Master of science thesis and a Minor field study report within the program of Civil Engineering and Urban Management, 30 ETCS credits

Vertical extensions of the Urban Swahili house
A proposal for a standardised two-storey construction

Hanna Kruse & Lotta Torstensson
This study has been carried out within the framework of the Minor Field Studies Scholarship Programme, MFS, which is funded by the Swedish International Development Cooperation Agency, Sida.

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Sigrun Santesson
Programme Officer
MFS Programme
Abstract

A decent shelter is a basic human need. In developing countries, where the industrialisation process is accompanied by rapid urbanisation, the population solves their housing situation within limits of their own savings. Therefore the majority of people in Tanzania still live in temporary, sprawling single storey dwellings which generate densification of houses and exorbitant travel distances. Occasionally settlement citizens are forced to omit job opportunities due to far and expensive transport.

Not only in the informal settlements but in Dar es Salaam generally, houses with more than one storey are very rare. The horizontal development of the city may be a consequence of deficient economical resources, inappropriate regulatory framework and production techniques. Vertical extension of houses could be more economic in terms of infrastructure provision, increase spatial qualities and generate important outdoor spaces. Created space between buildings will in its turn optimises cross ventilation and results in a better indoor climate.

The Swahili house is the predominant type of house found in Dar es Salaam. Its shape and layout are known by heart. Through generations, the skills of construction, has passed from one to another by practical participation. The change from rural to urban society now compels change in practice and building design. For poor families, the process of constructing a house is a complicated, prolonged and expensive procedure. Due to high cost of building materials, builders are often forced to quality compromises. This study will introduce the technique using semi-prefabricated construction elements as an option in affordable two storey housing. The analysis indicates that the use of these components could increase execution quality and durability of constructions. Using block elements, the prefab technique could be introduced, in a small scale, to self builders and local artisans without the need of governmental support and large industries.

Presented in this thesis are drawings for a vertically extended Swahili house type which may help dwellers to build a durable and affordable two storey construction.

Keywords: Informal settlements, building techniques, vertical extension, semi-prefab, Dar es Salaam.
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Terminology

Abbreviations & Acronyms

ARU      Ardhi University, Dar es Salaam, (previously: UCLAS)
CBO      Community based organisation
CCM      Chama Cha Mapinduzi. Ruling party in The United Republic of Tanzania
ILO      International labour organisation
KTH      Kungliga Tekniska Högskolan, *the Royal Institute of Technology, Stockholm*
LBT      Labour-based technology
NCC      National Construction Council
NHBRA    National Housing and Building Research Agency
NHC      National Housing Corporation
NGO      Non-Governmental Organisation
COET     College of Engineering and Technology
UCLAS    University College of Land and Architecture, Dar es Salaam (later: ARU)
UDSM     University of Dar es Salaam, Dar es Salaam
VETA     Vocational and Educational Training Agency, Tanzania

Swahili dictionary

Fundi    An informally trained artisan, including masons, carpenters, electricians and plumbers who are actively engaged in construction work at local neighbourhoods.
Mafundi  Mafundi is used with reference to more than one fundi
Makuti   Traditional, thatch roof covered with palm leaves
Mttaa  Leader of Sub-ward
1 Introduction

In developing countries, as Tanzania, where the industrialisation process is accompanied by rapid urbanisation, the population solves their housing situation within limits of their own savings. Simple building techniques often mean one storey buildings and result in low population densities and encroachment on spatial qualities.

As a single storey construction, the Swahili house is the predominant house type found in Dar es Salaam. Houses are affordable, often overcrowded but allows for savings by sharing spaces. The design is adaptable and suitable for self-help.

Although construction of the Swahili house is well known and can be carried out by local craftsmen, the high cost of building materials and inappropriate construction techniques often force builders to quality compromises. The change from rural to urban society now compels change in practice and building design.

“Tanzania, as other developing countries has been facing shortage quality and adequate housing for decades. Both pre and post independence governments realized the housing problems and the urgency to solve it.”

Dr. G.M. Kawiche, Chief Executive (NHBRA)

This project report is a direct continuation of the study “Housing Themselves. Transformations, Modernization and Spatial Qualities in Informal Settlements in Dar es Salaam, Tanzania”, written by Dr. Huba M Nguluma at Ardhi University in Dar es Salaam, Tanzania. Results from the study shows that a wide range of transformation activities are taking place in Dar es Salaam informal settlements and that the desire to modernise houses impels house owners to use modern building materials. The study illustrates problems emerging from house transformations such as; decrease of outdoor space, increase of housing density, blockage of ventilation and light in the transformed houses. The study also illustrates the process to address urban sprawl and how to efficiently use the outdoor space. It is declared that due to limited influence and technical support from professionals, generally the house types found in informal settlements are not constructed in a way that achieves desirable thermal comfort. Together with prof. emeritus Dick Urban Vestbro at The Royal
Institute of Technology (KTH) in Stockholm, Sweden we found an interesting way to form the project as a possible solution to some of the problems found in Dr. Ngulumá’s study.

1.1 Problem formulation

In Tanzania, informal settlements accommodate a wide range of social and economic groups of people, from poor to wealthy households. In general, one room accommodates a whole household and the numbers of persons living in each household are increasing.[40] As a corollary, housing developments in informal settlements are progressing very fast. Despite the lack of appropriate government policies most of the people manage to solve their housing issues. The rapid physical densification results in encroachment on spatial qualities such as daylight in rooms, cross-ventilation and squeezed outdoor spaces, where most of the household work is carried out. Most areas lack vehicular accessibility and existing roads are often encroached upon by house extensions. Even though the population density is increasing it is still quite low because the predominant horizontal development of informal settlements. [20]

Most houses in Tanzanian informal settlements are built with simple building techniques but of better quality than in shanty towns of other African cities. This is depending on several factors as; good security of tenure, a process of grass-root planning combined with gradual legalisation and regularisation and the use of materials well adapted to the Tanzanian climate. Houses without permanent building materials are being improved over time depending on the financial and social status of the owner. Old structures are often demolished and replaced with new houses. [40]

The informal settlement of HanaNasif was chosen as study area since it stands as a partially upgraded informal settlement with a relatively improved living environment compared to others, mostly because of its proximity to the city centre. The area was also suitable to study since background facts and interview materials were available and accessible in previous performed research. Somewhat increased land and property values in HanaNasif now also trigger house owners in some extent to transform and expand their houses as the settlement attracts many people searching for accommodation.

Briefly informal settlements are often associated with problems such as; low vehicular accessibility (transportation, ambulance, fire brigade),
seasonal flooding due to absence of proper drainage systems, lack of fresh water supply and space for infrastructure such as roads, drainage and water pipes. [40]

To build houses in more than one storey could reduce land coverage and may be a solution to some of these problems. Proper materials and skills can be found, but how can the local methods of building technology be developed but still be simple enough to be carried out by local craftsmen? This study investigates whether a technique using semi-prefabricated construction elements is a solution and an option in construction of affordable and durable two storey houses.

1.2 Aim of study

One way to allow further physical densification while securing basic spatial qualities such as daylight in rooms and cross-ventilation is to promote vertical extensions of buildings. The question is whether this can be done without increasing costs beyond affordability for the poor inhabitants.

The aim of this study is to explore possibilities to introduce affordable, flexible and realistic construction methods for a two-storey building which could be built by local craftsmen in different phases according to economical and family situations at the time. Special focus is put on the load bearing structure and how to find a construction solution which would fulfil the criteria mentioned above. During fieldwork it was realised that introducing a *new* construction method for the intermediate floor slab may not be a realistic or affordable way to solve the urgent need of Dar es Salaam informal settlements. The possibilities of implementing the idea for a construction in a reasonable time and to be able to distribute the knowledge to those who need it made us extend our focus, onto a “*new*” improved technique, with a construction alternative that uses the commonly known way of producing the intermediate floor slab. Since one of the most crucial objectives of the present study is to find a *realistic* way of transforming the Swahili House, the focus is also put on production of drawings and a proposal for a *standardised* two-storey construction. These drawings are meant to be spread out and used for free.

The enhanced technique for the intermediate floor slab and drawings for a standardised two-storey construction could generate a more affordable and shorter way of start-up and completing house constructions.
By improving simple traditional building methods, and produce more durable houses that conforms the local style may lead to sustainable development of informal settlements.

1.2.1 Target group

As mentioned in the previous chapter, the proposed construction aims at being suitable for people in the low income bracket but not the utter poorest group of people because of the physical size of the house and the material selection. Even thought, some materials could be found locally and free of charge, cement and metal sheeting may not be affordable for many poor families.

To build a two-storey house is an investment. To choose a more durable and expensive house construction dwellers ought to be certain of a continuation of their land tenure. This could be families with official security of tenure or plot owners who have land with good ground conditions and secured from future infrastructural activities.

The construction aims at being adapted to the coastal tropical climate zone in Tanzania but can be adapted without modifications in similar climate zones or even in warmer climate zones.

Depending on the chosen materials, the construction is most suitable as low-cost housing where soil is naturally available or could be bought for a small amount of money. In countries where labour is more expensive, production of building elements can be industrialised with advantage. For example, brick machines with electrical supply are being developed by the NHBRA. Techniques similar to the proposed in this thesis are also found in other parts of the world. [74]
1.3 Purpose of study

Briefly, the purpose of this study is to vertically extend the Swahili house type into a two-storey construction that is affordable to build and maintain, can be built with local knowledge and labour and consists of local building materials. The construction is supposed to be built with new but simple techniques, withstand weather conditions and natural forces such as rain, wind and soil erosion and is environmentally friendly by minimising transport of materials.

The final purpose of this study is to create and investigate the possibility of distributing drawings of a standardised and low-cost two-storey construction.

1.4 Research questions

Based on the problem formulation and aim mentioned above the following research questions are formulated:

How can a construction of a two-storey house be based on traditional earth building techniques? Which building materials will be most suitable for the qualities needed? How can simple solutions be found for transformation of a roof into a load bearing floor?

How can the local building technology be developed but still be simple enough to be carried out by local craftsmen? How can Mafundi be
trained to adapt these building techniques? How can incentives to introduce new building techniques and materials be found?

1.5 Delimitations

This study focuses on the technical solution for a two-storey house. This, for example could be; the system of joists, the load bearing walls and the complexity around these details. The architecture and the planning design are significant and aimed to be flexible, but it is not the main task of this thesis. Also this thesis does not investigate problems concerning real estate economics.

The target group is low-income people living in Urban African informal settlements. Therefore, the proposed solution of house construction does not include any sanitary system or drainage in the main building.

The background study includes a general description about the country of Tanzania, although focus is put on the urban informal settlement areas of Dar es Salaam. Their housing needs, building techniques and used materials have been studied more thoroughly.
2 Theory

Tanzanian housing strategies and planning policies has been exhaustively researched in several studies during the previous years. Many account Tanzanian building regulations and regulatory framework inappropriate and non-functioning, and policy changes that may support the urban development are intensely discussed. Affordable, durable housing is often put out as an urgent need.

This study can be seen as a continuation of a previous study conducted by Dr. Huba M. Nguluma which establishes that a solution to the reduced outdoor spaces could be vertical extensions. Other benefits in transforming vertically are the increase of indoor space and possibilities of better cross ventilation. Hence these benefits this study is focused on developing two-storey constructions for people with small private means.

The Ugandan architect Assumpta Nnaggenda-Musana assert in her doctoral thesis (2008) that virtually all houses in poor settlements are one storey self-built detached units, which is a fact that contributes strongly to urban sprawl. Her thesis, based on the case of Kampala, shows that the predominant horizontal development of housing in informal settlements leads to long distances to job opportunities and unnecessary and expensive lengths of infrastructure per capita. The author argues that local craftsmen and self-help builders should be trained to construct two-storey houses, which are affordable at the same time as they provide for more effective use of land.[42]

Since the purpose of this thesis is to find a technical solution for a two-storey building, literature in building technology are of special interest. We found the available published technical information insufficient regarding construction elements and engineering design. Very little has been written about how to build and construct houses for low income families. Although, affordable, local building materials are being studied, principally by NHBRA, National Housing and Building Research Agency and COET, College of Engineering Technology in Dar es Salaam. The research conducted by NHBRA is mainly concentrated on affordable single storey houses and development of a wall system made of soil-cement interlocking bricks. Development, durability and quality of this type of bricks have also been studied by Dr J.K. Makunza at the
College of Engineering [33]. Although sufficient strength of the bricks is documented, the NHBRA are predominantly using framed structures when constructing houses with more than one storey.[74] Based on technical results from previous studies, the present thesis will analyse and try to sort out whether the system of bricks may be suitable as a load bearing construction, at least for a two-storey house.

Design of an intermediate floor slab that may be suitable for local conditions in terms of the use of LBT\(^1\) and local building materials has been developed by Prof Mwamila and Dr Makunza at the Department of Structural Engineering, University of Dar es Salaam\(^2\). The proposed solution for the intermediate floor slab, presented in this study, is based on their final report, “Semi-Prefab Concrete Construction Techniques for Low Cost Housing” and ongoing research by Dr J.K. Makunza.[33]

An idea of a solution for the intermediate floor slab was found in early stages of literature studies. “Construction in developing countries. A guide for the planning and Implementation of Building Projects.” published by The Swedish mission council, describes a type of flat roof structure where hollow blocks function as permanent shuttering, allowing tensile reinforcement to be laid between the blocks. The authors also describe a more common technique consisting of hollow blocks between precast T-beams and the cast concrete.[50] Could this construction work as a load bearing slab?

Image 2: Example of a type of roof structure of burnt clay and concrete hollow blocks. [50]
Source: The Swedish Mission Council (1994); Construction in developing countries.

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\(^1\) LBT, Labour Based Technology will be discussed later in this chapter.

\(^2\) Later COET
Image 3: Flat roof of reinforced concrete with hollow blocks of burnt clay laid on precast concrete beams. [50]
Source: The Swedish Mission Council (1994); Construction in developing countries.

The geometry of the hollow slab element shown above is similar to a system of slab strips combined with T-beams under development by Dr J.K. Makunza at the College of Engineering in Dar es Salaam. There is no written report or tests determining the strength of a construction of that kind. This study will further investigate the technical aspects of the T-beam construction combined with the geometry of the slab elements developed by Dr J.K. Makunza.

To provide integrated thermal insulation in floor slabs, an example of geometrical similar constructions are being used in the United Kingdom.

Image 4: This ground floor system developed in the UK, utilises expanded polystyrene blocks combined with a structural topping to provide integrated thermal insulation.

The British traditional solution for suspended floors, utilizes a system comprises inverted ‘T’ beams infilled with either Thermalite or aggregate concrete blocks.
According to product retailer, the system is referred to as “quick, easy and economical to install and offers numerous advantages including improved acoustic performance and fire resistance.”[16]

The system is particularly suitable on intermediate floors for houses, where sound reduction, fire resistance and thermal mass are amongst the key advantages beam and block has over alternative systems.

2.1 Concept discussion
Below, definitions of some key notions for this study are discussed.

2.1.1 Informal Settlements
Severe problems exist in defining informal settlements. The definition is context-specific. Various definitions have thus been proposed, but what suggested by the UN Habitat Programme may be the most widely applicable. This defines informal settlements as:

- residential areas where a group of housing units has been constructed on land to which the occupants have no legal claim, or which they occupy illegally;
- unplanned settlements and areas where housing is not in compliance with current planning and building regulations (unauthorized housing).

Many other terms and definitions have also been devised for informal human settlements, for example: unplanned settlements, squatter settlements, marginal settlements, unconventional dwellings, non-permanent structures, inadequate housing, slums and housing in compliance etc.[58]

According to UN-Habitat; informal settlements are dense settlements comprising communities housed in self constructed shelters under conditions of informal or traditional land tenure. They are common features of developing countries and are typically the product of an urgent need for shelter by the urban poor. Informal settlements occur when the current land administration and planning fails to address the needs of the whole community. As such they are characterised by a dense proliferation of small, make-shift shelters built from diverse materials, degradation of the local ecosystem and by severe social problems.
Problems also occur in measuring the extent or defining the boundaries of such settlements. By definition, officially recognized boundaries to these settlements rarely exist, and the settlements themselves often merge almost imperceptibly into formal areas of housing, industrial or rural areas. [58]

Following factors have also contributed to the fact that the size and the number of informal settlements in Africa are increasing: [47]

- high population growth rates;
- rapid rates of urbanisation;
- slow economic growth rates; and
- inappropriate policies.

According to Ngluma (2003), informal settlements in the context of Tanzania refer to housing areas which have developed outside official land development process and procedure.

Kombe (1995:45) suggests that informal settlements in Tanzania refer to basically residential agglomerations where the status of land occupation is not illegal but the settlements have not been conventionally planned, surveyed and sanctioned by government institutions responsible for urban housing land delivery and management. Areas like these have been developed without the formal approval of public and land allocation authority. In Tanzania informal settlements are therefore not synonymous with slums or squatter settlements, since the emphasis is not on the illegality of land ownership or occupation but rather on the nature of a land development process.

Inappropriate regulations and non-functioning formal regulatory framework as well as the above mentioned aspects have contributed to the growth of Dar es Salaam informal settlements.[32] The process and costs in order to obtain permission from the local government are the major complicating factors. To have the permission to possess land, the plot has to be surveyed and located in an officially planned area. [47] The process associated with the acquisition of a building permit is inflexible and may not be very adaptable for low-income households. The informality is above all, still the predominant problem of all Dar es Salaam informal settlements.
2.1.2 Provider model

The provider model is a conception often used in development assistance. The model is characterised by the idea that ready-made standardised housing units for the masses are provided through centralised production [64]. In developing countries provider models may result in policies where informal settlements should be pulled down and replaced with mass produced minimum-standard housing units in permanent building materials and built according to strictly regulated urban plans.

High growth rates, a consolidated building industry and a good tax base are among other, preconditions for the provider model to be successful. Those preconditions are hardly ever fulfilled in low-income countries such as Tanzania.[64] According to Vestbro (2008); the modernist provider model has been applied with a certain success in some of the industrialized countries (Sweden for example), and been implemented uncritically in developing countries, without reflecting if the model may work out in local conditions.

When it comes to constructions, the provider strategy does not endorse knowledge improvements of local artisans or local production of building materials.

The model has been advocated by Government of Tanzania through providing people with shelter in attempts to solve housing needs. The model failed in implementation. Further reading about Tanzanian governmental planning policies is found in Chapter 5.1.

2.1.3 Enabling strategies

As a policy, enabling strategies usually includes active community participation, gradual slum upgrading (instead of slum-clearance), self-help construction techniques, relaxed space standards, and formalisation of informal settlements. Enabling strategies imply that local communities play the major role in improving their own living conditions.

In contrast to the provider model the enabling strategy is based on the idea that residents produce their own houses in an incremental process through self-help or with the help of small scale local construction companies [64]. In housing, the enabling strategies incorporate flexibility in construction step by step using affordable materials, and during construction permits use of other parts of the house for business.
Nowadays there is a fairly wide agreement that earlier existing housing policies have to be replaced by enabling strategies in order to cope with the problem of expanding urban slums in low-income countries. While lip-service is paid to the enabling housing strategy little is done to implement it in practice.

Self-help

The ability to use self-help is important in construction to facilitate affordable housing. The definition is not unambiguous. Self-help, defined by the German Development Assistance Association of Social Housing, as an “informal arrangement where a number of people coming together to help each other.” The organisational form and the workflow are dictated by the group and the group members, not by unsatisfying Governmental Building regulations. This type of housing accounts, today and historically, for most of the houses in the world. However predominantly this is a rural phenomenon and part of a form of life that disappears in large contemporary cities. Urban self-help housing just shares one single technique with the traditional rural model; families in both use their own unpaid labour to collect materials and assemble houses. According to Skinner, R J & Rodell, M J (1983); in every other way urban informal housing is its own distinguished area. Unlike in traditional self-help systems, conflictive, complicated processes are enclosed to the choice of land, design of house, the availability of labour and materials. With substantially less time than in rural areas due to labour occupancy seven days a week, houses had to be quick-made. Appropriate materials may be difficult to produce by family labour, and urban residents occasionally have to be satisfied with only collected waste materials. [48] Although, recycling is an important part of future sustainable development it may be difficult to build durable houses exclusively using goods found in the streets.

When used in construction, self-help or self-construction means that people build their houses on their own. If handiness is not enough to carry out construction work without professional back-up, self educated local craftsmen can be employed to supervise while family members contribute with work by doing easy tasks as brick-making or digging.[81] To hire craftsmen and be responsible for arranging construction work and development of your own dwelling might also be referred to as self-help. In which level does self-help appear in the urban society of Dar es Salaam? Does it exist at all? This thesis may consider self-help as the desire of families to change their circumstances and for
them to realise that it is possible to accomplish housing improvement with small means. Although in this thesis, when discussing further, self-help will be referred to as the definition of self-construction. Self-help housing means houses low-income families construct with their own unpaid labour.

The self-help concept is a part of the enabling strategies.

**Incremental development**

Contrary to inflexible master planning, incremental development is one way of implement enabling strategies in practice.[64]

Incremental development is usually defined as a progress without predetermined outcome. According to Vestbro (2008), housing must be seen as a continuous incremental process, and not as a physical object designed and built at one moment in time.

In this thesis, incremental development may not necessarily have to be a process done unstructured without a defined aim.

The proposed construction can be seen as incremental development of a two storey house and is based on techniques and methods that make it possible to complete building structures gradually, in different phases according to economical and family situation at the time. The structure may work as a single storey house in the middle of the process or as a completed two storey construction. Extensions and alterations are possible.

For example: In the first stage foundation and walls for the ground floor can be built. If a thatched roof is added, the building, or room can be used as a single storey building. The traditional or frequently used development of the house type does not necessarily have to be changed3. As long as the foundation is prepared for the resulting loads, dwellers can start with one room and thereafter continue with further horizontal extensions and vertical extensions. The intermediate floor slab and upper walls can be added after 5-7 years [82], when the thatched roof covers anyhow, are in need of replacement.

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3 Further reading is found in chapter 6.5.
Poverty
According to the UN Chronicle, the definition of poverty is as the total absence of opportunities, accompanied by high levels of undernourishment, hunger, illiteracy, lack of education, physical and mental ailments, emotional and social instability, unhappiness, sorrow and hopelessness for the future.

Although history shows that poor people can fight for their rights, poverty is also often characterized by a chronic shortage of economic, social and political participation, delegating individuals to exclusion as social beings, preventing access to the benefits of economic and social development and thereby limiting their cultural development.

For ease of reference and coherence in global assessments, development agencies often employ quantitative measures of poverty. The most widely used poverty threshold has been a US dollar a day per person at 1985 purchasing power. Many aspects of poverty, some of which are crucial to human rights, are not reflected in the statistical indicators.

As for statistics, poverty is habitually connected to lack of money. On the other hand, if people cultivate their own food they may live well without any income at all.

Through the Millennium Declaration and the Millennium Development Goals the world is addressing the many dimensions of human development, including halving by 2015 the proportion of people living in extreme poverty. Goals symbolises a commitment, but are often difficult to implement, especially when it come to poverty reduction.

Affordability
Most households in Tanzania finance their construction of houses with funds from their own savings, from salaries, allowances, and other benefits or from business incomes, sale of assets, income from assets rented out such as house rent, sale of goods and services, contributions from friends and relatives and inheritance. Affordability varies from case to case and totally depending on the personal assets mentioned above.

If one lives under affluent conditions it is hard to understand what it means to live off $ 1 or 2 per day. This is what the majority of slum dwellers do. With such low incomes survival strategies become neces-

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4 UNDP, 1999
sary. Food and distance to job opportunities become priorities, while infrastructural services and housing rank second or third. Affordability is more important than minimum standards.

1 USD a day may mean 60 USD a month for a household. Of this perhaps 50% has to cover food, 30-35% transport and others, while only 15%, i.e. 9 USD can be used for water, sanitation, electricity and the house itself. In Dar es Salaam, cost for transportation could be fairly high because of the horizontal development of housing in the city which has lead to long distances to job opportunities.

According to Sheuya (2004), transformers have to use their savings to build their houses in the start-up phase, while shelter microfinance institutions provide loans for improvements (extensions and alterations). [47] Despite that fact, to erect a house is often a prolonged process, since the majority of dwellers are hesitant to loans and rather pay for their building materials by using own savings.[85]

Distinct to most poor people of Dar es Salaam, this thesis defines an affordable building as a dwelling that will be economical for its whole lifespan. Not only to purchase or build. Will the purchase price for the elements, materials and machines used in the proposed standardized two-storey construction be larger compared if using temporary, earth materials without stabilizers? Since longer durability of materials compensate the initial expenses, over time durable materials could be considered more affordable than the cheapest on the market. It is not impossible that even the initial costs for proposed technique may be comparable to the cost of the most commonly used technique for the equivalent construction.

Adaptable design

Adaptable design has four sub-notions that will describe the concept itself; Extendibility, generality, flexibility and adaptable building materials.[86]

Extendibility means that a house can be extended in any direction. Both vertical and horizontal extensions are possible.

Generality in the context of adaptable design is linked to rooms. A general room is a space that can be used for many kinds of activities.
Flexibility has, in this thesis, several definitions linked to adaptable design. The first definition is flexibility of the design layout. The layout is flexible in the sense that partitioning walls can be moved in any way without destroying the load bearing capacity of the structure. The second definition is somehow similar to generality but is rather linked to who uses the rooms. In connection with the Swahili House it is flexible because it is not only a house for the nuclear family but also more commonly works as a multifamily unit where rooms could be let out to tenants.

Adaptable building materials are materials well suited for present climate and also adaptable in the sense that they are well suited for low cost housing. For materials to be suitable for low cost housing it is important that they are easy to manufacture and build with, dismantle and reuse.

2.1.4 Durability
What is a durable material for the Tanzanian urban population? Observed in Dr Nguluma’s study, not a single one of the transformed houses used traditional building materials on the extension. In Tanzania, concrete are produced by using non-renewable resources that degrade the environment. Due to use of these materials transformation activity has been found ecologically unsound.[40] Is a modern construction durable in the sense of sustainable development?

Is it old-fashioned to consider a strong, long lasting construction as durable? Isn’t the “modern” way of designing based on flexibility and generality? In that case, would a solid concrete structure be durable in the long run? What is most important for poor households, life-time durability of their property or adaptable design useful in generations? Does the urban population want to be able to maintain their house on their own or do they rather wish for a construction requiring no maintenance?

In this thesis, durability and durable materials are those materials that withstand the climatic conditions of the region and that are easy to maintain for ordinary people.

2.1.5 Local building materials
Local building materials may be defined as materials that are produced or found/bought in close connection with the construction site. This thesis does not consider imported goods as local building materials, although they can be bought locally. The price of materials is much
influenced by the need and costs of transportation. Although imported goods are sometimes of better price than the locally produced materials. The government has occasionally put tax up on imported cement to support the local industries [76].

2.1.6 Traditional and modern materials

Building materials traditionally used is referred to as *traditional building materials*. Examples in construction of the Swahili house are for instance; thatch used for roofing and mud and mangrove poles used in walls.

The *modern materials* used in construction could be defined very differently. Locally, durability is strongly related to the definition of modern materials. The most common definition is that modern materials are materials produced industrially. Shown in Dr Nguluma’s study, modern houses are regarded as better houses according to HanaNasif residents. In that case, better constructions refer to durability and people in informal settlements are convinced that industrially produced building materials are more durable than traditional building materials. Even if climatic properties are superior, materials such as thatch, soil and poles are considered as temporary materials, since they are traditional and as they have to be replaced in matter of a few years or maintained to sustain. Using this definition, modern materials are durable, since they need less maintenance and seldom have to be replaced within the same time span as traditional materials. A consequence of people’s admiration of modern materials may result in houses built on ignorance of how the materials perform. Research carried out on local and traditional building materials has so far not been sufficient neither communicated to the general public. This may be the reason why people have been short of information of the positive aspects of local or traditional building materials they are often neglected in favour of modern materials.

Another definition is that building materials are considered modern as people want to build with them as an architectural statement. Concrete is often considered modern but somehow expensive. Sometimes people are willing to pay more for materials just in order to feel like they live in a modern house. Aspiration to live in a “*modern*” house is discussed in Dr Nguluma’s study as one of the motivations for housing transformation.[40] A majority of people interviewed in the study prefer not to live in mud and pole houses, since they are built of traditional materials and associated with poverty and low social status.
The colonial view of traditional materials is that they are not durable in terms of long lasting. Could this thesis contribute to changed attitudes towards traditional building materials as soils to be considered modern and durable? It will also be explored if a modern construction, using locally available, traditional materials, could be affordable for the urban poor.

2.1.7 Labour based technology
According to ILO, labour based technology is: “A construction technology which aims to apply a labour and equipment mix that gives priority to labour, but supplements labour with appropriate equipment when necessary for reasons of quality or cost. While producing or maintaining constructions to a specified standard, in a cost-effective manner; people are employed with fair working conditions.” [16]

In this thesis, LBT refers to the use of employment intensive approaches to investments in infrastructure and service delivery, operation, maintenance, and the utilization of local resources.[1]

2.1.8 Semi-Prefab
A semi-Prefab construction technique is a compromise between full-scale prefabrication building systems and in-situ construction methods. Elements for walls or floor slabs forming the construction are normally assembled on site. Prefabricated construction elements can be manufactured directly at the building site, or bought ready to use. Prefabricated elements are of standard execution but could be combined to form unique structures. The semi-prefab technology yields more advantages if it is a standardization of the design and construction process.

2.1.9 Local craftsmen
A local craftsman or artisan is in Kiswahili called fundi. Mafundi is referred to as more than one fundi. Mafundi could be self educated, informally or formally trained. Unspecialised labour, which perform a number of different odd jobs are often called, unskilled. These people are also referred to as informal construction workers.

Dr Nguluma defines the fundi as a “self educated architect”. Her thesis maintains that the fundi plays the role of a formally trained architect and engineer in transformation processes carried out in the informal settlements.
In the present study, it was observed that *mafundi* operate in different ways. Dr Nguluma has categorized the local craftsmen into three different groups, according to their skills and method of work. The first category is an independent *fundí* who is hired for a certain skill. If the *fundí* need assistance he may hire a labourer himself and it is his responsibility to pay him or her. The second category is the *fundí* within a group of skilled and unskilled labourers. In this category the *fundí* works together with skilled or semi-skilled labourers. The third category of mafundi are often specialized in his (mostly men) special field of construction. When he gets a job of his speciality he collects a number of unskilled labourers to assist him to finish the job quickly.[40]

Mafundi are often considered as experts by the grass root level. On the other hand, educated engineers and architect may think mafundi are uneducated and lack appropriate knowledge to execute their work. This thesis will try to ascertain the skills of formally, informally, and self educated local craftsmen. What are their skills? Are they capable of carrying out construction works demanded for two storey houses?

**2.1.10 Density**

In this thesis the concept of density is divided into physical and population density.

The physical density is connected to space. Population density and physical density are depending on each other. When building single storey houses, population densities are kept low as the physical density is high which means encroachment upon spaces. By constructing two storey houses the population density is increasing and the physical density is decreasing. This means that great profits in terms of infrastructure provision can be made. More space between buildings and decreasing distances are obtained.
Methodology

The work for this study was divided into two stages. The first stage focused on collecting data and analyses with the aim to establish how and with which materials to build these two-storey constructions. It also strived to analyse the construction industry and how to apply for a building permit. The second stage aimed at the creation of standardised drawings and cost analysis for the proposed construction.

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3.1 Literature review

In addition to general information about Dar es Salaam, Tanzania and informal settlements, background studies include: Housing in informal settlements, building regulations and policies, the Swahili house type, building materials and construction elements etc. Special focus was put on the local construction situation, the possibilities of self-help, and the skills and techniques used by informal construction workers and
3 Methodology

Vertical extensions of the Urban Swahili House
Hanna Kruse & Lotta Torstensson

mafundi. Literature studies concerning earlier tested constructions have also been done.

3.2 Observations

When arriving in Dar es Salaam, the first priority was to study building technology and the construction process of a traditional Swahili house and investigate the aspects of construction in Tanzania. Both formal and informal construction sites around Dar es Salaam, Bagamoyo and Zanzibar were visited in order to study how local contractors build. Existing two-storey buildings in Dar es Salaam informal settlements were of special interest.

Observations were documented by photography.

![Image 5: Formal construction site located in Mbezi, Dar es Salaam.](image)

Photography: Lotta Torstensson

3.3 Inventory of local building materials

A significant part of the fieldwork was to survey the local building materials, including an inventory of the product range, cost analysis and quality investigation. Cost for transportation has also been included.
3.4 Case study methodology

Together with supervisor Dr. Huba M. Nguluma the informal settlement HanaNasif was selected as primary case study area. As a fairly upgraded informal settlement, the area was chosen primary because of its diverged population, which includes families within the target group criteria’s. Partly, the HanaNasif area has also been surveyed. Plot owners that possess the security of tenure are more likely to invest in erecting a two-storey building. Due to the security of tenure, increased land and property values also trigger house owners to transform and expand their houses as the settlement attracts more people searching for rental accommodation. As alterations is taking place, the need of vertical extensions of the built environment increase. A couple examples of two-storey constructions are found in the settlement, which generated interviews and observations suitable for this study.

