COMMUNITY INITIATIVE FOR THE VILLAGES IN UGANDA

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ABSTRACT

The project involves the design of a mixed use development In Mpirigwa village, Mityana district. The project focuses mainly on the design of low income and climate optimised dwellings with innovative housing qualities. With a critical approach to sustainability, the project focuses profoundly on social sustainability thereby engaging its users besides the usual sustainable aspects. The site is located in a rural setting therefore emphasis has been placed on the development of dwellings that integrate the requirements of a rural quality user profile .The project has therefore foreseen the development of different types of attractive dwellings to fit the specific user profile as a means to achieve the main goal of the project. The dwellings are designed according to design parameters that define an ideal home, not forgetting the immediate neighbourhood context. The project also incorporates commercial development into the design as a means to enhance the relationship between the design and its vicinity. Further more, in order to enhance the lives of the user profile, the project integrates a farming area onto the proposed site which on the other hand defines identity of the village in relation to one of the many economic activities that are carried out in that village.

INTRODUCTION

Over the past years, Uganda has witnessed a rapid increase in population of its occupants. The wide uneven distribution of resources within the country has led to the poor development of social services and infrastructure such as schools, hospitals, roads, housing etc. within some regions in the country.

We can all agree that balanced development is an abstraction. According to Debraj Ray (pg. 1 2010,) economic growth in developing countries has been widely uneven. All sectors do not simultaneously develop but rather in series. This has in turn been the cause of the major influx of people into the major towns of the country leaving the areas outside towns (villages) scanty. However, according to Cecilia (pg. 1) governments in Africa have found the issue of migration of people from villages to towns to be a problem rather than part of a solution. It is widely assumed that poverty causes the people to move rather than migration itself being the potential route out of poverty.

The villages are still lagging behind in terms of social and economic aspects. Turning the focus on the economic aspect, the people in villages mainly engage themselves in agricultural activities such as farming and animal rearing. However, the income generated from their economic back bone is not enough to improve the quality of their lives let alone their surroundings. Cecilia further writes that the economic, social and demographic transformations in most parts of Africa can be best understood as methods that are based on the complementary relationships between rural and urban developments. We look at rural developments sustaining the major urban markets. According to the United Nations, successful rural development stimulates and supports urban development, and urban development is often a key impetus to rural development, especially where the latter is based on relatively equal access to resources, that is, in most cases, access to small and medium size farming rather than agri-business production. (United Nations, 2006)

But how can rural developments be achieved and sustained with a rather alarming demographic situation? I believe this can only be addressed by the equal distribution of resources to enable the rural areas develop and sustain their systems. The built environment in villages is one of the major things that have suffered a huge blow due to lack of the means and funds to develop it. A huge percentage of people in the villages still use vernacular architecture (small round huts made of mud and grass) as a form of shelter. The state of villages in Uganda is complex in that it presents its self with challenges and opportunities which paves way for a clear definition yet to be achieved.

This thesis therefore explores the opportunities and challenges presented by a village called Mpirigwa, in Mityana district, Uganda. The thesis further establishes a community initiative in form of low income sustainable housing. Much as sustainability is used as a point of departure to address the key issues within the initiative, more emphasis is placed on the aspect of social sustainability thereby assessing the impacts of the initiative on the social well-being of the people in general. The thesis will also focus on the technical aspects during the development of the project as a means to address the engineering point of view in architectural design. The initiative will be developed on an urban scale in parallel to the neighbourhood scale. (housing units)

METHODOLOGY

Design of a project can tend to be complex due to the various parameters that have to be put into consideration. For this reason, the thesis partakes on the integrated design process as a form of methodology to tackle the key issues. The integrated design process is divided into 5 phases. This method is not always linear but there are different loops between the phases, as illustrated in figure 1. The method helps to create an overview of the project and throughout an itinerary process; the different aspects of the project are assessed and implemented. (Knudatrup,2004)

The integrated design process basically involves the incorporation of design principles and calculation parameters to come up with an optimum solution. This superintends the consideration of tools from the engineering discipline, experimental testing to figure out what happens when specific decisions are made and the possible outcomes in the project as demonstrated by parametric and behavioral studies. During her lecture, Hanne Tine Ring Hansen presented to us 7 steps of a project application methodology, and these included; identification of design parameters and ranges, identification and prioritization of sustainable indicators, identification of distribution functions for each design parameter, random generation of combinations, calculations, analysis of results and recommendations of design team.

The integrated iterative process involves the identification and definition of the design criteria such as building and context. In most cases, they are used as points of departure during the design process, rather not the process itself. Even though the design criterion is presented discretely, they cannot be treated separately despite the fact that they are interrelated and conflicting at specific times. The design criteria can be changed during the process because as stated in Anne Kirkegaard's lecture slides, 'A building is not an autonomous matter but a dynamic and interactive part of society, a context and a user's daily life.'

The integrated design phases are:

Problem formulation/project idea; which basically involves formulation and description of the problem. The purpose of this project is to establish a community based initiative during which low income housing units that are sensitive to sustainable aspects such as the well-being of people and the environment are to be set up on a 16 hectare piece of land in Mpirigwa village.

The analysis phase involves an analysis of all information and raw data that has been collected before the sketching process can begin. Raw data includes; information about the site, the architecture of the neighborhood, topography, vegetation, sun, light and shadows, predominant wind direction, access to the site, size of the site, neighboring buildings, the site's strengths, weaknesses and opportunities, the users' needs, technical criteria indoor climate and energy. This phase results into development of design criteria for the next phase.

The sketching phase is the phase where the professional knowledge of the architects and engineers is combined to provide mutual inspiration in the design process, so that the demands and the wishes of the building are met. (Knudatrup, 2004) During this phase, all demands are considered to find the best optimal solution which will meet the demands of the various housing units, the demands for logistics and materials, and other demands. This phase will further be demonstrated through sketches on paper, physical models and with computer-designed models.

The synthesis phase is the phase where the new building finds its final form and where all the design requirements and criterion have been achieved. This is the point where all elements in the iterative process flow together and the architecture, plans, functionality, aesthetics, the space design, working environment, room programme, principles of construction, energy consumption and indoor environment technology form a synthesis.

The presentation phase is the final presentation of the project. The outcome is presented in such a way that all qualities are shown to the advantage and clearly pointed out how the aims of the project have been fulfilled. This phase will include a project report with documentation of all aspects and description of the finished project in text, diagrams, facades, plans, architectural volumes, details and calculations which prove the measurable qualities.

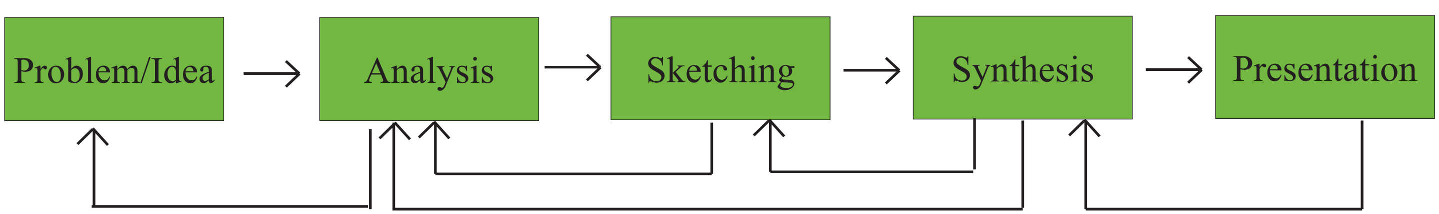


Figure 1: Integrated design process

PROGRAM

SUSTAINABILITY

Embarking on sustainability as a point of departure in this project requires me to acquire a standard understanding of sustainability in general and how I would want to go about with it. Sustainability is generally perceived in different ways hence having no precise definition to the term. Cultural theorist Tony Fry believes that the term sustainability is 'ill' defined: ''increasingly anyone would perceive sustainability as though its meaning was self-evident. What exactly is demonstrated to be sustainable, and what needs to be sustainable, generally is not specifically addressed.'' (Holmes, 2007:155) My understanding of sustainability is based on the Brundtland report from 1987, where sustainability is defined as, 'meeting the needs of the present generation without compromising the ability of future generations to meet their needs.' (Holmes, 2007 pg.154) In other words, sustainability is the ability to maintain the way of life without compromising the needs or potentials of future generations. To reach this goal, the report divides sustainability into three main issues; Social, Environment and Economic. The social aspect deals with issues that have direct impact on people, the environment aspect deals with nature, climate and energy resources whereas the economic aspect deals with social, ownership interest. (Vanderbilt.edu) My aim in this project is to have all the three aspects addressed with more emphasis placed on the social aspect. But how can sustainability be applied into architecture? Alana and Christopher write, 'A sustainable building can be defined as any building that has significantly lower negative environmental impacts than a traditional building. They then argue that societies in the past were sustainable, and we could get inspiration from their methods.' Sustainable residential design lies in ageless vernacular architecture, the kind of architecture that was practiced for most of human and continues to be practiced in the present. This approach relies on simple, renewable and naturally insulating materials and passive strategies like siting, thick walls and natural ventilation to keep the house cool. (Stano et Hawthorne, 2005 pg.12) In conclusion, I can say that a sustainable building must be designed in such a way that it facilitates sustainable existence and utilization during its life cycle.

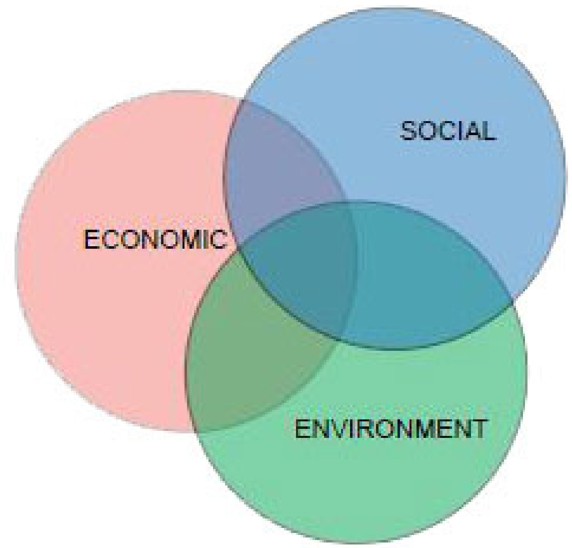


Figure 2: Sustainability diagram (Brundtland et. al. 1987:51)

Sustainable development

Chiu writes that housing by nature is multi-facated. She further writes that it consumes natural resources and produces and impact on the environment. (reference………) Despite all this, housing constitutes a major economic activity and impacts on the general economy in that it is a vital component of social development and quality of life. We also witness housing being a cultural norm that depicts the aesthetical values and way of life of man in a particular setting.

But why apply sustainable development strategies to housing; according to a publication in 1980, (World conservation strategy) the idea of sustainable development was a reaction to the urgency of creating a balance between the environmental protection and the economic development. As a result , the notion became a slogan after the WCED report was published in 1987.

In the long run, we also come across arguments about the issue of development. How can development be defined; according to Munro, (1995) development should be inclusive of all kinds of activities and processes that increase the capacity of people or the environment to meet human needs and improve the quality of human life. Munro further notes that development should not only include physical development of the environment but also health care, social security, education, nature conservation, cultural activities etc. He therefore sums up development as being a complex of activities, with partially social, economic, material resources, intellectual resources all of which enable people to reach full potential and enjoy a good life.

Environmental sustainability of housing.

Nijkamp and Soeteman write that environmental sustainability is the ability of the ecosystem to maintain or improve its quality, and to reach a long-term stable situation in spite of short-term changes (Nijkamp and Soeteman, 1988). If we specifically look at the ecology, we often look at activities that acknowledge biophysical limits and probably the need to maintain essential ecological processes and life support systems upon which all life depends. In operation terms, the principles of ecological sustainability involve; the rates of use of renewable resources not exceeding the rate of regeneration, the depletion rates of non-renewable resources not exceeding the rate at which renewable substitutes are invented and invested, rates of pollution not exceeding the assimilative capacity of the environment, waste emission not exceeding the assimilative capacity of the local environment (Caldwell et Zovabyi, 1998:151-2). In order to apply these principles to housing, we have to integrate the different ecological elements to the production and consumption processes of housing. We find that we have to assess the impacts of different dimensions during the execution of a project.

