac{0.300}{W/m^2\cdot°C}$$

$$0.300$$
Calculation of $U_{corr}$-value

Wall 150 mm insulation

<table>
<thead>
<tr>
<th>Layer</th>
<th>Material</th>
<th>$d$</th>
<th>$\lambda_{dewi}$</th>
<th>$\Delta\lambda_w$</th>
<th>$\lambda_{ber}$</th>
<th>$R = d/\lambda_{ber}$</th>
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</thead>
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<td>0.13</td>
<td>0.13</td>
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<td>1 - 2</td>
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<td>0.033</td>
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<td>0.135</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 - 4</td>
<td>Rse</td>
<td></td>
<td></td>
<td></td>
<td>0.04</td>
<td>0.04</td>
</tr>
</tbody>
</table>

$$R_T = 4.850$$

$$\Delta R_w =$$

$$R_T = 4.850$$

$$U_{ber} = 1/R_T$$

$$0.206$$

$$\Sigma \Delta U =$$

$$U_{corr} =$$

$$W/m^2 \cdot ^\circ C$$

$$0.206$$
APPENDIX 22

Calculation of $U_{corr}$-value  
Wall 200 mm insulation
Homogeneous structures

<table>
<thead>
<tr>
<th>Layer</th>
<th>Material</th>
<th>$d$</th>
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<th>$\Delta\lambda_w$</th>
<th>$\lambda_{ber}$</th>
<th>$R = d/\lambda_{ber}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>m</td>
<td>W/m$^\circ$C</td>
<td>W/m$^\circ$C</td>
<td>W/m$^\circ$C</td>
<td>m$^2$$^\circ$C/W</td>
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<td>0.13</td>
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<tr>
<td>3 - 4</td>
<td>Rse</td>
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<td>0.04</td>
<td></td>
<td>0.04</td>
<td></td>
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</tbody>
</table>

$$R_T = 6.366$$

$$\Delta R_w =$$

$$R_T = 6.366$$

$$U_{ber} = 1/R_T = 0.157$$

$$\Sigma \Delta U =$$

$$U_{korr} = W/m^2$$^\circ$C $= 0.157$$
### APPENDIX 23

<table>
<thead>
<tr>
<th></th>
<th>Roof</th>
<th>Wall</th>
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<tbody>
<tr>
<td></td>
<td>U-value (W/m².°C)</td>
<td>Area (m²)</td>
</tr>
<tr>
<td>1 Original structure</td>
<td>7,143</td>
<td>198</td>
</tr>
<tr>
<td>2 50 mm Insulation</td>
<td>0,654</td>
<td>198</td>
</tr>
<tr>
<td>3 100 mm Insulation</td>
<td>0,343</td>
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</tr>
<tr>
<td>4 150 mm Insulation</td>
<td>0,232</td>
<td>198</td>
</tr>
<tr>
<td>5 200 mm Insulation</td>
<td>0,176</td>
<td>198</td>
</tr>
</tbody>
</table>

All the U-values are taken from previous appendices (Appendix 13-22)
APPENDIX 24

Total Energy consumption: $E_{TOT} = E_{TRANS} + E_{ll} + E_{vent} + E_{free}$

$E_{ll}$ has been excluded since the water isn’t heated by bought energy. The water tanks are placed outside and the water is heated by the sun. $E_{free}$ has been excluded to make the calculation easier.

$E_{TRANS} = (\sum U \cdot A + \sum \Psi \cdot I + X) \cdot G_{gradtim}$

$\sum \Psi \cdot I$ and $X$ can be assumed to zero to make an easier calculation.

$G_{gradtim} = (T_i - T_u, \ annual\ average) \cdot 24 \cdot 365 = (22-26) \cdot 24 \cdot 365 = -35040$

$E_{TRANS} = (\sum U \cdot A) \cdot G_{gradtim}$

$E_{TRANS1} = -87129 \ kWh/\text{year}$
$E_{TRANS2} = -10828 \ kWh/\text{year}$
$E_{TRANS3} = -5817 \ kWh/\text{year}$
$E_{TRANS4} = -3970 \ kWh/\text{year}$
$E_{TRANS5} = -3020 \ kWh/\text{year}$

$E_{ll} = 0.33 \cdot n_{ll} \cdot V \cdot G_{gradtim1}$

$n = 0.5 \ air\ circulation/h$
$n_{ll} = 0.5 \ air\ circulation/h$
$V = 766,776 \ m^3$

$E_{ll} = -887 \ kWh/\text{year}$

$E_{vent} = 0.33 \cdot n \cdot V \cdot G_{gradtim1}$

$E_{vent} = -4433 \ kWh/\text{year}$

$E_{TOT1} = -92449 \ kWh/\text{year}$
$E_{TOT2} = -16148 \ kWh/\text{year}$
$E_{TOT3} = -11137 \ kWh/\text{year}$
$E_{TOT4} = -9290 \ kWh/\text{year}$
$E_{TOT5} = -8340 \ kWh/\text{year}$

Total cost/year:
1 kWh is estimated to cost 0.25 USD according to local inhabitants.