Local conditions, material data and other assumptions are based on observations and investigations made in HanaNasif. Procedures and structures at Kinondoni Municipality and HanaNasif’s community offices were observed to sort out bureaucratic problems regarding building permits and house construction.

3.5 Interviews

An important part before carrying out interviews was to find a suitable interpreter, who understands the importance of unbiased interpretation and have the ability to connect with persons being interviewed. To gain the interviewees confidence was very important in order to collect useful data and capture their true opinions.

In order to analyse used techniques and available knowledge, local craftsmen, mafundi\(^5\), a number of architects and engineers have been interviewed. The potential to train Mafundi to acquire improved technical skills in construction work has also been explored.

Furthermore interviews were conducted with a limited number of residents and the local government in HanaNasif settlement. The residents have been questioned about their opinions regarding present living situation and their thoughts about two-storey buildings. Those

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\(^5\) Fundi is an informally trained artisan including masons, carpenters, electricians and plumbers who are actively engaged in construction work at local neighbourhoods. Mafundi is used with reference to more than one fundi.
who already lived in two-storey houses were questioned on if and how they built their house and on advantages/disadvantages of living in two-storey houses.

In the second part of the fieldwork, the possibility of creating and distributing drawings of a standardised two-storey construction based on the most affordable building techniques and materials were studied. The procedures when applying for a building permit and other difficulties when distributing drawings have been of special interest. Local government in HanaNasif and the municipal authority were interviewed on the idea and possibility of distributing drawings for free.

Interviews with residents, mafundi, and community leaders were mostly carried out with the help of an interpreter. Architects, engineers, and at governmental institutions, English was widely spoken. Depending on language skills occasionally the interpreter was not needed. Direct translations were used in most cases and at times notes were made by the interpreter.

Image 6: Residents in HanaNasif.  
Photography: Lotta Torstensson
3.5.1 Key person interviews

Architects

- Nguluma, Dr Huba M at Ardhi University in Dar es Salaam, former PhD student of Dick Urban Vestbro. On modernization and transformations of informal settlements in Dar es Salaam.
- Mosha, Dr. Architect/Lecturer at Ardhi University (ARU) on Architecture in informal settlements.

Engineers

- Makenya, Dr. Engineer/Lecturer at Ardhi University (ARU) on building techniques.
- Mrema, Dr. Engineer/Materials laboratory director at University of Dar es Salaam (UDSM).
- Makunza Dr. Engineer at College of Engineering and Technology (COET), Dar es Salaam on affordable building techniques.
- Ndrimo, Mr Fred. Civil Engineer and lecturer at Ardhi University.
- Sariah, Mr. Engineer at testing laboratory at College of Engineering and Technology (COET), Dar es Salaam on strengths and testing of building materials.

Governmental and municipal institutions

- Kawiche, Dr. Chief Executive at National Housing and Building Research Agency (NHBRA) on research on building materials.
- Fundi, Dr Y.A.S. P Eng. ERB at National Construction Council
- Twwimanye, John. Civil Engineer at National Housing and Building Research Agency.

Community leaders

- Mtaa-leaders (head of sub-ward areas) of Mkunguni and HanaNasif ward.

University Research Staff

- Makoba, Dr. Lecturer at Ardhi University (ARU) on affordable building materials.
- Maro, Mr. Contractor and Lecturer at Ardhi University (ARU) on building techniques and cost for construction.
Local artisans (Mafundi)
- 7 local Mafundi on their skills in house building and existing methods of construction. *Kilwa Road, Dar es Salaam.*
- 2 Mafundi at site of residential building for police force.

Residents of HanaNasif informal settlement
- Residents of two-storey houses
- Residents with a diversified socio-economic situation
- Residents living in houses made of different materials

3.6 Analysis and calculations

Based on literature studies and own findings, the possibility of using new building techniques in order to optimise the structure in terms of durability and affordability has been investigated. Cost estimations and comparisons have been carried out between different types of intermediate floor slabs and different types of bricks for walling material. The analyses include cost of labour, materials, machines, transport of materials, etc.

Furthermore, analyses regarding the static system of the building have been carried out. The design has been determined through manual calculations and the design of the intermediate floor slab has been carried out using FEM-design.

3.7 Sampling

To determine whether the soil in HanaNasif was suitable for brick production, soil samples were collected and analysed.
3.8 Design and drawings

To produce standardised drawings an understanding of drawing technique used in Tanzania is needed. Architectural and structural drawings have been studied to obtain a general view of the used technical language and graphic layout of the drawings.

Feedback on the preliminary findings presented at the seminar in Ardhi University in Dar es Salaam was considered before design and production of standardised structural drawings. For further feedback, drawings have been shown to residents in HanaNasif at a community meeting. Final changes of drawings have thereafter been carried out according to criticism.

3.9 Problems of methods

Implementation of the locally used adoptions of the British Standards for calculations and drawings has been somehow difficult due to lack of accessible material and shortage of own practical experience. Where possible the British Standards and Tanzanian regulations have been used, in other cases the Swedish standards. Also, as drawings; according to Tanzanian standards they are supposed to be carried out in English. This could also be a problem for mafundi and house owners as most of them do not understand English.

As there is high uncertainty of materials (mainly concrete and reinforcement) strength, large safety margins have been considered. A
contradiction to this is found in the Tanzanian regulations. According to these, all loads are reduced with a factor 0.8 for constructions in informal settlements. A possible explanation could be that loads from fittings and furniture in low income areas are not as large as prescribed in the British Standards.

3.10 Criticism of sources

The economic comparison of the different materials is complicated, mainly because of the insecure formation of prices. Costs for material and labour are always negotiable and varies depending on season and from one day to another. Approximations of cost are made by operating contractors at Ardhi University and based on their experiences. Several errors in calculations have been found in cost of materials comparisons made by other institutions. These figures are therefore considered rather unreliable. Results of these researches will be used with awareness of that fact.

3.10.1 Possible Bias

Information gathered through interviews is based on personal subjective opinions and are therefore not always theoretically fully entrenched. The numbers of interviews carried out are too few to make an objective evaluation. Some information gathered is based on hearsay and has not been found documented. Due to the need of an interpreter to carry out interviews, information might have been lost through translation.
4 Context

4.1 Tanzania

![Map of Tanzania](image9.png)

**Image 9: Map of Tanzania**

**Source:** geology.com

4.1.1 Geography and Climate

Tanzania is the largest nation in East Africa covering almost one million square kilometres. The country has a varied landscape with high snow covered mountains, large lakes, barren steppe and savannah, plateaus, volcanic craters and the Indian Ocean. The highest point in Africa and one of the world’s largest volcanoes, Mount Kilimanjaro is found in Tanzania. Its peak is found 5 891 m above sea level. Africa’s largest and
the world’s second largest freshwater lake, Lake Victoria is also found within the country’s boundaries. [43]

The seasons in tropical areas are characterised by wet and dry seasons. Divided into two rainy seasons and two dry seasons, much of the country’s climate is controlled by the Indian Ocean’s monsoon winds, which bring with them two rainy periods – the long rains (masika) from March to May, and the lighter short rains (muvuli) between November and December. The hottest period is from November to February and the coolest from May to August. [43]

Due to the varying landscape there are great differences in climate and they vary over the year. Tanzania can be divided into six different climate zones: [3]

- The coastal tropical
- The Intermediate Tropical
- The Lakes
- The Plateau
- The Uplands
- The High Uplands

The climate in the coastal tropical, the Intermediate Tropical and the Lake areas are characterised by very high temperatures and high humidity. Even though these three climatic zones have similar climate there are great difference between the three areas. While the Lake area experiences hot days and rather cool nights the coastal tropical and Intermediate Tropical areas have very hot and humid climate both during day and night. During the periods before the rainy seasons the climate can be quite uncomfortable as temperatures can be as high as 27-35°C at the same time as the humidity is high. [3]

The plateau is situated at a higher altitude than the coastal tropical, the Intermediate tropical and the Lake areas and lies between 500-1200 m above sea level. The area experiences high temperatures during daytime and low temperatures and low humidity at nights. The landscape is seldom green, due to little rainfall, and comprises bush, grass land and woods. [3]

The Upland areas lie on a high altitude, over 1200 m above sea level. Temperatures are much cooler and humidity is lower compared to the
previous climatic zones described. The landscape is characterised by its green grass- and woodlands and on higher altitudes the landscape comprises forests. [3]

Dar es Salaam is situated in the Coastal Tropical zone. *Climate characteristics and its affects on construction details will be more closely described in chapter 7, since it is of major relevance to this study.*

### 4.1.2 Population and resources

Tanzania has an estimated population of 41 million of whom most are resided in mainland Tanzania [8]. The main part of the country’s inhabitants is of African origin, although people of Arabian, Asian, Indian and Pakistani ancestry comprise a significant component of the urban population. Tanzania is one of the least urbanised countries in Africa; its urbanised population is estimated at slightly more than 30 percent and the urbanisation rate is 7 percent [32]. There are 128 officially recognized tribes in Tanzania and the country possesses more cultures than any other country in Africa apart from Congo. The majority of the tribes are identified as members of the ethnic group Bantu. Other big ethnic groups are the Hamitic and Nilotic people. The nomadic Masai people are a part of the Nilotic ethnic group. Although Tanzania was established in the interests of colonial Europe the country has successfully forged a health sense of unity. Part of the reason for this success is that none of the nation’s tribes are forming a majority. The biggest tribe, the Sukuma comprises approximately thirteen percent of Tanzania’s population. Because of the many tribes there is a big mix of cultures in Dar es Salaam. The Swahili house is a very common house in Dar es Salaam and it is inhabited by people from many different tribes, not only by people who live according to the Swahili culture.

Four fifths of the economically active population is devoted to agriculture. The main cash crops are coffee, cotton, cashew nuts, tobacco, tea, sisal, coconuts and sugar. There are also great mineral resources in Tanzania which contributes to that the country is self-supporting in production of cement for the making of concrete and sand- or soil cement products used in construction. [52]

Dar es Salaam is the dominant industrial centre and main port with focus on government and commercial activity, although many administrative functions have been transferred to the capital city of Dodoma by the year of 2005. Since Tanzania has a high urbanisation rate great
efforts have been made to decentralise industrial development to other centres in the country. [16]

A previous steady migration into various urban centres has in recent years accelerated and is accompanied by urban poverty and results in an increasing demand for affordable housing.

4.1.3 Poverty

Since the mid 1990s, Tanzania has made substantial progress in terms of macro-economic stability and structural economic reformation. According to the Ministry of foreign affairs the economic growth is relatively high (6%, 2007) depending on low inflation, growing foreign investments and increased tourism. In August 2008, the annual inflation rates at 9.8% [53]. Despite these advances, Tanzania remains one of the poorest countries in the world. Nearly a fifth of the population does not have enough food to eat, and more than a third cannot satisfy basic needs.

Tanzania’s dependency on foreign aids is high, about 40% of budgetary resources are external. 22 multilateral and 25 bilateral donors are active in the country. The largest donors are the World Bank and the United Kingdom, accounting for 20 per cent each of total the aid. Denmark, Norway, Sweden and the Netherlands contribute about five per cent each. [28] The strategy for development cooperation with Tanzania has recently shifted in line with the new JAS6 from project and programme support to aid modalities, such as General Budget Support, GBS. The shift in financial modality presupposes a high degree of mutual trust between donor countries and Tanzania. A transition to a larger GBS component assumes that the Government of Tanzania seeks to foster democratic governance and that it takes rigorous action against corruption. Given the power imbalances in the country, there is some uncertainty as to how far a transition to GBS should go.[28]

Tanzania’s social development indicators show that little progress has been made over the last decade. Neither infant nor maternal mortality rates have declined to any great extent, mainly because of the difficulty to reach the most vulnerable and needy groups of people. Poverty

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6 Tanzanian Joint Assistance Strategy aims in particular to strengthen basic principles concerning national ownership of the development process and to harmonise the assistance and government processes. This is intended to make aid more efficient and easier to manage.
simulations by the World Bank indicate that the link between economic growth and poverty reduction is fairly strong in Tanzania. [28]

The impact of HIV/AIDS threatens future social and economic development. HIV prevalence is an estimated 7 per cent and the disease is the most common cause of death among the Tanzanian adult population. [28]

Poverty is much more obvious in urban than in rural areas. Dar es Salaam has experienced a substantial reduction in poverty, triggered by the growth of a strong private formal job sector that spilled over to the informal sector. Historical statistics indicate that urban population in Tanzania has been doubling every ten years during the period from 1948 to 1996. The increase is mainly caused by rapid urban growth without industrialisation. Since the beginning of the 1980s the standard of living and the quality of life for the majority of the population has been reduced in both urban and rural areas. [23]

The high level of poverty, which is prevailing situation for the urban citizens, can be reduced through human resource capacity building. Promoting local small enterprises and equipping people with appropriate knowledge could be one way to achieved, for example, improvement of housing.

4.1.4 Political Rights and Civil Liberties

When presidential and parliamentary elections were held in December 2005 the ruling party, Chama Cha Mapinduzi (CCM), won overwhelmingly. Execute power now rests with former Foreign Minister Jakaya Mristo Kikwete who was elected president with approximately 80 percent of the votes. The president serves a five year period and can be re-elected once. The constitution provides for universal adult suffrage and a unicameral National Assembly (the Bunge) holds the legislative power. The Bunge has 323 members of which 323 are directly elected, 75 are women, 10 are appointed by the president and five members are the Zanzibar legislature. Opposition parties were legalised in 1992, although Tanzania is not an electoral democracy. Eighteen opposition parties were represented in the latest election, but they tend to be divided and ineffectual. [13]

The constitution provides freedom of speech and the level of press freedom is higher in Tanzania than in other countries in Africa. The country has 50 newspapers but media influences are nearly limited to
urban areas. On Zanzibar, private broadcasters and newspapers are prohibited. [13] Freedom of religion is generally respected in Tanzania. In recent years tensions between religions have increased, although relations between the various faiths are mainly peaceful. [13]

Although Tanzania is considered a democracy with a high level of freedom, people do not have the right to own land. All land and plots are leased by the government. Security of tenure may be defined broadly as “the perceived right by the possessor of a land parcel to manage and use the parcel, dispose of its produce and engage in transactions, including temporary or permanent transfers, without hindrance or interference from any person or corporate entity”7 In Tanzania, the security of tenure is valid for 33, 66 or 99 years and guarantees compensation if the government commandeers land.[83] To obtain security of tenure the plot has to be surveyed. Since the main part of the Dar es Salaam citizens live in informal settlements, most of them do not possess any security of tenure.

4.2 Dar es Salaam

The Dar es Salaam region on the East Coast of Tanzania includes the municipalities of Ilala, Tememe, Kinondoni, and a few outlying areas.

Since its founding in the 1860s, Dar es Salaam has evolved from a minor mainland haven of Zanzibar’s Sultan Majid to become a sprawling, socially diverse city of major regional importance. The city is bordered by the Indian Ocean to the east and on all other sides by coast region. Dar es Salaam is at sea level and lies between 6.82° and 6.89° southern latitude and between 39.24° and 39.30° east longitude. The coastal tropical climate zone implies hot weather through the year with annual means from 21.5°C to about 31°C. The humidity is permanently high with mean values at 65-75%. Dar es Salaam, as the rest of Tanzania, experiences two rainy seasons; short rains in November to December and long rains in March to May and in total that is about 80-140 rainy days per year. [3]

The rapid urbanisation has made Dar es Salaam expand to become East Africa’s largest urban centre with a population of almost three million people [54]. In 1973 the Government decided to shift the national capital from Dar es Salaam to Dodoma as a measure of reducing congestion in

7 Bruce and Migot-Adholla, 1994
Dar es Salaam and promoting growth and development in Dodoma. The Programme has not been very successful.

Movement of people towards informal settlements is increasing in Dar es Salaam due to inability of formal systems to provide adequate housing. The population living in informal settlements is also increasing.[23]

Image 10: Unplanned settlement in Dar es Salaam

Source: [23]

4.2.1 Housing

Until the 1890s, the buildings that dominated the central part of the town had both Arabic and German architectural styles. The present land use structure for Dar es Salaam and house types in the city centre have been much influenced by early colonial planning. The housing programmes that were implemented following the colonial housing policy were based on ideas of racial segregation with separate housing schemes for Europeans, Indians and Africans. It was not until Tanzania
got her independence in 1961 that specific housing programmes to provide “modern” good housing for all citizens of Tanzania were founded. Even though the programme aimed at building permanent houses and demolishing “slums” constructed with traditional materials, Swahili house types still dominates the urban housing stock. [40]

Today, informal settlements form the major land use of Dar es Salaam city and movement of people towards informal settlements are increasing due to inability of formal systems to provide adequate housing. Detached single-storey houses are predominant. The majority of Dar es Salaam’s 54 main informal settlement areas are found along or around major city transportation axes, others have been developed around industrial or university areas. Dar es Salaam displays more housing problems than other urban centres in Tanzania. [23]

The main environmental problems in Dar es Salaam City includes mounds of uncollected waste that were both an eyesore and a health hazard; unsanitary conditions resulting from inadequate access to a clean and safe water supply and an inadequate sanitary waste disposal system; air pollution; traffic congestion; unguided urban growth characterised by informal settlements and un-serviced housing areas and a growing informal sector.[45]

4.2.2 Administrative Structure

Administratively, the city is divided into four local authorities: Ilala, Kinondoni and Temke Municipalities, along with the Dar es Salaam City Council (DCC). Each Municipality is composed of wards, and below the wards, the sub-wards, with the Mtaa-leaders⁸. The Ten Cell Units are further down the hierarchy and at present time they consist of 8-15 houses. [47]

4.2.3 Crime

“Peace and development are linked to each other. Hopeless poverty makes people desperate. The suffering it engenders, such as lack of adequate and secure food and shelter for their children, a sense of personal worthlessness because they have no way of providing a decent livelihood for themselves or their

⁸ The leader of a sub-ward. The main task of the Mtaa-leader is to help residents with problems concerning housing issues such as disputes about land etc.
families, and a denial of healthcare or education. All such things can cause breakdown in social peace.”

Mwalim Julius K. Nyerere

Dar es Salaam has had a reputation of being a relatively low-crime area but the last few years, the daylight armed robberies have increased rapidly. When sun sets there is no longer safe to stay in the streets. To secure property and provide safe shelters houses and plots are adjusted to the new situation. Windows and doors are provided with steel gratings. All households, that can afford it, have their own night guards and a fence surrounding their plot areas.

Corruption is a serious problem in Tanzania and very frequent problem in the construction industry. A national anticorruption plan has been developed to empower the Prevention of corruption Bureau. Guidelines for concluding contracts and re-examine procedures for procuring public goods are to be improved. Police abuse is said to be common. [13]

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* President of Tanganyika 1962-1964 & President of Tanzania 1964-85.
4.3 HanaNasif

Image 11: Dar es Salaam, location of study area, HanaNasif  
Source: Google maps

An area of great interest for this study is the mature settlement of HanaNasif with a high development density and many related congestion problems. As HanaNasif was developed before 1980, it is considered an old informal settlement. The main character of these settlements is the high density to which land is put and the irregular pattern to which houses have been organised. [40]
HanaNasif is located in a low land area, 4 kilometres outside the Dar es Salaam city centre. The settlement has an estimated area of 8.09 km² and is bordered in the north by a planned residential area and to west by Kawawa road and the Msimbasi valley forms the southern and eastern borders.[47] The settlement is situated in Kinondoni Municipality and is divided into three different sub-wards; Mkunguni, HanaNasif and Kisuto. HanaNasif and Mkunguni are informal settlements while Kisuto is semi-formal in sense of inadequate infrastructure.
In 2008, the HanaNasif ward had a population of 40,754 which comprised 20,413 males and 20,341 females. The settlement is mixed socio-economically, containing people of higher socio economic status as well as government civil servants living in reasonable accommodation. The number of households were, in 2002, 8693 divided into 3401 houses and 186 ten-cell units. The average yearly growth rate for the last five years is calculated to 5.5%. [80]

Community services are provided by a number of committees such as; Kamati ya Elimu - Education Committee, Kamati ya Afya - Health Committee, Kamati ya Ulinzi - Security Committee, Kamati ya Ukinwmi - HIV AIDS Committee and Kamati ya Mazingira - Environmental Committee. Committees gather regularly once a month. [80] Two primary schools (Mkungumi and HanaNasif) and one secondary school (Tarimba) are located in the community.

The majority (90%) of houses in the settlement are built with sand-cement blocks and roofed with corrugated iron sheets. [80]

### 4.3.1 History

Before HanaNasif developed into an informal settlement, it was a swamp area with stagnant water. The land was principally used as a coconut and cashew nut plantation. Other crops as Cassava, sisal and rice were also cultivated.

In 1964, natives were kicked out of the area but in 1967 they returned, empowered, to acquire land. Houses were built of mud and wattle with coconut leaves for roofing. And at that time there were only three houses made of concrete and bricks. In 1971 more modern materials were introduced in house construction. At that time a concrete brick was sold for 20 TShs\(^{10}\).[79]

In 1992 the community mobilised themselves to build a drainage system. The construction works started in 1994 and the drainage system covers more than 2.5 kilometres. In 2000 the work was finished. Labour-Based Technology (LBT) and community contracts were used in executing the construction works. According to Sheuya (2004), the decision to use LBT and community contracts was made to create employment

\(^{10}\) 1000 TShs = USD 1 = 7.50 SEK (Nov 2008)
opportunities which would generate income for poor people, empower the community and build capacities of the stakeholders. In the project larger organisations as ILO, UNCHS and UCLAS provided the labourers with the technical assistance and the funds were provided by UNDP, the Ford foundation and the National Income Generation Programme (NIGP). [47] Further reading about Labour-Based Technology can be found in chapter 6.

4.3.2 Upgrading Programme

HanaNasif, one of the oldest informal settlements in Dar es Salaam, has been affected by a community based infrastructure upgrading project since 1995 and a wide range of transformation activities have taken place in terms of extensions and alterations.

The HanaNasif Settlement Upgrading Project was initiated by Women Advancement Trust (WAT)/Human Settlement Trust in 2003. WAT was funded by a Norwegian NGO, NBBL and Canadian Organization. The survey project covered the Mkunguni and HanaNasif sub-wards. During the project, 1131 out of 2729 houses were involved. Some other houses have been built in restricted areas and some have been surveyed by individual house owners. [9]

To make the implementation smooth and effective the local government carried out a campaign to mobilise the residents to participate. The initiative facilitated the reduction of boundaries disputes. The cost of the collective survey was 30,000 Tshs per plot compared to cost for individual surveys (about 500,000 TShs). 11

Development projects implemented so far in the HanaNasif area include:

- Construction of drainage system,
- Construction of water supply points (kiosks),
- Road construction

Since the upgrade of the drainage system it is claimed that none of the residents have been affected by floods as it earlier used to be quite common. According to the Mtaa-leaders of HanaNasif but a bit hard to believe, roads are passable throughout the year and, the water is now readily available at all times. As the infrastructure has been improved

11 1000 TShs = USD 1 = 7.50 SEK (Nov 2008)
the maintenance of buildings and the degree of informality have been reduced. [79]

According to the Commission on legal empowerment of the poor (2006), after executed survey of the HanaNasif area, values of plots have increased and residents are now guaranteed to receive fair compensation from the government if the area is needed for public use in the future.

As a result of having an area surveyed, boundary conflicts will be diminished since every individual will have a secured plot (rights of occupancy). Likewise, family income will increase since property owners will have reliable sources of income. Individual house owners would also be able to use their title deeds to secure loan from various financial institutions. [9]
5 Housing in informal settlements

The United Nations Habitat organization estimates that more than one billion people today live in urban settlements without security of tenure, sanitary facilities or infrastructural services such as drainage, clean water and roads. In Sub-Saharan Africa 72 per cent of the urban population live in “slums”. The equivalent figure for Asian cities is 42 per cent, while it is 32 in Latin America.[54]

More than 70% of the urban population in Dar es Salaam live in informal areas. According to Nguluma (2003), informal settlements in Tanzania diverge from settlements for low-income people in other parts of the third world, in three major ways; The diversified socio-economic situation of the residents, political land security and the use of permanent building materials.

*The diversified socio-economic situation of the residents in Tanzanian informal settlements is quite different than in other countries. In other countries there is often a strict demarcation of the different income-brackets while the informal settlements of Dar es Salaam often accommodate a variety of people with different income levels, although the least mature areas and settlements closest to the city seem to be occupied by low-income people.*

The *Political land security* differs as well, as the public security of tenure is typical in Tanzania where the government owns the land. People are residing illegally on the land but there is no party willing to evict people. Most people in rural areas inherit land. [86]

Most buildings in Tanzanian informal settlements are of better quality than in shanty towns of other African cities since they are often built with *permanent building materials* such as concrete, sand- cement blocks and corrugated iron sheets. Houses without permanent building materials are being improved over time through gradual development which depends on the financial and social status of the owner, but still there are houses built of temporary materials such as mud and poles. Regarding the materials used for buildings there are no big differences between formal and informal settlements, although in informally planned areas, the semi-permanent materials are more commonly used.
Many informal settlements have well functioning social institutions such as schools, dispensaries, restaurants and different types of shops. The major problem is mostly the lack of good public services such as low levels of infrastructure, poor sanitation, inadequate waste systems, and inadequate social services. Survival strategies that create multi functional house units are often built without adhering to regulations and building standards, which are inappropriate anyway. House extensions increase densities and cause more efficient use of land, low accessibility and poor internal circulation. According to Dr. Huba M. Nguluma houses in HanaNasif are compact, leaving limited space, although sufficient, around buildings and many houses are incomplete since the building process is incremental.

Houses in Dar es Salaam’s settlements are of a diverse design, ranging from single room expandable houses to simple huts and spacious two-storey buildings although the Swahili house is the dominant one. This is specific for Dar es Salaam. The standard of housing depends on the income of the dwellers. The house construction process is mainly financed through household resources and construction works are carried out by skilled or semi-skilled labourers. Formally trained architects, engineers or planners are involved only on rare occasions. [84]

Multi family household occupation characterises housing tenure in informal settlements and the majority of dwellers in Dar es Salaam informal settlements are tenants and generally they are willing to pay extra for better housing. The demand for affordable rental housing exceeds the supply. It is often more expensive to rent than own and house owners interviewed would like to extend their rental stock in order to generate a higher level of income. [85]

5.1 Planning policies

One of the main problems encountered by third world governments is how to deal with the cause and effects of slums and informal settlements. As well as in other cities, Dar es Salaams informally planned settlements are an intricate issue.

The Tanzanian National Human Settlement development policies shall;

- Promote development of human settlements that are sustainable
- Facilitate the provision of adequate and affordable shelter to all income groups in Tanzania.
In Dar es Salaam these goals are far away from fulfilment. In absence of formal affordable housing, the majority of the urban population has resolved to accommodate themselves in overcrowded and substandard dwellings mainly in informally planned areas. This may be because the government does not have enough resources to increase the housing standards?

### 5.1.1 Government Strategies

Initiatives taken by city authorities, with government backup, have not so far, yielded anticipated results. Urban planning and management policies have focused on the supply driven approach, provider models, which are characterised by the idea that ready-made standardised houses are produced for the masses. Since upgrading was not seriously implemented these strategies have yielded limited success in solving the problem with adequate housing, densification, nor directly benefit the poor. Current rates of urbanisation in Africa exhibiting problems such as high child mortality, low life expectancy, environmental hazards and poor housing combined with overcrowding. Even though urbanisation is linked with previously mentioned negative factors there are also positive ones. The life expectancy is low, but higher than in rural areas. Urbanisation promotes business activities which makes it possible for people to earn their living. The negative factors mentioned are similar to those of Western Europe during early industrialisation in the early 19th century. Unlike the west, rapid urban growth in Sub-Saharan Africa is not associated with economic development although the informal sector is fairly productive.[20] High growth rates, a consolidated building industry and a good tax base are among other, preconditions for the provider model to be successful. Those preconditions are hardly ever fulfilled in low-income countries such as Tanzania.[64] According to Vestbro (2008), Tanzania does not have, because of the large informal sector, a large enough construction industry which can build high standard modern houses even if the resources are available.

The government has in the past tried, although not very seriously, several strategies of improving urban informal settlements of Tanzania;

- **Land Regularisation of the 1950s:** The aim of urban housing policies during the colonial period was to facilitate political control and exploitation of natural resources for export to Europe and to pro-

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12 More than two persons per room.
provide housing to colonial administrators. The policies were based on racial segregation. A Royal Commission on Land and Population was appointed but although a comprehensive and reasonable guide to manage problems of land use, communications, industrial development, recommendations were merely shelved off. [47]

- Squatter clearance through the “Slum clearance programme” (1964-1969): The purpose of this strategy was to clear the land by demolishing the existing informal settlement and resettle the inhabitants. National Housing Corporation could not build enough units to accommodate all the affected families. The programme had small impact on the overall housing situation but it took forty years until the government realised that they could instead of demolishing, regularise and upgrade the settlements. [20]

- Direct housing provision, particularly through National Housing Corporation and “The squatter upgrading programme” (1974-1977, 1978-1981): in 1972 the government officially recognised the existence of informal settlements and with financial assistance from the World Bank another operation was introduced to benefit more than 600 000 low-income inhabitants. In this case house owners were not compensated for demolition of houses in order to relieve space for installation of infrastructure. The displaced inhabitants could therefore not build comparable houses that met the unrealistic, required building standards. Due to overrun of costs, the program was not implemented, the numbers of surveyed plots were reduced and some settlements were eliminated. [86]

- Community Infrastructure Upgrading Programme in The sustainable cities programme in Tanzania 1992-2003: The long term objective of this programme, sponsored by UN-Habitat and World Bank funding, was to improve the living standards and the economic conditions in 31 informally planned settlements in Dar es Salaam through the provision of basic infrastructures and services. Main transformation activities were upgrading of roads, footpaths, drainage, solid waste containers, street lights and public toilets. [56] The programme had difficulties applying upgrading in practice but the programme resulted in the Dar es Salaam Strategic Urban Development Plan in 1999 and the HanaNasif Com-
munity-Based Upgrading Project, described earlier. [47] It may be questionable and barely sustainable to base a programme on extended resources.

5.1.2 Enabling Strategies

The current approach of planning, which was officially established in 1994, generally involves three key-actors; local community based organisations, local governments and national/international donors, is supposed to be referred to as Enabling Strategies. The idea is to provide people with means for self-help instead of providing them with finished products, which will not contribute to further development of their knowhow. Enabling strategies is based on reaching sustainable development and that is in this case achieved by teaching the dwellers how to construct their own houses. Local governments are contributing with help through vocational training in construction and the community based organisations have different programmes with an enabling strategies approach. Even though they have several programmes, none in the HanaNasif area had any connection with house construction.

Even though the enabling strategies approach has been officially recognized since the mid 90s it has had a small effect. As many new ideas, enabling strategies has encountered difficulties in the introduction phase. There are many obstacles in the beginning of the process and often it may be a question of attitude among the decision makers. According to Vestbro (2008) it is because authorities in low-income countries do not understand, or are not interested in applying the enabling strategy, that the informal settlements continue to grow.[64]

The use of big donors for funding may not be in line with enabling strategies. Although, centralised coordination and resources for implementation may be needed for infrastructure services, for providing laws, access to land and credit. The challenge for authorities when handling the need of upgrading informal settlement is to know at what level to stop applying centralising techniques.

5.1.3 Ongoing programmes and activities

Citywide Strategy for the Upgrading of Unplanned and Unserviced Settlements in Dar es Salaam by 2015: The latest strategy is in line with two targets of the Millennium Development Goals. These are; Target 10: Reduce the proportion of people by half without sustainable access to safe drinking water and adequate sanitation by 2015 and Target 11: Achieve a significant improvement in the lives of at least 100 million
slum dwellers by 2020 which means that it approximately will cover 1/7 of the needs. The strategy is aimed at implementing urban policy reforms and to prepare a citywide upgrading programme, which will improve the living conditions of the urban poor. The estimated cost for the programme is approximately US$ 770,000. Positive capacity-building interventions regarding housing are that the private sector and NGOs will be involved in the preparation of the action plan to support the process and identify their areas of interest. [56] All actions are supposed to be designed with the objective of recovering cost and maximising local contributions. The intentions of the program will include local involvement and are inline with enabling strategies although it seems hard to fully eliminate the supply driven approach.

The government is now, in collaboration with development partners as UN-Habitat and the government of China, trying to address the housing difficulties. A large construction project, which will result in 40 low-cost high rise buildings, is soon expected to start. The project is aimed at improving housing and an accomplishment of the operation will spare 75% of the residents in Kinondoni, Temeke and Ilala from living under poor conditions. The idea is to grant poor women the use of an apartment, and give loan under special arrangements. [10] The fact is that Tanzanian construction business is mainly controlled by foreign consultants and large construction projects like this show a minimal involvement of local contractors or designers. The programme is completely based on the provider strategy and does not endorse knowledge improvements of local artisans. The figures of improvement seem a bit optimistic and costs of apartments will probably not be affordable for the low-income bracket.