During the conception stage, factors such as choice of site, development intensity on the local ecological systems and the opportunity to maximize existing infrastructure should be evaluated. During the design stage, factors such as minimal future alteration, energy saving, minimal resource utilization, efficient waste management, the use of eco-friendly materials, construction systems and simple life styles are profoundly evaluated.

At the construction stage, the concerns are mainly the extent of using eco-friendly construction materials, minimization of disruption to the local environment such as dust, noise and traffic; and the minimization of hazards caused by the disposal of construction wastes and hazardous materials. At the occupation stage, we find concerns related to the environment unfolding, such as, the use of domestic fuel, intensity of air-conditioning, ventilation, lighting, air quality etc. However Chiu writes that the environmental impacts and quality are largely attributed to the planning, design and construction processes of the previous stages, however residents could alter the intended or unintended environmental impacts of the physical layout.

During the final stage of demolition, we have to be critical about resource conservation and the impact of the demolition process on the environment. These impacts could include; preservation of heritage value building, environmental hazards are minimized and whether recycling of building materials and components is put into consideration.

Social sustainability of housing

Social sustainability has more points of perception as compared to ecological and economic sustainability. Munro's interpretation of social sustainability equates social sustainability with ecological sustainability, and hence analogous to ecological limits, there are social constraints limiting development, and these are set by social norms (Munro, 1995). We therefore realize that in order to achieve ecological sustainability, the social structures, values and norms have to be changed so that they are conducive to the sustainability of the environment. We find such an interpretation to be environment oriented.

Cultural sustainability of housing

According to Schusky and Culbert, culture is a broad concept whose definition should cover three major dimensions. The first dimension being the aesthetic and artistic dimension. This covers elements such as fine arts, music, popular culture, performing arts, and so on. The second dimension involves the cultivation of the mind and spirit. This further incorporates knowledge, belief, religion and ideologies, the third dimension being the anthropological aspect which pertains to the way of life and social aspect of human behavior (Schusky et Culbert, 1973). Culture in the long run has its own impacts because of its ability to accumulate over generations, its diversity, and ability to give identity to a place over different time periods. Therefore the correlation between culture and sustainable development could be "culture is the means by which man adapts to his environment and secures things that he needs for his survival" (Schusky et Culbert, 1973:45). Therefore, this makes the culture of a place inseparable from the natural environment and it therefore has a role to play in the pursuit of environmental sustainability of a place.

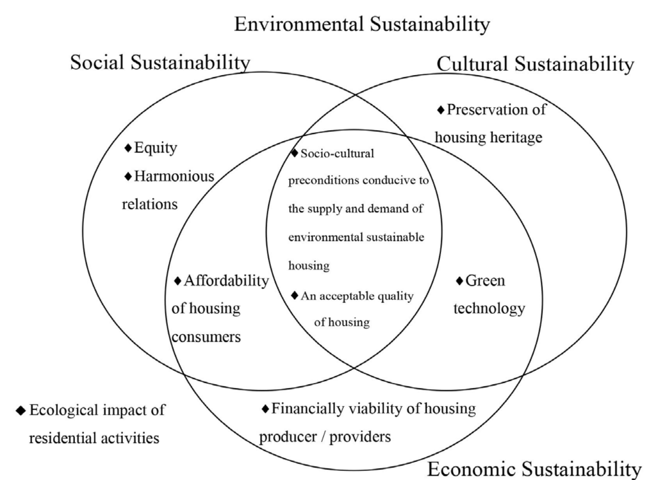


Figure 3: Sustainability of housing (Schusky et Culbert, 1973)

APPROACH TO SUSTAINABILITY

Environment

Climatic variations and environmental issues have over the years been a focal point of major discussions. In order to tackle these challenges, strategies have been developed in order to address the issues. As a result, studies concerning the different elements that have an impact on the environment have been carried out e.g. studies of low energy houses have shown that the energy for the production of a house can account for 40%-60% of the total energy use (Thormark, 2005:pg. 429) However, studies have also shown that even if the energy for operation was very low in one building, the total energy maybe even higher than in a building with a higher amount of energy needed for operation (Thormark, 2005:pg. 1019). This would mean that strategies to tackle the impact of building on the environment during their production have to be developed.

In order to tackle the environment issue in this project, I have taken upon the Green building index assessment tool as my point of departure. This tool will be used to assess the environmental impacts in terms of the rate of depletion of land resources, ecological impacts on climate, the use of renewable and non-renewable energy, energy efficiency, waste generation and management and the maintenance of completed properties.

Green Building Index

The GBI is Malaysia's industry recognized rating tool for buildings to promote sustainability in the built environment and raise awareness among the involved parties about the environmental issues and their responsibility to the future generations. This tool basically provides an opportunity to design and construct green sustainable buildings that are energy efficient, water efficient, provide healthy indoor environment, better connectivity to public transport and the adoption of recycling and greenery for projects.

Even though this tool is developed specifically for the Malaysian tropical climate, this project situated in Uganda takes upon the GBI due to the similarity in climate in both countries, that is, tropical type of climate. Furthermore, the government of Uganda has not yet established a firm assessment tool for its construction Industry which rather compels me to take upon Malaysia's innovative tool. The Green Building Index is based on six main criteria as follows:

Energy efficiency

In order to improve energy consumption in the project, the project will focus on optimizing building orientation on site, minimizing solar gains through the building envelope, harvesting natural lighting and adopting the use of renewable energy. With reference to renewable energy, the project intends to incorporate active solar strategies such as solar thermal collectors and photovoltaic panels to harness the solar energy that they capture. In addition to solar strategies, biomass, in which organic plants materials are converted into various forms of biofuel is a supplement to the project. Biofuels include a wide range of fuels which are derived from biomass. Biodiesel is made from vegetable oils, animal fats or recycled greases. Biodiesel can be used as a fuel for vehicles in its pure form, but it is usually used as a diesel additive to reduce levels of particulates, carbon monoxide, and hydrocarbons from diesel-powered vehicles.

Sustainable site planning and management

In order to address the issue of sustainable site planning and management, strategies to incorporate well planned access routes to the site and within the site will be incorporated into the project. Access routes will be planned in such a way that they enable easily access to public transportation. Community services, open spaces and landscaping will also be integrated into the project in order to enhance the live ability of the occupants. Greenery around buildings positively influences the quality of the internal environment of a building through protection against direct sunlight, wind and sound barriers etc.

The project will also implement storm water management on site and will also reduce the strain on the existing infrastructure capacity. On the other hand, waste treatment during building and site operation is important as this could save on the energy used thereby saving the nature in return (Robert H, 2011).

Waste management strategies will be put in place to conserve the environment and reduce environmental impacts arising from construction activities. This will be achieved by establishing and implementing comprehensive construction waste management and recycling schemes. These schemes can be over seen by proper disposal of waste off site, provision of waste bins and waste centers, monitoring and training of staff on the construction waste management schemes.

Materials and resources

The project intends to use environment friendly materials sourced from sustainable sources such as soil and wood, which can also be recycled in the long run. Waste recovery minimizes the requirement for landfill and their associated environmental impact (Crawford, 2011:11). Sensitive selection of materials and their reusing and recycling can significantly decrease the embodied energy during the building process. The potential energy saving through recycling is about 50% of the embodied energy. The more energy needed for operation decreases, the more important it is to pay attention to energy for material production and to the aspects of the recycling potential. The recycling potential can be defined as the potential for environment benefits from recycling building materials after refurbishment or demolition (Thormark, 2001:429). The use of local materials in the project decreases the energy used for transportation of materials to the site thereby having less impact on the environment.

Water efficiency

Current water levels are dropping therefore treatment of rain water and waste water is necessary in future projects. The project will incorporate a rain water harvesting system on site which will be a water catchment of surface run off from roofs. This water can then be cleaned chemically and stored for human consumption. The project also intends to incorporate a water recycling system for waste water coming from wash basins, kitchen sinks etc.

Indoor Environment/climate

As people spend 90 % of their time at home, this demands for comfortable living conditions such as thermal comfort, ventilation, acoustics and daylight. These aspects have an impact on the health and stimulate human performance [Active House, 2010]. It is therefore a goal of this project to ensure that these aspects are addressed through defined standards but at the same time creating spaces that could enhance the living quality for the occupants.

Acoustics

Building acoustics play a significant role in indoor climate, especially when it comes to the quantity of noise entering or leaving a house. The noise can be minimized by using sound insulation, in terms of airborne sound insulation and impact sound insulation. Solid brick or block walls will provide adequate acoustic separation between classrooms and offices where the separating walls extend to the underside of the roof. Acoustic ceiling tiles are rarely used and are only effective when the metal grid is stopped at internal walls; metal grids continuous above two classrooms will transmit sound clearly from one room to another. Plaster ceilings perform well acoustically for speech absorption even without full height interior walls but any holes in the ceiling will allow sound to travel through to neighboring rooms (eMiEA, 2014).

Day light

Studies have shown that light does in fact affect human well-being. Daylight stimulates the creation of vitamin D which is the essential for the metabolism of calcium. Daylight not only sets biological rhythms, but also hormonal rhythms, as they are synchronized directly or indirectly with the daily cycle of light and dark (Wurtman, 1975:69). Essentially daylight is also about vision and contributes to the perception of space. According to the East African building regulations, Windows are to be located in order to provide good natural light to every room to reduce power consumption. Power supply is irregular and electric lighting should not be relied upon. Long thin buildings provide the best natural light and ventilation when orientated on an east-west axis. Single loaded corridors are recommended to provide the best natural lighting for corridors and classrooms. Light colored ceilings provide reflected light deep into a room.

Indoor air quality

An important parameter for good indoor air quality is the level of pollution in the rooms. However, there is no common standard index for the indoor air quality. The quality of air is influenced by the emission from the occupants and building components. The needed ventilation rate is based on health criteria and comfort criteria. A comfort criterion is related to the perceived air quality which includes odour level and irritation (DS 15251, 2007). Under the evaluation method based odour where people and building components are the main pollution source, the expected percentage of dissatisfied (PD) should be below 20% with an airflow of 7 l/s per person and 0.35 l/s pr. m2, assuming it is a very low polluting building. The sum of the total ventilation rate from both people and building components can be described as: qtotal = n*qp + A*qB. (DS 15251, 2007:33). The project will therefore involve the use of low volatile organic compound materials in order to have a less impact on the quality of indoor air.

Ventilation

According to eMiEA, Passive ventilation is best created through cross ventilation. This is normally achieved through open windows on opposite sides of the room and via vents above windows and doors. This enables ventilation to occur even when windows are closed and the room is uninhabited. Passive ventilation will therefore be provided for in the project above all windows and doors. Roof spaces will also be provided with vents and insect screens. The use of Light colored reflective roofing materials will reduce heat gain through the roof by 16%.

Figure 4: Environmental mood board

Social aspects

The project aims to establish a community initiative that involves the design and construction of low income sustainable housing. However, this project also looks to directly involve the people of Mpirigwa village in the construction of their own houses. On a social dimension, this objective rather enhances components such as neighborliness, social mix, life style affected by the housing design and a sense of community. Even though these components are intangible, some of them can be measured by quantitative indicators for instance, social mix can be based on the number and nature of contacts with neighbours and the activity levels of the residents. The project will also enhance the quality of housing and the living environment and these will be addressed as discussed under the environmental approach to sustainability. The enhancement of the quality of housing will therefore improve the aspects of housing equity, standards and affordability.

Cultural aspects

As a means to uphold the cultural values of Mpirigwa village, the project will draw inspiration from the vernacular architecture of Buganda kingdom, the kingdom in which Mpirigwa village is situated. Vernacular architecture is one that is synonymous with the African society and in this case, Uganda. Mr. Nelson Abiti, Conservator Ethnography, Department of Museums and Monuments, explains that it is called vernacular because the building principles were never written down but rather passed on from one generation to another through word of mouth. One characteristic that was common to the architecture was the circular shape they took and all the materials were never imported but made locally in every region. A strategy to borrow ideas from this kind of architecture would therefore have the cultural norms of the people of Mpirigwa village reflected in their built environment.