1 23112 USD/year
2 4037 USD/year
3 2784 USD/year
4 2323 USD/year
5 2085 USD/year
## APPENDIX 25

Assessments of risk of condensation and moisture damages in building structure
Without dehumidifiers

<table>
<thead>
<tr>
<th>Layer</th>
<th>Material</th>
<th>d</th>
<th>$\lambda_{ber}$</th>
<th>$R = \frac{d}{\lambda_{ber}}$</th>
<th>$\Delta T$</th>
<th>Boundary layer</th>
<th>Temp T</th>
<th>$\nu_s$</th>
<th>$\delta$</th>
<th>$Z = \frac{d}{\delta}$</th>
<th>$\Delta \nu$</th>
<th>$\nu$</th>
<th>RF %</th>
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<tbody>
<tr>
<td>Unit</td>
<td>m</td>
<td>W/m°C</td>
<td>m$^2$ C/W</td>
<td>°C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>0 - 1</td>
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<td>0.130</td>
<td>0.286</td>
<td>0 22.0 19.41</td>
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<td>140%</td>
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<td>Insulation</td>
<td>0.05</td>
<td>0.033</td>
<td>1 22.3 19.74</td>
<td>1 25.6 23.80</td>
<td>25·10$^{-6}$ 2000 0.034</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>27.22</td>
<td>114%</td>
</tr>
<tr>
<td>2 - 3</td>
<td>Concrete</td>
<td>0.23</td>
<td>1.7</td>
<td>2 25.9 24.21</td>
<td>3 26.0 24.47</td>
<td>1·10$^{-6}$ 230 000 3.966</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>23.25</td>
<td>96%</td>
</tr>
<tr>
<td>3 - 4</td>
<td>Rse</td>
<td>0.040</td>
<td>0.088</td>
<td>4 26.0 24.47</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>23.25</td>
<td>95%</td>
</tr>
<tr>
<td></td>
<td>$R_T = 1.820$</td>
<td></td>
<td></td>
<td>$Z_{TOT} = 232 000$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[
\Delta T = (\Delta T_{TOT} / R_{TOT}) \cdot R
\]

\[
\Delta \nu = (\Delta \nu_{TOT} / Z_{TOT}) \cdot Z
\]

RF (Relative humidity) is assumed to be 95% outside

$\Delta \nu_{TOT}$ (addition of moisture) assumed to be 4 g/m$^3$
## APPENDIX 26
Assessments of risk of condensation and moisture damages in building structure
With dehumidifiers

<table>
<thead>
<tr>
<th>Layer</th>
<th>Material</th>
<th>d</th>
<th>$\lambda_{ber}$</th>
<th>$R = d/\lambda_{ber}$</th>
<th>$\Delta T$</th>
<th>Boundary layer</th>
<th>Temp T</th>
<th>$v_s$</th>
<th>$\delta$</th>
<th>$Z = d/\delta$</th>
<th>$\Delta v$</th>
<th>$v$</th>
<th>RF %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unit</td>
<td>m</td>
<td>W/m°C</td>
<td>m°C/W</td>
<td>°C</td>
<td>°C</td>
<td>g/m²</td>
<td>m/s</td>
<td>s/m</td>
<td>g/m³</td>
<td>g/m³</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 - 1</td>
<td>Rsi</td>
<td>0.130</td>
<td>0.286</td>
<td></td>
<td>0</td>
<td>22.0</td>
<td>19.41</td>
<td>11.65</td>
<td>60%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 - 2</td>
<td>Insulation</td>
<td>0.05</td>
<td>0.033</td>
<td>1.515</td>
<td>25·10^{-6}</td>
<td>2 000</td>
<td>0.100</td>
<td>11.65</td>
<td>59%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 - 3</td>
<td>Concrete</td>
<td>0.23</td>
<td>1.7</td>
<td>0.135</td>
<td>1·10^{-6}</td>
<td>230 000</td>
<td>11.500</td>
<td>23.25</td>
<td>96%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 - 4</td>
<td>Rse</td>
<td>0.040</td>
<td>0.088</td>
<td></td>
<td>4</td>
<td>26.0</td>
<td>24.47</td>
<td>23.25</td>
<td>95%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[ \Delta T = \left( \Delta T_{TOT} / R_{TOT} \right) \cdot R \]
\[ \Delta v = \left( \Delta v_{TOT} / Z_{TOT} \right) \cdot Z \]

RF (Relative humidity) is assumed to be 95 % outside and 60 % inside because of dehumidifiers

$\Delta v_{TOT}$ (addition of moisture) assumed to be 4 g/m³