5.2 National Institutions
Since independence there have been a number of government led initiatives geared towards reorganise the local construction industry. During the fieldwork we came across a number of National Institutions focusing on improving living conditions for the urban poor and upgrading building techniques in the informal settlements of Tanzania. Although Tanzania has made a change towards enabling strategies, some institutions are still practicing the modernist, provider model. So far it has been more initiatives than achievements, although some good intentions are noted. Below there is a selection of the most important institutions;
5.2.1 National Construction Council
The National Construction Council (NCC), half funded by the government, was established in 1981 to promote the development of the construction industry. NCC has established a central reservoir of information which stakeholders in the construction industry can refer upon. Examples are data banks on: prices of building materials, cost indices, research and construction activities, building materials, civil work contractors, civil engineering consultants and training institutions. [33]

An important aspect of NCC’s work is development and training for the informal construction industry through various courses. The council has also taken a leading role in promoting the use of locally produced building materials and adaptation of innovative technologies. [33]

The National Construction Council is in some of its practicing areas in line with the enabling strategies which will strengthen a sustainable local construction industry.

5.2.2 National Housing and Building Research Agency
The largest problems for the majority of dwellers in Tanzania have continuously been the high cost of construction and how to afford a decent shelter. These problems led to the formation of National Housing and Building Research Unit (NHBRU), in 1997. NHBRU later became The National Housing and Building Research Agency (NHBRA) and is a semi autonomous Government Executive Agency under the Ministry of Lands, Housing and Human Settlements Development and they are responsible for research on low cost housing.

The agency was established in 1997 and their main objectives are;

- To ensure that research results and technical information on Human Settlements Development is made available to everyone who needs them.
- To promote affordable and durable local building materials and associated technologies, and appropriate housing construction techniques.
- To provide building research consultancy services.

NHBRA also provides full training in; soil stabilised brick and burnt clay bricks making, building construction, the making of roofing tiles for
self help housing, and Day-to-day maintenance. Read appendix B & C for more details regarding soil stabilising bricks.

The NHBRA is an excellent example of practicing enabling strategies by developing affordable building techniques, providing local mafundi training and promoting new durable building materials.

5.2.3 National Housing Corporation

National Housing Corporation's mission is to provide and facilitate the provision of good quality housing and other buildings in Tanzania for use by members of the public for residential and for commercial purposes.

The Corporation (NHC), acting under the Ministry of Lands, Housing and Settlements Development, is a public enterprise, established in 1962 and reconstituted in its present form in 1990. As a part of the provider strategy, the purpose of the reconstitution was to enable NHC to play an aggregate role in the housing sector and enhance the limited traditional role of NHC of constructing low and medium cost houses for sale as well as for renting in urban areas.[63] A small number of units were built; no evictions were executed despite lack of rent payment which resulted in bad maintenance.[86] Also if rent is not paid the production of new housing will be affected.

The activity; Construction of Houses for Sale is the major role of NHC. Currently it is contributing with 12 per cent of the total capital although it has a very big growth potential given the high demand for housing in Urban Tanzania. [39]

5.2.4 Ardhi Institute

The Ardhi institute, now Ardhi University, (previously: UCLAS) was established in 1972 with the aim of training professional cadres for the development of human settlement sector. The college educates architects, town planners, land surveyors and building economics etc.

5.3 Regulations and standards

A constrained supply of informal urban housing entails slums in which people carry out housing activities. The main obstacle, despite the financial one, faced by house owners is to construct in line with building standards.[32] Despite lack of appropriate building regulations, people solve housing problems their own way. The necessity and the demand of an adjustment of Tanzanian building regulations have been thor-
oughly investigated by researchers and presented in official reports. Independently they described the importance to relax building regulations and to give more right to residents for participation.

The 90% decline in purchasing power over the last ten years, has also contributed to the fact that low income house owners have been ignoring formal planning standards and regulations, creating and adopting their own informal structures in order to get access to affordable housing. Transformations are done through informal arrangements with personnel of public utility. In consequence of incorrect use of materials, poor people often end up with unnecessarily expensive constructions. [23]

The ongoing UN-HABITAT project, Cities without slums, which includes Dar es Salaam, will review building codes and standards to improve affordability. Taking affordability into account in the lower segments of the target population, the revised building by-laws will focus on optimising standards for the health and safety of residents. The new regulations are expected to redefine the concept of dwellings, the amount of floor space required and the permissible plot coverage. The new adoption of performance standards for construction will allow for a greater range of materials and construction technologies and be more suitable for incremental housing development. [56]

5.3.1 Tanzanian Building Regulations

In 1997, the Tanzanian Building Regulations were developed to replace the old Township Building Rules Chapter 101 of 1930. The regulations are to be applied to all urban areas and are supposed to represent a standard of good practice to control all building development in the country and at the same time take into consideration relevant conditions such as technologies, climate, building materials etc. The purpose of the regulations was to ensure safety, health, welfare and accessibility of buildings as well as rational use of resources and energy conservation. The regulations are based on the British Standards and not really well adapted to local conditions which might be considered a problem; through revision the regulations could be more applicable. The regulations are divided into two parts. Part I applies for all non-structural and non-storied buildings of less than 280m² of ground floor area. Part II regulates all multi-storey and structural buildings with more than 280m² ground floor area. [62]
Since 1997, the regulations have had some minor complementary additions. The latest update, the Tanzanian building Regulations of 2001 require a building permit before erecting, converting, transforming or make any alterations of a structure of any building. Architectural and structural drawings shall also be submitted by the authority for approval. Residents in informal settlements are therefore advised to survey and set ownership before erecting buildings. Drawings are not handled by Municipal authorities unless they have stamps from an engineer, registered in the Architect and quantity surveyors registration board. The drawings will not gain legal force until they are also stamped by the Municipal council after receiving a building permit. [83]

To construct and erect a house in an informal settlement is often a prolonged process. Construction work should start within 12 months after the issuance of the building permit, but first, the owner must submit a written notice to the municipal authority with the expected start-up date. The construction work should also be carried out to completion in accordance with approved drawings in a reasonable time.[47] For the duration of the “reasonable time”, authorities normally specify a period of three years after receipt of the offer letter. As most houses (86%) get completed within a period of five to ten years the “reasonable time” does not meet the demands of the dwellers [32]. To comply with regulations, dwellers had to apply for a new building permit for every new phase of the transformation process. Penalty, if a house has been built without a permit, is 2 % of total cost. If the building is correctly constructed and not conflicting with land use or other regulations, a building permit can subsequently be applied for. [83]
The figure above shows the formal, and the alternative, informal procedures of land development. With the formal approach, the appropriate infrastructure can be provided before houses are built and people move on to land. The informal way is to inhabit a plot followed by constructing a house and then, if economical conditions allow, try to obtain legal land tenure. Infrastructure is often neglected and limited to vacant spaces.

5.4 House types

The present house types in the city centre of Dar es Salaam have been much influenced by colonial planning and by the 1891 building regulations for Dar es Salaam. During these regulations the planning ideas were mainly based on racial segregation and the city was divided into zones where various standards of buildings were applied. In recently developed informal settlements, houses have been developed with fairly low densities. Because of the mixture of different income-brackets in the settlements, dwellings differ from fairly large detached houses to small Mud-and-pole structures. [41]

When classifying house types, commonly categorisation is based on number of storeys, spatial organisation, use, and roof structure. House types found in informal settlements cannot always be categorised using the same criteria. [41] An identification of house types found in HanaNa-sif settlement in Dar es Salaam has been conducted by Dr Nguluma (2006). Her studies led to classification of the following house types;

- Urban Swahili house type (35%)
- Modified urban Swahili house type (20%)
- Rooms in line house type (15%)
- L-shaped house type (9%)
- U-shaped house type (11%)
Vertical extensions of the Urban Swahili House
Hanna Kruse & Lotta Torstensson

5 Housing in informal settlements

- Two storey house type (3%)
- “Other” house type (7%)

The denominations of the house types also summaries the main physical and layout characteristics of these houses. As for the city of Dar es Salaam, the Swahili house and the extended (modified?) Swahili house type dominates the housing stock. *The Swahili house and its variations are described more detailed below.*

### 5.4.1 The Swahili house

The Swahili house is found in the coastal and lake climatic zones. Its history goes as far back as the thirteenth century. At this period of time, the East African coast started getting populated with people from several ethnic groups, such as African, Arab, Persian and Indian [24]. According to Vestbro (1975), the origin of the Swahili house is thought to be both from the Swahili city states (stone buildings of foreign traders) and the circular Zaramo house made of grass. These house types may later be modified to accommodate Arabic culture and urban life.

![Image 14: A Swahili house with thatch roof at the Village museum in Dar es Salaam](Image)

*Photography: Lotta Torstensson*

Originally, the Zaramo tribe lived in fortified villages which amounted to wooden stockades with pointed tops and a wall of entangled torn bush which surrounded the villages. The rectangular shapes that later replaced the round houses and were referred to as the Swahili house, indicating that it not only exists in Zaramo territory, but all along the coast. (Swahili = coast). Rectangular shaped houses were also observed to be common all the way from Mozambique, in the south, to Somalia, in the north, which supports this theory.
In Today’s modified Swahili house, the layout has progressed from containing communal to more private dwelling spaces. The number of rooms is generally increasing as the size of a house enlarges. Variations of the spatial organisation are said to constitute upon the basic symmetrical principle.

The traditional urban Swahili House is characterised by its veranda in the front, three rooms on each side of a central corridor from which all rooms are accessed, and the backyard. The house type is in general spatially defined using these crucial qualities. The Swahili house is considered flexible because the ground plan can be changed within the limits of the basic structure. The addition of new rooms, changed positions of doors or windows has led to various forms diverging from the original house design. The advantages of the Swahili house compared to other house types are that it allows for flexibility in furnishing and functional use. Rooms can also be added at the main house or in the backyard.[40]

In most cases the Swahili houses are used for rental purposes. Each tenant occupies one or two rooms together with household members. It is also common that tenants and owners share the house and its communal spaces.

In original appearance the walls of the Swahili house are made of mud and poles and covered by a hipped roof. Small windows characterises the facades of these houses which are occasionally plastered. Foundations are often of coral plinths but can by advantage be replaced by a strong and durable soil foundation obtained with 10% cement. The facades are occasionally plastered. The mud-and-pole built Swahili House can still be found, especially along the seacoast.[41]

The construction of the Urban Swahili House has its origin in different mud-and-pole techniques which later developed into stone building techniques and towards the present technique mainly using sand-cement blocks. When it comes to new modern buildings erected in informal areas, the sand-cement blocks are almost exclusively used. The spatial characteristics of the urban Swahili house are similar to the Swahili house.[40]

According to Vestbro (1975) the Urban Swahili House are defined as being a multi-family unit of at least four rooms. Distinguishing features of the house are:
- Multifamily unit – savings by sharing spaces
- Overcrowded but affordable
- Built by self-learnt local craftsmen
- Stimulates small scale house owners to provide rental accommodation
- Adaptable design, suitable for self-help and use of outdoor space

Image 15: A typical urban Swahili house in HanaNasif informal settlement area

Photography: Lotta Torstensson

The Modified Urban Swahili house is a combination of different house types, usually a combination of the urban Swahili House type and the room in line house type. According to Nguluma, if two out of the five major characteristics of the urban Swahili house are fulfilled, the house type is classified as a modified Swahili house. Like the “ordinary” urban Swahili house, the modified urban Swahili House accommodates tenants, owners or both. [40]

The Swahili house, the urban Swahili house and the modified urban Swahili house are all double banked and because of this it is not easy to facilitate cross ventilation. Multiple use of space such as cooking in bedrooms exposes occupants to health detrimental and the addition of rooms increases problems of ventilation.
Spatial Design

The space of the Swahili house is divided into four categories; indoor, outdoor, private and public. In the front, the public outdoor space of the house is found and at the back; the private. The backyard is occasionally enclosed by a fence and within it, kitchen, storage and toilet facilities are located. Outdoor spaces serve an important function and are areas for work, socialising and preparing meals. The courtyard was traditionally used for most of the household activities while the veranda was used by males for guest entertainment. Because of the increase of mixed cultures, traditions and customs found in urban areas nowadays, this pattern is gradually changing.[43] The layout, shape and form are based on the same principles as the Zaramo house, only a larger number of rooms with the provision of a courtyard and outdoor building is what differs.[86]

The rooms are relatively large and quadratic, approximately measuring 4 x 4 meters, formed by the limited rafter span of the mangrove poles used in traditional buildings. The arrangement of rooms allows for the division of the house into various combinations of household units. The central corridor is used as a passage, for storage, for personal interaction and occasionally it serves as the kitchen.[63]
A modified urban Swahili house type could be of the original spatial organisation of the traditional house or be a result of larger transformation activities in terms of extensions and alterations [41]. Adjustments can be limited and consist of changes in door and window openings. When the owner and its family are the only residents in a modified urban Swahili house, the backyard is fenced in which indicates that it is for private purposes only. The social interaction with neighbours is narrow compared to when the house accommodates tenants. In that case the backyard is rather for joint use. When houses accommodate both tenants and owner, indoor and outdoor spaces are also shared.

Even though transformation activities are taking place there are often elements of the original Swahili house that do not change. According to Nguluma (2003), the corridor is one of those important elements, since it is used for socialising and gives easy access to rooms with possibilities to let without interfering with other residents. [40]

The “modern” layout of the Swahili house originates from the modified urban Swahili House type and its layout is shown in the drawing below.

![Sketch of a modern layout for the Swahili house type.](image)

**Figure 3: Sketch of a modern layout for the Swahili house type.**

**Source:** Mgube, Mr Gilbert. (2008)

The two rooms closest to the entrance are replaced by a kitchen/dining room and a lounge room.[73] This fieldwork and earlier studies has shown that a self-contained house, where toilet, kitchen and bathroom are located inside the main house, is considered modern and preferred
by HanaNasif residents. Nevertheless, its spatial design would decrease the area available for tenants, and so also the household income.

5.5 Standardised house design

In 1962, president Nyerere outlined a programme of slum-clearance in order to replace what was considered to be unhygienic and technical deficient houses. National housing Corporation was established to coordinate low-cost housing on a national level. According to a five-year-plan, 5000 mud-and-pole houses in Dar es Salaam were to be pulled down and replaced with new durable structures. The program consisted of replacing the mud-and-pole structured house with a concrete block structure of the same or similar spatial organisation. For the replacement twelve low-cost house types were designed. With one exception, these designs were closely related to the privately built Swahili house type. Seven of the house types were all variations of what was earlier called the urban Swahili type house. [63]

The NHC low-cost house constructions consisted of a concrete slab foundation, plastered and painted concrete block walls, hard-board ceilings, sawed timber for joineries and a roofing of bush poles bearing corrugated metal sheets. At the beginning, attempts were made to use self-help volunteers supervised by the NHC for the construction work. This attempt failed mainly due to bad discipline. [63]

During the first five years of the slum-clearance policy, the housing deficit accumulated instead of being reduced. With some adjustments for planned roads, new houses were built at the same place as the old ones. The later results of the policy were in some areas a decisive upgrade in terms of accessibility for cars and sanitary standard. [63] The outcome of the slum-clearance project may have contributed to negative attitudes towards standardised house design. Similar houses jointly situated in large areas are perceived as creating a “ghetto” image [72].
Currently, the NHC is constructing two types of houses for sale, in Mbweni, Dar es Salaam. Compared to the project described earlier, this concept is a very different attempt to solve the urgent housing need. The types of houses that are being constructed in this estate are up-market bungalows and double storey houses. These houses are constructed in medium density plots. The estate is serviced with fully developed on- and off-site infrastructure that includes water, electricity and estate roads. The design ranges from three to four bedroom houses. [39]

The current project seems controversial since the NHC was established to construct low cost houses for the urban low and middle income people. The ready-made houses, provided by NHC, are in most cases too expensive for families in informal settlements. The production does not involve local participation or opportunities to reduce cost by using self-help. Very few possess the cash in hand needed for buying the house units. Since only a small number of dwellers want or are in the position to be able to loan money from banks, incremental development are the single alternative for poor people to put up a decent dwelling.

Standardised house types are described below; [39]
Figure 5: Double storey House (Type MB1): The ground floor of the house consists of a sizeable sitting-room, dining-room, one en-suite bedroom, kitchen, store, carport, toilet and bathroom. The first floor consists of a bathroom, toilet and three bedrooms one of which is en-suite. The size of the house is 420 m\(^2\). Price: USD 140 000\(^{13}\).

Figure 6: Bungalow (Type MB2): The house consists of three bedrooms one of which is en-suite, sitting–room, dining–room, kitchen, store, carport, toilet and bathroom. The size of the house is 203 m\(^2\). Price: USD 72 000\(^{14}\).

In previous attempts to use standardised house design, the provider model have been practiced for implementation. House units were fabricated through centralised production, based on a consolidated building industry. The process comprised a minimal participation of local artisans.

During the slum clearance programme houses that were built were all single storey units and population density were decreased instead of increased which is needed. Neither will the ongoing project result in improvements within that field since it is focused on constructing up-market bungalows constructed in medium density plots which are not in any way affordable for the urban poor. Also this example illustrates the urgent need for affordable two-storey house constructions.

\(^{13}\) TShs 140,000,000 = USD 140 000 = 1 050 000 SEK (Nov 2008)

\(^{14}\) TShs 72,000,000 = USD 72 000 = 540 000 SEK (Nov 2008)
6 Local construction situation

The gap between the formal and informal construction sector in Tanzania is considerable. A major part, 80%, of the domestic construction industry, is considered informal. The imbalance between the parts and the importance of informal construction workers in Tanzania has been clarified in working papers by International Labour Organisation, ILO and the domestic National Housing and Building Research Agency, NHBRA. The reports indicate that an increased interchange between the parts may help to strengthen the informal sector.

To describe difficulties faced by the informal and formal construction sector in Tanzania, the introduction of this chapter illustrates the overall construction situation of the country. The following parts will further investigate the small scale construction works mainly performed informally.

In IET Newsletter Issue 1 2008, published by The Institution of Engineers in Tanzania, it is reported that the volume of construction in Tanzania is estimated as US$ 600-700 millions per year as a total. Over 70% of the construction business is controlled by foreign contractors and consultants. Local firms handle small and minor work projects and there is stiff competition between firms as well as low profitability. Despite a large number of firms, the combined capacity, resources and skills are too weak to meet the market demand for large projects. Globalisation has exposed local consultants and contractors to greater international competition with lack of investment capital as the major challenge.
Current ongoing larger construction projects in Tanzania show a minimal involvement of local contractors. Their lack of involvement decrease exchange of knowledge and may lead to absence of capacity and competitiveness improvements of the local contactors. These are some of the challenges to capacity building of local consultants and contractors in the constructing industry in Tanzania described in the article written by Professor Mawenya, A S. [31]

Worldwide, construction sector is considered to be one of the most corrupt of all sectors. The problem is most acute in developing countries, where corruption often accounts for leakages of 20% or more. As a result, project planning is distorted, construction quality undermined, maintenance neglected and professional standards compromised. In Tanzania, corruption is widespread in public procurement and contracting, involving an estimated 70% of all contracts. It manifests itself in all stages of the construction project and causes huge economic losses to the country. Many construction costs suffer from unjustified cost variations that end up with the government paying up unjustifiable sums. Philip Marmo, the Minister of State in the Prime Ministers Office responsible for Parliamentary Affairs, expounded that “Corruption in the construction sector has reached shocking levels and bribery was fast growing in the construction of public buildings and roads”. If companies which have won tenders to execute the jobs keep bringing about costly variations such that the projects end up costing far more than the contracted sum may be a signal for the existence of corruption.[14] In donor funded projects corruption often appears as imperfect competition and results in lack of confidence to work carried out by local consultants and contractors. [18]

The informal construction sector in Dar es Salaam consists primarily of small-scale units, groups or individuals, established for the purpose of creating their own employment and income by selling labour or construction materials. The informality of the sector is demonstrated by the way the agreements are made between the construction workers and their clients, who are generally private house owners. They make verbal agreements without any legal enforcement, often leading to loss of benefits in the process.

The formal construction industry has a large contribution to the country’s overall development. The impact on social and economic development is significant. On average the contribution of the sector to the GDP ranges between 4 and 5%. [46] The figures could be compared to indus-
trial countries like Sweden where the percentage has been stable over the years at about 10% of the GDP. Hence, recent years have seen a decrease of the contribution which is still large but now approximately 8%. [7] The informal sector is referred to as informal because the units are not registered and not recorded in any official statistics. The sector is increasingly perceived as one of the key factors in future economic prosperity.[19] If the informal construction industry in Tanzania would be included in the GDP, the contribution to development may increase considerably.

A number of construction sector institutions, for example, the Building Research Unit and the National Construction Council have been created with international assistance from Sweden, Norway and Finland. Their biggest mistake during the years, concluded after evaluation by Sida, was to ignore the 80% of the construction industry that is informal. The International Labour Organisation (ILO) therefore attempted to redress this imbalance with the project “Informal Constructions workers in Dar es Salaam, Tanzania”, in 2007. [18] The interesting objectives of the project was to help informal construction workers to work together to identify and address key problems that they face in their working lives. It was also aimed at building the capacity of the local actors, using workshops, so that they can carry on after the end of the project. [18] In small scale, this concept could also be used to introduce mafundi in construction of a vertically extended Swahili house. Training of local artisans is further discussed in chapter 6.3.

6.1 Labour-based technology (LBT)

If making a comparison, the major difference between construction sites in Tanzania compared to sites in an industrialised country, is the amount of workers at site. The concept is called labour-intensive or labour-based technology and is defined in the theory chapter. [1]

The labour based technology in Tanzania expresses, not very surprisingly, a high demand of manual labour. Concrete trucks and cranes for construction are rare, even at large formal construction sites in Dar es Salaam. Materials, tools and building element are transported entirely using manual labour (see image below). Wheelbarrows are occasionally used to transport materials but construction lifts are rarely present at sites. The LBT itself increase the extent of employment and contributes to poverty eradication.
The state of labour-based technology in Tanzania has been analysed by the International Labour Organisation and is described in the report; *A Review of Current Practice since 2005*. According to the review, there have been joint efforts towards promoting maximizing and mainstreaming the use of LBT in the country, since realizing the potential of Labour Based Technology in infrastructural works and poverty reduction. [1]

To develop the domestic construction sector there are problems to overcome. Expert’s negative attitude to the informal sector, lack of understanding of affordable solutions and enabling strategies may be important issues to solve.[86]

### 6.1.1 Management & site supervision

A problem with labour-based technology is the high demand of supervision at construction sites. [82] The system of paying labour by piece work may generate incentives for efficacy, at the expense of outcome quality. Cash payment on a daily basis would on the other hand slow down the construction process. A balance between these two principles might be an approach to attempt to solve the problem, but that could be hard to accomplish.

According to the National Housing and Building Research Agency (*NHBRA*); the labour-based technology used in Tanzania confronts following major difficulties;

**Planning**

Overall delays are consequences of poor purchasing procedures, lack of prior planning and the fact that critical activities are not identified in early stages. [6]
Supervision and Foremen

Generally building sites in Tanzania have, due to shortage of funds, an insufficient number of supervisors compared to the very large quantity of workers. According to NHBRA, most local foremen have no training in supervision and some cannot read and understand drawings. In complex projects, poor supervision leads to that work have to be redone several times which will reduce productivity and increase wastage of materials. [6]

Transport

Sites often lack temporary roads and poor site layout leads to excessive double handling of materials. Local labour is being used to cut costs for transport.

Labour

The large amounts of workers can at times cause conflicts in forms of free space and logistics, which in its turn increase the demands for advanced site-management. Workers are switched randomly from one work to another, and may therefore as a result never be able to become familiar with any activity [6]. Due to workers lack of commitment, a Foreman is almost always needed. When hiring concrete workers it is absolutely necessary to employ the union leader to control them. Nearly all site workers are casually employed which makes it difficult for them to prepare for work the next day, because they simply does not know if they are going to have one [6].

Tools and usage of tools

Shortage of tools and use of unsuitable tools are common. If there are mechanical tools available, there are often problem how to handle them properly. Inefficient uses of concrete and mortar mixers often appear. One explanation to the poor handling skills of tools is that they have been provided with the tools without getting any training in how to use them.[6] This could be a result of the earlier provider approach of assistance as development agencies have sent their own staff, tools and techniques to build houses for the poor through different projects [28].

Materials and water

Water supply is not regular which for instance makes watering during mixing and curing of concrete unreliable. The awareness of changes in weather, well-known by locals, is also important to estimate the most suitable time for concrete works. Due to the lack of cover ups, it is vital
to avoid heavy rains during early stages of curing. Quality of water could also be a problem in some areas. For example when mixing concrete, it is important to minimise the salt content of the water.[82]

Security
Building materials and tools can not be left on site unguarded, not even during daytime. Workers have been caught stealing or hiding materials from site.15 [82]

6.1.2 Quality control
Quality control of materials is a huge problem in Tanzania. Despite the problem of knowing actual quality of bought goods, contractors also have to assure that the materials bought are the same that actually reach the building site.

Mafundi interviewed assert that at large, formal construction sites, work is done according to regulations and drawings. Samples from every mix of concrete and every set of blocks are to be tested at the Material testing lab at the College of Engineering. Interviews and test examples at the testing lab indicate that is often only two or five blocks that are actually being tested. These samples, which quality in most cases varies a lot, will verify the average strength of the whole load of blocks. [77] Test results examples can be found in appendix C. To simplify the process and to ensure correct mixing of concrete and at informal construction sites, it is said that the amount of labour hired are commonly being adjusted to the current concrete mixture. If a 1:2:6 concrete mixture is used, one worker carry cement, two men carries sand and six carries aggregates to the mixer.

At informal construction sites, normally, Mafundi works by experience learnt from years of practise at formal and informal sites. Since there are no written contracts, officially Mafundi are never to be held responsible for their constructions. Quality in terms of durability is often compromised and rationalized. For example; to cut costs when making concrete, clients often want to mix cement with a larger amount of sand. According to Mafundi interviewed, although knowing that reduced cement percentage will decrease the load bearing capacity and quality of the concrete, they hardly ever refuse to comply with clients, but will call

15 Stolen cement are later sold at the price of TShs 5000 per bag instead of TShs 13 500.
in question. Informally, the fundi is responsible for quality six months after completing the structure.

Many informal construction sites experience deficient water supply. When making and curing concrete, craftsmen are left to rely on local knowledge about weather and time for the next expected rainfall.

According to regulations, all building sites are to be controlled by the municipal engineer before every major action. Workmanship is compared to the drawings at these stages; setting out, foundation excavation, building to column footing, reinforcement’s column bases and ground beams, concreting, block work to plinth-level, concrete over site, ground floor column, reinforcement, shuttering, steel fixing, drains and external finish. Municipal inspections are rarely carried out for regular single storey buildings in informal settlements. While other constructions than single storey houses are unusual in informally planned areas, it is very likely that municipality pay attention to, and demand regulations to be followed for those kinds of houses.

6.2 Informal construction workers and artisans - Mafundi

There are many ways of getting into the informal construction sector. Some workers are introduced into the sector through friends or parents; some have other relatives as apprentices. Others enter the industry through their own volition. The reason is often economic hardship.

The population of informal construction workers in Dar es Salaam has in 2007 been identified by International Labour organization. The report, “Informal Constructions workers in Dar es Salaam, Tanzania” presents findings from a Participatory Action Research project in Dar es Salaam. The project was able to identify a total of 26,383 informal construction workers in Dar es Salaam. 74% (7 799) of the 10 510 found in the Kinondoni district were classified as unskilled 16. [18] The study aims at addressing difficulties, gather workers at the grass roots and mobilize them through a participatory approach. The negative aspects of mafundi business and the results of the project are further described later in this chapter.

To operate successfully as artisans in the informal sector young people require a range of knowledge and skills. The main part the informal construction workers acquire their skills informally by word to mouth

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16 Unskilled labour has not participated in organised training of any kind. Includes material producers such as sand diggers, stone crushers and helpers.
and gain experience through working with experienced fundi before becoming independent. [18] The construction workforce in Dar es Salaam consists largely of migrants from rural areas. Most of them have finished their primary education and have had some informal training from their fathers or other relatives for another five to six years. 90% of them joined the industry after completion of primary education. The informal construction sector absorbs a lot of unskilled labour without further education. The fact that many workers join the construction sector due to lack of employment opportunities in other sectors makes a negative selection. Many workers would like to further extend their skills by getting formal training both theoretically at college and on sites.

The 1991 informal sector survey showed that 95% of mafundi serve their customers within their local areas. Mafundi interviewed in present study were predominantly selling their labour to private dwellers. Employment is based on informal, verbal agreements between the workers and the client, who may be a contractor or sub contractor but is more often a private house owner. Building owners buy the material required for the construction and hire the workers as they are needed. A fundi often act as a foreman, assist house owners in purchasing building materials and hire a selection of skilled and unskilled workers. [81] Masons tend to become leaders in the building process and may affect the choice of other mafundi like plumbers, carpenters and electricians. The informal construction workers get no protection from any regulatory authorities. They are exposed to harmful work practices without any compensation or insurance in case of accidents.

Multiple occupations of mafundi are found to be the norm. This may be due to seasonal variations in demand. Construction activity slows down during the rainy season and many construction workers switch to other activities such as farming, fishing or petty trading. [18]

In Dr Nguluma’s study it was noted that the role of architects and engineers are marginalized by the fundi. For transformations and single storey houses, the fundi and house owners normally take care of the design. The fundi normally build without any drawings. A fundi may also assist developers in the design stage by looking at the site and advising the client on the appropriate orientation of the building, number of rooms and sizes. Usually the design does not include much more than the size of the house, number of rooms and the type of house.
When aspects are agreed upon, the fundi use his standard solution for technical problems and details.

The methods of payment are informal. Most workers are paid on the basis of a completed task. Depending on the preference of the contractor, the type of work and the building owner, payment can also be based on time or piecework. Monthly payment is very rare. Often payment is made when work is finished. Workers paid on a time basis are usually paid daily. The informal construction workers can stay without work for long periods of time and are paid only when work is available. The earnings of construction workers fluctuate widely according to the availability of work. [18]
Most Mafundi are experts on their special field of construction and are not very familiar with the overall process. Erecting a house will therefore involve a large number of workers which would bring problems concerning management and logistics as described in the previous chapter.

A number of difficulties in construction work were identified by the informal construction workers themselves in a workshop arranged by the ILO. The problems are the following: irregular job availability which in turn creates uncertain and fluctuating income, lack of permanent premises for their businesses, poor working tools, lack of insurance (social security), lack of protective gear leading to unsafe work, lack of formal training, lack of recognition, low payments, delayed payments, lack of business knowledge, knowledge of their labour rights, lack of access to credit facilities. The core problem facing the informal construction workers were addressed as the scarcity of jobs. The inadequate market for their services is supposed to be an effect of the common negative attitude that is linked to their workmanship. The failure of the Government to recognize the informal construction workers was also perceived to be hampering their ability to gain access to technical assistance, credit and other inputs, as well as to gain access to public sector contracts. It also became apparent during the workshop that the existing legal and regulatory frameworks are unknown to informal construction workers and not readily applied to this part of the industry. The capacity building, or action phase of the ILO project was aimed at facing the problems addressed by the participants and enable informal construction workers to get better access to the markets. [18] The vision was that with the acquisition of formal training, both theoretical and practical, the construction workers would improve their workmanship and this would lead to increased earnings. Problems were encountered and it was concluded that informal construction workers are generally unable to meet even the ancillary costs\textsuperscript{17} of technical training. Such training has therefore been subsidised. The impact of training on earnings is yet to be established.

\textsuperscript{17} Some students could not afford the daily bus fare to the training centre, others could not raise the money needed to meet certain requirements of the training institute, for example photographs for identity cards, examination forms and overcoats.
Lack of organization among informal construction workers is also a barrier to finding solutions to the problems. As for other categories of workers in Tanzania, the rights of informal artisans are limited. Yet, less than 5 percent of the labour force is linked to a union. [13]

The main conclusion of the study is that policy changes are needed to improve the situation for formal construction workers of Dar es Salaam. Political will is needed for opportunities to be taken advantage of. Yet, present study shows that short practical training could have an impact on mafundi skill and business. Effects of courses and problems concerning gathering and attracting mafundi are discussed in the following chapter.

6.3 Capacity building

The higher learning institutions including the College of Engineering and Technology of the University of Dar es Salaam and Dar es Salaam Institute of Technology have training modules on LBT in the undergraduate and post graduate courses. [1] Although universities expand their study programmes, supply of certified architects and registered engineers in Tanzania still do not meet with the demand.

According to the 1991 census data, the Tanzanian formal sector was estimated only capable of absorbing between 7 to 10% of the new entrants into the labour market. Formalised training for the formal sector is a national requirement however it has only a very limited relevance for the employment chances of the majority of people who generally have no access to training. Even though, there are a number of competent Mafundi who have learnt their trade on the job, it is clear that many more are needed. This underlines the need for suitable training.