Figure 5: Social and cultural mood board

Construction methods as a means to sustainable development

The world at large is faced by a number of problems, two of the main problems being global warming and economic/ financial crisis. With the two above mentioned problems merging and sprawling throughout the entire continent, there has been the urgent need to come up with solutions to reduce or to eradicate the problems of global warming and global economic crises. This has therefore resulted into the different sectors of the economy coming up with drastic measures to curb the issues. As part of its role in fighting the two mentioned crises, the construction industry is therefore coming up with quite a number of building technologies to help curb two of some of the world's major crises. In relation to the above mentioned issue, the South African construction industry came up with a building technology called Hydraform building technology in 1988. This form of building technology would help tackle their problems of resource exploitation for example, cutting down of trees to burn construction bricks etc. This form of construction would help reduce some of the environmental problems like global warming and on the other hand help with the financial issues facing the world at large. In the long run, this form of building technology proved to be outstanding which has therefore seen the building technology develop and extend to other parts of the world.

Hydraform building technology

Hydraform building technology is the type of building system that involves the use of blocks manufactured from a mixture of cement and soil. This type of building technology was discovered and first used in South Africa, and later sprawled throughout Africa, and is now being used in quite a good number of countries out of Africa (The non-hub story 2015).

Hydraform building system consists of the following two technologies which include:

Compressed soil cement block technology, which compresses a mixture of soil and cement into a soil cement block.

Dry stacking blocks which involves, the shape of the blocks helping in the interlocking of the individual blocks there by reducing the use of mortar.

During the construction of low cost housing to upmarket estates, schools etc., machines can be used to manufacture the blocks that are used to construct the structures. Hydraform's mobile machines, using three inputs namely, soil that can be acquired from the construction site, cement in small amounts to provide stability to the blocks and water, are used to manufacture interlocking blocks. The hydraform interlocking blocks lock front to back, top and bottom so that the blocks can be dry stacked there by saving time during construction.

Mortar is only used at the lower part of the foundation and at the upper most end of the wall which makes the dry stacking system very unique. Approximately 75% of the building does not require the use of mortar (The non-hub story 2015). Hydraform buildings have characteristics such as good thermal qualities, structural strength, durability and they are aesthetically attractive due to the use of local soil. Advantages of hydraform building systems include the following:

Construction costs are minimum.
Easy construction therefore, less time consuming.
Possibility of the use of unskilled labour
Construction in remote areas is possible due to the availability of mobile machines.

Agricultural communities in Africa are characterized with Hydraform's building technology as the technology is becoming quite popular. Soil that is dug up, usually at the construction site and little amounts of cement can be used in the manufacture of the building blocks that can be used in the construction of structures e.g. farm houses, farm storage facilities etc. The blocks can be manufactured on demand and are also cost controlled easily (The non-hub story 2015).

But why use inter-locking blocks?

According to Steven Tucker, International sales manager at hydraform, using interlocking blocks has numerous benefits. One of the advantages being the fact that they can be dry-stacked with no mortar. In the long run, the process of construction is faster. This building system has been extensively tested for structural strength and durability as well as for fire, rain and sound resistance.

Hydraform's block making machines only use three inputs, namely soil that can be sourced on site, a small amount of cement that provides stability to the blocks, and water. As a result, the machines are ideal for sites where transport costs for cement and sand are high. They are also an eco-friendly, cost-saving alternative to conventional vibration machines. Hydraform machines are available in diesel or electrical options. Depending on the model, the machines have the capacity to produce between 1,500 and 3,000 blocks per eight-hour shift.

The machines are relatively labour intensive, requiring about six operators. Tucker says that for most companies and governments this is an advantage because it creates employment opportunities and allows for skills transfer.
According to Tucker, the company's technology is par-

ticularly popular in Africa's mining industry, where entire communities often have to be relocated to make way for new mines.

Technical aspect of hydraform building systems

The hydraform building technology has replaced the commonly used brick and mortar with hydraform bricks, though; the other components of the usual building systems have not been changed. The face brick finish of the blocks is extremely attractive and the blocks provide a pre-pointed straight masonry. Plaster or paint can be applied on the walls or they may even be left exposed. The hydraform block making machines make the manufacture of blocks the site of construction itself. The interlocking construction makes it possible to construct structures that are load bearing as well as structures consisting of frames (The non-hub 2015).

During the usual construction, the usage of bricks is good but the application of mortar makes the overall masonry weak because mortar is usually weak. Contrary to that, the problem of weak masonry is rather eradicated by the use of hydraform blocks which virtually do not use mortar hence making the over all masonry very stable and uniform. Dry interlocked blocks are flexible during application and are technically the best for constructing structures that are resistant to earthquake. Blocks having vertical and horizontal cavities are usually used during the construction of earthquake resistant structures.

Figure 6: Construction method mood board

CASE STUDIES

The following case studies mainly focus on how each project has played a role towards sustainable development in its particular context. The case studies reveal how they have individually approached the main 3 aspects of sustainability, that is, environment, social and the economic elements.

Nadunget Housing Project- Northern Uganda

The northern part of Uganda, is situated within the tropical region, and for a very long time, the region faced and suffered a civil war that has lasted over 20 years. The north-eastern part in particular, is occupied by the Karamajong tribe, a tribe known to be normadic. As one of its strategies to restore peace and harmony in the northern part of Uganda, the government came up with a solution which was to uplift karamoja region in terms of development to a level similar to the rest of the country in the housing sector. Therefore, the government of Uganda in collaboration with with hydraform building technology South Africa, over saw the set up of the biggest hydraform housing project in North-Eastern Uganda. Nadunget housing project was to ensure that people of the region move from the simple grass-thatched settlements, to permanent hydraform houses. The Nadunget Housing project comprises of 20 iron sheet-roofed 3 bedroomed units completed with water tanks, solar panels, latrines and a communal bore hole. Hydraform provided training to the local people of Karamoja who in turn, after training, constructed the housing units (Proscovia 2009).

The project was initially fully under the control of hydraform, South Africa. Later, the local people were involved in the project as well. The local people together with the Ugandan Army situated in the North Eastern part of Uganda were trained on how to use hydraform machines to make blocks. Because the hydraform technology is simple and very easy to learn, it paved way for unskilled labour there by cutting costs that were used to set up the entire Nadunget project.

The hydraform machines, produce approximately 240 blocks per hour, however some machines can produce as many as 400 blocks per hour (The non-Hub story 2015) therefore, this factor enabled and increased the ease of construction with a rather appropriate speed. The 20 unit project was completed within a period of less than a year.
The hydraform blocks interlocked with each other, therefore, mortar was not needed so much during the construction of the Nadunget housing units. The Soil used in the manufacture of the hydraform blocks was readily available on site, a small amount of cement and water was used in order to strengthen the blocks therefore, the cost of construction was low.

The north-eastern part of Uganda is remote. Remote areas make construction rather difficult but because Hydraform technology is equipped with mobile machines, construction was made rather easier since, the hydraform machines that manufacture the blocks were delivered directly to the Nadunget construction site.

The manufacture of hydraform blocks does not require burning of the block itself. Therefore, no wood will be required to burn the blocks. The north-eastern part of Uganda, has little or no trees at all, therefore, no trees were cut down in order to provide fire for the blocks, on the other hand, there was no environmental pollution due to the burning of trees, hence, hydraform technology prevented environmental degradation during the construction of the Nadunget Housing project.

Because soil was used during the manufacture of the blocks, the blocks' appearance is very pleasing and they do not require plastering. The exterior of the housing units were left as face brick finishes. They appear beautiful both inside and on the outside.

The hydraform housing project in Nadunget was a success which has led to the wide spread of hydraform building technology in the Northern region of Uganda.

Figure 7: Nadunget housing project

Figure 8: Housing unit equiped with a solar panel.

Gando Primary School, Gando Village, Burkina Faso

Gando primary school is as a result of one man, Francis kere a Burkina Faso born architect's desire to sensitize the importance of education, local tradition and skills.

Kere set up a fund raising association (Bricks for the Gando School) with friends and the government of Burkina Faso as a result of the urge to provide a school with good facilities to his home town. A group of people were trained and equipped with the technique of compressed earth which brought about a mix of local and international components during the execution of the project.

The local climate of Gando is the greatest form giver of the building. The simple plan arranges three classrooms linearly, broken by covered outdoor areas. The classrooms are separated by covered exterior teaching spaces, which link the building to the surrounding landscape.
A corrugated metal roof hovers above the load-bearing walls of compressed earth, also used for the ceiling. The roof, wall and ceiling construction all allow for cooling of the interior, an important consideration in Gando.
The heavy block work ceilings, walls and beaten earth floors make use of the materials thermal mass in moderating internal temperatures. A wind channel has been formed between the roof and ceiling to expel hot air, drawing in fresh air at low level. Commonly found industrial materials have been carefully used to create a simple yet poetic

Figure 9: Form of the building

Figure 10: Covered exterior teaching spaces

piece of architecture.
On a social point of view, all people involved in the project management of this project were natives of the village, and the skills that were learned here were projected to be applied to further initiatives in the village and neighboring villages. According to the Aga Khan, the initiative has been borrowed by two neighbouring villages which also subsequently built their own schools as a cooperative effort. The local authorities have also recognized the project's worth: not only have they provided and paid for the teaching staff, but they have also endeavored to employ the young people trained there in the town's public projects, using the same techniques.

This particular project clearly depicts how community cohesion and project management can be beneficial in using local building techniques and also inspiring local natives in villages to complete their own projects.

Figure11: Sorrounding context of the building

Figure12: Interior of the classrooms

SITE ANALYSIS

The site analysis is an element in site design which involves surveying or studying the existing environment and how it will influence the structure's design and layout on the site. The site analysis in this project is to be addressed in 3 major phases; the research phase in which the problem and its definition are clearly stated, the analysis phase which involves the programming of the site as well as site and user analysis which focuses mainly on the in-depth below.

The site analysis is developed with an impression that it will facilitate the easy inventory of site elements and analyse these factors relative to the required needs and aims. Information about the characteristics of the site including topography, climate, wind patterns, vegetation is also gathered and analysed in order to incorporate it into the design.

The main aim of this project is to design low income housing units that are sensitive and reactive to sustainable aspects such as the well-being of people and the environment on a 16 hectare piece of land in Mpirigwa village, Mityana district.

Mpirigwa village

Mpirigwa is a village located in Mityana district in central Uganda. The district is approximately 77 km west of Kampala, the capital of the Uganda. According to the Ministry of Finance, Planning and Economic Development, the district is estimated to be occupied by an estimate 311,600 people. Agriculture is the main income generating activity in the district with the two major cash crops being coffee and tea.

Figure13: Location of Mpirigwa village

Mapping

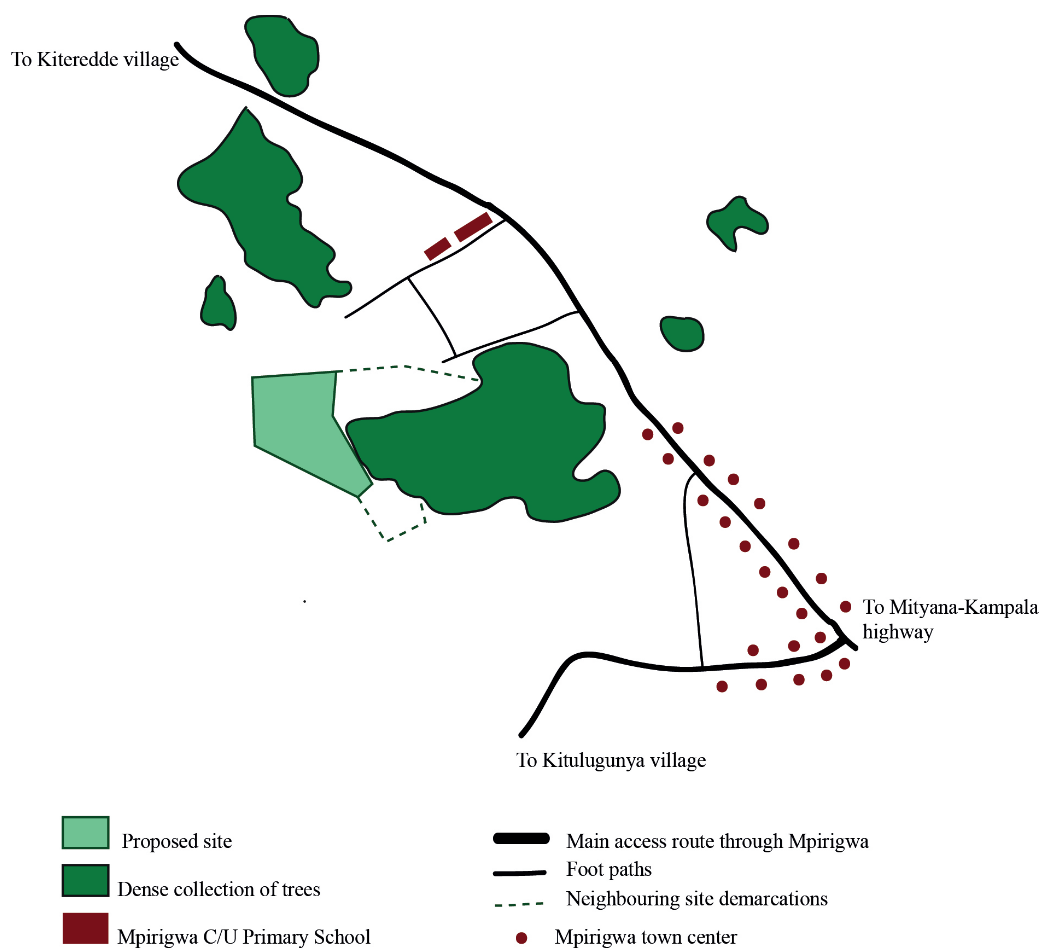


Figure14: Diagram showing access and the site’s proximity

Typology

The site has within its proximity, a scanty development of tiny illegally set up houses that form Mpirigwa town. The small houses harbor shops where people in the area go to buy their needs. These houses however have no defining architectural patterns due to the fact that they were set up illegally by squatters. These houses are all 1 storey high and were built using materials such as bricks and cement. A few houses in the local town are defined by the old Asian type of architecture which was introduced to Uganda during the pre-colonial era. In addition to that, legal set ups such as schools exist within the surroundings of the site, e.g. Mpirigwa Church of Uganda Primary School, which is neighboring the site towards the North West direction. The legally set up structures were emanated using modern forms and materials of construction e.g. bricks, cement, blocks, iron sheets etc.

Knowledge of the typology of buildings and their architecture is important during design because it enables architectural integration and coherence of the new project. The project will not ignore typical features within the proximity of the site, but will not; on the other hand strictly copy the architecture that currently defines the area. The balance between the new and the old must be found.

Functions

During the development of the project, sustainable development will not only focus on the building design but rather the community as well. The project will look to enhance the sustainable behaviours of the occupants at a neighbourhood scale. In order to facilitate this, a study is carried out to establish what types of functions exist within the area. From the study, it is revealed that there exist two primary schools within the vicinity of the site. One of the primary schools is located approximately 800m from the proposed site of the project. There exist tiny shops in Mpirigwa town that are below standard. The people within the area cannot acquire all their basic needs from the shops that exist in the area.

The area has a number of open fields where the local people go to engage themselves in activities such as sports and traditional ceremonies.

From the above analysis regarding functions within the area, the project is inclined to integrate more function such as cafeterias, a kindergarten, a community hall into the design in order to enhance the social well-being of the people of Mpirigwa village.

Traffic

The site can be accessed by a marram road that leads to the Mityana-Kampala high way. The marram road from Kikonge town on the main highway is about 9km to Mpirigwa town. It is poorly maintained and has no provisions for infrastructure such as drainage. This road is also not busy with respect to cars but rather a few motorcycles that pass every now and then transporting people from the high way to Mpirigwa town and the villages beyond. The proposed site is however not easily accessed by the existing roads; it however has a few foot paths and small roads close to it that lead to neighboring establishments such as the primary school and homes.
A strategy will therefore be developed to improve accessibility to the site. New roads, foot paths and bicycle lanes will be integrated into the design and coordinated with the existing road structure in order to make the site accessible by cars, bicycles and pedestrians. The use of public transport small motorcycles is the dominating form of transport in the area; therefore this will further be enhanced in relation to the proposed street structure of the site and area.

Greenery

Greenery is generally important within any context. Trees and greenery is a natural barrier against noise, dust and help prevent over heating (Swistock, Dewalle et Farrand 2005). It is also an aesthetic feature and has a positive impact on the human mind (Ulrich, 1986). People feel better when surrounded by nature therefore it is important to analyse the existing greenery and vegetation on and off site to help with further enhancement of the green areas and also develop new ones. The site is currently occupied by long green grass and a few thickets. Towards the south west end of the site is a dense collection of trees. These trees can provide raw materials in form of timber to the proposed project.

Topography

The proposed site lies on a steep slope and its spread along 1180m and 1347m above sea level. The slope diminishes towards the south end of the site. Underneath the steep terrain lay fertile soils that facilitate the growth of any kind of vegetation. The steep gradient of the site however brings about concerns such as surface run off during heavy rains. There is the need to consider developing a strategy for storm water management, on and off site during the rainy seasons of the year.

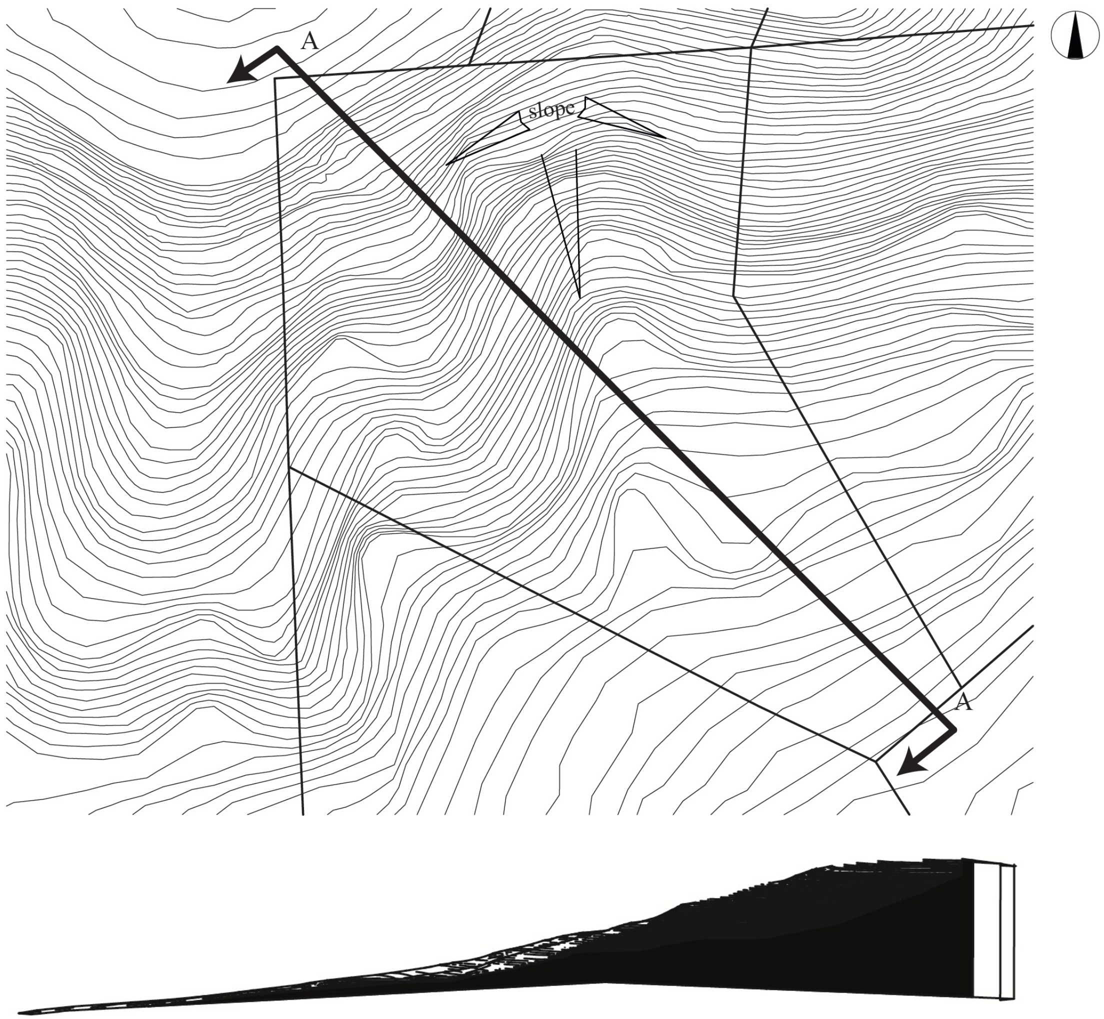


Figure15: Section A-A through the proposed site, height difference 160metres

CLIMATE

Sun

Uganda lies along the equator and it experiences tropical type of climate which is characterized by wet and dry seasons. The climatic analysis in this project is gathered from the country's National meteorological center in Entebbe. The sun in Uganda rises at 6am and sets at 6pm. Mpirigwa is situated approximately 32o 10'E and lies close to the equator which simply implies that the region receives sunlight throughout the year. The sun is right over head the equator during the months Of March and September, and this makes these months the hottest periods in the year.

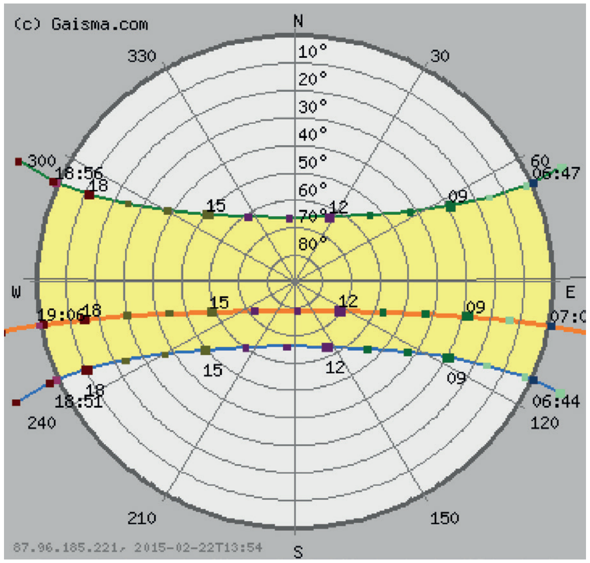


Figure16: Stereographic diagram of the sun's path over Mpirigwa (Source: Gaisma.com)

Temperature

Mpirigwa is characterized by the tropical type of climate; therefore average temperatures vary from as low as 15oC to 21oC.Th warm temperatures are normally felt during the hot seasons which spread thrice in a year. Chances of precipitation during these months are very minimal; however, this is contrary to the wet season. Temperatures tend to drastically fall to as low as 16oC

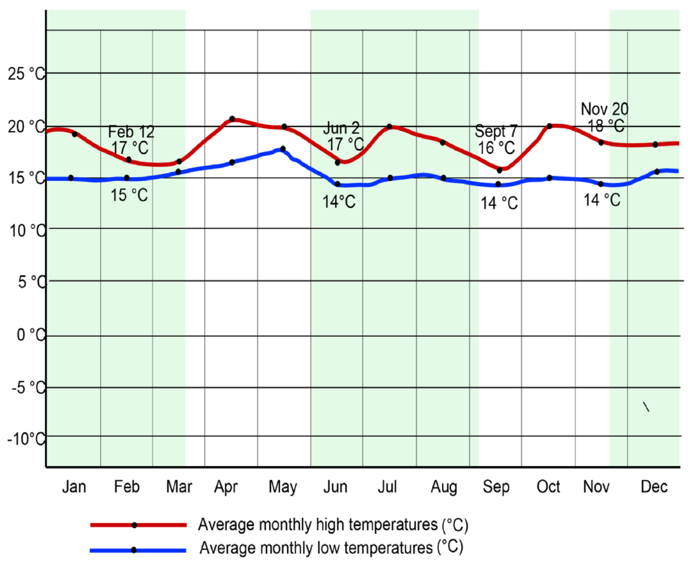


Figure17: Line graph showing average annual temperatures of Mpirigwa village.