As a supplement to the formal training, integrated non-formal training can help to qualify various target groups to acquire technical, business and communication skills. According to ILO, the training has to be job- and market-related, short and inexpensive. Institutions that provide theory and practical training in LBT and inline with enabling strategies include NHBRA, NCC and Vocational and Educational Training Authority (VETA). [1]
The study “The education and training of artisans for the informal sector in Tanzania” by Kent, David W. & Mushi, Paul S. D. (1996), examines both the structures and processes that assist in the training of youth who aspire to become artisans working in the informal sector and the operational characteristics of subsistence and small-scale enterprises. The research provides a composite picture of the factors which influence education and training in the context of the informal sector. [19]

The establishment of the Vocational Training Centres and improvement of training institutes and universities has not been enough to eliminate the shortage of skilled manpower. When introducing a new building technique, such as the soil-cement interlocking brick-technique, a training programme for local mafundi could speed up the development and propagate the availability and knowledge. Some kind of training has been held occasionally by NHBRA, COET and local skilled Mafundi. The outcome of such training has been studied by evaluation of a seven days course held in Bagamoyo by local fundi at the request of College of Engineering and Technology in Dar es Salaam. After participation in the course it was simple for mafundi to proceed with brick production without supervision. Some mafundi bought interlocking brick machines for their own housing projects. According to fundi, generally the tech-
Technology is now spreading and many people are becoming aware and interested in the technology since it is cheaper compared to the previously used standard techniques. There are still problems to overcome such as gathering and attracting unskilled and semi-skilled labour to such training and to find incentives for artisans to buy new machines for the technical change. In present situation, the market price of interlocking soil-cement bricks is high, due to poor availability. These facts reduce the cost-efficiency of the building technique which could be more affordable if widely spread.[74]

The earlier described ILO-project “Informal Constructions workers in Dar es Salaam, Tanzania” could be adjusted to build the capacity of the local actors in the area of two-storey constructions.

6.3.1 Vocational Education and Training Authority (VETA)

The authority is by the 1994 Act of Parliament, an autonomous government agency which provides basic and specialized training to meet the need of both the formal and informal sector. A decentralised, regionally based vocational education and training system is set up to meet locally identified requirements for skilled training and craftsmanship.

The Dar es Salaam Regional Vocational Training and Services centre provide vocational training courses for civil trades. Courses aim at integrating business and entrepreneurial skills, trade calculations, English, engineering science, technical drawings to address real work situations and translation of vocation skills into business enterprises. Training in civil trades include: construction skills (masonry and blocking), specialized woodwork skills (carpentry and joinery), painting and decoration, along with civil draught. [65]

According to the ILO, the informal construction workers do not use VETA-centres because they cannot afford the fees for training or the time away from work.

6.3.2 Ardhi Institute

The Ardhi institute, now Ardhi University, (previously: UCLAS) was established in 1972 with the aim of training professional cadres for the development of human settlement sector. The college educates architects, town planners, land surveyors and building economics etc.
6.4 **Self-Help**

Self-help as in self construction is very rare today in Dar es Salaam informal settlements. Some assert that self-help in terms of building your own house does not exist as well as there is no culture of maintenance.[73] This could be an affect of authority failure of specific planning and building standards for housing in line with the available resources.

Yet, family help can reduce costs for construction. In early stages of development, block production showed that family labour could replace wage labour and save expenses for poor households during the construction process.

In the question of transformation progresses observed in Dr Nguluma’s study, the execution phase were done by both the owner and the fundi while the actual construction work normally were carried out by the fundi. 98% of the residents interviewed in the study said that the construction activity was done by the fundi, while only two owners who are mafundi themselves carried out the transformation activity. Finishing were also generally done by the fundi especially floor screed, plastering and painting.

The fact that labour costs are small compared to the costs of materials, could explain why house owners hire mafundi instead of constructing buildings themselves.

6.5 **The small scale construction process**

To construct and put up a house in an informal settlement is often a prolonged, incremental process.

Usually when erecting a regular single storey house in an informal settlement there is no involvement of professional contractors or civil engineers. The direct actors in the informal housing construction are mafundi, labourers and house owners. The house owner is usually the manager of the whole process and the one that initiates the job while carrying out most of the preparations before construction. The role of the owner is to plan for the transformation process while the fundi plans for the execution of the work. Some owners and even tenants play the role of fundi, as they possess building skills, thus participating fully in the whole process of transformation. Salaries and income from small
businesses constitute the major sources of incomes for housing transformation in HanaNasif. [40]

Construction processes often start with collecting and production of building materials. Those families who are financially stronger than the average prefer to buy already produced concrete blocks. However, those who are poorer may start the process by collecting sand, then buying one or more bags of cement, hiring a *fundis* to produce concrete blocks. Cement blocks could thus be produced in small numbers until the desired number is achieved.[40] This procedures can in advantage still be followed when producing soil cement bricks. Purchase of corrugated iron sheets and timber for the roof structure are also often made in small numbers until the targeted number is attained.

According to Shuyua (2004), the construction of a Swahili house can be divided in two main phases; the first is referred to as the start-up phase and the second as the transformation phase. In the start-up phase dwellers have to consider the location of the house in relation to the sides of the plot. The second consideration is whether to start constructing the main house or the outlaying buildings. The existing finances control whether to begin with temporary or permanent construction materials. The *transformation phase of house construction is elaborated below.*

### 6.5.1 Transformations

Motives for carrying out house transformations are primary; to earn income through letting out rooms, accommodate children and relatives, provide working spaces for household members, build durable houses or to provide social infrastructure.[47]

According to Dr Nguluma there are several different ways of transforming existing houses in informal settlements. Her study identifies three main transformation methods. The first method is to completely remove the old structure and replace it with a new one. It can be carried out by putting up the new structure around the existing. The remaining part of the transformation is to tear down the old structure and start building the foundation. After foundation works are completed, erecting the partitioning walls could start. This method is appropriate since no temporary accommodation during the first stage of the construction works will be needed. Problems with accommodation will not appear until reaching the phase of putting up the partitioning walls. Problems might appear in terms of safety. Since new houses are being built...
around the old ones while people still live there, it is a risk that walls might collapse and cause injuries. During fieldwork it was observed that this method seemed to be the most popular way of transforming old structures. Several mud and pole structures with one or perhaps only half a brick wall finished were found. Many of the extensions seemed like they had been interrupted a long time ago.

The second technique used is to transform existing houses in different stages by replacing one room at a time with the new structure. This technique does not require all funds at once and thereby no stress is put upon the owner of the house. Choosing this technique of transformation, space has to be put off in favour of construction works. This means that space will be cramped during this period. Reasons for transforming houses are the lack of indoor space and as transformations take place, the size of rooms are often also increased. This in its turn leads to reduction of outdoor space.

The third technique studied by Dr Nguluma is of an entirely different kind and it is only available for those with large plots. The technique is to build an entirely new structure beside the old one which can be done in several stages. The initial building could be a smaller complex and as funds are raised, further extensions could be added to the structure. The old mud-and-pole structure is; demolished, used to accommodate family members as families grow, or is given up for renting purposes.

These three transformation processes are all concentrated on horizontal extensions which results in reduction of outdoor space. Backyard areas used for social purposes, cooking and cleaning etc. are diminishing as transformations take place. A vertical extension of the urban Swahili house type might be a solution to avoid these problems.
As moving around in the HanaNasif area, only a couple of vertical extended structures were found. This may not come as a surprise since it, to construct a two-storey building, requires more advanced building techniques, skills of labour and larger funds than when using conventional methods of construction. [41] Building techniques of present two-storey houses will be evaluated in the following chapter.

6.6 Building techniques

Through generations, the skills of constructing a house, has passed from one to another by practical participation\textsuperscript{18}. The shape and layout of the Swahili house were known by heart which planning no problem. The change from rural to urban society now compels change in practice and building design.

Traditionally build houses are often not subsistent to the high moisture content of the air, the heavy rainfalls and the high amount noxious

\textsuperscript{18} Learning through practical participation may also be referred to as self-help.
animals\textsuperscript{19} that characterises the local climate. Therefore these structures require more regular maintenance than modern buildings. If the building materials are locally available the maintenance is easy, but in urban centres traditional materials are not always easy to get hold of.

As described earlier, the technology level used by informal construction workers is considered to be very varied and occasionally unsatisfying for the project performed. Mafundi’s knowledge on issues pertaining to their trades and tools used in executing their works may be very crude. Informal construction workers often back away from open competition due to lack of confidence regarding quality of their work, perhaps as a result of low technical knowledge and lack of formal training. [18]

It is crucial to involve local mafundi in the development and adaption of traditional technologies to the urban society and local climate. Suitable training is essential to strengthen their confidence and belief in the qualities of their constructions. It is vital to take advantage of local knowledge and to combine it with improved techniques to provide durable houses and sustainable development.

6.6.1 Mud’n wattle

The mud-and-pole or mud’n wattle construction technique is the most commonly used in the traditional Swahili House and walls based on soil has for a long period of time been the only realistic alternative for the majority of low-cost housing. The mud’n wattle construction is most common in Tanzanian rural areas but can still be found in the urban informal settlements in Dar es Salaam. The technique is even said to be outdated and no longer considered as a sustainable form of construction for the urban society.

The walls are usually made from poles, saplings, covered with mud. Occasionally various stones are used as wall supplement. The choice of poles depends on the availability but normally consists of sisal, bamboo or mangrove. The roofing cover is typically woven palm leaves, makuti. The life-span of a mud’n wattle house is relatively short and often due to lack of foundation, limited to around five years, depending on climate and workmanship. The pole structure is rapidly deteriorating if not using termite resistant poles such as mangrove poles. The mud is usually mixed with cow dung or ant-hill soil which is not very damp

\textsuperscript{19} Noxious animal contributes to the degradation process of mud’n pole structures and soft wood.
resistant. The durability of the walls could be improved by using cement or lime based plasterers. Lime based plasters often provide better adherence to the wall compared to cement based plasters that often crack and deteriorate.[3]
crafted by the NHBRA, due to lack of capital and capacity. There is also phlegm among dwellers when introducing techniques not commonly used. Further reading on soil-cement bricks are found in chapter 7.

6.6.3 Two-storey constructions

Two storey houses are rare in informal settlements. This is mainly because construction techniques are expensive, generally material consuming and the workmanship is not normally carried out by local artisans.

Image 22: Woman showing the stairs to the upper storey in a Hana Nasif two storey building
Photography: Lotta Torstensson

In HanaNasif, out of 3401\textsuperscript{20} houses, less than ten two-storey houses are found. Some of those houses were built with only one storey at first but were, after time, converted into two-storey houses. One house visited had even been constructed to carry the load of three storeys. The only building technique observed in two storey constructions was a structure of reinforced concrete pillars and beams. The intermediate floor slab was made of reinforced concrete constructed with softwood mouldings. To increase incentives for two storey houses, building techniques has to be developed to be affordable for people with low incomes and simple enough for the local craftsman (Fundì) to build.

In contradiction to the commonly opinion, Dr. Huba M. Nguluma’s study and performed fieldwork indicates there are Mafundi who controls techniques used for two storey-buildings. In Dr. Huba M. Nguluma’s study it is noted that in two-storey houses, which require reinforcement, contractors were not used; it was only a fundì who was involved. However, mafundi interviewed in present study, said they were neither willing nor capable to erect a two-storey building without architectural and structural drawings.

According to regulations a site engineer is also required to manage the construction works, when erecting two storey buildings. Hypothetical, drawings and the construction process are said to be inspected by a District Engineer on a regular basis.

6.6.4 Semi-Prefab construction techniques

The Semi-prefab construction technique is a compromise between prefabricated construction elements combined with in-situ construction methods for the purpose of reducing construction time, lower the cost as well as improving the quality control of constructions. It uses full-scale prefabricated building materials produced with simple techniques and machinery and in-situ construction techniques without the auxiliary means normally required in conventional construction works. This technique has its benefits if the prefabricated elements are standardised and introduced on the mass production market. This yields reduced production time and facilitates optimal use of materials with smaller amount of waste products. \cite{33} Prefabricated elements are often of better quality than those cast on site, since production can be more

\textsuperscript{20} Houses were counted in 2002, according to CDA in HanaNasif.
carefully regulated and controlled.[50] Problems regarding the construction technique are analysed in the discussion chapter. There are several different semi-prefabricated systems available for use in constructions. There are systems for walls, slabs, columns, roofs and beams, some of which are intended to be used in the design of the proposed standardised two-storey construction.

A survey performed by Dr Mwamila and Dr Makunza of the College of Engineering and Technology in Dar es Salaam has showed that there is very little use of prefabricated construction components in Tanzania. There are only three companies manufacturing semi prefabricated elements and the industries are all situated in the Dar es Salaam area. Irrespective of mass production, pre manufactured components have many advantages compared to conventional methods.

At the College of Engineering and Technology in Dar es Salaam a study showed that the production of slab strips for constructing intermediate floor slab elements was 60% cheaper compared to the production of solid reinforced concrete elements. It was found that the use of locally available soils for interlocking brick-making in addition to the production of slab strips are suitable for low-cost housing and contribute to strong and long lasting constructions. Recommendations were mainly based on arguments for affordability and durability. The semi-prefab technology is not only suitable for low income households but for all different types of households independently of income.

6.7 Building Materials

According to the National Bureau of Statistics (2005), the majority of residential houses (incl. rural areas) in Tanzania are made of temporary and semi-permanent materials. In 2000, sun dried bricks covered approx. 30% of the use for house walls. Concrete, cement and stone covered 15% and other materials like poles, grass, branches and mud supply just about half. Two major roofing materials were categorised as grass and leaves and corrugated sheets, the quantity were equally shared. A quarter of houses were floored by cement based materials and 70% had earth floors. As foundation concrete, cement or lime mortar accounted for one third. 50% of the buildings had no foundations.[36] These figures represent an average of the whole country, where rural houses still mainly are built with earth-based and natural materials. Dar es Salaam and other urban centres show a very different situation, where modern materials represent a huge share of the market. [40]
6.8 Costs for construction

Normally, a bill of quantity is the best basis for cost calculations in Tanzanian formal construction industry. Estimations are also done based on drawings in early stages. However, both detailed construction cost calculations and construction control are very much neglected, and more so for cost control. In the case of constructions in informal settlements, cost calculations and actual expenses hardly ever correspond. Drawings are seldom created and cost for materials change from one day to another. These facts often result in either the fundi suffering from low profit or the project had to be put on hold, due to lack of assets.

The National Construction council has defined the elements of direct building costs as; Material costs, labour costs, machinery and plant costs, transport costs and site overhead costs. Overhead costs include; building fees, administration overhead costs, profit and taxes.

To cut costs, unskilled labour is principally used for preparatory basic work, such as digging for foundation and transport of materials. Their meagre payments can be based on the expenses of a daily meal for them and their family.[82] Local labour is used to minimise transportation costs. Site overhead costs involve salaries for supervisors, a foreman and storekeepers and the maintenance of machinery.

According to Fundi interviews, approximately cost for constructing a one-storey four bedroom building is about 40-60 million TShs ($40 000-60 000), and for a two-storey building TShs 80-120 million depending on materials used and location. The price determination, before making an agreement for the construction, is based on a first inspection of the site and the valid plan-drawings. The agreements between the parties are typically oral and there are no written contracts. The labour charges for a six roomed, Swahili house made of interlocking brick technique is about TShs 1.8 million ($18 000), and for an equivalent building made of sand-cement blocks about TShs 2 million.[81] As shown above, labour costs are small (less than 30%) compared to the costs of materials, which could be a contributing fact that explains why house owners hire Mafundi instead of construct buildings themselves.

If constructing a two-storey building, according to regulations, architectural and structural drawings and calculations are needed. Approximately 6-12% of the total construction cost goes to architectural drawing works and the structural design and calculations defray 2-4%. [78]
7 Design

The shape and layout of the Swahili house type are, in Tanzania, well known by heart. Through generations, the skills of construction, has passed from one to another by practical participation. The change from rural to urban society now compels change in practice and building design.

Presented in this thesis is a proposal for a vertically extended Swahili house type. Erection of double storey houses may allow additional outdoor space between buildings which in its turn optimises cross ventilation and results in a better indoor climate. In Dar es Salam settlements, two storey buildings will rise above single storey houses and the rooms at the upper floor will be exposed to the wind and obtain adequate daylight and views.

The design proposal is based on the physical layout of the Swahili house. Since it is the predominant type of house found in Dar es Salaam, design improvements in terms of function, comfort, health and aesthetics, are of highest priority. The fact that local artisans are familiar with the structure as well as affordability are fulfilled through shared spaces is also a great contribution to the choice of house type.

This chapter describes general important aspects when designing a house and focus on specific details to take into consideration when developing the traditional Swahili house type to an urban two-storey building. The projected stages of progress are roughly pictured as follows.
The pictured transformation of the Urban Swahili house type:

Past: Mud’n wattle
      Thatched roof

Present: Sand-cement blocks
        Corrugated iron sheets

Future: Two-storey,
      Semi-prefabricated
      Construction

7.1 Two-storey constructions

Compared to a single storey dwelling, erecting a two-storey building is generally more complicated. In the following section, aspects specific for a two-storey construction are reflected and discussed.

7.1.1 Regulations

Since two-storey constructions are unusual in informally planned areas and it is very likely that municipality pay attention to them it is important that houses are built in line with regulations.

The main obstacles when building a two-storey construction, compared to a single storey house, are the need of structural drawings and a building permit. Structural drawings are demanded by regulations likewise as they may be entailed for mafundi to erect multi-storey buildings. Building permits for single-storey houses are also required by regulations but authorities seem to ignore that fact when it comes to informally built constructions.
The bureaucratic process of applying for a building permit is an extensive and time-consuming process. According to Kironde, quoted in Vestbro (2008), it takes more than four years to get a piece of land and accomplish a house construction. Standardised drawings which are in accordance with building regulations may shorten the handling of drawings and minimise remarks at the municipality.

In Dar es Salaam, two out of three dwellings have been built without a building permit on land which has not been zoned for residential use.[20] Most of these houses are single storey buildings. Since two-storey buildings are inspected frequently by municipals, regulations are more important to obey for house owners that intend to build multi-storey houses.

7.1.2 Security of Tenure

The HanaNasif area has been partly surveyed. Plot owners that possess security of tenure may be more likely to invest in erecting a two-storey building. Due to the security of tenure, increased land and property values also trigger house owners to transform and expand their houses.
as the settlement attracts more people searching for rental accommoda-
tion.

Although security of tenure should be considered mainly positive, some negative effects are pointed out by Payne. He claims that land tenure is defined as “the mode by which land is held or owned, or the set of relationships among people concerning land or its product.” According to Payne, this means that security of tenure is possible for anyone to enjoy but that land ownership virtually retain no rights such as to develop, transfer or sublet their land. From this point of view the benefits of possessing security of tenure are limited.

The feeling of safety to have your own land and shelter may be the most important effect of possessing the security of tenure. The fact that the government could not force families to leave their houses without economic compensation must increase incentives for building durable constructions.

7.1.3 Architecture

The spatial design of the proposed construction is to be based on the layout of the traditional Swahili house type. This is mainly to ensure that mafundi are familiar with the design and to continue promoting household to provide rentable rooms for families who cannot afford to build their own house. The layout design of the Swahili house type also facilitates the use of external and internal walls as the load-bearing structure. Since blocks are commonly used as walls in framed structures it would considerably reduce costs for construction if blocks could eliminate the concrete frames and carry the vertical loads in it self. Load bearing walls of the interlocking brick type would also demand less skilled labour since knowledge of reinforcement is not needed in same extent as for framed structures.

Earlier studies and results from this fieldwork have shown that a self-contained house is considered modern and preferred by HanaNasif residents. In the “modern” layout of the urban Swahili house type the two rooms closest to the entry are replaced by a kitchen/dining room and a lounge room.[73] Toilet, kitchen and bathroom are located inside the main house. If residents could choose, that is how they would want their house to be like. Nevertheless, the “modern” spatial design would decrease the area available for tenants, and so also the household income.
The proposed design for the vertical extended Swahili house type is meant to improve the housing situation for people with small private means. Therefore, to reduce the degree of difficulty and expenses, stairs are put on the outside of the building, toilets in the outlaying buildings and cooking is suppose to mainly take place outside since no chimney is installed. If all these functions were located inside, it would considerably increase costs of construction. Although, since the design is flexible, there is still an option to build a self-contained house based on the chosen spatial layout.

### 7.1.4 Attitudes towards two-storey constructions

According to interviews carried out by Nguluma in 2003, dwellers of HanaNasif that had made vertical extensions on their houses did not care whether they blocked ventilation and light from the neighbouring houses. Their only concern was to fulfil their own needs, in seeking more space for their families.

If the proposed standardised two-storey construction is to be implemented, an important factor is that the residents have a positive attitude towards these kinds of buildings. When asking residents of HanaNasif informal area how they would feel about living on the upper floor of a
two-storey building most of them cannot even imagine how it would be. Attitudes towards two-storey constructions were nevertheless positive. Many felt that living on the upper floor were modern and a part of the urban development which would improve their quality of life. Other sees two-storey buildings as income generating since house owners would get more rooms for letting out. Problems pointed out were mainly concerning privacy issues and fear that buildings might collapse. When asking how inhabitants would feel if their neighbours erected a two-storey building a few replied that it would be an infringement up on their private life since many of the residents does not have roofs over their pit-latrines. People were also a bit hesitant when it comes to multi-storey buildings as direct consequence of an eleven-storey building collapsing in downtown Dar es Salaam in June 2008.

When questioning people who already lived in two-storey buildings on advantages/disadvantages some had experienced some initial complaints from neighbours and community. Those problems were cleared up and complaints faded out. The overall attitude around most dwellers interviewed in HanaNasif was that living in a two-storey building would carry a certain respect in the settlement.

7.2 Climatic design

When constructing a house, climatic aspects have to be considered. Nights in Dar es Salaam seldom offer any greater relief from the heat of the day thus shading and maximum ventilation is desired. The choice of proper building materials, design and orientation of buildings are of great importance in order to achieve endurable living conditions. As stated in Dr Nguluma’s study, “Classification of House types in Developing Countries. Findings from Dar es Salaam city, Tanzania”, it is necessary for professionals to promote house types which improve comfort and support house builders in informal settlements to adapt to desirable climatic needs.

Residents of HanaNasif consider climatic comfort as an important factor in modern housing design.

In the area of climatic design, two studies of importance to the present have been conducted. The first report, “Rural low-cost houses” by C. Svärd; (1980), provided advice concerning design and choice of materials for rural housing in Tanzania. As a continuation, in 1999, Ministry of Lands and Human Development published guidelines for rural housing
in the study “Climate and design in Tanzania” which was conducted by Bodoegaard. The study explains principles for construction details that will extend the durability of houses built in the different climate zones of Tanzania. Although both reports aim at rural housing, many technical details can be applied also for urban buildings. Recommendations from the studies combined with local deviations are explained below.

7.2.1 Orientation of buildings

According to Bodoegaard (1999) houses located in coastal tropical climate areas should be orientated in such a way that the long walls of the house are perpendicular to the dominant wind direction. Winds in Dar es Salaam are created by the monsoon. The pattern of these winds is determined by diurnal changes creating great variations of wind direction and speed through the year. The monsoon winds are to a great extent predictable. When ventilation is most required during the hottest season the monsoon winds are blowing from the North/East direction therefore one should orientate buildings with their long walls in this direction. Previous tests on air movement patterns has showed that greater wind turbulence is obtained when orientating windows oblique to the wind direction compared to positioning windows at a right angle to the wind direction which might be considered when erecting a building.[3] The settlement of HanaNasif is situated on flat low-lying areas with little possibility of sea breeze exposure to obtain good cross-ventilation. Although important, it may be hard to follow certain recommendations in the areas studied, due to the overcrowded living conditions.

Another way to increase ventilation is to orientate buildings to reach a channelling wind effect. In high density informal settlements this effect is not present anywhere except on the main roads. Spacing between buildings is of equal importance to maintain good ventilation. In many informal areas it is almost an impossibility to attain adequate spacing; distances between buildings often were less than half a meter.

As sun is at zenith during mid-day most of the radiation falls on the roof of the house. Therefore in order to minimise the solar heat-gain houses should be orientated in such manner that main elevation surfaces of the house are facing North and South.
### 7.2.2 Layout

On the subject of indoor climate, the Swahili house is not optimal with its double-banked layout. In the coastal tropical climate zone houses should preferably be single-banked to obtain maximum cross-ventilation. In order to allow maximum air-flow through the house there should be no internal obstructions such as partitioning walls. In many houses observed partitioning walls weren’t extended all the way up to the ceiling, which increases the effect of cross-ventilation. On the other hand it transmits noise which may be considered as a problem since the Swahili house often accommodates more than one family. Other obstructions to adequate ventilation are the fenced in backyards and window gratings.

### 7.2.3 Design of construction elements

There are two major factors which reduce life span of buildings. The first is rain water penetrating the roof and wall structure and the second is water rising from the ground due to flooding. The two factors may cause rot and mould, biological attacks, termites and structural damage to the foundation. The design of construction components are of great importance to expand the lifespan of a house and provide comfortable indoor climate.

*Design of elements of vital importance for the urban Swahili house type is described below.*

#### Roofs

The shape of the roof also has an impact on the indoor climate. There are three main types of roofs; gable, hipped and gambrel roofs. The gabled roof has its advantages since it is easy to construct and are preferred if alterations and horizontally extensions are planned. The construction also allows a higher degree of ventilation through the gables if constructed without a ceiling. The shape for the roof of a Swahili house is traditionally hipped. The hipped roof is more difficult to extend than other shapes but has its advantages since it provides overhangs on all four sides of the house and then protects the wall from the sun and rain.
The gambrel roof is a combination of the two previous mentioned and provides adequate ventilation and protects all four walls of the building. The roof shape requires higher skills of labour, which could be considered as a disadvantage. Flat roofs are also common, mainly in upcountry rural areas, but are difficult to keep waterproof and are often more expensive than previous types. [49]

The overhangs of roofs for a single storey building should be large with a minimum of 600 mm to protect walls from sunlight and water. For two-storey houses the overhang must be larger. A ventilated roof structure provides better thermal conditions. According to Bodoegaard, the actual effect is highly overestimated. Constructions that generate desired ventilation effect may be difficult to accomplish. Even though a ventilated roof structure may have little impact on indoor climate it can extend the life-span of the construction by preventing rot and mould growth. The ceiling is sound-absorbing and will reduce annoying noise from heavy rain falls. In many cases, the iron roofing sheets are used without any ceiling provision and this makes the room unbearably hot during daytime [3].

**Walls**

A wall should be designed to meet various requirements in order to achieve stability, accommodation of movements, resistance to rain penetration, durability, fire resistance, thermal properties and other construction details.[29]

Walls shall be designed in order to maximise cross-ventilation. To obtain as much cross-ventilation as possible large openings in the walls are required. According to Bodoegaard the open or open able area should be at least 50% of the total wall area. These openings can be represented by windows but also by screen walls of special cast soil- or sand-cement blocks. Large openings also generate problems since they make excellent ways of penetrating driving rain to get in which may cause rot and mould and may possibly damage insufficiently designed foundations or floors. Security issues such as burglary are also to be considered.[3]
Foundation

A major difficulty when erecting a building is to construct the foundation; many houses in the informal settlement of HanaNasif have no foundation or floors at all. A proper foundation is a necessity to obtain a durable and hygienic house. Houses without proper foundations are easily damaged at the base by either rain or moisture rising from the ground. During rainy seasons, the HanaNasif area is often flooded due to characteristics of the ground and poor drainage systems. HanaNasif used to be a swampy coconut plantation area with stagnant water. Walls erected directly on the ground are therefore easily damaged by rain and moisture. When soil supporting the walls is eroded it may cause cracks or even make walls collapse. Water or moisture that penetrates walls makes the house moist and unhealthy. In order to minimise surface water from interfering with buildings it is important to slope the ground away from the house.[3]
Floors
Traditionally floors were made of trampled soil; sometimes it is plastered with mud to act as a binder. A common problem with these simple soil floors was that they were often in level or even below outer ground level causing rain water flowing inside the house or often penetrating to the surface of the floor. To avoid the problem, the floor is brought up to a height of at least 150 mm above ground level with a back fill sandy soil that is free from roots. The back fill is topped up with a mud-plaster. The construction is not a very long lasting solution but common in poor rural areas. Soil floors should be seen as a temporary measure. [49]

7.3 Building materials
The main principle for choice of materials should be to utilise local, traditionally used building materials as far as possible.

The advantages and reasons are mainly:

- The materials are usually very cheap. Soil, for example are easily available and can be obtained without payment.
- Traditional local materials are easy to maintain and replace as they can be found near building sites
- Local production will contribute to economic development of the informal settlement.
- Local materials are often well suited to the climatic conditions.[49]

In spite of the certain advantages of traditional materials, it has become a common practice to use “modern” materials when it comes to house
extensions in urban settlements. Architects and authorities neglect the use of traditional materials, in preference to the more popular materials like concrete blocks, even though regulations do not make any restrictions. Most designs specify the use of modern materials, concrete blocks and corrugated iron sheets or tiles for walls and roofing respectively.

Around the world, earth materials are intensively used and therefore proved to provide good quality housing. Traditional materials may need modifications or treatment to fulfil modern requirements but the intention is to show that they can be used to construct buildings considered as modern houses.

### 7.3.1 Limitation by Tanzanian regulations

In the national human settlement development policy it is stated: *Raw materials such as sand cement blocks, burnt bricks, timber, roof tiles and corrugated iron sheets, aggregates, nails, cement, sand etc are very essential in the construction of damp proof durable buildings. They should be available in large quantities and at affordable prices to encourage housing construction. The production of these building materials can be promoted by encouraging the establishment of building material’s industries* [61].

Neither stabilised soil nor soil-cement is mentioned in these policies. Tanzania Building Regulations often suggest an appropriate building material for the specific element. If alternative materials, which are not pointed out in the standards, are used they have to be up to the satisfaction of the Authority. This fact obstructs dissemination of new materials.

### 7.3.2 Adoption to climate

Due to the climatic conditions in the Dar es Salaam area, the choice of proper building materials is of great importance. To suit the hot humid coastal climate, all building elements should be as light weight as possible to minimise heat-storage capacity. *The benefits and disadvantages concerning climatic qualities of specific materials in construction elements will be further described in chapter 8.*

Roofs and walls with low heat storage capacity are preferable. To minimise heat storage, the recommended thickness of walls should not exceed 150 millimetres. Traditionally, organic walling materials have been used such as mangrove poles, sisal poles, palm leaves and grass etc. These materials have terrific climate qualities but since they are organic they are highly susceptible to rot, mould, fungal growth and are hazardous in terms of fire risk. They could be used if treated with
preservatives but are not likely obtained everywhere. A commonly used product for preserving timber is waste oil from cars, but it can be questioned as a long lasting preserving product since it has no documented effect and isn’t environmental friendly.

Modern walling materials as soil-cement or sand-cement blocks have many advantages in terms of durability etc. but their thermal characteristics are inferior. Due to the dense mass these materials store heat during daytime and at night emits the stored heat and cause high indoor temperatures. By reducing the thickness of these blocks to a maximum width of 150 mm they make a good walling material. Hollow bricks will reduce the heat storage capacity even further.

### 7.3.3 Raw material potential

Generally there are an abundance of raw materials for construction purposes in Tanzania. To promote sustainable development and as long as the road and railway transportation is not sufficiently developed, it is important to utilize, as far as possible, locally available materials.
A large quantity of clays and limestone for burning and laterite soils suitable for stabilization with cement and lime are found within country boundaries. Clays are found nearly everywhere; however availability of fuel is, due to deforestation, decisive concerning burnt bricks. Soil-cement made of soil found at building sites can be used when making, blocks, bricks, foundation, external and internal walls, floors, sewage and drainage pipes and pit latrines. Soils with less than 45% silt and clay, liquid limits less than 45% and plasticity less than 25% are suitable for cement stabilisation. The most important factors affecting the strength of compacted soil-cements are dry density, cement content, curing period and method. [30]

Limestone can be used as building stones, aggregates for concrete and ballast. Minerals with satisfactory composition suitable in cement
manufacturing, is found on the coast near Mbeya in the southern part of Tanzania.[43]

Gypsum is found in high grade contact forms in granular rock or with impurities of earth and sand in lake beds. The material is primarily used for plaster, gypsum boards, plasterboards, building blocks, floor and roof tiles as well as a retarder for Portland cement. [43]

Silica sand is found close to Dar es Salaam and Caoline and Bentonite can also be found locally. Iron and coal are found close to each other which create good opportunities for future steel manufacturers.

The quality of structural timber wood in Tanzania is underestimated and the field of application is almost exclusively roof structures. The two different types of wood suitable for construction are soft- and hard wood. Soft wood is more fragile than hard wood and must be pressure impregnated to withstand attacks from termites and wearing. Soft wood is durable for 5 to 10 years if impregnated. In spite the fact that hard wood is more sustainable, high prices make pressure impregnated soft wood more commonly used since it is much cheaper.