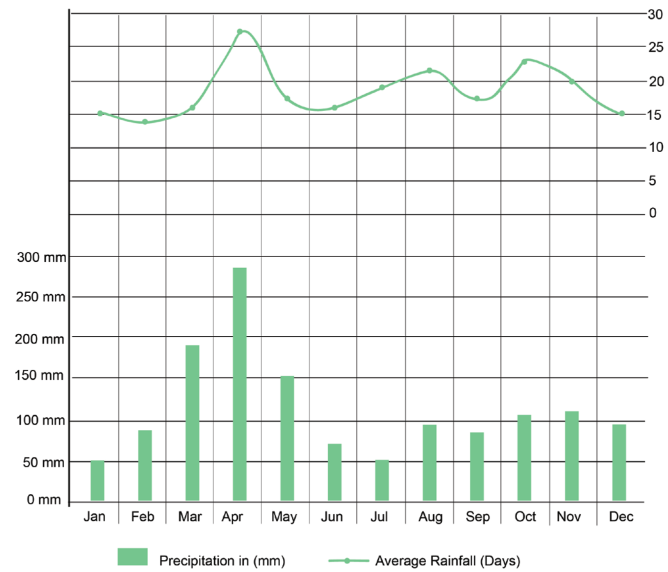


Figure18: Bar and line graph showing the amount of rainfall (mm) and average rainfall days in Mpirigwa village

Winds

As a strategy for passive cooling, wind acts as an element of natural ventilation and in the process cools the building and people. Unlike the sun, the wind changes throughout the day and year, depending on the location. When it encounters an obstruction, it flows around the object and continues in the same direction. The air flows from a region of high pressure to a region of low pressure which is an essential principle in cross ventilation and stack ventilation principles. The wind speed varies with height and terrain, which means that the speed increases with increasing height. In a dense urban area, the rate at which the wind speed increases is slower compared to an open or rural area. The rate is also known as wind profile (sustainability workshop.autodesk.com/buildings/wind). The wind data provided by the meteorological center gives a qualitative estimate of the wind in general. The chart shows the wind frequency and speed (m/s) of Mpirigwa from different directions over a period of 15 days.
The frequency of the wind is higher as the graph moves outward the radial scale. Each color describes the wind speed in different ranges, light color for low wind speed and dark color for high wind speed (Mesonet.agron.iastate.edu/).

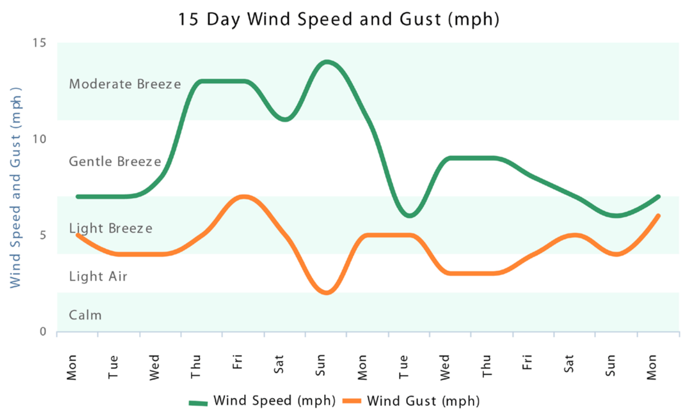


Figure19: Line graph showing wind speed and gust in Mpirigwa village

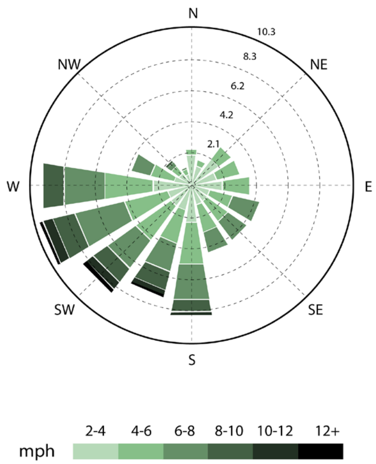


Figure 20: Windrose diagram over a fortnight.

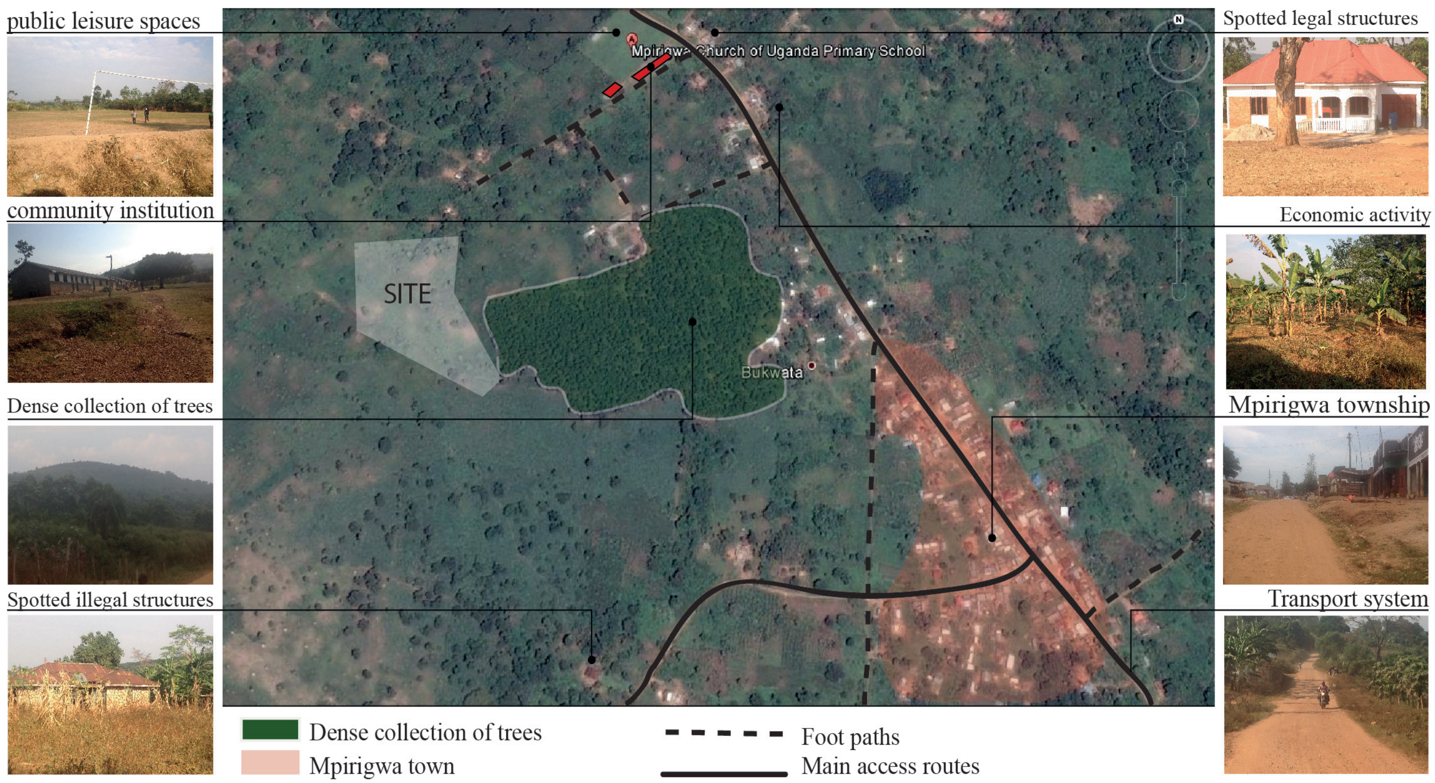


Figure 21: A walk through Mpirigwa village

SWOT Analysis

SWOT	Component	Strengths	Weaknesses	Opportunities	Threats
Neighbourhood context	Existing and projected vehicular movement patterns.(Major& minor streets)	Existence of a major route that connects the Mpirigwa village to the Mityana-Kampala highway and to the neighbouring villages beyond Mpirigwa.	The street structure in the area is not developed in terms of infrastructure such as street drainage patterns, and the roads are not well maintained to a reasonable state.	The village is easily accessed off the Mityana-Kampala high way.	Transportation of materials and other services to the proposed site will be very cumbersome.
	Existing and condition of the buildings in the neighbourhood		The existing buildings in the village are in a poor state and most of them were set up illegally.	The proposed project takes the initiative to define the architectural patterns in Mpirigwa village.	Mpirigwa village is delicate in terms of defining the built environment of the area.
	Street lighting pattern		The area has no street lighting patterns.		The area gets really dark at night which threatens the safety of people moving at night.

Natural physical features	Topography	Sloppy terrain		The sloppy nature of the site will facilitate the creation of different levels and hierarchy within the design. Ease the view towards the south, down the slope.	Difficult or cumbersome for handicapped users. Management of surface run off (storm water management)
	Soil types	Very fertile loam soils	The soils need to be covered by vegetation in order to remain compact and to maintain their strength	Vegetation can easily grow without the provision of supplements such as manure. The soils facilitate the easy growth of cash crops such as tea and coffee. They facilitate the use of simpler methods of construction such as strip type of foundation, unlike the raft and pad types of foundations	Clearing of vegetation opens up the soils to soil erosion and cases of soils sliding down the hill.

	Existing natural land features on proposed site	The site has a dense collection of trees bordering it towards the south east end. The site is also covered by a short thicket of vegetation and scanty trees.		The trees facilitate the formation of serene green outdoor spaces. The trees also act as natural barriers to wind, noise and dust. The trees strengthen the soils thereby eliminating catastrophes such as landslides and heavy soil erosions. The vegetation facilitates proper drainage of surface runoff.	The vegetation and some trees have to be uprooted in order to create space for the construction of the project. This in turn has a negative impact of the environment in form of environmental degradation.

Utilities	Water supply	Mpirigwa village has a piped water supply system that lies along the road that leads to Mpirigwa village and beyond.		The proposed site has access to clean piped water for domestic use.	
	Electricity supply	The village is equipped with hydro power lines for electricity.		The proposed site has access to hydro power which provides an alternative to energy resources within the project.	
	Sewer system		Mpirigwa village lacks a sewerage system.		Improper disposal of waste and grey water within the proposed project.

Climate	Sun's path and orientation.	Abundant sunshine.		Passive solar strategies such building orientation, the use of natural day light, and the use of renewable energy through the integration of solar cells into the design.	Harsh weather conditions such as too much sun and heavy rains damage building facades and materials.
	Rainfall variations.	Average precipitation of 250mm of rainfall per month.		The heavy rains provide water for domestic use and for watering plants and vegetation.	
	Wind speed and direction	Moderate wind speeds flowing at 15mph		Passive cooling strategies through the use of cross ventilation and side ventilation.	

Table 1: Swot analysis analysing the strengths, weaknesses, opportunities and threats involved in the project.

USER PROFILE

Mpirigwa being a village in Mityana district, the project is inclined to focus on the development of farming community. This is as a result of farming being the economic back bone of villages in Uganda. As earlier noticed during the site study, Mpririgwa is home to a few major cash crops in the country like tea and coffee.
The project intends to work around a mixed type of development where we shall see a set-up of housing development parallel to a farm where the inhabitants can grow cash crops like tea and coffee. The housing project will be divided into multiple types of homes in order to facilitate the different groups of people living in Mpirigwa village.
The farm incorporated into the project will be large enough to suit the needs of all occupants within the project.
During the site analysis, it was revealed that only a primary school and secondary school existed within the vicinity of the proposed site, as a result, the project intends to incorporate a kindergarten on site to provide schooling for infants of ages 3-5, this will be strategically placed to enable easy access by families with infants.
The project will also incorporate a community center where people in in Mpirigwa village can converge to engage themselves in social activities and interaction.

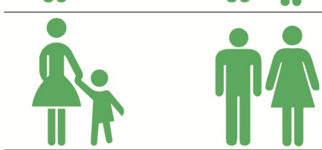
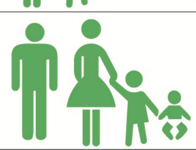
	PROFILE	APARTMENT TYPE	SQUARE METERS
	- Single - Couple	1 bedroom	50-60 m^2
	- Single & children - Couple	2 bedrooms	60-80 m^2
	- Family	2-4 bedrooms	80-140 m^2

Table 2: User profile

Design criteria

Master plan (sustainable site planning)

Ecological

- The proposed site contains a thicket of short vegetation and scattered trees, therefore an appropriate amount of this vegetation will be maintained and protected in order to enhance the site's sustainable urban planning.
- Minimal impact of run off to adjacent water bodies.
- Storm water management (Drainage systems and detention tanks)
- Control and reduction of the urban heat island effect through the use of appropriate landscape materials, paved and impermeable surfaces, and reducing energy consumption.
- Reduce water consumption and protect water body quality.
- Encourage access to public transportation and facilitate non-motorized commuting.
- Proper disposal of waste on the site
- The use of renewable energy resources.
- Enhancement of mixed land use
- Concentration and compactness

Social

- The provision of educational opportunities
- Health protection
- Freedom from crime
- Cultural and leisure opportunities
- Strength of a community (human interaction)
- Local food production
- Identity
- Human needs

Neighbourhood context

Siting

The building should be located in such a way that they avoid flooding zones, landslides and other natural hazards.

- Building orientation and shading; the buildings should be located on an east-west axis where possible to avoid unnecessary glare and overheating. Windows should be minimized on the east and west elevations and large overhangs provided to the north and south to generate mid-day shades. The roof form is used to create large overhangs to shade walkways and outdoor sitting areas.
- Building shape; symmetrical, compact, simple buildings with a regular plan form to enhance performance

when subjected to lateral loads such as earth quakes.

- Retaining walls; they should be free standing and separated from the buildings to ensure noninterference with the building structures in case the retaining walls collapse.

- Privacy
- Diversity
- Courtyards

Indoor climate

- Acoustics; solid bricks to provide adequate acoustic qualities. The use of plaster ceiling to enhance speech clarity during heavy rainfall.
- Lighting; windows are positioned in such a way that provides good natural light to every room. A light colored ceiling to provide good reflected light deep into the room.
- Ventilation; open windows on opposite sides of rooms and vents above windows and doors to enable cross ventilation. Light colored reflective materials to reduce heat gain through the roof.

Renewable energy resources

- Solar cells; integration of solar thermal collectors on roof tops of all buildings to generate energy for lighting and other electrical appliances.

VISION

The vision of this project is to create a mixed use development that is sensitive to both the environment and the social well being of the people.

PROCESS

URBAN SCALE

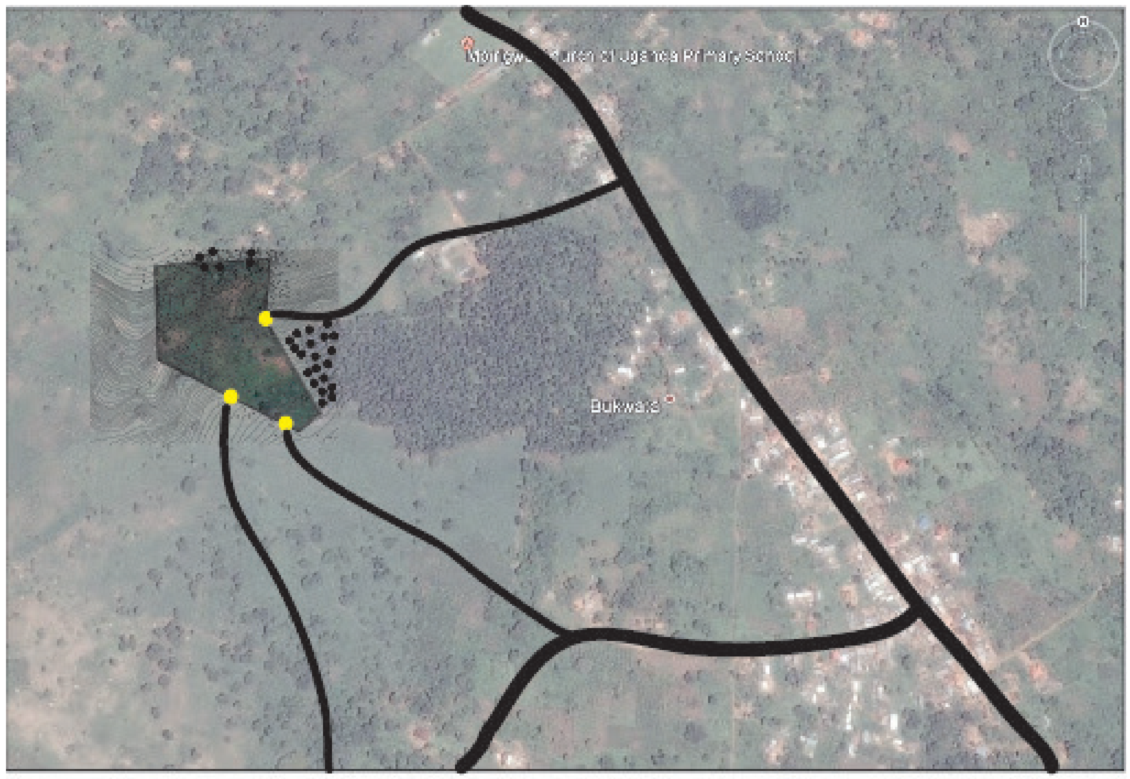
Accessibility to the proposed site

During the development of the master scheme, a variety of parameters have been put into consideration with the scheme's main point of departure being the accessibility to the proposed site and its integration with the exisitng street structure in Mpirigwa village. Mpirigwa village does not have a properly planned structure system therefore the proposed accessibility routes have to be structured in such a way that creates synergy with the existing street structure.

Strategy

Access to the site is from both the Eastern and southern ends of the site. The southern and Eastern ends also provide easy access to the steep slopes of the site, which in this case are to be used for economic activities, that is, farming (figure 22). The access point through the southern end is within or nearest to Mpirigwa town Centre thereby enabling easy access to the site from Mpirigwa town Centre.

Definite and relatively few paths and roads leading into the site in order to enable successful definition of the proposed neighborhood.



Exisiting street structure

Proposed access routes

Access points to the site

Figure 22: Proposed accessibility points on the site

Street structure on site

The three access nodes on the site are linked together by a hierachical street structure. Along the southern boarder is a street that leads to the farming area. This street creates an artificial boundary to the proposed site thereby strengthening the identity of the proposed project. The street further creates the possibility of expansion of the community outwards towards the western direction. All major roads within the proposal form artificial boundaries to the site . All the streets passing through the site divide the site forming different subcultures, its on the basis of these subcultures that the community is sprawled.

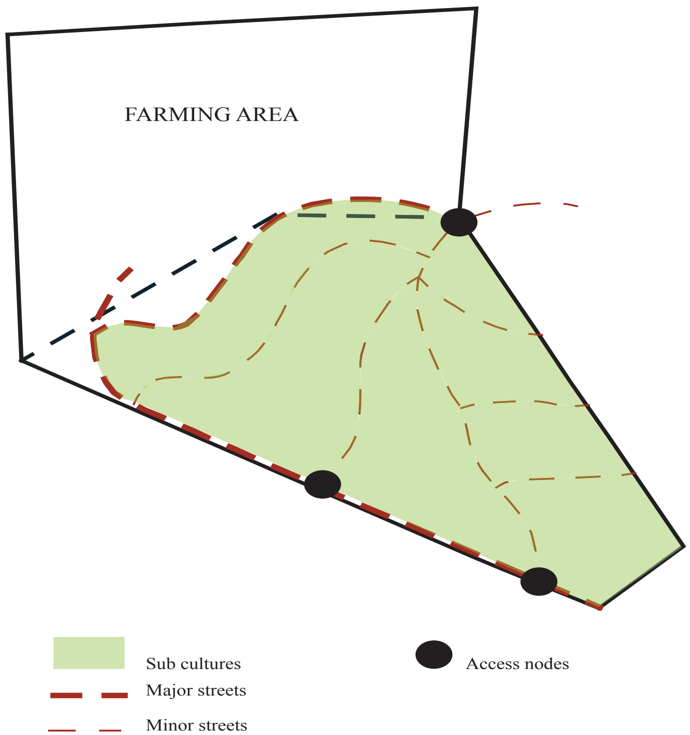


Figure 23: Proposed accessibility points on the site

Neighbourhood context

Sketch 1

The idea was developed using the proposed street structure as a point of departure. Compact volumes (figure 24) were placed on site in such a way that defines the boundaries of the different subcultures that were created by the street structure. The volumes created the possibility of creating different realms within different subcultures depending on the typology occupying that particular space, this is due to the fact that the volumes close off to the outter spaces and create inner closed up outter spaces.

However, this kind of closed up volumes seemed to have have been problematic with respect to the topography of the site. Questions regarding the structural integrity of such big volmes on a very steep slope arose which led to the further development of the volumes. The volumes were dissolved by creating spaces within the compact volumes (Figure 25).
However, this kind of arrangement was quite alienated from what the local people in the village have been acquainted with.

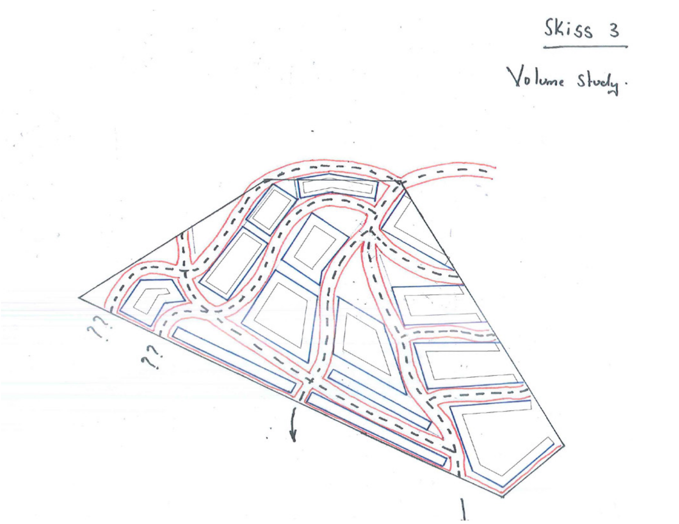


Figure 24: Closed compact volumes

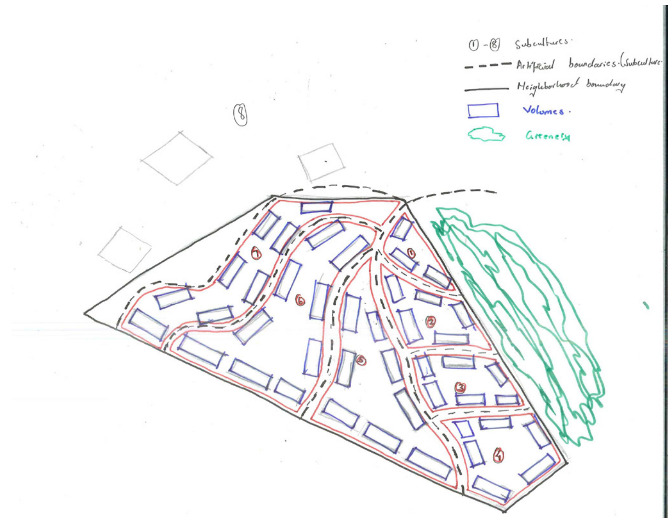


Figure 25: Spaced compact volumes

Sketch 2

Contrary to using one big mixed use building/block, the project proposes a micro urbanisation made by solid and empty spaces, enclosed and open areas in nature, (figure 26).

Fragmentation

The total surface required is distributed amongst free standing units. These units relate to the vernacular architectural form arrangement in an African traditional society (figure 27). Contrary to the vernacular form of architecture, the units emanate in a delicate relationship of proximity and distance, thereby creating a recognizable urban form. The units are bound together in clusters by streets to form identifiable neighbourhoods. The streets that bound the neighbourhoods are easily accessed by the adjacent neighbourhoods thereby making them a public entity, i.e a meeting place for the occupants within the community. The neighbourhood is also subjected to a public space in the centre which can be easily accessed from all point of the site.. The boundaries of the neighbourhoods (streets) within the community also intersect at specific points thereby forming edges that are characterised by public qualities.