7.3.4 Availability
Most building materials and product industries including cement factories are located in Dar es Salaam and Tanga town. Building materials manufactured or produced include cement, metal products as roofing sheet and hardware and wood products. If utilised properly, this factors could make buildings more affordable in the Dar es Salaam area, compared to rural parts of the country.

Appropriate soil for brick production is found in most areas of Dar es Salaam city and suburbs. If not available at site, soil can be bough from adjacent quarries. Other common building materials such as cement, reinforcement bars, roofing sheets and timber are found frequently along streets in most parts of town. For better prices, there are also market places for building materials found outside the city.
Soil for making of bricks can be found locally in the HanaNasif area and according to the soil sampling test made at the NHBRA it is of good quality for brick making. In the design process it is important to utilise local materials as far as possible. By avoiding long distance transports the construction will promote sustainable development as well as cut costs. Further reading about production of interlocking bricks is found in Appendix E.

Inadequate production and escalating prices of cement has been an unsolved problem for a long period of time in Tanzania. Producers blame production costs such as electricity, fuel etc. The high prices (TShs 25 00021/bag of cement, 2008) have highly affected the development in construction industry. Three cement factories demands for government intervention. The government had given permission to import cement but this has not yet solved the problem. To reduce transportation costs the government is encouraging cement factories to open local branches. [46]

7.3.5 Quality
The use of locally produced materials has its disadvantages. Even though locally produced materials, such as reinforcement bars and cement, sold in the streets, are asserted to be of the same quality or occasionally even considered better than imported or industrially manufactured products, they are often of poorer quality.

21 Normal price is 13 000 TShs, 2008.
If locally produced materials and elements are used it might be a problem to secure that the construction assembled withstands the calculated load stresses. Hence this problem, to secure that all locally produced materials reaches a certain minimum standard they must be controlled by testing.

Due to problems to secure and measure quality of materials, static calculations have to be done with large safety margins.

7.3.6 Attitudes towards local and traditional building materials

People living in informal settlements seem to have a negative attitude towards traditional building materials.[40] Attitudes are influenced by the fact that house owners spend a lot of their resources in repairing or re-constructing houses built with traditional materials. Many explanations are possible but, according to Dr. Nguluma’s study, most people in HanaNasif prefer modern building materials like concrete blocks rather than earth or soil blocks. As discussed in the theory chapter, modern building materials are associated with durability, but the aesthetic qualities of the building could be as important as the quality of the building materials.[41]

Problems with locally produced building materials could be the fact that they might give industrially produced materials a bad reputation. Many materials as sand-cement blocks and bricks are often produced on site by laymen such as house owners or helper to the fundi and it may be difficult to assure that the product manufactured is as durable as required. If the locally produced blocks and bricks start deteriorate on an early stage, people may change their attitude towards earth produced materials and may think that all earth produced, even industrially produced are of low quality. However, people want to produce their own building materials since they believe that they then are in control of the production and can confirm the quality of the elements. [85]

7.4 Structural design

As discussed earlier two storey houses are rare in informal settlements. The observed building technique is invariably a structure of reinforced concrete pillars and beams. Masonry elements, principally sand cement blocks are used as external and partitioning walls. This construction system requires quite advanced execution skills and generates an unnecessary expensive building.
For the geometry of a Swahili house type, calculations indicate that the quality and strength of block and bricks produced locally in Dar es Salaam are sufficient to carry loads of an intermediate floor slab and a wall of an upper storey. This eliminates the need of additional structural pillars.

There are several benefits in constructing a house with load bearing walls instead of using a framed structure which would be considered the normal way of constructing with bricks and blocks. As it is cheaper to build without frames it can also be considered safer and easier to build as less skilled labour is required. Of course there are certain requirements that have to be fulfilled to assure the construction is safe.

7.4.1 Loads

Tanzanian standards are based upon the British Standards why all calculations executed are based on the same.

Dead loads are calculated from the actual known weights of the materials used. Where there is doubt as to the permanency of dead loads, such loads should be treated as imposed loads.

Imposed floor loads are linked to the type of activity/occupancy for which the floor area will be used in service. The floors should be designed to carry the uniformly distributed or concentrated load, whichever produces the greatest stresses in the part of the floor under consideration. The category adopted for the type of activity/occupancy is in our case: Domestic and residential activities. The specific use is all usage within a self-contained dwelling unit.[4]

The imposed load on roof with no access is in this case a uniformly distributed load measured on plan for roof slopes of 30° or less.[5] In areas where snow loads exist, it will be the dimensioning load which will not be the case in this thesis.

Wind load is the load due to the effect of wind pressure or suction. The wind loads have been taken into consideration through stabilising measures. For further reading on total stability see chapter 7.4.3.

Earthquake loads have not been taken into consideration since Dar es Salaam is situated in earthquake safe areas.

For further reading and actual values; see appendix K4.
7.4.2 Load bearing capacity

Load bearing walls should be design to carry in plane horizontal loads induced by wind, bracing effects or earthquake. The load bearing capacity of the brick work depends upon the thickness and number of joints, type of bond and the brick exactness. A prior study by Dr J.K. Makunza, College of Engineering, Dar es Salaam, has shown that the average compression strength for a wall made of interlocking bricks is 0.38 N/mm². [29] In order to determine the strength of the walls, sample specimen walls were built. Estimations were based upon “Rilem” compressive test.

The new improved interlocking brick measures 300 x 150 x 125 mm and has two holes (R =31 mm). The system facilitates clean wall assemblage at corners and can be adapted to suit earthquake prone areas by adding reinforced concrete in some of the holes. The holes reduce the amount of material as well as the weight of a brick. Furthermore the holes influence heat insulation and reduce the heat storage of the building.

The method of compaction of bricks is very important for the compressive strength of the wall. A conclusion based on results from the study is that compaction by hand cannot achieve a high degree of compaction that is required for an element suitable for more than a one storey building.

7.4.3 Total stability

As shown in appendix K4 the quality and strength of blocks and bricks produced locally in Dar es Salam are sufficient to carry vertical loads of an intermediate floor slab and wall of an upper storey with the chosen geometry.

Three different measures are contributing to the total stability of the proposed structure. As the construction isn’t framed the cavities in corners are filled with reinforcement bars and concrete to stabilise the structure. The ring-beam has two purposes in the structure. While it contributes to the total stability of the house it also works as a lintel over windows and door openings. Also the interlocking effect between the bricks probably contributes the most to the total stability.

[29] In the study, two and a half brick wide and five courses high wall were built and placed on foundation beams (300 mm width, 250 mm height and 1200 mm long). The beams were made of concrete grade C30 so that the offer a higher load of resistant than the bricks.
7.4.4 Complexity

Production of soil-cement interlocking blocks is not a complicated procedure. Crucial stages in the process are the mixing of soil-cement and the curing of blocks. NHBRA offers and recommend press operators/owners to attend a two days practical training course. The courses are open for all people that wish to attend and can be held in the local village. Regarding slab elements as the intermediate floor slab construction, is it the making of the moulding form and compaction of the elements that could be difficult to get properly manufactured.

On the other hand it has been found that the use of semi-prefabricated building elements will not only cut cost for construction but might also simplify and improve qualities of execution. Without a demand of advance skills, erection of wall and accomplishment of floor slabs can easily be carried out at site. For example, the complex workmanship of reinforcing can be reduced to the construction of the ring-beam. Since the technical skills of Mafundi are varied, simplifications in the completing process are likely to improve functioning quality.

As noted previously, the construction activity is often guided by the fundi whose expertise is acquired on the job through learning by doing. Regarding simple houses, mafundi seem to have the technical skills to handle the construction activities. Most people also appear to have reliance in Mafundi workmanship.

According to Dr Nguluma’s study, one of the problems presented by housing transformation is limited skills of the local mafundi for complicated transformations. Field observations also indicate a number of substandard workmanship like uneven plastering and roof-fixing problems (figure 6.4). According to the ILO, the combination of lack of formal training and poor working tools may be the explanation to poor-quality workmanship.

The issues of mafundi and their workmanship are in detail discussed in Chapter 6.

The simplified execution of semi-prefabricated constructions on site may also further promote the use of labour based technology.
7.5 Affordability

To construct durable houses, affordability for the urban poor is the most important aspect of this project. As problemised in the theory chapter, affordability is hard to define and totally depending on personal assets.

The concept and the design of the proposed two-storey house does not aim towards the utter poorest people since their money hardly cover daily basic needs. Though difficult, the intention is to reach out to as many families as possible in the low income bracket. Those families that decide to build two-storey houses may leave cheaper houses behind, which could be taken over by poorer households.

To introduce standardised drawings to families where the first priority is not a two-storey house, could be challenging. Since most households in Tanzania finance their construction of houses with funds from own savings it is important that the construction can be erected step by step but still be partly functional during the different phases of construction. It is therefore also crucial to inform house owners that it is important and economical to plan for later stages of construction.

In an urban city, where wood or stones are hard to find, the cheapest way to put up a shelter might be by collecting waste material, poles and mud, try to put that together and place some kind of cover on top. For many families that would be affordable but may not last the next storm or rainfall. We believe, for a dwelling to be affordable and reliable, the house should be constructed to, comprise a fairly long life expectancy, have the possibility to be practically erected by local craftsmen or with self help, and easy to maintain.

7.5.1 Cost analysis

A range of factors influence the cost of a building project. Included are normally design variables such as a building’s total height, width, floor to ceiling height, type of construction, methods of construction (e.g. in-situ or prefabricated, framed structure or load bearing walls). Specifications mentioned above influence the cost of a building equally with factors such as: land terrain, type of ground: rocky, made-up or swampy land; site location like when construction of a building is at a congested or a remote site or where services such as electricity, water, telecommunication and roads are difficult to access, are all combined with the plot location. These factors vary and are not evaluated in the cost analysis.
In this thesis, cost analysis mainly evaluates methods of construction, type of construction and selection of materials. Cost for building permit, survey of land or plot rental, will not be considered since it is irrespec-
tive of the choice of materials or building technique. Furthermore, those expenses are normally fairly low compared to the in Tanzania two determining factors for the total cost for erecting a building; material (incl. machines) and labour. These components are further discussed and specified in the text below.

The layout of the modified Swahili house type is partially adjusted to the available knowledge and the masonry building techniques. Although, the traditional layout is suitable for the use of load bearing internal walls, all two storey buildings observed in informal settlements of Tanzania use a construction of framed structures. Therefore, this thesis concentrates on; and evaluates the possibility to use walls of soil-cement and sand cement as the load bearing structure. The cost analysis will calculate if the masonry technique for a two-storey house is an affordable alternative for the urban poor.

The new proposed layout for the vertical extended two storey Swahili house type is developed to further promote the use of earth material and easy available techniques.

The range of material and design to be analysed are an adjustment of affordability, local tradition, availability and complexity. The selected materials and building techniques were analysed in order to evaluate which best fulfilled the requirements for wall and intermediate floor slab of a low-cost construction.

Previously cost analysis of both soil cement interlocking bricks and semi-prefabricated floor slab constructions has been carried out by the NHBRA and the College of Engineering in Dar es Salaam.

The NHBRA has in 2005 constructed a 138.8 square meters, single storey demonstration house constructed with walls of soil cement interlocking bricks, stones for foundation and sisal tiles for roofing. The soil was dust from a stone quarry, the interlocking soil cement bricks were made at site using interlocking press machine from NHBRA’s laboratory. The labourers were local youth trained by NHBRA in a seminar conducted in the area and supervised by researchers from the NHBRA. According to the project report savings are 44% compared to common techniques (Sand-cement bricks, metal sheet roof cover). If supervision allowance
are excluded the saving may increase up to 65%. The latter figures assume that labourers are free and that water for brick making and curing does not need to be bought and transported to site.

**Labour**

The demand and qualification of labour is depending on building technique and execution. Different parts of execution require more or less skilled labour. Several phases of contract work can be performed by “unskilled” labour depending on process and components. The type or qualification of labour needed in the compared building structures have been studied in detail. *Further reading in appendix E.*

The labour cost for productions of soil-cement bricks consists of the following components:[30]

- Selecting and digging the soil
- Drying, crushing and sieving
- Mixing the soil, cement and water
- Compaction of bricks
- Stacking the moist curing bricks

The first two components in production of soil-cement bricks can be carried out by labourers without any extended knowledge, which minimises the cost for construction. Mixing, compaction and stacking may be supervised by or performed by a trained local artisan.

*Appendix E will further show data and result of labour cost for the specific constructions.*

**Materials and machines**

The economic comparison of the different materials is complicated, mainly because of the insecure formation of prices. Cost for material and labour are always negotiable and varies depending on season and from one day to another. The prices also vary widely depending on location and costs for transportation. The distance from the distribution centre is of importance due to high fuel costs. Many earthen materials such as soil, stone, lime and bush poles can at some locations be obtained for free.

The raw material for production of *soil-cement bricks* includes cost for soil, cement and water.
Making the *intermediate floor slab* of hollow slab elements and inverted T-beams requires, and generates cost for; hard wood or steel for moulding forms, cement, sand (*if not available on site, costs include transportation*), water and reinforcement bars for T-beams.

Soil could often be collected for free, if found on site. If suitable soil is not available, normally the expenses are just for transportation of soil from quarries. Water with sufficient quality may not be available on site which contributes to increased costs or impaired execution of design. The price of cement is somehow constant, although negotiable. One bag of cement costs approximately 13 500 TShs\(^{23}\) and makes about 90 bricks.

*Approximate costs for masonry walls and the floor slab are evaluated in appendix F1 & F2.*

**Initial costs**

When introducing a new material and a new construction technique initial costs for buying machines and training of artisans can appear comparatively high. In course of time, as a well-known technique, machines will be cheaper and bricks could be sold for a better price.

The initial costs for an artisan or a dweller utilising the technique with interlocking bricks are mainly expenses for the interlocking block press machine and equipment for soil-sampling and testing (such as a bucket, oil can, sieve, shovels, broom, Karai’s\(^{24}\), bottle, shrinkage box etc.) *Appendix B further describes the procedures and tools needed for block production.*

For the hollow slab elements and the inverted T-beams, moulding forms, if made of hard wood, last through construction of a single Swahili house. Some initial costs will therefore be appurtenant to each project rather than to introducing the technique. The main part of the costs is in spite linked to the investment of the interlocking block press machine.

**Time**

The comparison of building techniques and building materials does not consider time as an important factor when building affordable houses. Labourers are often paid per piecework and no expensive machines are put on hold if the commissioner of a building runs out of money.

\(^{23}\) TShs 13 500 = USD 13.5 (Nov 2008)

\(^{24}\) A small bowl
Since land are occupied informally and leasing land for most cases are fairly cheap, time for construction at site are not central when determining costs. If new methods save material and also costs it would be considered a better option compare to a slightly faster method. Summing-up, time has not the same value in Tanzania as it has in the developed part of the world.

7.6 Security and Safety precautions

In recent years, Dar es Salaam crime rate has increased rapidly. A study conducted in 2000 in the city of Dar es Salaam under the “Safer Cities Project” found out that the most prevalent crime in Dar es Salaam is burglary. According to Dr Nguluma’s study, security is one of the factors leading to house transformation. Interviews describe that provisioning of burglar proof doors and windows is becoming increasingly common in HanaNasif. Families that can afford it, have their own night guards and a fence surrounding the plot area to improve security. Fences and window gratings have negative effects on both ventilation and daylight in rooms and corridors.

Image 28: Improved security with a gate.

Photography: Lotta Torstensson
Timber walls and walls made of bricks are often neglected, due to security reasons, such as increased possibility for burglars to demolish walls. Experience from Iringa region shows that thieves can easily remove some bricks or parts of mud walls, break in and steel properties.[29]

Soil has naturally good fire resistant properties. Due to fire hazard, buildings made of timber are not allowed in cities. Windows secured with burglar bars is also a serious problem since they are very dangerous in case of a fire since they cannot be used as fire exits if the door is blocked.
8 Solution alternatives

Based on literature studies and field work findings, the possibility of using new building techniques in order to optimise the structure in terms of durability and affordability has been investigated. Cost estimations have been carried out for used types of intermediate floor slabs and those have been compared to existing and new techniques under development. For walling material the most common technique, using sand cement blocks, has been compared to the rather unknown soil-cement interlocking brick technique developed by the NHBRA. The analysis includes cost of labour, materials, machines, transport of materials, etc.

The main focus of this thesis is put on finding an affordable and durable design solution for the intermediate floor and the load-bearing structure of a two-storey building. The design solution is limited to solve problems for these major important construction parts considering adaptation to climate, affordability for low-income dwellers and durability of materials. During fieldwork it was realised that standardised drawings could not be done without considering the most obvious problems regarding roofs, floors and foundation. The last part of this chapter describes the most common materials and alternative elements that can be used while constructing floor, roof and foundation for a house of the urban Swahili house type.

8.1 Intermediate floor slab

Cost and quality comparisons between different types of intermediate floor slabs have been carried out. It has been found that the use of Semi-Prefabricated building elements will cut cost for construction without reduced quality. Semi-Prefabricated elements will reduce construction time, lower the cost as well as improve qualities of constructions. The costs are presented as the cost for a two-storey Swahili house.

The following existing techniques have been studied and are described below; solid reinforced concrete slab, prefabricated slab strips – “the low cost slab” and the technique using composite slab with reinforcement sheets. These three construction alternatives will be compared to the hollow slab elements combined with the inverted T-beam, which will be further investigated and analysed in this thesis.
8.1.1 Solid reinforced concrete slab

Reinforced concrete slabs are constructed on temporary platforms of timber boards. The in situ floor slab is casted integrally with the framework of columns, walls and beams (ring-beam) forming the structure of the building. It adds to and forms parts of the overall strength of the building structure. Unlike precast units, in situ concrete is essentially a plastic material and can before setting be designed to suit irregular shapes and geometries. The big disadvantage of casting a floor slab “in situ” is the considerable amount of formwork that is required to support the wet concrete until it has set and gain sufficient strength to support itself. Formwork is costly and time consuming and can seldom be used more than three of four times depending on quality. It also interferes with other trades during construction, which are prevented by a multiplicity of struts supporting the formwork from working below the newly cast slab.

In Dar es Salaam, the solid reinforced concrete slabs are almost exclusively used when constructing the intermediate floor slabs for small and medium sized buildings. The technique is fairly well known among local artisans, Mafundi. Since there is no tradition of multi-storey housing in informal settlements of Dar es Salaam, there is not much experience of those kinds of construction works among Mafundi. A designer is
required for the dimensioning of reinforcement bars and the practical workmanship must be done with precision. Drawings for reinforced concrete floor slabs are often detailed and, if not familiar with the technique, they can be hard to comprehend. According to interviews, Mafundi could carry out the construction work if provided with drawings designed by an Engineer.

The casting and curing procedures are in need of freshwater supply, which could be hard to supply in some areas. Therefore concrete works sometimes has to be scheduled to coincide with rainfall. Concrete floors cast under average site conditions are subject to the vagaries of weather. It is important but tough to prevent concrete and moulds from dirt during the casting and curing.

Briefly, the advantages and disadvantages using a conventional solid reinforced concrete slab are;

+ Well known technique
+ Fast production
+ Forms a monochromic structure with the ring-beam
+ Two-sided drying of concrete

- High cost for form work
- Large amount of cement required
- Large amount of steel for reinforcement bars required
- High demand for auxiliary supports
- Demands educated artisans at site

**Costs**

Cost for an intermediate floor slab for a extended 106 square meter Swahili house type are approximately 3 900 000 TShs.\(^{25}\) If using self-help of family members expenses will be slightly reduced.

*Further details regarding cost analysis, are shown in appendix F:2.*

\(^{25}\) TShs 3 900 000 = USD 3 900 (Nov 2008).
8.1.2 Slab Strips – “The low cost slab”

Image 30: Prototype of a Slab strip element developed and manufacture at COET by Prof. B.L.M. Mwamila and Dr J.K. Makunza.

Photography: Lotta Torstensson

One of the disadvantages of the solid in situ concrete slab is its considerable weight and its large cost of material. This could be greatly reduced if the slab is hollow.

This type of intermediate floor slab is constructed in three different stages. The first step of the process is to produce the pre-fabricated slab elements, as seen in the picture. The following procedure is the manufacturing of slab strips. When the slab strips are placed at the load bearing structure, the intermediate floor slab is completed by filling up with concrete.
The system of slab strips has been developed and studied in an AICAD\textsuperscript{26} sponsored pilot project by Prof. B.L.M. Mwamila and Dr J.K. Makunza. The element was named “the low cost slab” because it requires less concrete compared with a regular solid reinforced concrete slab and it is simple in construction and can be lifted up manually. No form work is required at the building site which cuts cost for it.

The mould for manufacturing of the slab elements is made of hard wood. The process of producing slab elements involves a number of steps that have to be repeated with every element, which prolongs the production time. The fact that the construction can be lifted up manually are considered positive in the referred study. Although as the elements are fixed together, the part of the intermediate floor slab is quite heavy and two people per meter length are required when positioning the construction. The entire production is intended to be performed at the building site to fit the idea on using the enabling strategies. There is also an uncertainty of how well the interacting forces between concrete used to fix the reinforcement to beams and topping-up concrete are.

Briefly, the advantages and disadvantages using the slab strip technique are;

+ No form work required
+ Requires less concrete compared to solid concrete slabs
+ Lightweight construction compared to solid concrete constructions
+ Enhanced insulation properties
+ Less demand for auxiliary supports
+ Ample ducting space for service lines
+ Simple in-situ construction
+ Assembled on ground
+ Approximately 35\% cheaper compared to a solid reinforced concrete slab
+ Lifted up manually, cheap as no machines are required

− Heavy to be lifted up manually
− Not well known technique
− Initial costs for making moulding forms
− Do not form a monochromic structure with the ring-beam
− Time-consuming manufacturing of hollow slab elements

\textsuperscript{26} African Institute for Capacity Development
– Interacting forces between concrete used to fix reinforcement to beams and topping-up concrete not verified

**Technical details**

**Slab Elements:**

Ratio of materials: 1:8 (1 part of cement, 8 parts of sand). One bag of cement produces 30 elements.

Water cement ratio: 0.30-0.35. The moist mortal is filled in the mould in three stages.

Compaction is made in different stages by a timber rod. After 24 hours the mould is removed, the elements are cured in water for 7 days and then left for further curing in air during 4 days.

**Slab strips:**

The slab element is joined together with cement mortar with a ratio 1:6.

Reinforcement: Y10 or Y12 placed on both sides of slab elements. The reinforcement bars are plastered to join with the element.

Curing and hardening: 14 days

**Floor slab:**

The slab strips are lifted up and formed to a slab panel. The panel are filled up with suitable concrete of grade C20.

According to the test made in the project by Prof. B.L.M. Mwamila and Dr J.K. Makunza, the strength of the hollow slab constructed with the slab elements are almost equal to a solid slab with the same amount of reinforcement.

**Costs**

For the 106 square meters large, vertical extended Swahili house type presented in this study cost for the intermediate floor slab will turn out as follows; price for a floor slab made of “low cost slab strips” are
approximately 2 685 545 TShs,\textsuperscript{27} which is 68\% of the expenses for an solid reinforce concrete floor slab. If slab-strips are bought prefabricated, costs are calculated to turn out around 3 492 688 TShs, still 11\% less than for the present used construction.

According to a cost comparison made by Prof. B.L.M. Mwamila and Dr J.K. Makunza, a 4 m x 4 m slab panel made of slab strips is about 60\% of the cost of a single concrete slab.\textsuperscript{[33]}

_Further details regarding cost analysis are shown in appendix F:2._

\textsuperscript{27} TShs 2 685 545 = USD 2 686 (Nov 2008).
8.1.3 Composite slab with reinforcement sheets

The essential nature of the system is that the profiled steel sheeting acts as both a form and reinforcement to the final concrete slab. The use of the sheeting as a form is similar to its use in roofing and cladding. The difference in the design of composite deck profiles compared with the solid reinforced concrete slabs is the unique bond between concrete and steel. In the final concrete slab, the steel sheeting provides all necessary bottom reinforcement for a span of approx. 7-8 meter.

The trapezoidal shaped profile reduces the volume of concrete used, with resultant savings in structural and foundation costs.

Briefly, the advantages and disadvantages using Composite slab with reinforcement sheets are;

+ No extra form work required
+ Cuts use of reinforcement bars
+ Minimal training of labour required
+ Light, fast and easy to work with
+ Low concrete usage
+ Minimises source of errors
The sheets are not locally produced
Large amount of cement required
High risk of corrosion of the profiled steel sheets

In further studies it could be interesting to elucidate the possibility of using topping-up soil-cement instead of concrete. The use of soil-cement as topping-up is quite uncertain as the soil could have high contents of salt and therefore have a negative impact on the reinforcement sheets. The profiled steel sheets are also not produced in Tanzania and must therefore be imported.

**Technical details**

Quality of steel: S 320 GD+Z
Nominal thickness of steel: 0.85 mm
Weight: 8.9 kg/m²
Tensile yield stress \([f_{tyk}]\) 320 MPa
Moment of inertia \([I_L]\) 33.0 x10⁴ mm⁴/m
Plastic moment capacity \([M_{pk}]\) 5.29 kNm/m
Shear capacity \([\tau_{uk}]\) 0.306 MPa
Effective slab thickness \([d]\) h-19 mm

**Costs**

Outlays for a composite slab with reinforcement sheets are highly depending on the import price of the iron sheets. At present these sheets are not produced locally and have to be transported to Tanzania. Considering the assumed price for transport, the cost for the intermediate floor slab of the 106 square meters large vertical extended Swahili house type presented in this study will turn out as follows; Costs for a composite slab with reinforcement sheets are approximately 3 800 100 TShs,²⁸ which is about the same as for a solid reinforce concrete floor slab. If reinforce iron sheets, in the future, could be manufactured

²⁸ TShs 3 800 000 = USD 3 800 (Nov 2008).
locally, expenses for a floor slab may be considerably reduced. Even in a low cost house, a composite slab with reinforcement sheets could then be considered as an economical solution for the intermediate floor.

*Further details regarding cost analysis are shown in appendix F:2.*
8.1.4 Hollow slab elements & inverted T-beam

Image 32: Prototype of a hollow slab element developed and manufacture at COET by Dr J.K. Makunza.

Photography: Lotta Torstensson

This type of intermediate floor slab is, as the alternative above, also constructed in three different stages. The first step in the process is to produce the hollow slab elements and the T-beams. The following procedure is to place the T-beams at the load bearing structure and position the slab elements resting on the T-beams. When these stages are settled, the intermediate floor slab is completed by filling up with concrete.

With this technique, the slab elements are lifted up one by one which is a significant advantage compared to the previous construction described. The load bearing capacity is secured by the T-beams and relying on the interaction between the beams, the concrete and the slab elements of the intermediate floor construction.

Prefabricated units are best for regular shapes and loads and the technique is most suitable in buildings where a great deal of repetitive construction work is required, as in the Swahili house type. This technique reduces the amount of props and the consumption of material as no formwork is required for casting.
Briefly, the advantages and disadvantages using hollow slab elements and inverted T-beams when constructing the intermediate floor slab are:

+ Elements are easy to carry and placed one by one
+ No form work required
+ Requires a smaller amount of concrete
+ Enhanced insulation properties
+ Less demand for auxiliary supports compared with a regular solid reinforced concrete slab
+ Openings for service ducts etc. can easily be arranged.
+ Simple in-situ construction

– Not well known technique
– Initial costs for making moulding form
– Time-consuming manufacturing of hollow slab elements

Technical details

This system of hollow slab strips combined with T-beams is under development by Dr J.K. Makunza at the College of Engineering in Dar es Salaam. There is no written report or tests determining the strength of the construction.

The geometry of the hollow slab element is similar to a roof structure found during early literature review. Chapter four in “Construction in developing countries” published by The Swedish mission council, describes a type of construction where hollow blocks function as permanent shuttering, allowing tensile reinforcement to be laid between the blocks. When concrete is cast, it becomes a T-beam deck made up of a 50 mm slab and tensile reinforcement beams. A more common technique is to lay hollow blocks between precast T-beams and then cast the concrete. This study will further investigate the technical aspects of this type of construction combined with the geometry developed by Dr J.K. Makunza.
Costs

For the 106 square meters large, vertical extended Swahili house type presented in this study cost for the intermediate floor slab will turn out as follows; price for a floor slab made made of hollow slab strips, precast joist and topping-up concrete are approximately 3 036 000 TShs,\(^{29}\) which is 77% of the expenses for an solid reinforce concrete floor slab.

*Further details regarding cost analysis are shown in appendix F:2.*

\(^{29}\) 3 036 000 TShs = USD 3 036 (Nov 2008).
8.2 Load bearing walls

The layout design of the Swahili House facilitates the use of external and internal walls as load-bearing structure.

Advantages and disadvantages using walls as the structural system are:

+ Reduced cost of construction compared to a framed structure.

+ Demands less skilled labour since knowledge of using reinforced structures is not needed in same extent as for framed structures.

- The size of the rooms is limited due to walls are load bearing instead of pillars in framed structures.

- Windows and door openings are fixed.

The design of walls for the Swahili house type has changed over the years from different types of grass and soil, mud-and-pole type of walls, to those made of solid concrete or other cement based walls and today the most frequently used material for external walls in informal settlements are blocks made of sand-cement.

Soil walls are fairly durable if properly protected from water and are not attacked by termites and fungus to the same extent as a pole structured wall. To provide good stability for a single storey house, the walls has to be at least 300 mm thick.[49] Clay bricks make a good walling material as they are durable and can be produced on site if suitable clay is available. The production of burnt clay tiles has a high demand for firewood and it contributes to deforestation, hence not sustainable.

The traditional wall materials for the Swahili house type are not possible to use as load bearing structure in a two-storey house. Instead, the hollow soil-cement interlocking bricks have been studied to see whether they are suitable in the usage as load-bearing walls instead of concrete framed structures or sand-cement blocks. Cost analysis has been made to compare which technique is most suitable for low-cost housing.
8.2.1 Sand cement blocks

Sand-cement and concrete blocks are very durable, strong and water resistant but requires high amounts of cement and therefore very expensive. If sand can be obtained without long transport, the production of sand-cement blocks could be encouraged.[29]

The blocks are easy to compact and many people are familiar with the production process. Production of blocks takes place at several levels of mechanism and capital investment. A self-builder could do all operations by hand only using a wooden mould or shuttering for compaction and a contractor could rent or buy a compaction machine.

![Image 33: Construction of a house made of sand cement blocks situated in Mjmweema, close to the southern beaches of Dar es Salaam, 2008.](image)

Photography: Lotta Torstensson

The geometry of sand cement blocks varies but they are normally produced with the dimensions of approx. 450 mm x 230 mm x 150 mm.[81] The larger thickness compared to soil-cement interlocking bricks decrease the fear of burglar breaking in and of structures collapsing. Nevertheless, the thickness requires more cement that has to be bought and transported to site. The thick massive walls also have a great heat storage capacity and will emit heat during night.
Sand cement blocks are produced and sold informally in every community.

**Costs**

For the studied vertical extended Swahili house type approximate cost for walls made of sand cement blocks are 6 350 800 TShs.\(^{30}\)

*Further details regarding cost analysis are shown in appendix F:2.*

### 8.2.2 Soil-cement interlocking bricks

![Image of hollow soil-cement interlocking brick](image)

Soil is a good building material but has two major weaknesses. First; soil is easily damaged by water, second; it has low tensile strength. Unstabilised, sundried bricks will overtime start eroding when they come in contact with water. To overcome these weaknesses, soil is stabilised with a stabiliser such as cement, lime or bitumen. The most suitable soil for stabilisation is sandy soils or lateritic soils. The clay content in the soil ought to be 10-40% to be suitable for brick making and can be determined by basic field tests. Soil with higher amount of clay can be used but then lime is included instead of cement.

Stabilised soil interlocking bricks are made from ordinary soil mixed with a small amount of cement and then highly compacted in a brick press resulting in a solid, dense and low cost building material. Suitable soil can be found frequently close to construction sites, for example

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\(^{30}\) TShs 6 350 800 = USD 6 351 (Nov 2008).
when digging holes for septic tanks. Cost for material and transportation will therefore be reduced. If soil is not available on site it can be bought from quarries, where soil is waste material\textsuperscript{31}.

Soil-cement interlocking bricks do not require any mortar, which reduces the demand for cement (approx. 5\%) and considerably reduces the production time of a building. A three roomed house can be built in a month with interlocking bricks compared to three months for an equivalent house using sand-cement blocks. The cost for building a six-roomed interlocking brick house is only two thirds compared to the cost for a sand-cement block construction.[33]

\textbf{Image 34:} Hollow soil-cement interlocking bricks to be assembled at a construction site in Kinondoni, Dar es Salaam \hspace{1cm} \textbf{Photography:} Lotta Torstensson

Soil-cement bricks are made solid or hollow. Hollow soil-cement interlocking bricks are developed by the NHBRA among others. The cavity in the wall will reduce the heat flux by ventilation through the holes of the bricks. The dimensions of the bricks and the holes make the wall less heavy and it can be considered as a fairly lightweight wall. Heat transmission in the soil-cement bricks is lower than in conventional concrete blocks, therefore also cooling of the building is better provided.

If properly manufactured, soil-cement interlocking bricks are suitable for use in load-bearing walls.

Some of the advantages using soil-cement interlocking bricks are:

- Require less amount of cement compared to sand-cement blocks.
- Cut cost for transportation and soil since it can often be found on site.
- No mortar required.

\textsuperscript{31} The only costs are from packing (10 000 TShs per truck-load) and transportation.
• Holes reduce heat capacity and make installation of service lines easier.
• Less skilled labour could be used instead of masons.
• Due to the increased price of traditional material, especially bush poles, the material cost of soil-cement is lower than for improved mud-and-pole constructions.
• Bricks can be made with a wide range of soil types.
• Strength is sufficient, as distinct from mud blocks, for one or two storey buildings.
• Can be produced on site and in all seasons.

The production of soil-cement bricks and the interlocking principles used when erecting walls are both ideal for self-help constructions. Mafundi are not always required since the production techniques are very simple to learn and can easily be passed forward. The method of casting bricks is simple as one person can easily operate the machine used on its own. If a settlement invests in a machine for making interlocking bricks it stays in the area and may be useful to more than one household.

The interlocking brick building technology is both simple and quick and will also reduce clearing of trees. Compared to a solid concrete wall there is no form work needed when erecting a wall made of interlocking bricks. The construction technique neither requires any burning of bricks which also further reduces use of firewood (for fuel) and is therefore more environmentally friendly.

Throughout Tanzania soil-cement should be considered in sand deficient areas. Due to economic and social factors soil-cement is not likely to be used as wall material in rural areas were traditional materials are free, readily available, and can be improved by simple methods. However, most potential building sites in Dar es Salaam posses soil suitable for cement stabilisation. Still, there are problems to overcome such as to find incentives for artisans to buy new machines for the technical change. In present situation, the market price of interlocking soil-cement bricks is high, due to poor availability. These facts reduce the cost-efficiency of the building technique which is, even if it is not widely spread, more affordable than the commonly used sand-cement technique.
Costs

For the studied vertical extended Swahili house type approximate cost for walls made of soil cement interlocking bricks are 4,307,100 TShs\textsuperscript{32}. These figures are calculated considering buying ready-made soil cement interlocking bricks. The costs are about 68% compared to sand cement blocks. If manufacturing of bricks are taken care of, further reduction of expenses are estimated to 15%. Costs for a wall made of soil cement interlocking bricks are about 58% compared to the price for sand cement blocks. If suitable soil is found at site walls made of soil cement may cut costs by half.

All cost compilations includes the charge for buying an interlocking brick machine.

*Further details regarding cost analysis are shown in appendix F:2.*

According to the cost report for the *Mbweni demonstration house* made by the NHBRA, cost for a 150 mm thick wall made of soil cement interlocking bricks (ratio 1:16, as HanaNassif) are 40% compared to sand cement blocks (ratio 1:8). This price was without considering salary for labourers, expenses for water for brick making and curing. Neither having a watchman at site was considered. [74]

8.3 Roofing

Traditionally, roofs have been covered with thatch or soil. Thatching comprised mainly grass, reeds or palm leaves (*makuti*). Thatched or soil roofs provide a comfortable indoor climate but last only for about 5-10 years. *Makuti* gives adequate ventilation, has low thermal capacity and high insulation value. [3] Even though it is fairly well adapted to the coastal tropical climate it is not very durable and has rapidly been replaced with corrugated steel sheets.

8.3.1 Steel sheets

These thatch roof coverings still exist, mainly in rural areas but are today generally replaced by steel sheets. The sheets used are mainly locally produced galvanised corrugated steel sheets or the precoated, troughed steel sheets. Precoated sheets are slightly more expensive\textsuperscript{33} but are more durable. Imported aluminium sheets are expensive and used only on public buildings where requirements demand a life expectancy

\textsuperscript{32} TShs 4,307 100 = USD 4,307 (Nov 2008).

\textsuperscript{33} 1000 TShs = $1 per tile (Nov 2008)
of 100 years. As described, steel sheets are more durable than thatch but have lower thermal capacity which increases the temperature indoors as heat from the sun is transferred by radiation. The steel sheets have a reflective surface coating to minimise heat transmission. As a result of high salt content of the air in coastal areas they will shortly start corroding and lose their reflective surface. Preventive measures can be made by applying protective paint before corrosion starts. More durable are aluminium sheets since their coating is long lasting.

8.3.2 Tiles

Clay tiles make an excellent roof covering as they are durable and waterproof. Disadvantages are their heavy weight which demands a strong supporting structure. As iron sheets, tiles are bad thermal insulators causing heat transfer. Even in this case the use of firewood is considered a problem therefore the cement based tiles are preferred.


Soil-cement tiles with sisal reinforcement have been developed by the NHBRA. These were originally made with aluminium moulds from used aluminium sheets. The project has been facing some problems, since the price of aluminium has increased. Plastic moulds have replaced the aluminium forms but the moulds are still too expensive for producing affordable tiles for the urban poor. Cost analysis made by the NHBRA shows that the use of micro concrete sisal reinforced tiles instead of corrugated iron sheets will save up to 45% depending on gauge.[39] These figures were made when aluminium moulds were available. Currently the production of sisal tiles is very small. The savings are also overestimated since the need of substructure increased due to larger dead loads from the tiles.
8.3.3 Supporting roof structure

The roof structure is traditionally made of branches, wooden poles, bamboo, or sisal poles. If constructed in a proper manner poles make a very good, adequately strong roof structure and can support many types of roofing materials. [3] Traditional materials have during the last 25 years occasionally been replaced by sawn timber which is the most commonly used roof structure in urban areas at present. The timber is often treated softwood or hardwood. Because of its durability, the latter one is much more expensive than the treated softwood; hence not affordable for urban dwellers.

8.4 Foundations

Soil-cement is expected to be cheaper than concrete for foundations in most areas with lateritic soils. This is due to the cement saving and the fact that only simple tools are needed for compaction. The often used coral plinth foundation for the Swahili house can by advantage be replaced by a strong and durable soil foundation obtained with 10% cement.

8.4.1 Trench

A cheap and simple foundation technique is to dig a trench deep enough to reach firm soil without any roots and fill it with stones. A depth of 300-400 mm is commonly adequate. The trench should have a width of 300-400 mm and be filled with stones to ground level. The upper layer is jointed with mortar and forms a proper base for the wall. This type of foundation is suitable for any kind of wall. [49] If erecting a mud-and-pole structure the poles are stuck in the trench and then stabilised with mortar. When cement or lime is used, the foundation can be brought up above ground level, to at least a height of 500 mm on the outside, in order to protect the base of the wall.

8.4.2 Strip foundation

When erecting walls of durable materials like concrete, sand- or soil-cement bricks a strip foundation is most commonly used. A trench is dug with the same measurements in addition to the stone filled trench foundation (it should have a width of 200-300 mm wider than the wall erected). A strip footing is made of soil-cement or solid concrete and should have a thickness of 100 mm if constructed with concrete or 150 mm when made of soil-cement. The foundation wall is erected to a height of at least 500 mm above ground level if the material of the wall itself is easily damaged by water. [49]
According to the NHBRA, a strip foundation made of soil cement (1:10) instead of concrete (1:3:6) will save 38% of the costs. Compared to cement-sand (1:10) the cost will decrease 31%.[74]

**Image 36:** To the left: Masonry foundation wall on a reinforced concrete strip footing. Right: Strip footing.

### 8.5 Floors

The most hygienic and durable floor can be retrieved when executing it as a floor slab of solid concrete or soil-cement. The floor has a thickness of at least 50-75 mm. In order to get a sufficiently hard floor surface, extra cement is added in the top layer. The back fill material mainly comprises well compacted sand and/or gravel, stones or macadam with a minimum thickness of 100 mm. [49]
9 Results

Construction of a house in Tanzania is often a prolonged process because of the considerably high costs. As building a house in general takes several years, the construction process can be considered incremental. The proposed vertically extended Swahili house type is designed with the possibility to be built in stages as money is earned. An idea for the construction process is to finish the first floor and then wait until it is possible to carry on the construction work.

The house is able to be fully functional in the first step by putting a roof structure on the masonry walls. The roof can consist of thatch up until the next phase in construction takes over. When possibilities arise for a continuation, the initial measures in phase two are to construct the ring-beam and the intermediate floor slab. Thereafter, walls of the upper floor can be built and the thatch roof can be replaced with the final roof cover. Further technical details will be presented in the following paragraphs.

The main part of fieldwork results are presented as architectural and structural drawings for the proposed standardised house construction. Drawings are attached to this final report.

9.1 Architectural design

The spatial design of the proposed construction is based on the layout of the traditional Swahili house type. This is mainly to ensure that mafundi are familiar with the design and the construction process. The development of the Swahili house type also contributes to affordability by generating savings through shared spaces and continuously promotes households to provide rentable rooms.

The layout design also facilitates the use of external and internal walls as the load-bearing structure which considerably reduces costs for construction.

The proposed design for the vertically extended Swahili house type is meant to improve the housing situation for people with small private means. Therefore, to reduce the degree of difficulty and expenses, stairs are put on the outside of the building, toilets in the outlaying buildings and cooking is supposed to mainly take place outside since no chimney is installed. If all these functions were located inside, it would considerably increase costs of construction. Although, since the design is
flexible, there is still an option to build a self-contained house based on the produced standardised drawings.

As people have different preferences when it comes to spatial design, the layout can be changed in any way as long as load bearing elements are kept in position. If changing these elements, calculations and drawings have to be revised. Mafundi involved in construction work can normally advise the client and help to plan proper orientation of the house, positioning of doors and windows. Mafundi also advice on room sizes, depending on the available plot size and number of rooms needed by the client.

According to interviews, people in HanaNasif regard a better house as for example a house with large windows and a good floor finish, which renders daylight and easy cleaning. Their opinions and these aspects are among others taken into consideration when sketching the proposed design and are presented in the standardised drawings.

9.2 Structural design

Apart from affordability, analyses indicate that inferior execution quality and durability of constructions are major issues regarding creation of houses in Dar es Salaam. Therefore the structural design of the proposed two storey building is based on existing simple building elements that could be further extended in its area of utilisation. The technique could be developed locally and executed using self-help. Combined with improved technique, vital local knowledge is taken advantage of.

Blocks and bricks can be seen as prefabricated building elements and are commonly used in Dar es Salaam informal settlements. Elements are produced locally and are at present often creating walls of urban Swahili houses. Materials used in elements fairly well withstand weather conditions and natural forces such as rain and wind. Standardised prefabricated elements are often of better quality than those cast on site, since production can be more carefully regulated and controlled. Hollow bricks and slab elements not only save material but also have an upgraded thermal function.

Today, prefabricated wall elements is only utilised in single storey constructions and as infill walls in framed structures. However, analysis in this report shows that the strength of the blocks is sufficient to carry
vertical loads of a two-storey building and be suitable as load bearing elements.

By using prefabricated elements in the construction of both walls and the floor slab could reduce construction time at site, lower the cost for labour and material as well as improving the quality control of constructions. Pre produced elements also diminish problems with unreliable water supply when casting concrete at sites.

Elements used in the proposed construction can be manually produced and included within in the field of Labour based technology. The LBT itself could increase the extent of employment and contributes to poverty eradication.

9.2.1 Load bearing structure
Outer and internal masonry walls have been chosen as load bearing structure. Walls are made of the interlocking brick type. Partitioning walls can be erected in the first phase of construction but as the intermediate floor slab is to be cast it is important that the partitioning walls do not carry any load. This can easily be fulfilled by not finishing the last “round” of bricks when putting up the walls.

To stabilise the structure, the cavities in corners are filled with reinforcement bars and concrete and are then connected to the ring beam.

9.2.2 Construction solutions
Affordability has had a great influence upon the choice of material and construction solutions. Limitations are set by the small economic assets. Compromises in terms of function or thermal qualities are sometimes accepted to uphold affordability. Durability are strongly linked to affordability and therefore also of major importance.

To fulfil spatial qualities, materials are chosen to suit the hot humid coastal climate. Cavities in bricks and slab elements minimises heat-storage capacity.

By using local materials and locally produced elements the construction is environmentally friendly by minimising transport of materials. Locally produced materials and building elements create job opportunities which contribute to sustainable development.
Intermediate floor slab

In this thesis, three alternative constructions for an intermediate floor slab have been studied to see whether the present used solid reinforced concrete slab could be replaced with a better and more affordable solution. A technical and an economical evaluation have been carried out to determine the best alternative for a low cost intermediate floor slab.

The construction preferred instead of the present used solid reinforced concrete slab is the semi-prefabricated hollow slab elements & inverted T-beam. The hollow elements decrease concrete consumption which contributes to affordability. The construction is economical as no moulding forms or timber for formwork is required. Since the T-beams already have a certain load bearing capacity less demand for auxiliary supports are needed.

The execution of floor slab is a simple in-situ construction. Elements are light weight and put in place one by one before casting concrete.

Due to the long introduction time of new ideas, the technique is not yet widely spread. Since the ambition is to implement the construction, the standardised drawings have an alternative solution with a solid reinforced concrete slab as an option.

Today, these elements are developed using a concrete mixture. This is considered acceptable since concrete is produced locally in Dar es Salaam factories and does not need to be imported. Possible further studies would be to investigate if soil cement could be used for these elements.

According to the cost analysis the cost for construction of a semi-prefabricated slab is 77% of the cost when constructing a solid reinforced concrete slab. For actual values and cost analyses; see appendix F2.

Walls

As walling material the soil-cement interlocking bricks will be used as both load bearing and partitioning walls.

Stabilised soil interlocking bricks are made from ordinary soil mixed with a small amount of cement and then highly compacted in a brick press. Suitable soil can be found frequently close to construction sites why cost for materials and transportation will be reduced.
A soil sample taken at a construction site in Mkunguni ward, HanaNasif has been tested and analysed. Bottle test shows that soil originating in the study area is suitable for making cement stabilised soil bricks. *Further analyses are found in appendix C.*

The interlocking technology is both simple and quick. Since no mortar is required, no masons need to be employed. This eliminates additional cost for workers, material and supplementary cost for transport.

Compared to framed structures, the interlocking system demands less skilled labour on site, since knowledge of reinforcement is not needed in the same extent.

The production of soil-cement bricks and the interlocking principles used when erecting walls are both ideal for self-help constructions. Mafundi are not always required since the production techniques are very simple to learn and can easily be passed forward.

Regarding thermal comfort, solid block elements would delay the cooling process of the building why the hollow interlocking bricks are more suitable. The main contributing factor to cooling of the building in the hot-humid climate is although to make sure the building is properly ventilated.

The cost for erecting a two storey Swahili house made of soil-cement interlocking bricks are 58% compared to a house made of sand-cement blocks. If usable soil could be found at site, costs could be reduced by halve. *For actual values and cost analyses; see appendix F2.*

**Roof**

Roof trusses are made of soft wood. The roof truss design is different from the technique used in Sweden. The geometry used in Tanzania is not effectively designed for carrying heavy loads. The Tanzanian technique cut use of timber which makes it cheaper and since heavy loads such as snow do not exist, there is no reason to change the commonly used design.

In the standardised drawings, corrugated iron sheets have been chosen as roof cover. This may not seem like the best choice as the iron sheets contribute to high indoor temperatures. The construction solution chosen is a compromise between durability, affordability and availability. The reason for choosing corrugated iron sheets is that they are easily
available and fairly cheap. Thermal comfort is improved by installing a ceiling at the upper floor.

To reduce sound level and optimise thermal comfort, thatch could be placed upon the metal sheets. This would also preserve the traditional performance of roofs but probably not be affordable for poor households.

**Additional construction solutions**

Remaining construction solutions emerge in the standardised drawings but are not presented in this chapter since they have not been further studied.

**9.3 Skills and training of local artisans - Mafundi**

Even though, there are a number of competent Mafundi who have learnt their trade on the job, it is clear that many more are needed. The establishment of the Vocational Training Centres and improvement of training institutes and universities has not been enough to eliminate the shortage of skilled manpower.

Previously organised mafundi training courses show that practical education results in increased skills. After initial guidance the artisans were able to make bricks without any supervision. Suitable training is essential to strengthen their confidence and belief in the qualities of their constructions.

According to Dr. Huba M. Nguluma’s study there are Mafundi who controls techniques used for two storey-buildings. Mafundi interviewed in present study, said they were neither willing nor capable to erect a two-storey building without architectural and structural drawings. The important matter to sort out it is maybe not whether the artisans have the ability to construct two-storey houses; it is rather a question where and how educational practise can be improved.

The technology level used by informal construction workers is considered to be very varied and occasionally unsatisfying for the project performed. Generally building sites in Tanzania have, due to shortage of funds, an insufficient number of supervisors compared to the very large quantity of workers. By using readymade elements, the work carried out at construction sites demand less skilled labour and in addition less site supervision. The technique will also reduce the risk of making fateful mistakes at site hence increase outcome quality of constructions.
9.3.1 Self-help
Self-help as in self construction is very rare today in Dar es Salaam informal settlements. Yet, family help can reduce costs for construction. In early stages of development, block production showed that family labour could replace wage labour and save expenses for poor households during the construction process.

9.4 Standardised drawings
The main obstacles when building a two-storey construction, compared to a single storey house, are the need of structural drawings and a building permit. Since two-storey constructions are unusual in informally planned areas it is very likely that the municipality pay attention to them. Hence it is important that houses are built in line with regulations.

The bureaucratic process of applying for a building permit is an extensive and time-consuming process. It may take more than four years to get a piece of land and accomplish a house construction. Standardised drawings which are in accordance with building regulations could possibly shorten the handling of drawings and minimise remarks at the municipality.

There will be an option whether to use the commonly known technique of producing the intermediate floor slab or use the proposed new improved and cheaper slab strip technique. Drawings are made according to Tanzanian standards. The standardised drawings are found in appendix L.
10 Analysis & discussion

Two storey houses will not solve the unacceptable housing situation that is present for many poor families in developing countries. For the lowest income bracket, who are struggling for food on the table it is impossible to afford or even dream of constructing a two storey house.

Neither are vertical extensions of houses a complete solution for infrastructural or density issues. But hopefully, implementing the ideas could improve quality of life for some families.

10.1 Selection of study area

The settlement area of HanaNasif is partially upgraded. The area has a functioning infrastructural system with both proper storm drainage system and good accessible roads. The area has constructions of varying quality ranging from worn mud n’ wattle constructions to well constructed two storey constructions. The wide range of constructions made this area appropriate to study. Since the area is fairly well provided with basic infrastructural functions, some families may have possibilities to carry on vertical extension of their houses.

10.2 Spatial design

When asking around, many dwellers in Dar es Salaam informal settlements would prefer a modern self-contained house. This means that toilette and kitchen is found inside the house.

As described earlier, to cut costs, no chimney is installed in the proposed construction as cooking is supposed to mainly take place outside. Observations show a different reality. All households visited were in general cooking some kind of food in the corridor. This is not only during rainy seasons. Therefore a cooking stove connected to a chimney is recommended if affordable.
10.2.1 Flexibility

The traditional or frequently used development of the house type does not necessarily need to be changed. The new proposed construction technique for the Swahili house and the vertically extended Swahili house still allows addition of new rooms as long as the foundation is prepared for the entire floor area and loads.

If the standardised drawings should be used directly the spatial design and the construction are somehow fixed. Although, the ground plan can be changed, if taking into account that limits are set by the maximum
span of beams and the position of load bearing walls. Since only the outer walls and the corridor walls are carrying loads the partitioning walls can be moved without endangering the stability of the house.

As the bricks used are interlocking they are a lot more difficult replacing compared to regular blocks with mortar. Then the flexibility of the Swahili house in terms of moving door and window positions will decrease. Still it is possible to cut new openings using the appropriate tools.

10.3 Two-storey buildings

The proposal is intended primary for new buildings. A reconstruction of all existing single storey houses into two-storey houses would not provide more space for infrastructure and streets etc.

As a comparison, if all single storey houses are replaced with two-storey buildings with same ground floor area, the Floor Area Ratio\(^{34}\) will be doubled. According to Dar es Salaam Master Plan (1979:91,) central area design guidelines for communities like HanaNasif prescribes a FAR of 0.5, 30% site coverage and a maximum building height of 30 feet. According to studies made by Dr Lupala, J. [27], consolidated high density, low-rise informal settlements like HanaNassif revealed a land coverage of 41.5%. Generally, single storey house types dominate in these areas and the FAR is 0.41. If one third of the houses in the settlement were vertically extended instead of horizontally, FAR would increase to 0.55. Vertical extension may replace some existing buildings that now encroach upon streets and common areas. Site coverage could then also be reduced inline with the Dar es Salaam master plan.

10.3.1 Technical solutions

As mentioned earlier three aspects are of major importance for the choice of technical solutions. Constructions suggested may be the most suitable considering affordability, durability and satisfactory opportunities for high execution quality.

The choice of a solid reinforced concrete slab as the intermediate floor was not the most affordable solution according to cost analysis.

\[^{34}\text{FAR = total built up area is divided by the land covered by buildings. Since floor area ratio takes into consideration the height of buildings, it has been frequently used as a tool to regulate physical density and townscapes or skylines.}\]
The alternative using hollow slabs made of slab strips manufactured from masonry elements where actually the cheapest solution, however cost analysis and technical development of the low-cost slab elements made by Dr. Makunza were based on the construction of a 4x4 m floor slab. Conditions of a continuous beam or floor slab are different. The assembly of beams including reinforcement is supposed to be carried out at ground. Interacting forces between concrete used to fix reinforcement to beams and topping-up concrete where not verified and the amount of reinforcement appeared too weak to handle the bending moment for the actual span. As the strips are supposed to be fixed together before they are placed at the walls, the movement is to be considered as a risk. Moreover it was also found hard to rationalize the production of elements.

The most suitable solution according to execution quality might be the composite slab with reinforcement sheets. The construction is easy to execute and demands less technical knowledge of workers. Since the reinforcement sheets at present have to be imported the construction solution will not support community development or increase technical knowledge of local artisans. On the other hand, if the sheets could be produced locally, industries would support both aspects. In further studies it could also be interesting to elucidate the possibility of using topping-up soil-cement instead of concrete which could result in major cost reductions.

Using soil cement interlocking bricks as walling material for the proposed two storey construction was a matter of course. Using the technique in the proposal may create more durable houses and in a way support the NHBRA and contractors to increase the production and knowledge of technique and make it available to reduce costs for more poor dwellers.

10.3.2 Risks

When introducing new techniques there is always a risk of faults in construction as it has not been fully investigated and tested. With time, new techniques can be improved, more durable and safe.

There is also a big risk letting inexperienced artisans construct houses with new unknown techniques. Since two storey houses a rare, mafundi obviously lack experience. Risks could be minimised by arranging training in construction with new techniques. Previously in some extent
houses have been provided through international organisations or governmental programmes. Own staff were sent with tools and techniques, occasionally unsuitable for local conditions. During these programmes, local artisans never had the chance to build up their knowledge.[28]

10.3.3 Indoor climate

The indoor climate is an important issue, and by choosing the right materials and providing for proper ventilation it could be vastly improved. As the proposed construction in this thesis is a compromise between durability, affordability and availability, as mentioned in chapter 9, this issue has not been fully prioritised.

There are both positive and negative effects when erecting two-storey constructions. As the construction rise above surrounding buildings the upper storey obtain better daylight and cross ventilation and at the same time as the building decreases the daylight in surrounding single-storey houses. Although daylight is limited in single-storey houses lying next to two-storey houses the buildings acquire better shading and possible reduction of indoor temperature. If clustered narrow houses are transformed to, or built as multi-storey constructions the benefits mentioned above regarding ventilation will decrease.

10.3.4 Quality of outdoor space

Two storey buildings would provide coolness and shadow areas for outdoor activities. A negative affect would be that higher buildings also block daylight and wind outside. To minimise these problems, control of distance and relationship between buildings will be needed.

A two storey house can accommodate more people, which may to some extent increase the demand for latrines. If space for additional latrines is not available, outdoor spaces could be negatively affected.

10.4 Standardised drawings

The idea of distributing standard “prototype” drawings for free was well accepted by the local government in HanaNasif. Apart from practical and marketing problems, the main difficulty of distributing standardised drawings is that they have to be linked to a specific area and a specified plot before gaining legal force. One idea is to provide drawings with contact information on where to find architects and engineers who can provide the drawings with the required stamps.
It has been noticed that there are some hesitance when it comes to standardised houses. The architecture and layout of a house is very important to the individual resident and therefore they want to have the opportunity to decide on their own how it would look like. People are reluctant of using standardised structures out of fear of creating a "ghetto" image as in the slum clearance programme. These are issues that might be considered as problems when distributing standardised drawings. Variations in materials and colour of façade, roof and windows generates differences between houses that may reduce homogeneity. The idea is not to erect these standardised structures in vast areas, but drawings are to be distributed to individuals who are in the position of building new houses. When introducing standardised drawings, the main concern is to provide people with information enabling them to build a two-storey house with less amount of money compared to consulting architects and engineers.

10.4.1 Provider approach?

The proposed standardised drawings for the vertically extended Swahili house are intended to be available free of charge and will therefore reduce engineering and architectural costs for poor households. This can be considered as a provider approach but since only drawings are offered, residents still have the opportunity to use incremental development, self-help and local Mafundi, much referred to as parts of the enabling strategy.

Incorporating enabling strategies and incremental development does not mean that professional guidance is not required. As stated by Vestbro (2008); “On the contrary, creative engineering, design and planning efforts are needed in order to find new affordable solutions.” He describes the challenge as the difficulty to get a balance between centralising techniques and the freedom for residents to build their own neighbourhoods.
10.4.2 Implementation

The procedures of implementation of the proposed standardised drawings have been considered, but execution has not been covered within limits of this thesis.

A possible way to implement the idea with the standardised drawings could be as follows: At a local meeting, the drawings and the present thesis would be presented to the residents of HanaNasif settlement. Residents, Mtaa-leaders and the local government could give their comments on the spatial design and the material selection for further alterations. The possibilities of constructing a prototype house may be investigated together with a local Engineer and contractor as a continuation of this report. The standardised drawings could then be distributed to residents who are in the start up-phase of erecting a two-storey construction. The standardised drawings are meant to be distributed for free and could preferably be handed out to the people through the local community offices. Architects and structural engineers at Ardhi University are said to be available to assist builders with stamps which will legalise the drawings.
10.5 **Difficulties**

10.5.1 **Dwellers thoughts on stability**

The daily sense of security has a large impact on the choice of building materials and techniques. Residents feel more confident having a 230 mm thick wall, even thought a 150 mm wall is sufficient in most cases in terms of load bearing capacity.

As a consequence of an eleven-storey building collapsing in downtown Dar es Salaam in June 2008 people are also a bit doubtful when it comes to multi-storey buildings. Their fear of neighbours or their own house collapsing, could restrain them from building more than one storey. Currently this episode has had a large impact on the attitude to multi-storey constructions. This insecurity might be reduced after time as two-storey houses get more common in settlements.

10.5.2 **Find incentives for new technology and materials**

The NHBRA has since the 1970’s developed and tried to introduce soil-cement bricks as a new low-cost building material. Still, the technique is unknown by the majority of dwellers and used only of rare occurrence. Difficulties and obstacles when introducing new elements requiring new construction and manufacturing methods clearly appear. Presence of material will after time lead to general acceptance and increased knowledge which will reduce costs for production.

In a report written in 2005, the NHBRA states; “Judging from the number of buildings already constructed by many in Dar es Salaam it is evident that, this technology (meaning interlocking soil-cement bricks) will spread very fast.” According to people interview and responsible staff at the NHBRA, the technique has not been spread as fast as they first believed it would. People are still doubtful and prefer old reliable alternatives.

The biggest challenge for the NHBRA is still to get the new technology accepted by the public in general, the contractors, engineers and architects. It is therefore important that organisations such as NHBRA, ILO and NCC continue to provide training for mafundi to further develop and spread more durable and affordable materials. The advantage of using interlocking soil-cement bricks instead of cement consuming sand-cement blocks had to be further introduced to be accepted in informal settlements. Mafundi ought to be trained but also provided with incentives to buy and use machines for production of soil-cement bricks. For the most parts knowledge has to be spread. Even Lecturers at
Ardhi University are not familiar with this money and time-saving technique.

Another problem with the present situation is that the market price of interlocking soil-cement bricks is high, due to poor availability. These facts reduce the cost-efficiency of the building technique which could be more affordable if widely spread.

10.5.3 Insecurity of land tenure

As Nnaggenda-Musana, Assumpta stated in her doctoral thesis in 2008, security of tenure is still more important than the state of the house. It is only when incomes increase further the house itself starts to become a priority.[34]

Informality of areas is a major issue to solve in Dar es Salaam. If there is no guarantee for dwellers to be able to stay on the land they are not likely to invest in durable constructions.

10.5.4 Regulations

The compressive strength of the tested walls of soil cement in Prof. Mwamilan and Dr Makunza’s report falls below the minimum value given in BS 5628 table 2. This may be attributed by irregularities in the thickness of the bricks. This could be considered a problem when applying for a building permit as the wall does not meet the requirements but it is unlikely to be a problem as the NHBRA are promoting and using the bricks. According to our calculations the wall is strong enough to carry an intermediate floor slab.

10.5.5 Drawings

Legalisation of drawings has to be made by receiving a stamp from an authorised architect and an engineer. Although staff at Ardhi University are said to be available to assist builders it is an uncertainty. Problems could also occur if the Municipalities do not accept our drawings and the static calculations.

Obviously, marketing and distribution of drawings could not be carried out through internet which would have been an easy solution. Distribution had to go through the university or the local government and their offices. Although drawings are meant to be distributed for free there may be some problem with corruption and second hand sales.
Since English are widely spoken among engineers, architects and high educated in Tanzania, drawings are commonly written in English. Most mafundi speak only their tribal language and some Swahili. Therefore the produced drawings might need to be translated to be useful for the target group intended.

10.5.6 Uncertainty of sources

The mixing ratio for interlocking bricks in the test made by Dr J.K Makunza was 1:15. 1 part of cement and 15 parts of crusher dust from Kundichi quarries. The determined ratio for soil found in HanaNasif is 1:16 but the compressive strength which is used in calculations is still based on bricks made with a mixing ratio of 1:15.
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Vertical extensions of the Urban Swahili House
Hanna Kruse & Lotta Torstensson

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Appendix A: Questionnaire

Dwellers in HanaNasif informal settlement

1. Background information

The house is:
- Owner only
- Tenants & owner
- Tenants only

Owners name:
Person interviewed:
House no:
Sex:
Date:
Education:
No of persons in household living together:
No of persons living in the house:

2. General

When did you start living in this house?

Where did you live before?

Are you the first one to live in this place?

When was this house constructed?

Who built it? (Mafundi)

How long did it take to complete the house?
Vertical extensions of the Urban Swahili house

Hanna Kruse & Lotta Torstensson

Were there any problems during the construction of your house?

Has your house been transformed?

3. Vertical extensions

If you had the opportunity to live in a two-storey building how would it be planned in terms of distribution of rooms and space?

If you had the chance to choose your way of living would you choose to live in a two-storey building?

How would you feel about living on the upper floor?

Can you see any problems in living in a two-story building (tradition, contradictions)?

How would you feel if your neighbours transformed their house into a two-storey building?

Have you ever considered the possibility to vertically extend your house?

Do you think a vertical extension will modernise your house?
What do you think the positive/negative things are about a vertical extension?
Appendix B: Production of soil-cement interlocking bricks

The method used by the NHBRA when producing soil-cement interlocking bricks is an improved technique with its origin in Nairobi, Kenya. This appendix contains the most important parts of a manual meant to be a guideline for people using interlocking brick machines. Included are also prices, difficulties and local adjustment.

Stages involved in brick production

- Soil selection and testing
- Soil preparation
- Batching
- Dry and wet mixing
- Production of bricks
- Curing
The interlocking press Machine

Machines for manufacturing bricks can be bought from the NHBRA for 400 000 TShs ($400) or from other supplier for approx. 680 000 TShs. If the settlements are supported by local authorities or the community, manufacturing machines can be jointly bought. Expenses for buying one solid or hollow interlocking soil-cement brick is about 350 TShs.

To operate the block press a minimum of two people are required for a small production capacity, while a minimum of 4-6 people will be needed for a mass production.

Soil selection and testing

The right type of soil for SSB (stabilised soil blocks) production should contain approximately 30-40% clay and 60-70% sandy soil. The soil used should also not have particles exceeding 6 mm. The layer of sub-soil found immediately below the top soil is in most cases naturally stable and most suitable for production of stabilised soil bricks.

Before any block making commences, the soil to be used must be tested to determine its suitability and the amount of stabiliser to be used. After determining the suitable soil by using the test described below, it is advised to manufacture bricks of different ratio for test sample purposes.

Bricks should be made with 7% minimum cement content. Higher cement contents will give stronger and more durable bricks but will lead to a more expensive construction. [30]
The bottle test
The aim of this test is to approximately determine the amount of clay, silt, sand and gravel in the soil. The result gives the percentage content of the fine and coarse particles in the soil sample. To perform the test, a clear bottle, water and regular salt are required.