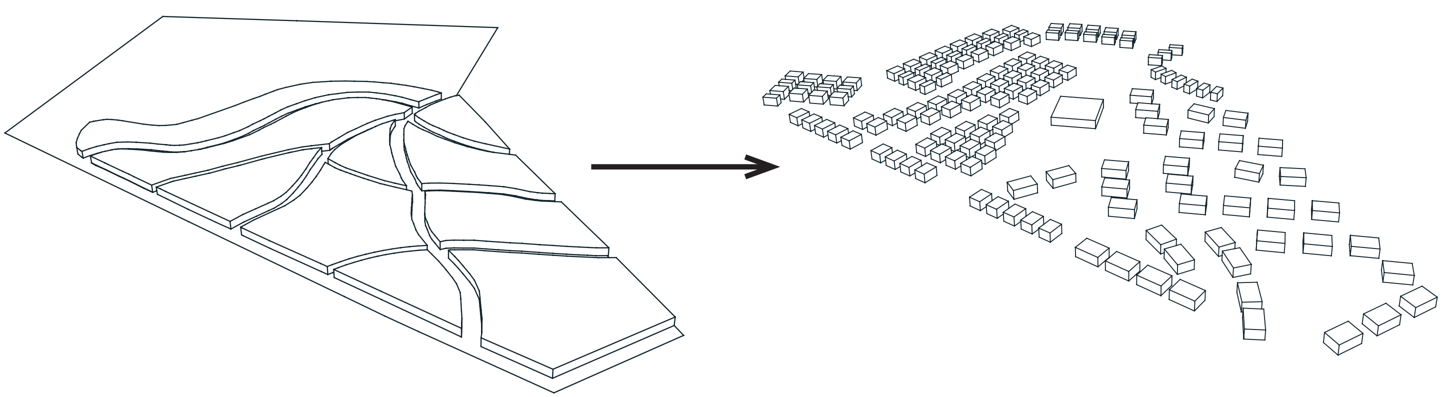


Figure 26: Fragmentation of big blocks into smaller blocks

Figure 27: Arrangement of vernacular housing in African traditional society

Volume study

The volumes on site are characterised by a 1 storey height of 3000mm. The volumes are placed on site in such a way that they should be built on native ground rather than on fill (figure 28). The volumes therefore gradually follow the topography's contour lines towards the lowest part of the site. The volumes are arranged in a cluster form in order to create an urban expression that is recognizable. The volumes are also arranged adjacent to the proposed street structure on site thereby giving definition to the artificial boundaries of the different sub cultures on site.

Figure 28: Clash (builidng Vs topography)

Solar study

The conceptual site solar studies reveal that shadows are cast along the east-axis of the volumes between november and March and slightly change between March and november. These developments further reveal and establish design criteria with respect to the architectural scale of the the project. The studies also reveal that outter spaces towards the south and north directions of the volumes are least affected by shadows cast by the volumes, which simply implies that these spaces have access to direct sunlight through out the year.

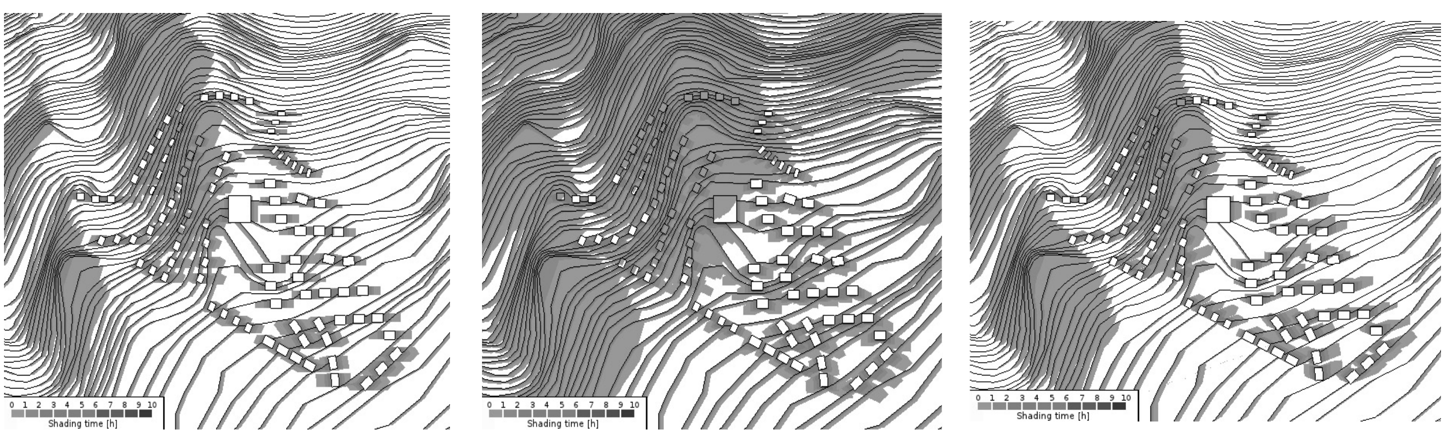


Figure 29: Conceptual site solar study (google sketch up)

ARCHITECTURAL SCALE

Room programme

Currently, the most common room programme in the villages of uganda takes its point of departure from the Asian Architecture most notably the Indian-Duka which was introduced to Uganda during the colonial rule (Ugpulse.com, 2015). The housing units are composed of one rectangular or square volume that is divided into two parts by most probably a piece of cloth (curtain). The front part of the house is used for common spaces such as the living room and dining area where as the back part of the house is used for the more private functions such as bedrooms (Figure 30). The bedroom in this case is a shared realm amongst the occupants of the home. The proposal looks at the integration of different realms within a home in order to suit or serve its users' needs sufficiently. The room programme illustrates the different spaces and their corresponding areas within the specific types of housing units (Table 2).

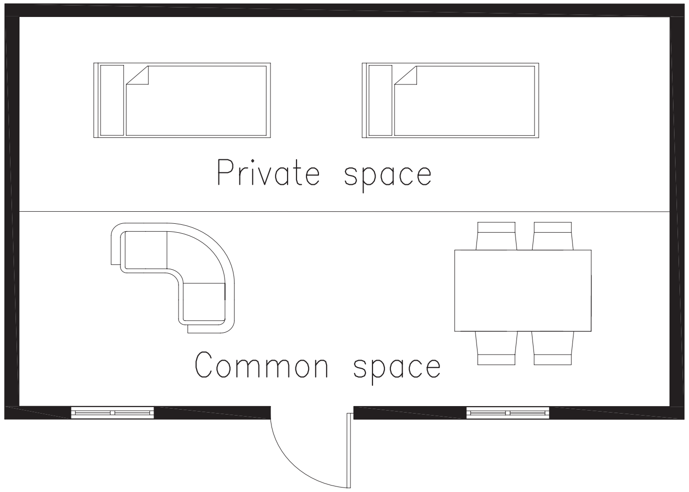


Figure 30: Lay out of housing plan in villages.

The project therefore establishes a efficient room programme for three house typologies, based on the requirements and needs of the local people (Table 3) A bubble diagram is then used to establish the relationship between the different spaces with relation to proximity (Figure 31). The bubble diagram also defines the various spaces in terms of which spaces are next to each other or far away from each other in three categories; that is, strong medium and weak. The placement of the different bubbles does not necessarily reflect the circulation within the programme

ROOM PROGRAMME

Single's units		Couple's units		Family units	
Space	Area (sqm)	Space	Area sqm	Space	Area (sqm)
bedroom	8,8	Bedroom	12	Parents' bedroom	13,5
living area	8,4	Living area	16,5	Grand parents' bedroom	13,5
private space	4,5	Private alcove	3	children's bedroom	22,5
kitchen	3,2	Private space	4,8	Living area	32
toilet	1,2	Kitchen	4,9	Kitchen	8
bathroom	1,2	Toilet	1,2	Toilet	1,2
kitchen (outside)	8,3	Bathroom	1,2	Bathroom	1,2
Porch	4,2	Kitchen (outside)	8,3	Kitchen(outside)	8,3
		porch	7,4	Courtyard	10
Total	39,8	Total	59,3	Total	110,2

Table 3: Room programme of the particular housing typologies

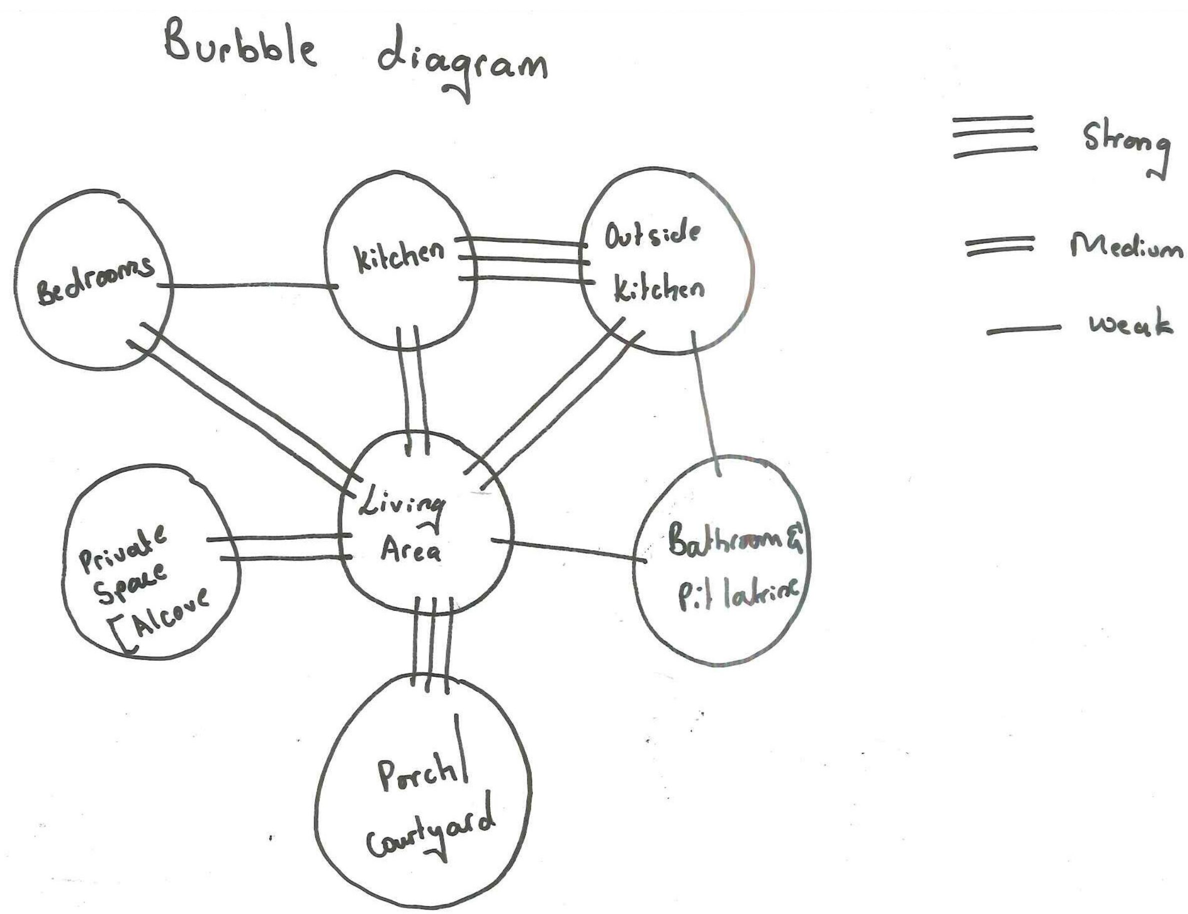


Figure 31: Bubble diagram showing the relationship between the spaces

Volume study

The home stead is fragmentated into three volumes, the main house, kitchen and the wahsrooms. The volume structure is as a result of the requirements and ways of living in the villages. The kitchen has been detached from the main building simply because kilns have been introduced to the villages of Uganda as a sutainable strategy to over come the use of trees for firewood (GmbH, 2015). Even though strategies have been established to improve such technologies in villages, the local people have not found them necessarily important. More sensitisation is required in order to educate the local people about the new improved technologies. Kilns are usually characterised by a great amount of smoke and high degrees of heat that is as a result of burning firewood to cook food hence the necessity to detach the kitchen from the main house.
The washrooms are characterised by a deep pithole (latrine) which for health reasons must be detached from the main house and situated a few metres away from the main house and further away from any water source e.g a well, river or lake.
The three volumes are hierachical further giving definition to the spaces that are enclosed within. (For inspiration, the Moriyama house was analysed to establish the relationship between detached volumes.