The testing procedure:
- A clear bottle is filled with soil up to approximately a third full
- Clean water is added until two thirds of the bottle is full
- A pinch of salt is added to the bottle contents
- The bottle is closed and thoroughly shaken for about a minute
- The bottle is left on a flat base for approximately 30 min. As the soil settles, the big particles settle at the bottom and the fine once on top.
- By looking closely at the soil contents it is possible to determine where the clay starts. The percentage of clay is determined after measuring the height of clay and divides it with the total height of the soil.

Less than 10%: The soil is not suitable for stabilisation as it will be difficult to manually handle the bricks from the machine due to lack of cohesion.

Greater than 40%: The soil is not suitable for making stabilized soil blocks unless some sand is added. A larger clay amount if not mixed with sand demands a higher percentage of cement. This will make the technology uneconomical and also result in high risk of blocks cracking.

The box test – linear shrinkage test
The box test is used to determine the amount of cement stabilizer to be used. To perform the test, a simple box made of wood with internal dimensions of 600 mm x 4 mm x 40 mm is required.

Test procedures:
- The inside of the box is oiled
- Soil is mixed with water until saturated
- The box is filled with wet soil and excess soil is removed by leveling the top
- Box is left to dry for 7 days
• After seven days the shrunken and cracked soil is pushed to one end of the box and the gap on the other end is measured. This indicated the overall shrinkage of the soil.

• The table below is used to determine the cement/soil ratio to be used.

<table>
<thead>
<tr>
<th>Shrinkage</th>
<th>Cement (buckets)</th>
<th>Soil (buckets)</th>
<th>Approximately numbers of blocks from one bag of cement.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 12 mm</td>
<td>1</td>
<td>18</td>
<td>110 Blocks</td>
</tr>
<tr>
<td>12 mm – 24 mm</td>
<td>1</td>
<td>16</td>
<td>90 Blocks</td>
</tr>
<tr>
<td>25 mm – 39 mm</td>
<td>1</td>
<td>14</td>
<td>85 Blocks</td>
</tr>
<tr>
<td>40 mm – 50 mm</td>
<td>1</td>
<td>12</td>
<td>75 blocks</td>
</tr>
</tbody>
</table>

### Making blocks

Crucial stages in the production process are the mixing of soil-cement and the curing of blocks. To secure a satisfactory compression strength the soil-cement mixture has to be well compacted when bricks are made.

One cement bag\(^{35}\) will be enough for producing approximately 100 hollow bricks.[81] Depending on the efficiency of labour, 200-500 pieces can be made each day (8h).

### Preparatory steps

The soil must be dry in order to mix well with cement and are therefore dried in the sun for a few days.

### Screening

Large gravel particles are removed and lumps are broken up before the soil is used. The whole soil is passed through a 5 mm screen to remove remaining large particles.

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\(^{35}\) One bag of cement cost 13 500 TShs (USD 13.5) in the Dar es Salaam area but are more expensive in rural areas.
Mixing
Dry soil is mixed with dry cement at the predetermined proportion of shrinkage. The quantities of both soil and cement are measured by using a container and mixed until showing a uniform colour. Water is added by sprinkling until the mix has the correct consistency.

Brick moulding
There are four stages in the process of moulding the bricks using the brick press machine.

- Filling the machine with soil: The amount of soil required is measured by the volume which fills up the mould box.
- Compressing: For proper compaction the handle must be brought to a horizontal position to complete the stroke until it touches the sizzling pan.
- Ejecting the brick: The ejection of bricks is made manually and therefore also a crucial part of the production.

Lifting away and curing: Blocks are lifted away by placing hands flat on sides and laid in the shade for curing. Bricks are cured by keeping them damped for a period not less than 7 days by spaying them with water daily and cover them with damp hessian or grass.

Testing
For every day’s production, 3 blocks should be picked randomly for testing. The blocks can with simple practical methods be tested for compressive strength and water absorption. This can be made at the building site by the local Fundi.

Drop test
A block is lifted up to a height of 1 metre from a hard ground and then dropped. If the block remains in one piece, only breaking the edges, the block has passed the test and will meet the standard with are comparable to burnt bricks or concrete blocks, which require a compressive strength of 2.5 kN/mm².
3 point bending test
A brick is placed between two bricks as shown in the picture. A minimum weight of 90 kg (an average man holding a few blocks) is placed in the centre of the block.

Types of bricks
The interlocking bricks and its geometry have been developed since first implemented. Improvements of the profile has lead to a more simplified moulding machine, enhanced practical workmanship and a cheaper, more affordable design.

The interlocking press machine can manufacture different brick shapes according to bonding requirement.

Main brick types are;
- Full brick
- Three quarter-bat
- Half-bat
- Centre half-bat
Appendix C: Soil sampling and testing, HanaNasif

Sample was taken at a construction site in Mkunguni ward, HanaNasif. Soil was brought up from a depth of approximately 15 meters. The sample was transported to the NHBRA for testing and analyses.

**Bottle test:**

- Total height of sample: 450 mm
- Measured height of coarse particles: 170 mm
- Percentage of coarse particles (clay): \( \frac{170}{450} = 0,377778 = 38\% \)

Bottle test shows that soil found in HanaNasif area are suitable for making cement stabilised soil bricks.
Shrinkage test:
Measured shrinkage after seven days: 12 mm

According to the Soil/Cement Ratio mixing Guide, mixing ratio is 1:16 and approximately 90 bricks can be produced per bag of cement from the soil found in HanaNasif area.

Results
Bottle test shows that the soil sample originating in the HanaNasif area is suitable for making cement stabilised soil bricks. Mixing ratio is approximately 1:16 but has to be determined for soil available at the site location.

Comments:
The low range of shrinkage indicates a smaller amount of clay than what was determined in the bottle test. A large amount of clay-sized material in the soil sample could explain the diverse results.
### Appendix D: Costs for building materials & machines

<table>
<thead>
<tr>
<th>Material</th>
<th>Unit</th>
<th>Quantity</th>
<th>Rate (TShs)</th>
<th>Volume (m³)</th>
<th>Cost/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>bag*</td>
<td>5</td>
<td>13500</td>
<td>0,2</td>
<td>67500</td>
</tr>
<tr>
<td>Sand (Makoba)</td>
<td>kg</td>
<td>7000</td>
<td>70000</td>
<td>4,5</td>
<td>15556</td>
</tr>
<tr>
<td>Sand (Fred)</td>
<td></td>
<td></td>
<td>50000</td>
<td>4,0</td>
<td>12500</td>
</tr>
<tr>
<td>Aggregates (Makoba)</td>
<td>kg</td>
<td>7000</td>
<td>210000</td>
<td>4,5</td>
<td>46667</td>
</tr>
<tr>
<td>Aggregates (Fred)</td>
<td></td>
<td>180000</td>
<td></td>
<td>4,0</td>
<td>45000</td>
</tr>
</tbody>
</table>

**Mixed Concrete (Sand Cement)**

| Concrete C20 1:2:4             | m³         | 7        | 278889     |             | 39841   |
| Concrete C15 1:3:6             | m³         | 10       | 384583     |             | 38458   |

| Treated timber 50x100          | m          | 1        | 3000       |             |         |
| Iron sheets 3x0.85m            | psc        | 1        | 7200       |             |         |

**Reinforcement local**

| D12                            | m          | 1        | 1288       |             |         |
| D16                            | m          | 1        | 2291       |             |         |

**Reinforcement bars**

| 16 m                           | m          | 12       | 25000      |             |         |
| 12 m                           | m          | 12       | 15000      |             |         |
| 10 m                           | m          | 12       | 9000       |             |         |
| 8 m                            | m          | 12       | 7000       |             |         |
| 6 m                            | m          | 12       | 5000       |             |         |

| Timber for form-work 150x25    | m          | 3,35     | 3500       |             |         |
| Timber for form-work 2"x4" (130x65) | m²       | 1        | 12000      |             |         |

**Form-work (incl labour)**

| Props (Fred)                   | pcs        | 2000     |           |             |         |
| Props (Makoba)                 | pcs        |          |           |             |         |

| Nails 2 1 1/2" appr 200pcs     | kg         | 2700     |           |             |         |
| Water                          | m³         | 1        | 6500       |             |         |
| Water                          | liter      | 20       | 50         |             |         |

| Soil***                         | m³         | 10       | 120000     |             | 12000   |

**Complete simple building with self-help**

|                        |            | 100000   |            |             |         |

* 5 bags approx = 1 m³
** Diameter available 6, 8, 12, 16, 20, 25, 32 mm
*** Price mostly dependent on costs for transport
### Machines

<table>
<thead>
<tr>
<th>Machines</th>
<th>Purchase Price</th>
<th>Hire</th>
<th>Price/Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete mixer</td>
<td>50 000</td>
<td>50 000</td>
<td></td>
</tr>
<tr>
<td>Concrete vibrator</td>
<td>50 000</td>
<td>30 000</td>
<td></td>
</tr>
<tr>
<td>Transportation of machines</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Portable vibrator for tiles(^{\text{36}})</td>
<td>150 000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interlocking brick machine</td>
<td>400 000-680 000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^{36}\) Machines are produced locally by the NHBRA. The purchase price has in recent years been reduced from 250 000 to present 150 000. Although, the production price of sisal tiles has increased due to escalating price of aluminium sheets for formwork.
Appendix E: Labour cost and production time

Labour
Depending on the preference of the contractor, the type of work and the building owner, payment for labour are based on time or piecework. Payment fluctuates widely according to availability of work. Costs for labour are therefore imprecise approximations. *See chapter 6 for further details.*

The NHBRA calculate the cost for labour as 30% and the cost of material as 70% of the total cost.

In this thesis, costs for labour are based on pricing shown below;

<table>
<thead>
<tr>
<th>Rate of labour for low-cost housing</th>
<th>( \text{TShs/pcs} )</th>
<th>( \text{TShs/day} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mafundi per piece-work</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 block</td>
<td>250</td>
<td></td>
</tr>
<tr>
<td>1 block above 1,5 m</td>
<td>300</td>
<td></td>
</tr>
<tr>
<td>Labour</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unskilled</td>
<td>5000</td>
<td></td>
</tr>
<tr>
<td>Skilled</td>
<td>Range from 10000-15000</td>
<td>12500</td>
</tr>
</tbody>
</table>

Assumptions of the amount of labour needed for each activity in the different phases of construction are based on information gathered during fieldwork. Approximations originate from interviews with contractors as well as being a consequence of observations at building sites. As both skills and rates of workers vary heavily, assumptions are connected with a great deal of insecurity.

Approximate time of production

*Sisal Tiles:* One labourer can produce approximately 300 pieces of sisal tiles each day (8h), using a portable vibrator. 300 tiles cover 27m². Tiles dry for 24 h before put in water for 7 days curing.

*Interlocking bricks:* Assumed that two persons operate the interlocking brick machine approximately 350 psc of interlocking bricks are produced each day.[74]

*Sand cement blocks:* As Interlocking bricks, read above.
Concrete work: To minimize cost for machines, the amount of workers employed is intended to be enough to do all the concrete work in one day. To prevent overcrowded spaces the quantity of people is limited to not more than 40 people per machine (Waterboys not included). Workforce for concrete works are listed in table F:2b.

In present cost analysis the amount of labour at site is linked to the volume of concrete. Costs for labour are reduced with the decreased volume of concrete.

Slab elements: Slab elements for intermediate floor slabs are not yet introduced to the market or in production, which make approximation of time for production a bit uncertain. Test made by Dr. Makunza at COET, shows that after some training 100 elements per day might be produced. Calculations of costs in this analysis are based on the assumption that three workers produce 50 elements each day. If assembly of moulding forms is simplified, efficiency may increase. [76]
Appendix F: Cost analyses

F:1 Load bearing walls

As shown in appendix K, the quality and strength of block and bricks produced locally in Dar es Salaam are sufficient to carry loads of an intermediate floor slab and wall of an upper storey with the chosen geometry.

Available materials for production of blocks/bricks suitable for load bearing walls are soil cement and sand cement. Currently, none of those alternatives are being used without a supporting structure of pillars. For single storey houses sand-cement blocks are preferred among builders instead of sand cement bricks.

Production of sand-cement blocks is of frequent occurrence in Dar es Salaam informal settlements. Although savings could be achieved if blocks are produced through self-help and own family labour. Manufacturers of soil cement interlocking brick are not common in the same extent. The market price for ready-made soil cement interlocking bricks is therefore proportionally high. Cost for the different alternatives have been estimated and are shown below.

Since interlocking bricks are chamfered, plastering work and rendering could get slightly more expensive compare to if sand cement blocks are used. Those costs are not included in cost estimations.

Geometry

<table>
<thead>
<tr>
<th>Wall</th>
<th>Perimeter (m)</th>
<th>Wall Area</th>
<th>A above 1,5m</th>
<th>A below 1,5m</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st floor</td>
<td>73.11</td>
<td>170.0</td>
<td>60.3</td>
<td>109.7</td>
</tr>
<tr>
<td>2nd floor</td>
<td>76.51</td>
<td>176.0</td>
<td>176.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Total</td>
<td>346.0</td>
<td>236.3</td>
<td></td>
<td>109.7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Block/Brick</th>
<th>Interlocking brick</th>
<th>Sand-Cement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width (m), w</td>
<td>0.150</td>
<td>0.230</td>
</tr>
<tr>
<td>Lenght (m), t</td>
<td>0.300</td>
<td>0.450</td>
</tr>
<tr>
<td>Height (m), h</td>
<td>0.125</td>
<td>0.150</td>
</tr>
<tr>
<td>Hole radius (m), r</td>
<td>0.031</td>
<td></td>
</tr>
<tr>
<td>Volume (m³)</td>
<td>0.005</td>
<td>0.016</td>
</tr>
<tr>
<td>Area (m²)</td>
<td>0.038</td>
<td>0.068</td>
</tr>
</tbody>
</table>
Alt 1 - Bricks and blocks are bought ready manufactured

<table>
<thead>
<tr>
<th>Interlocking Brick</th>
<th>Unit</th>
<th>Quantity</th>
<th>Rate TShs</th>
<th>Total (TShs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>pcs</td>
<td>9 225</td>
<td>350</td>
<td>3 228 902</td>
</tr>
<tr>
<td>Labour at site</td>
<td>day</td>
<td></td>
<td>728 169</td>
<td>728 169</td>
</tr>
<tr>
<td>Foreman</td>
<td>day</td>
<td></td>
<td>350 000</td>
<td></td>
</tr>
<tr>
<td>Mortar</td>
<td></td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>4 307 071</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sand-Cement block</th>
<th>Unit</th>
<th>Quantity</th>
<th>Rate TShs</th>
<th>Total (TShs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>pcs</td>
<td>5 125</td>
<td>900</td>
<td>4 812 717</td>
</tr>
<tr>
<td>Labour</td>
<td>pcs</td>
<td>1 625</td>
<td>250</td>
<td>406 167</td>
</tr>
<tr>
<td>Labour (above 1,5 m)</td>
<td>pcs</td>
<td>3 501</td>
<td>300</td>
<td>1 050 172</td>
</tr>
<tr>
<td>Mortar</td>
<td>m³</td>
<td>7</td>
<td>39 841</td>
<td>281 791</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>6 350 846</strong></td>
</tr>
</tbody>
</table>

*If using soil cement* (% ) USD $ SKr TShs
Alt 2 – Interlocking Bricks are produced at site.
Assumed that 350 psc are produced each day. Two persons operate the interlocking brick machine.

<table>
<thead>
<tr>
<th>Material cost for production of interlocking bricks</th>
<th>Unit</th>
<th>Quantity Cement</th>
<th>Rate TShs/kg</th>
<th>Quantity Soil</th>
<th>Rate</th>
<th>No of bricks</th>
<th>Rate/Brick</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil ratio 1</td>
<td>kg</td>
<td>50</td>
<td>13500</td>
<td>900</td>
<td>6.32</td>
<td>110</td>
<td>174</td>
</tr>
<tr>
<td>1:16 Hana Nasif</td>
<td>kg</td>
<td>50</td>
<td>13500</td>
<td>800</td>
<td>6.32</td>
<td>90</td>
<td>206</td>
</tr>
<tr>
<td>Soil ratio 3</td>
<td>kg</td>
<td>50</td>
<td>13500</td>
<td>700</td>
<td>6.32</td>
<td>85</td>
<td>211</td>
</tr>
<tr>
<td>Soil ratio 4</td>
<td>kg</td>
<td>50</td>
<td>13500</td>
<td>600</td>
<td>6.32</td>
<td>75</td>
<td>231</td>
</tr>
</tbody>
</table>

Material cost for production of interlocking bricks if soil are found at site

<table>
<thead>
<tr>
<th>Material cost for production of interlocking bricks if soil are found at site</th>
<th>Unit</th>
<th>Quantity Cement</th>
<th>Rate TShs/kg</th>
<th>Quantity Soil</th>
<th>Rate</th>
<th>No of bricks</th>
<th>Rate/Brick</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:16 Hana Nasif</td>
<td>kg</td>
<td>50</td>
<td>13500</td>
<td>800</td>
<td>0.00</td>
<td>90</td>
<td>150</td>
</tr>
</tbody>
</table>
Vertical extensions of
the Urban Swahili House
Hanna Kruse & Lotta Torstensson

Appendix

Interlocking brick

<table>
<thead>
<tr>
<th>Material</th>
<th>Unit</th>
<th>Quantity</th>
<th>Rate TShs</th>
<th>Total (TShs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brick material Ratio 1</td>
<td>pcs</td>
<td>9 225</td>
<td>174</td>
<td>1 608 933</td>
</tr>
<tr>
<td>Brick material Ratio 2</td>
<td>pcs</td>
<td>9 225</td>
<td>206</td>
<td>1 901 734</td>
</tr>
<tr>
<td>Brick material Ratio 3</td>
<td>pcs</td>
<td>9 225</td>
<td>211</td>
<td>1 945 053</td>
</tr>
<tr>
<td>Brick material Ratio 4</td>
<td>pcs</td>
<td>9 225</td>
<td>231</td>
<td>2 126 705</td>
</tr>
<tr>
<td>Ratio 2 (Soil found at site)</td>
<td>pcs</td>
<td>9 225</td>
<td>150</td>
<td>1 383 815</td>
</tr>
<tr>
<td>Interlocking brick machine</td>
<td>pcs</td>
<td>1</td>
<td>400 000</td>
<td>400 000</td>
</tr>
</tbody>
</table>

Labour

<table>
<thead>
<tr>
<th>Task</th>
<th>Unit</th>
<th>Hours</th>
<th>Rate TShs</th>
<th>Total TShs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digging soil</td>
<td>day</td>
<td>28</td>
<td>5000</td>
<td>140 000</td>
</tr>
<tr>
<td>Drying, crushing, sieving</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixing soil, cement, water</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compaction of bricks</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stacking and moist-curing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brick making</td>
<td>day</td>
<td>28</td>
<td>5000</td>
<td>140 000</td>
</tr>
</tbody>
</table>

| Total Soil Ratio 1            |        |       |           | 2 288 933  |
| Total Soil Ratio 2            |        |       |           | 2 581 734  |
| Total Soil Ratio 3            |        |       |           | 2 625 053  |
| Total Soil Ratio 4            |        |       |           | 2 806 705  |
| Total Soil Ratio 2 (Soil found at site) |         |       |           | 2 063 815  |

| Labour at site                | day    | 28    | 728169    | 728 169    |
| Foreman                       | day    | 28    | 12500     | 350 000    |

<table>
<thead>
<tr>
<th>USD $</th>
<th>SKr</th>
<th>TShs</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL</td>
<td>3660</td>
<td>27449</td>
</tr>
<tr>
<td>TOTAL (Soil found at site)</td>
<td>3 141 984</td>
<td></td>
</tr>
</tbody>
</table>

Reduced cost for interlocking bricks

- 85% Percent of cost compared to ready-made soil-cement bricks
- 58% Percent of cost compared to ready-made sand cement blocks

Reduced cost for interlocking bricks when soil is found at site

- 49% Percent of cost compared to ready-made sand cement blocks

According to research carried out by the NHBRA, savings for a 150 mm thick wall made of cement soil (Ratio 1:16, as found in HanaNasif.) compared to a wall made of cement sand blocks are approx. 55% (depending of cement ratio). The difference can be explain depending on the fact that the NHBRA assume that labourers are free and that water for brick making and curing does not need to be bought and transported to site.
### F:2 Intermediate floor slab

**Geometry, table F:2a.**

<table>
<thead>
<tr>
<th>Intermediate floor of the proposed</th>
<th>Perimeter (m)</th>
<th>Floor Area (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>two-storey Swahili house (Sw H)</td>
<td>41.81</td>
<td>106.3</td>
</tr>
</tbody>
</table>

*Approximately costs for labour.* [82]

When casting a concrete floor slab, usually the amount of workers employed is adjusted to be enough to perform all the concrete and reinforcement work in one day. If using a concrete mixer machine the quantity of workers are limited to approximately 40 people from considerations of space. *(Waterboys not included).* [82] Calculations of costs for the intermediate floor slabs are based upon these assumptions. As described by a local contractor, listed below are the different kinds of workforce needed when casting a normal concrete floor. [82]

**Workforce for concrete works, table F:2b**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Unskilled</th>
<th>Skilled</th>
<th>Rate (TShs/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete mixing</td>
<td>1</td>
<td></td>
<td>5 000</td>
</tr>
<tr>
<td>Carrying water from source to tank</td>
<td>2</td>
<td></td>
<td>10 000</td>
</tr>
<tr>
<td>(if nearby)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water from tank to machine</td>
<td>1</td>
<td></td>
<td>5 000</td>
</tr>
<tr>
<td>Cement to mixer</td>
<td>1</td>
<td></td>
<td>5 000</td>
</tr>
<tr>
<td>Sand to mixer</td>
<td>3</td>
<td></td>
<td>15 000</td>
</tr>
<tr>
<td>Aggregates to mixer</td>
<td>6</td>
<td></td>
<td>30 000</td>
</tr>
<tr>
<td>Concrete to bucket</td>
<td>3</td>
<td></td>
<td>15 000</td>
</tr>
<tr>
<td>Carrying to site (20 pers/100m²)</td>
<td>21</td>
<td></td>
<td>106 300</td>
</tr>
<tr>
<td>Foreman</td>
<td>1</td>
<td></td>
<td>12 500</td>
</tr>
<tr>
<td>Vibrator controller</td>
<td>1</td>
<td></td>
<td>5 000</td>
</tr>
<tr>
<td>Reinforcement installation</td>
<td>2</td>
<td></td>
<td>10 000</td>
</tr>
<tr>
<td>Form-work</td>
<td>3</td>
<td></td>
<td>15 000</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>44.26</td>
<td>1</td>
<td>233 800</td>
</tr>
<tr>
<td>Total using Self-help</td>
<td>-</td>
<td>5</td>
<td>208 800</td>
</tr>
<tr>
<td>5 family members</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Workforce needed for the common solid reinforced concrete floor slab were estimated based upon the assumed workforce listed above. In the cost analysis of the remaining floor slabs, the amount of labour has been calculated approximately as a part of the workforce estimated for the solid reinforced concrete slab, *alt 1*. For each slab, the number of workers has been adjusted depending on the required volume of concrete.

**Alt 1 - Solid reinforced concrete slab**

The main building technique observed in formal and informal multi storey constructions were a structure of reinforced concrete pillars and
Vertical extensions of the Urban Swahili House

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beams. Floor slabs were made of reinforced concrete constructed with softwood mouldings. To compare the different solution alternatives with the existing technique, first cost analysis regarding a simple solid reinforced concrete slab were carried out.

Reinforcement, table F:2c.

<table>
<thead>
<tr>
<th>Reinforcement bars, D12</th>
<th>Quantity</th>
<th>Length (m)</th>
<th>Total Length (m)</th>
<th>Cost (TShs)</th>
<th>Cost/m² (TShs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper edge</td>
<td>31</td>
<td>3.4</td>
<td>105.4</td>
<td>131 750</td>
<td></td>
</tr>
<tr>
<td>Bottom</td>
<td>31</td>
<td>8.6</td>
<td>266.6</td>
<td>333 250</td>
<td></td>
</tr>
<tr>
<td>Bottom</td>
<td>22</td>
<td>12.45</td>
<td>273.9</td>
<td>342 375</td>
<td></td>
</tr>
<tr>
<td>Upper edge</td>
<td>4</td>
<td>2</td>
<td>8</td>
<td>10 000</td>
<td></td>
</tr>
<tr>
<td>Upper edge</td>
<td>36</td>
<td>2.8</td>
<td>100.8</td>
<td>120 000</td>
<td></td>
</tr>
<tr>
<td>Upper edge</td>
<td>7</td>
<td>2.8</td>
<td>19.6</td>
<td>24 500</td>
<td></td>
</tr>
<tr>
<td>Upper edge</td>
<td>13</td>
<td>2</td>
<td>26</td>
<td>32 500</td>
<td></td>
</tr>
<tr>
<td>Total upper edge</td>
<td></td>
<td></td>
<td>800.3</td>
<td>324 750</td>
<td>3 055</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>1601</td>
<td>1 000 375</td>
<td>9 411</td>
</tr>
</tbody>
</table>

Quantity and dimensions are according to static calculations as seen in appendix K.

Cost for ring beam, table F:2d.

<table>
<thead>
<tr>
<th>Ringbeam</th>
<th>Area (cross-section)</th>
<th>Length (m)</th>
<th>Cost/m (TShs)</th>
<th>Cost (TShs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All 1- solid concrete floor slab</td>
<td>0.02625</td>
<td>50.15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concrete</td>
<td></td>
<td></td>
<td>1 046</td>
<td>52 449</td>
</tr>
<tr>
<td>Reinforcement 4 x D8</td>
<td></td>
<td>175</td>
<td>583</td>
<td>102 083</td>
</tr>
<tr>
<td>2 x D10</td>
<td></td>
<td>12.8</td>
<td>750</td>
<td>9 600</td>
</tr>
<tr>
<td>3 x D12</td>
<td></td>
<td>19.2</td>
<td>1 250</td>
<td>24 000</td>
</tr>
<tr>
<td>Stirrups</td>
<td></td>
<td>58.2425</td>
<td>583</td>
<td>33 975</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>222 107</td>
</tr>
</tbody>
</table>
## Total cost for alt 1 - Solid reinforced concrete slab, table F:2e.

<table>
<thead>
<tr>
<th>Item description</th>
<th>Unit</th>
<th>Quantity/m²</th>
<th>Rate; TShs</th>
<th>Cost/m²; TShs</th>
<th>Cost/Sw H</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete C20 (1:2:4 mix)</td>
<td>m³</td>
<td>0,15</td>
<td>39 841</td>
<td>5 976</td>
<td>635 269</td>
</tr>
<tr>
<td>Concrete C15 (1:3:6 mix)</td>
<td>m³</td>
<td>0,15</td>
<td>38 458</td>
<td>5 769</td>
<td>613 218</td>
</tr>
<tr>
<td>Reinforcement (Steel bars)</td>
<td>m</td>
<td>15</td>
<td>1 250</td>
<td>9 411</td>
<td>1 000 375</td>
</tr>
<tr>
<td>Ringbeam</td>
<td>pcs</td>
<td>1</td>
<td></td>
<td>2 089</td>
<td>222 107</td>
</tr>
<tr>
<td>Form-work</td>
<td>m²</td>
<td>1</td>
<td>12 000</td>
<td>4 720</td>
<td>501 720</td>
</tr>
<tr>
<td>Form-work edge</td>
<td>m</td>
<td>41,81</td>
<td>1 045</td>
<td>411</td>
<td>43 682</td>
</tr>
<tr>
<td>Props</td>
<td>pcs</td>
<td>1</td>
<td>2 000</td>
<td>8 000</td>
<td>850 400</td>
</tr>
<tr>
<td>Labour</td>
<td>m²</td>
<td>44,0</td>
<td>233 800</td>
<td>2 199</td>
<td>233 800</td>
</tr>
<tr>
<td>Labour using self-help</td>
<td>m²</td>
<td>39,0</td>
<td>208 800</td>
<td>1 964</td>
<td>208 800</td>
</tr>
<tr>
<td>Machines (Hire and Transport)</td>
<td>pcs</td>
<td>2</td>
<td>130 000</td>
<td>4 127</td>
<td>8 254</td>
</tr>
<tr>
<td>USD $</td>
<td></td>
<td></td>
<td>36 934</td>
<td>3 926 051</td>
<td></td>
</tr>
<tr>
<td>SKr</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TShs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL (1:2:4)</td>
<td></td>
<td></td>
<td>3 879</td>
<td>29 093</td>
<td>3 879 000</td>
</tr>
<tr>
<td>Total using Self-help</td>
<td></td>
<td></td>
<td>3 879</td>
<td>29 093</td>
<td>3 879 000</td>
</tr>
<tr>
<td>TOTAL (1:3:6)</td>
<td></td>
<td></td>
<td>36 726</td>
<td>3 904 000</td>
<td></td>
</tr>
</tbody>
</table>
Alt 2 - Hollow slab made of slab strips manufactured from masonry elements

**Geometry, table F:2e.**

<table>
<thead>
<tr>
<th>Item description</th>
<th>(m)</th>
<th>Area (m²)</th>
<th>Volume (m³/pcs)</th>
<th>Spacing beams</th>
<th>Volume (m³/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slab strips - the low cost slab</td>
<td></td>
<td>0,013693</td>
<td>0,0041079</td>
<td>0,280</td>
<td>0,048903571</td>
</tr>
<tr>
<td>bw</td>
<td>0,020</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b</td>
<td>0,280</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>h</td>
<td>0,165</td>
<td></td>
<td>42,8571429</td>
<td></td>
<td></td>
</tr>
<tr>
<td>x</td>
<td>0,300</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bf</td>
<td>0,025</td>
<td></td>
<td></td>
<td>40</td>
<td></td>
</tr>
</tbody>
</table>

**Total cost for alt 2 - Hollow slab made of slab strips manufactured from masonry elements, table F:2e.**

<table>
<thead>
<tr>
<th>Item description</th>
<th>Unit</th>
<th>Quantity</th>
<th>Rate; TShs</th>
<th>Cost/m²; TShs</th>
<th>Cost/Sw H</th>
</tr>
</thead>
<tbody>
<tr>
<td>Masonry element*</td>
<td>pcs</td>
<td>1714</td>
<td>500</td>
<td>857 143</td>
<td></td>
</tr>
<tr>
<td>Moulding form**</td>
<td>pcs</td>
<td>1.000</td>
<td>50 000</td>
<td>470 50 000</td>
<td>50 000</td>
</tr>
<tr>
<td>Sand-cement</td>
<td>m³</td>
<td>7.042</td>
<td>39 841</td>
<td>2 639 280</td>
<td>567 280</td>
</tr>
<tr>
<td>Labour (Prefab)***</td>
<td>day</td>
<td>102,857</td>
<td>5 000</td>
<td>4 838 514</td>
<td>282 300</td>
</tr>
<tr>
<td>Labour (at site)</td>
<td>day</td>
<td>6.000</td>
<td>5 000</td>
<td>282 300</td>
<td></td>
</tr>
<tr>
<td>Reinforcement D12</td>
<td>kg</td>
<td>3,750</td>
<td>1 450</td>
<td>5 438 578</td>
<td>578 006</td>
</tr>
<tr>
<td>Reinforcement (Steel bars)****</td>
<td>m</td>
<td>800,3</td>
<td>750</td>
<td>3 055 324 750</td>
<td>324 750</td>
</tr>
<tr>
<td>Topping-up concrete (1:2:4 mix)</td>
<td>m³/m²</td>
<td>0,097</td>
<td>39 841</td>
<td>3 870 411 412</td>
<td>171 429</td>
</tr>
<tr>
<td>Form-work (edge)</td>
<td>m</td>
<td>41,810</td>
<td>1 045</td>
<td>411 43 682</td>
<td></td>
</tr>
<tr>
<td>Props</td>
<td>pcs/row</td>
<td>2,000</td>
<td>2 000</td>
<td>1 613 171 429</td>
<td></td>
</tr>
<tr>
<td>Labour (at site)*****</td>
<td>day</td>
<td>28,495</td>
<td>151 413</td>
<td>1 424 151 413</td>
<td></td>
</tr>
<tr>
<td>Machines (Hire and Transport)</td>
<td>pcs</td>
<td>1,000</td>
<td>130 000</td>
<td>1 223 130 000</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>USD $</th>
<th>SKr</th>
<th>TShs</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 493</td>
<td>26 195</td>
<td>22 616</td>
</tr>
</tbody>
</table>

**Percent cost of hollow slab strips, precast joist and topping-up compared to solid concrete floor**

<table>
<thead>
<tr>
<th>Alt</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>89</td>
<td>Percent cost of hollow slab strips, precast joist and topping-up compared to solid concrete floor</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Alt</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>68</td>
<td>Percent cost of hollow slab strips, precast joist and topping-up compared to solid concrete floor</td>
</tr>
</tbody>
</table>

**Remarks**

Cost analysis and technical development of slab elements made by Dr. Makunza are based on the construction of a 4x4 m floor slab. Conditions of a continuous beam or floor slab are different. Moreover, the assembly of beams including reinforcement is supposed to be carried out at ground. Furthermore interacting forces between concrete used to fix

---

* Approximation of rate made by Dr. Makunza
** Moulding form made of hard wood
*** Assumed that three labourers produce 50 slab elements per day
**** Extra upper edge required
reinforcement to beams and topping-up concrete are not verified. The amount of reinforcement also appears too weak to handle the bending moment for the actual span.

**Alt 3 - Composite slab with reinforcement sheets**

*Costs for imported items, table F:2x.*

<table>
<thead>
<tr>
<th>Item description</th>
<th>Unit</th>
<th>Quantity</th>
<th>Rate; SKr</th>
<th>Rate; TShs</th>
<th>Cost/Sw H</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plannja Combideck</td>
<td>m²</td>
<td>106,3</td>
<td>132</td>
<td>17 600</td>
<td>1 870 880</td>
</tr>
<tr>
<td>Transport*</td>
<td>kg</td>
<td>29,5</td>
<td>5 000</td>
<td></td>
<td>666 667</td>
</tr>
</tbody>
</table>

*Total cost for alt. 3 - Composite slab with reinforcement sheets, table F:2x.*

<table>
<thead>
<tr>
<th>Item description</th>
<th>Unit</th>
<th>Quantity</th>
<th>Rate; TShs</th>
<th>Cost/m²; TShs</th>
<th>Cost/Sw H</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imported iron sheet</td>
<td>m²</td>
<td>29,5</td>
<td>17 600</td>
<td>17 600</td>
<td>1 870 880</td>
</tr>
<tr>
<td>Transport</td>
<td>kg</td>
<td>0,0</td>
<td>6 272</td>
<td></td>
<td>666 667</td>
</tr>
<tr>
<td>Concrete (1:2:4 mix)</td>
<td>m³</td>
<td>0,14</td>
<td>39 841</td>
<td>5 578</td>
<td>592 918</td>
</tr>
<tr>
<td>Reinforcement (Steel bars)*</td>
<td>m</td>
<td>320,2</td>
<td>750</td>
<td>3 055</td>
<td>324 750</td>
</tr>
<tr>
<td>Form-work (edge)</td>
<td>m</td>
<td>41,81</td>
<td>1 045</td>
<td>411</td>
<td>43 682</td>
</tr>
<tr>
<td>Props</td>
<td>pcs</td>
<td>0,5</td>
<td>2 000</td>
<td>1 000</td>
<td>106 300</td>
</tr>
<tr>
<td>Labour (at site)**</td>
<td>day</td>
<td>36,4</td>
<td>233 800</td>
<td>1 833</td>
<td>194 880</td>
</tr>
<tr>
<td>USD $</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SKr</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TShs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| TOTAL                     |      |          |            | 3800           | 3 800 077 |

*Percent cost of composite slab with reinforcement sheets compared to solid concrete floor slab* 97%

**Remarks**

Outlays for a composite slab with reinforcement sheets are highly depending on the import price of the iron sheets. At present these sheets are not produced locally and have to be transported to Tanzania. If reinforcement iron sheets, in the future, could be manufactured locally, expenses for a floor slab may be considerably reduced. Even in a low cost house, a composite slab with reinforcement sheets could then be considered as an economical solution for the intermediate floor.

---

1. High degree of insecurity of cost for transportation of material
2. Only upper-edge required
3. The amount of labour at site are reduced with the decreased volume of concrete
Alt. 4 - Hollow slab elements, precast inverted T-beam and topping-up concrete

**Geometry, table F:2x.**

<table>
<thead>
<tr>
<th>Item description</th>
<th>(m)</th>
<th>Lenght</th>
<th>Area (m²)</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strip-element</td>
<td>0,45</td>
<td></td>
<td>0,33</td>
<td>0</td>
</tr>
<tr>
<td>bw</td>
<td>0,15</td>
<td></td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>b</td>
<td>0,33</td>
<td></td>
<td>0,1</td>
<td>0,09</td>
</tr>
<tr>
<td>h</td>
<td>0,15</td>
<td></td>
<td>0,025</td>
<td>0,09</td>
</tr>
<tr>
<td>x</td>
<td>0,1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>hf</td>
<td>0,025</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bf</td>
<td>0,09</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rows</td>
<td>22</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pcs/row</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| T-beam           | 21  | 5,55   | 0,0224    | 459,65 | 0,19   |

**Spacing beams**

| Topping-up       | 0,0272| 0,53 | 0,05 |

**Concrete/Sand cement**

<table>
<thead>
<tr>
<th>Item description</th>
<th>Unit</th>
<th>Quantity</th>
<th>Rate; TShs</th>
<th>Tot. Volume</th>
<th>Cost/Sw H</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slab strips</td>
<td>pcs</td>
<td>440</td>
<td>38 458</td>
<td>14,9</td>
<td>571 106</td>
</tr>
<tr>
<td>T-beam</td>
<td>pcs</td>
<td>21</td>
<td>38 458</td>
<td>4,0</td>
<td>154 676</td>
</tr>
</tbody>
</table>

**Cost for ring beam, table F:2x.**

<table>
<thead>
<tr>
<th>Ringbeam</th>
<th>Area (cross-sektion)</th>
<th>Lenght (m)</th>
<th>Cost/m (TShs)</th>
<th>Cost (TShs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alt 3- Hollow blocks, inv. T-beam</td>
<td>0,04875</td>
<td>41,45</td>
<td>1 942</td>
<td>80 507</td>
</tr>
<tr>
<td></td>
<td>0,05625</td>
<td>8,7</td>
<td>2 241</td>
<td>19 497</td>
</tr>
<tr>
<td>Reinforcement, 4 x D8</td>
<td>200,6</td>
<td>583</td>
<td>117 017</td>
<td></td>
</tr>
<tr>
<td>Stirrups</td>
<td>58,2425</td>
<td>583</td>
<td>33 975</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td>250 996</td>
</tr>
</tbody>
</table>
## Total cost for alt. 4 - Slab made of hollow slab strips, precast joist and topping-up concrete. Table F:2x.

<table>
<thead>
<tr>
<th>Item description</th>
<th>Unit</th>
<th>Quantity</th>
<th>Rate; TShs</th>
<th>Cost/m²; TShs</th>
<th>Cost/Sw H</th>
</tr>
</thead>
<tbody>
<tr>
<td>Masonry element</td>
<td>pcs</td>
<td>440.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moulding form</td>
<td>pcs</td>
<td>1.0</td>
<td>50 000</td>
<td>470</td>
<td>50 000</td>
</tr>
<tr>
<td>Sand-cement</td>
<td>m³</td>
<td>14.9</td>
<td>38 458</td>
<td>5 373</td>
<td>571 106</td>
</tr>
<tr>
<td>Labour (Prefab)*</td>
<td>day</td>
<td>26.4</td>
<td>5 000</td>
<td>1 242</td>
<td>132 000</td>
</tr>
<tr>
<td>Labour (at site)</td>
<td>day</td>
<td>4.0</td>
<td>5 000</td>
<td>188</td>
<td>20 000</td>
</tr>
<tr>
<td>T-beam</td>
<td>m</td>
<td>179.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moulding form</td>
<td>pcs</td>
<td>1.0</td>
<td>50 000</td>
<td>470</td>
<td>50 000</td>
</tr>
<tr>
<td>Sand-cement</td>
<td>m³</td>
<td>4.0</td>
<td>38 458</td>
<td>1 455</td>
<td>154 676</td>
</tr>
<tr>
<td>Labour (Prefab)**</td>
<td>day</td>
<td>8.4</td>
<td>5 000</td>
<td>1 185</td>
<td>126 000</td>
</tr>
<tr>
<td>Labour (at site)</td>
<td>day</td>
<td>2.0</td>
<td>5 000</td>
<td>94</td>
<td>10 000</td>
</tr>
<tr>
<td>Reinforcement 3xD12</td>
<td>m</td>
<td>538.7</td>
<td>1 250</td>
<td>6 334</td>
<td>673 313</td>
</tr>
<tr>
<td>Reinforcement 2xD16</td>
<td>m</td>
<td>359.1</td>
<td>2 083</td>
<td>7 038</td>
<td>748 125</td>
</tr>
<tr>
<td>Topping-up concrete (1:2:4 mix)</td>
<td>m³/m²</td>
<td>0.1</td>
<td>38 458</td>
<td>1 974</td>
<td>209 805</td>
</tr>
<tr>
<td>Form-work (edge)</td>
<td>m</td>
<td>41.8</td>
<td>1 045</td>
<td>411</td>
<td>43 682</td>
</tr>
<tr>
<td>Props</td>
<td>pcs/row</td>
<td>1.0</td>
<td>2 000</td>
<td>395</td>
<td>42 000</td>
</tr>
<tr>
<td>Labour (at site)***</td>
<td>day</td>
<td>15.1</td>
<td>5 000</td>
<td>708</td>
<td>75 270</td>
</tr>
<tr>
<td>Machines (Hire and Transport)</td>
<td>pcs</td>
<td>1.0</td>
<td>130 000</td>
<td>1 223</td>
<td>130 000</td>
</tr>
<tr>
<td><strong>USD $ SKr TShs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>28 560</strong></td>
<td><strong>3 035 978</strong></td>
</tr>
</tbody>
</table>

Percent cost of hollow slab strips, precast joist and topping-up compared to solid concrete floor **77**

* Assumed that three labourers produce 50 slab elements per day
** Assumed that two labourers produce 5 T-beams per day.
*** The amount of labour at site are reduced with the decreased volume of concrete
Appendix G: Income, expenses and cost of living

According to interviews the average household income in the HanaNasif settlement is 700-1000 TShs per day. House owners can increase their income, if leasing rooms, with 20000-40000 TShs for each room every month.

For a plot in a Dar es Salaam informal settlement, people can expect to be charged with approx 200 000- 400 000 TShs\(^{37}\). In HanaNasif, value of land is rising due to the increased formality of the area. In this case the price has increased to approx. 1 000 000 TShs per plot. Lend and property tax per year is approx. 10 000 TShs, according to plot size.

\(^{37}\) 1000 TShs = USD 1 = 7.50 SEK (Nov 2008)
Appendix H: Procedures when applying for building permit

1. **Survey:** The plot has to be surveyed by Municipal land surveyor or private actor.

2. **Letter of right of occupancy:** Apply for a letter of right of occupancy at the Ministry of Lands

3. **Block plan:** Drawings according to land use has to be made.

4. **Prepare Drawings:** Single floor (3 copies). Architectural drawings required *(With stamp from a registered Architect)*; plan, section, elevation, details, Installations (septic tank etc). If the building has more than one storey, structural drawings are needed. These should be made by a registered Engineer and stamped by the Engineering registration board. Calculations and drawings of important structures (beams, foundation etc) and details should also be attached.

5. **Apply for a building permit**

6. The documents are overlooked by the Municipal administrator. The design, land use and plot coverage are controlled.

7. **Form:** The owner had to fill a Form.

8. **Register errand:** The errand is registered in a book at the Municipal office. Date, Area, Plot nr, Type of construction (transform, new building or alteration), plan nr for office use, address, name, payment and recite no are registered and documented.

9. The documents are taken to the **Municipal land officer** for a signature. *(see first page)*

10. **Inspection of plot:** The owner has to point out and show the plot to the Municipal Architect. The MA inspects the plot *(see second page)* and observes the area conditions (swamp, slope etc).

11. After inspection documents has to be **signed by the Municipal chief Architect**.

12. **Town planner** controls use of land and put his signature on the papers.

13. **Environmental and health officer** controls ventilation, toilets according to house residents, drainage, etc.
14. If the building is considered as a multi-storey building, the drawings and calculations also had to be checked by a structural engineer at the Municipality.
15. For larger projects, drawings are also controlled by the fire brigade.
16. **Approved at a monthly meeting**: All building permit applications are filed and prepared. The permits are approved at a monthly meeting. The meetings are held by a committee, lead by the Municipal chief Architect (Chairman) and composed by land officers, surveyor, council members.
17. Building permit is prepared and sign by Municipal Engineer and Town planner.
18. **Announcement** in Newspaper and on Notice boards.
19. **“Form of notice”**: Owner of plot has to fill in a “Form of notice” that had to be signed by a Municipal building inspection, four days prior construction start-up. A “Notice of commencement of Building” also has to be received. If the permit has to be reissued, the costs are reduced by half.38
20. **“Completion letter”**: After finishing construction works the owner had to write a letter to the Council and ask for a “completion letter”.
21. **Inspection**: The building has to be inspected and approved by the chief Architect

---

38 Building permit expires if; project not started 6 months after permit been granted or project not completed within 3 years.
Appendix I: Inspection list for Municipal engineers

All building sites are to be controlled by the municipal engineer before every major action. These are;

1. Setting out
2. Foundation excavation
   - Strip foundation
   - Column footing
3. Building to column footing
4. Reinforcements column bases and ground beams
   - Including shuttering and starter bars
5. Concreting
6. Block work to plinth-level
7. Concrete over site
8. Ground floor column
   - Reinforcement
   - Shuttering
9. Ground floor DPC and block work superstructure
10. Shuttering for ............beams
11. Steel fixing for ............floor slab and beams
12. Concreting for ............floor slab and beams
13. Drains
14. External finish

See also list for one storey buildings. The workman ship is compared to the drawings. If construction work has started before inspection, materials have to be tested.
### Appendix J: Intermediate floor slab - Material Value Analysis

<table>
<thead>
<tr>
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Alt 1. Solid reinforced concrete slab
Alt 2. Slab Strips – “The low cost slab”
Alt 3. Hollow slab elements & inverted T-beam
Alt 4. Composite slab with reinforcement sheets
Appendix K: Static calculations
Appendix K1

FEM-calculation on solid reinforced concrete slab

Data

Slab thickness: 150mm
Safety class: 2
Grade of concrete: C16/20
Exposure class: XS 1 (airborne chlorides)
Lifetime class: L50
Creep factor: 1
Shrinkage: 0.1x10^{-3}
Reinforcement: Ss 260

Loads

Imposed floor load: 1.5 kN/m²
Dead load: 3.6 kN/m²

Design load: 1.4x3.6+1.6x1.5 = 7.44 kN/m²

Comments

The applied reinforcement has been analysed and recalculated to be appropriate for the construction of the slab. The reinforcement for the slab is presented in the set of drawings that is drawn.
Applied reinforcement at bottom

12400 = 283 mm²
Applied reinforcement at top
Missing reinforcement bottom x
(No reinforcement is missing according to calculation)
Missing reinforcement bottom y
(No reinforcement is missing according to calculation)
Missing reinforcement top x
(Reinforcement is missing in upper left corner, the result is slightly higher crack widths, but
still within accepted limits)
Missing reinforcement top y
(Reinforcement is missing in corners, the result is slightly higher crack widths, but still within accepted limits)
Noder

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<th>X (m)</th>
<th>Y (m)</th>
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Resultatinformation

Beräkning med hänsyn till uppsprickning för betongelement.
Inga spänningar redovisas i analysresultatet!

Max pos. moment - 1:a ordn.

<table>
<thead>
<tr>
<th>Element</th>
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<th>V kN</th>
<th>N kN</th>
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Max neg. moment - 1:a ordn.

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<th>M kNm</th>
<th>V kN</th>
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**Element: a fa / C12/16**

**Lastfall: brott**

**Material - C12/16**

Betongmaterial: C12/15

- $Ec = 18750$
- $f_{sc} = 188.41$
- $f_{ct} = 188.41$
- $Ec = 18750$
- $f_{sc} = 188.41$
- $f_{ct} = 188.41$

**Tvärsnitt fa**

- $A (\text{mm}^2): 3.114 \times 10^4$
- $I_y (\text{mm}^4): 1.271 \times 10^8$
- $I_z (\text{mm}^4): 3.840 \times 10^6$
- $I_{xtp} (\text{mm}^4): 1.287 \times 10^6$
- $y_{tp} (\text{mm}): 80$
- $z_{tp} (\text{mm}): 99$
- $W_{yp} (\text{mm}^3): 1.143 \times 10^6$
- $W_{yp} (\text{mm}^3): 1.287 \times 10^6$

**Kapacitet Element: a**

<table>
<thead>
<tr>
<th>Momentkapacitet</th>
<th>Tvärkraftskapacitet</th>
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</thead>
</table>
| $x_1 (\text{m}) - x_2 (\text{m})$ | $M_x (\text{kNm})$
| $x_1 (\text{m}) - x_2 (\text{m})$ | $V_c (\text{kN})$
| 0.00 - 3.88 | 9.50
| 0.00 - 3.88 | 9.01
| 3.88 - 5.00 | 11.05
| 3.88 - 5.00 | 9.16
Kontroll Element: a

Beräkning utförd enligt 2:a ordningens teori. Kontroll avseende knäckning ut ur ramplanet utförs enligt BBK kap 6.3.3.2.

Momentkapacitet (Dim.snitt x=2.00 , pos moment)
\[ \frac{M}{M_u} = \frac{5.73}{9.50} = 0.603 < 1 \]

Momentkapacitet (Dim.snitt x=5.00 , neg moment)
\[ \frac{M}{M_u} = \frac{-7.42}{-11.05} = 0.672 < 1 \]

Momentkapacitet (Dim.snitt x=5.00 , biaxielitet)
\[ \frac{M_y}{M_{yu}} + \frac{M_z}{M_{zu}} = \frac{-7.42}{-11.05} + \frac{0.00}{4.66} = 0.672 < 1 \]

Tvärkraftskapacitet (Dim.snitt x=5.00 )
\[ \frac{V}{V_c} = \frac{8.73}{9.16} = 0.953 < 1 \]

Element: b  fa / C12/16

Lastfall: brott

Material - C12/16

Betongmaterial: C12/15  Ec = 18750  fsc = 188.41  Fst = 188.41
f cc = 6.39  Fct = 0.58  Huvudarmering: Ss260  Es = 158730

Kapacitet Element: b

Momentkapacitet
\[ x_1(m) - x_2(m) \quad M_u(kNm) \]
\[ 0.00 - 1.51 \quad 11.05 \]
\[ 1.51 - 3.55 \quad 9.05 \]

Tvärkraftskapacitet
\[ x_1(m) - x_2(m) \quad V_c(kN) \]
\[ 0.00 - 1.51 \quad 1.51 - 3.55 \]
\[ 9.16 - 9.01 \]

Kontroll Element: b

Beräkning utförd enligt 2:a ordningens teori. Kontroll avseende knäckning ut ur ramplanet utförs enligt BBK kap 6.3.3.2.

Momentkapacitet (Dim.snitt x=2.49 , pos moment)
\[ \frac{M}{M_u} = \frac{1.61}{9.50} = 0.170 < 1 \]

Momentkapacitet (Dim.snitt x=0.00 , neg moment)
\[ \frac{M}{M_u} = \frac{-7.42}{-11.05} = 0.672 < 1 \]
Kontroll Element: b

Momentkapacitet (Dim. snitt x=0.00 , biaxiellt)
\[ \frac{M_x}{M_{xy}} + \frac{M_y}{M_{yx}} = -7.42/-11.05 + 0.00/4.66 = 0.672 < 1 \]

Tvärkraftskapacitet (Dim. snitt x=0.00 )
\[ \frac{V}{V_c} = 7.24/9.16 = 0.790 < 1 \]
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Tvärsnittsdata

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<th>h (m)</th>
<th>z (m)</th>
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Resultat

Beräkning med hänsyn till uppsprickning för betongelement.
Inga spännings redovisas i analysresultatet!

Max pos. moment - 1:a ordn.

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<th>V kN</th>
<th>N kN</th>
<th>Lastfall</th>
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Max neg. moment - 1:a ordn.

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<th>Element</th>
<th>M kNm</th>
<th>V kN</th>
<th>N kN</th>
<th>Lastfall</th>
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<tr>
<td>b</td>
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Element: a  fa / C12/16

Lastfall: brott

Material - C12/16

Betongmaterial: C12/15  Ec = 18750  fsc = 188.41  Fst = 188.41
fcc = 6.39  Fct = 0.58

Huvudarmering: Ss260  Es = 158730

Tvärsnitt fa

fa
Tvärsnittsvärden för osprucket tvärsnitt
A (mm²): 3.114e4  i_y (mm): 64  z_{tp} (mm): 99
I_y (mm⁴): 1.271e8  i_z (mm): 35  W_{y5} (mm³): 1.143e6
I_z (mm⁴): 3.840e7  y_{tp} (mm): 80  W_{z5} (mm³): 1.287e6
L(m): 0.0  Iz (mm⁴): 3.840e7

Kapacitet Element: a

Momentkapacitet
x_1(m) - x_2(m)  M_u (kNm)
0.00 -  2.93  9.50
2.93 -  3.55  11.05

Tvärkraftskapacitet
x_1(m) - x_2(m)  V_c (kN)
0.00 -  2.93  9.01
2.93 -  3.55  9.16
Kontroll Element: a

Beräkning utförd enligt 2:a ordningens teori.
Kontroll avseende knäckning ut ur ramplanet utförs enligt BBK kap 6.3.3.2.

Momentkapacitet (Dim.snitt x=1.42 , pos moment)

\[
\frac{M}{M_{\mu}} = \frac{3.10}{9.50} = 0.326 < 1
\]

Momentkapacitet (Dim.snitt x=3.55 , neg moment)

\[
\frac{M}{M_{\mu}} = \frac{-3.22}{-11.05} = 0.292 < 1
\]

Momentkapacitet (Dim.snitt x=1.42 , biaxiellt)

\[
\frac{M_y}{M_{\mu y}} + \frac{M_z}{M_{\mu z}} = \frac{3.10}{9.50} + 0.00/4.66 = 0.326 < 1
\]

Tvärkraftskapacitet (Dim.snitt x=3.55 )

\[
\frac{V}{V_c} = \frac{6.06}{9.16} = 0.661 < 1
\]

Element: b  fa / C12/16

Lastfall: brott

Material - C12/16

Betongmaterial: C12/15  
Ec = 18750  
\( f_{sc} = 188.41 \)  
\( f_{ct} = 188.41 \)  
\( f_{cc} = 6.39 \)  
\( f_{ct} = 0.58 \)  
Huvudarmering: Ss260  
Es = 158730

Tvårsnitt fa

fa

Tvårsnittsvärden för osprucket tvårsnitt

L(m): 0.0

\( I_y (\text{mm}^4) : 3.114 \times 10^8 \)  
\( i_y (\text{mm}) : 64 \)  
\( i_z (\text{mm}) : 35 \)  
\( z_{tp} (\text{mm}) : 99 \)  
\( W_{yo} (\text{mm}^3) : 1.143 \times 10^6 \)  
\( W_{yu} (\text{mm}^3) : 1.287 \times 10^6 \)

Kapacitet Element: b

Tvärkraftskapacitet

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<th>( x_1 (\text{m}) - x_2 (\text{m}) )</th>
<th>( M_y (\text{kNm}) )</th>
<th>( V_c (\text{kN}) )</th>
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<tbody>
<tr>
<td>0.00 - 1.45</td>
<td>11.05</td>
<td>9.16</td>
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</tbody>
</table>

Kontroll Element: b

Beräkning utförd enligt 2:a ordningens teori.
Kontroll avseende knäckning ut ur ramplanet utförs enligt BBK kap 6.3.3.2.

Momentkapacitet (Dim.snitt x=0.00 , neg moment)

\[
\frac{M}{M_{\mu}} = \frac{-3.22}{-11.05} = 0.292 < 1
\]

Momentkapacitet (Dim.snitt x=0.00 , biaxiellt)

\[
\frac{M_y}{M_{\mu y}} + \frac{M_z}{M_{\mu z}} = \frac{-3.22}{-11.05} + 0.00/4.66 = 0.292 < 1
\]

Tvärkraftskapacitet (Dim.snitt x=0.00 )
Kontroll Element: b

\[ \frac{V}{V_c} = \frac{2.51}{9.16} = 0.274 < 1 \]
LOADING FOR BUILDINGS appendix K4

Imposed floor and roof loads

Single family dwelling unit

\[ q_{1k} := 1.5 \, \frac{kN}{m^2} \]

Balconies

\[ q_{2k} := 1.5 \, \frac{kN}{m^2} \]

Roof load (no access)

\[ q_{3k} := 0.6 \, \frac{kN}{m^2} \]

Dead loads

Reinforced concrete

\[ g_{1k} := 24 \, \frac{kN}{m^3} \]

Roof structure

\[ g_{2k} := 0.2 \, \frac{kN}{m^2} \]

Walls

\[ g_{3k} := 5.7 \, \frac{kN}{m} \]

Concrete

\[ g_{4k} := 20 \, \frac{kN}{m^2} \]

Design of ring beam

Loads

\[ g_k := g_{1k} \cdot 0.15 \cdot 2.5 + g_{2k} \cdot 2.5 + g_{3k} \]

\[ g_k = 15.2 \, \frac{kN}{m} \]

\[ q_k := q_{1k} \cdot 2.5 + q_{3k} \cdot 2.5 \]

\[ q_k = 5.25 \, \frac{kN}{m} \]

Design load

All design loads are reduced with a factor 0.8 according to low cost housing regulations

\[ \text{Design load} := (1.4 \cdot g_k + 1.6 \cdot q_k) \cdot 0.8 \]

\[ \text{Design load} = 23.744 \, \frac{kN}{m} \]

\[ l := 1.5m \quad \text{Span} \]
\[ V := \frac{\text{Design load}}{2} \quad \text{V} = 17.808 \text{kN} \]

\[ M_s := \frac{\text{Design load} \cdot l^2}{12} \quad M_s = 4.452 \text{kN} \cdot \text{m} \]

\[ M_f := \frac{\text{Design load} \cdot l^2}{24} \quad M_f = 2.226 \text{kN} \cdot \text{m} \]

**Bending reinforcement**

\[ b := 0.15 \text{m} \quad d := 0.279 \text{m} \quad f_{cu} := 15 \text{MPa} \quad f_y := 250 \text{MPa} \]

\[ K := \frac{M_s}{f_{cu} \cdot b \cdot d^2} \quad K = 0.025 \]

\[ z := d \left( 0.5 + \sqrt{0.25 - \frac{K}{0.9}} \right) \quad z = 0.271 \text{ m} \]

\[ A_{ss} := \frac{M_s}{0.95 \cdot f_y \cdot z} \quad A_{ss} = 69.2 \text{ mm}^2 \quad 2\phi 8 \]

\[ K := \frac{M_f}{f_{cu} \cdot b \cdot d^2} \quad K = 0.013 \]

\[ z := d \left( 0.5 + \sqrt{0.25 - \frac{K}{0.9}} \right) \quad z = 0.275 \text{ m} \]

\[ A_{sf} := \frac{M_f}{0.95 \cdot f_y \cdot z} \quad A_{sf} = 34.082 \text{ mm}^2 \quad 2\phi 8 \]

\[ A_{tot} := 4 \cdot \pi \cdot (4 \text{mm})^2 \quad A_{tot} = 201.062 \text{ mm}^2 \]
Shearing reinforcement

\[ v := \frac{V}{b \cdot d} \quad v = 0.426 \text{ MPa} \]

\[ v_c := \frac{100 \cdot A_{\text{tot}}}{b \cdot d} \quad v_c = 0.48 \]

\[ \frac{v_c}{2} < v < \left( v_c + 0.4 \right) \]

\[ \frac{A_{sv}}{s_v} = \frac{0.4 \cdot b}{0.95 \cdot f_y} = 0.253 \frac{\text{mm}^3}{\text{N}} \quad \text{Maximum spacing} \quad 0.75 \cdot d = 0.209 \text{ m} \quad \phi 8 \text{s200} \]

Ring beam over verandah

\[ g_{\text{v}} := g_{1k} \cdot 0.15 \cdot 0.875 \text{m} \quad g_k = 3.15 \frac{\text{kN}}{\text{m}} \]

\[ q_{\text{v}} := q_{1k} \cdot 0.875 \text{m} \quad q_k = 1.313 \frac{\text{kN}}{\text{m}} \]

Design load

\[ \text{Design}_{\text{load}} := \left( 1.4 \cdot g_k + 1.6 \cdot q_k \right) \cdot 0.8 \quad \text{Design}_{\text{load}} = 5.208 \frac{\text{kN}}{\text{m}} \]

\[ l := 4.7 \text{ m} \quad \text{Span} \]

\[ V := \frac{5 \cdot \text{Design}_{\text{load}} \cdot l^4}{8} \quad V = 15.299 \text{ kN} \]

\[ M_s := \frac{\text{Design}_{\text{load}} \cdot l^2}{8} \quad M_s = 14.381 \text{ kN} \cdot \text{m} \]

\[ M_f := \frac{9 \cdot \text{Design}_{\text{load}} \cdot l^2}{128} \quad M_f = 8.089 \text{ kN} \cdot \text{m} \]
Bending reinforcement

\[
b := 0.15 \text{m} \quad d := 0.279 \text{m} \quad f_{cu} := 15 \text{MPa} \quad f_{y} := 250 \text{MPa}
\]

\[
K := \frac{M_s}{f_{cu} \cdot b \cdot d^2} \quad K = 0.082
\]

\[
z := d \left(0.5 + \sqrt{0.25 - \frac{K}{0.9}}\right) \quad z = 0.251 \text{ m}
\]

\[
A_{ss} := \frac{M_s}{0.95 \cdot f_y \cdot z} \quad A_{ss} = 241.552 \cdot \text{mm}^2 \quad 3\phi 12
\]

\[
K := \frac{M_f}{f_{cu} \cdot b \cdot d^2} \quad K = 0.046
\]

\[
z := d \left(0.5 + \sqrt{0.25 - \frac{K}{0.9}}\right) \quad z = 0.264 \text{ m}
\]

\[
A_{sf} := \frac{M_f}{0.95 \cdot f_y \cdot z} \quad A_{sf} = 129.08 \cdot \text{mm}^2 \quad 2\phi 10 \quad A_{sf} := 3 \cdot \pi \cdot (6\text{mm})^2 + 2 \cdot \pi \cdot (5\text{mm})^2
\]

\[
A_{tot} = 496.372 \cdot \text{mm}^2
\]

Shearing reinforcement

\[
v := \frac{V}{b \cdot d} \quad v = 0.366 \cdot \text{MPa}
\]

\[
v := \frac{100 \cdot A_{tot}}{b \cdot d} \quad v_c = 1.186
\]

\[
v < \frac{v_c}{2} \quad \text{No shearing reinforcement required}
\]
Load on wall

Loads

\[
g_k = g_1k \cdot 0.15m \cdot 5.1m + g_2k \cdot 5.1m + g_3k \quad g_k = 25.08 \frac{kN}{m}
\]
\[
g_k = q_1k \cdot 5.1m + q_3k \cdot 5.1m \quad q_k = 10.71 \frac{kN}{m}
\]

Design load

\[
\text{Design load} := (1.4 \cdot g_k + 1.6 \cdot q_k) \cdot 0.8
\]
\[
h := 300mm \quad b := 150mm \quad r := 31mm
\]
\[
A_{\text{brick}} := h \cdot b - 2 \cdot \pi \cdot r^2 \quad A_{\text{brick}} = 3.896 \times 10^4 \cdot \text{mm}^2
\]
\[
\sigma := \frac{\text{Design load} \cdot 1000mm}{x \cdot A_{\text{brick}}} \quad \sigma = 0.322 \cdot \text{MPa} \quad \sigma_{\text{max}} := 0.38 \quad \text{OK!}
\]

Load on ground beam

\[
g_k = g_1k \cdot 0.15m \cdot 5.1m + g_2k \cdot 5.1m + 2g_3k \quad g_k = 30.78 \frac{kN}{m}
\]
\[
g_k = q_1k \cdot 5.1m + q_3k \cdot 5.1m \quad q_k = 10.71 \frac{kN}{m}
\]

Design load

\[
\text{Design load} := (1.4 \cdot g_k + 1.6 \cdot q_k) \cdot 0.8
\]
\[
\sigma_{\text{max}} := 0.1 \text{MPa} \quad x := \frac{\text{Design load}}{\sigma_{\text{max}}} \quad x = 481.824 \cdot \text{mm}
\]

Ground beam will be given a width of 500mm

The ground beam is not reinforced according to recommendations by Tanzanian engineers.
Loads for calculation of slab strip system

\[ h := 215\text{mm} \quad b := 530\text{mm} \quad A_{\text{cavity}} := 0.016449\text{m}^2 \]

\[ A := h \cdot b - 2 \cdot A_{\text{cavity}} \quad A = 0.081\text{ m}^2 \]

Dead load \( g_k := A \cdot \frac{g_{4k}}{1 \cdot \text{m}} \quad g_k = 1.621 \cdot \frac{\text{kN}}{\text{m}} \)

Imposed floor load \( q_k := b \cdot q_{1k} \quad q_k = 0.795 \cdot \frac{\text{kN}}{\text{m}} \)

Design load \( := (1.4 \cdot g_k + 1.6 \cdot q_k) \cdot 0.8 \quad \text{Design load} = 2.833 \cdot \frac{\text{kN}}{\text{m}} \)

Further calculations according to appendix K1-K3
Appendix L: Structural drawings