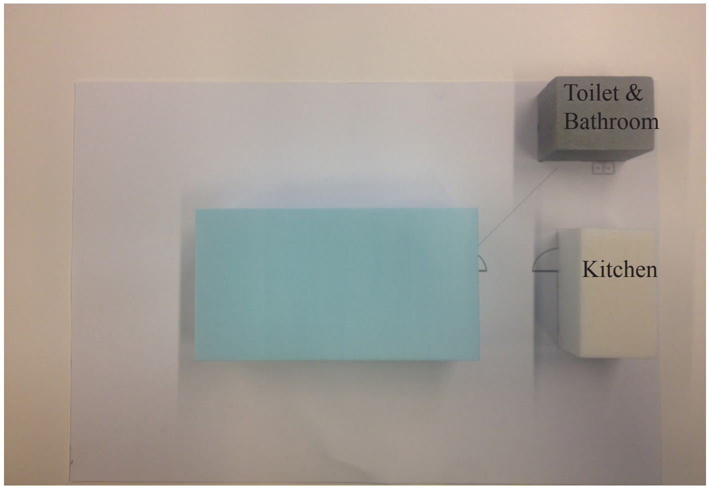


Figure 32: Volumes showing fragmentation of a home stead

Figure 33: The Moriyama house (Wohnmodelle.at, 2015)

Plan Layouts

The single users layout is made up of a simple open space that is characterised by alcoves for specific functions. The common spaces are adjacent to the outter detached spaces to enable efficient circulation between the various spaces. The sleeping area on the other hand creates a barrier between the more open public spaces and the more enclosed private spaces. The different spaces in the layout lay along the east-west axis in order to achieve the best quality of light required in each space.

The layouts are also characterised by a porch that is closed off thereby creating and individual territory. The porch also provides main access into the buildings.
The couple's layout on the other hand is characterised by a shared realm and private realms. The private realms create the possibility of individual spaces when deemed necessary.
The family's layout is characterised by four realms; the parent's realm, children's realm, grandparent's realm and

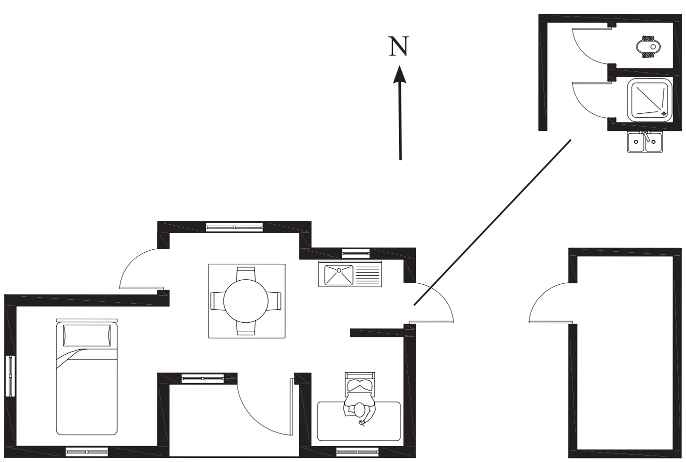


Figure 34: Single user's layout

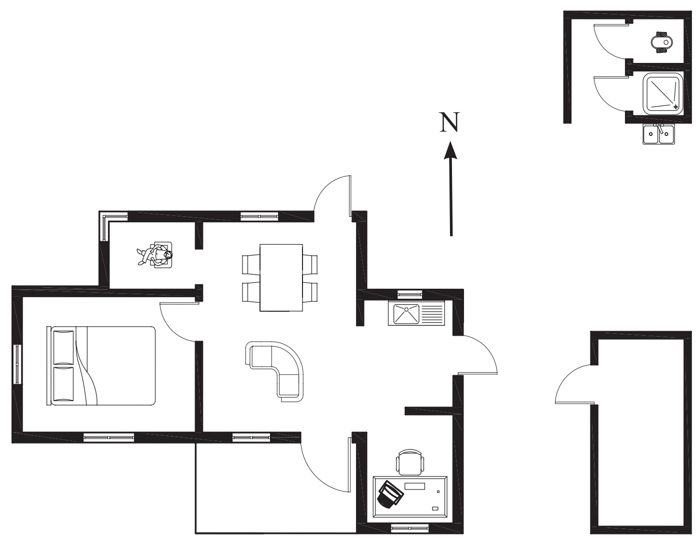


Figure 35: Couple's layout

the shared realm. These realms are all separate to create the appropriate quality as per the users. The realms are linked together by a hall way that is opened up to the outside space.
The layout plans have entrance points through either side of the plans to enable easy accessibility and circulation between the inside spaces and the outter private and public spaces.
The layout plans of the detached spaces are closed off from the public spaces in order to create a private quality. for the users (Christopher Alexander,1977)

Figure 36: Family layout

Facade expression

The facade is designed in such a way that permits air flow and light penetration into the houses to create good qualities while protecting against harsh weather conditions such as wind and rain. Earth is used to create the bricks as a strategy to address the environmental aspect of sustainability with relation to materials.
The facades are characterised by window and door openings on the north and south facing facades in order to avoid un necessary glaring and over heating. The openings on the facades are also placed in such a way that allows light into the various spaces from more than one direction.

The facades also enable easy accessibility to the outside spaces.
The roof structure is designed in such a way that enables air flow through the roof structure. The roof structure collects and diffuses the heat from the sun thereby keeping the houses cool. The roof structure also has a provision for overhangs to protect the facades of the building against direct solar rays and rains. The roof slants at angles to hernesss renewable resources such as solar energy and rainfall.

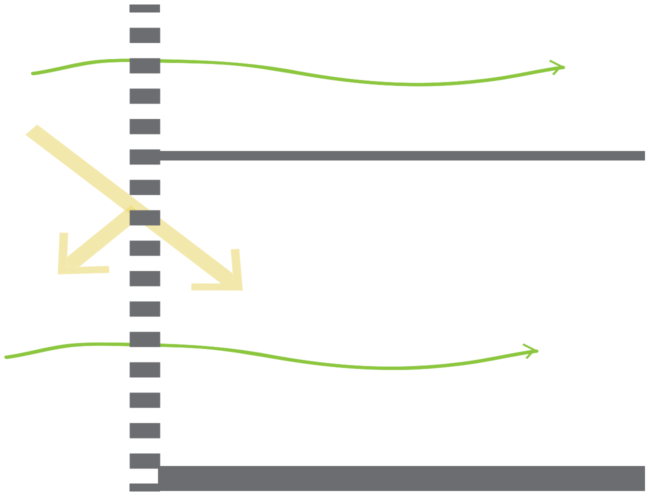


Figure 37: Perforated brick facade

Figure 38: Termitary house in Vietnam (Dezeen, 2015)

Figure 39: Facade expression of single user's house, front elevation

Climatic sections

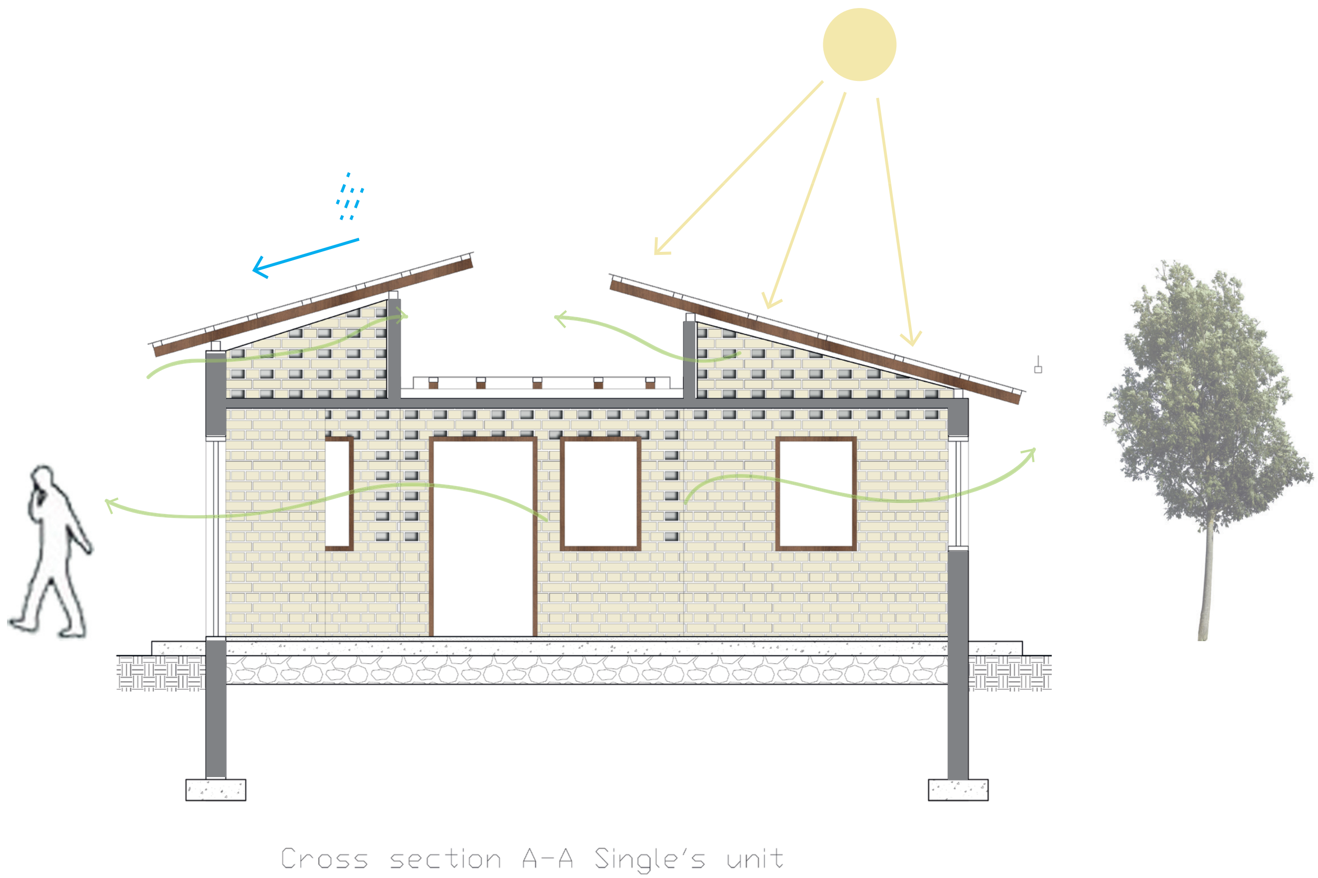


Figure40: Latitudinal section through the single user's house

Site and construction management

Construction system

External Foundation Wall

Local brick foundation wall with reinforced concrete slab is used to support the weight of the structure as well as the live loads and to transfer all loads into the ground beneath.. The skirt wall in form of a non-structural concrete skirt is built around all houses to protect the building foundation and to provide valuable space for activities such as washing and cooking.The skirting wall could vary in width, 450-600mm wide.

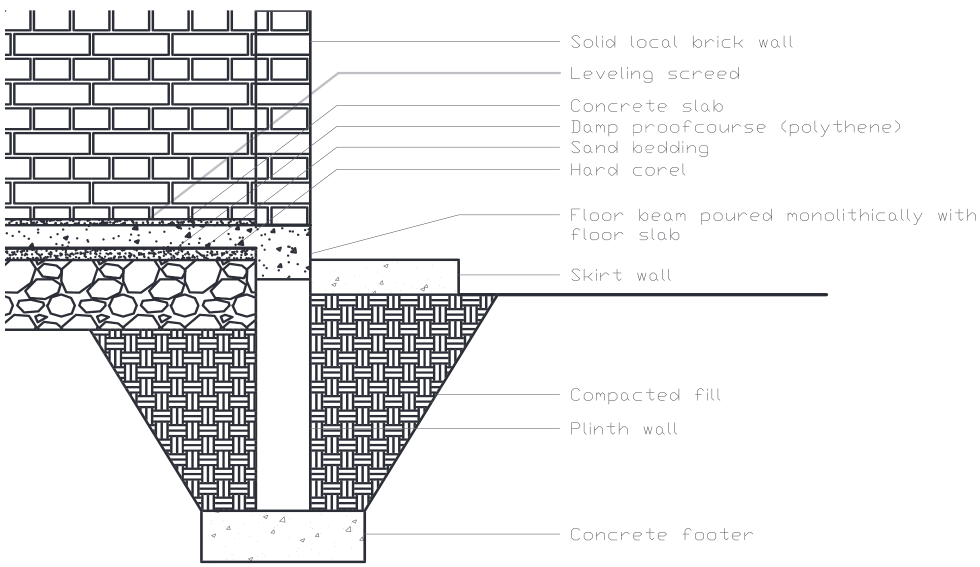


Figure41: Construction system of a strip foundation

Wall system

The wall is comprised of compressed earth bricks. Reinforced columns are however established at every corner of the house in order to provide lateral stability during the earth quakes. The compressed earth bricks have grooves and flanges which fit together to allow the bricks to be laid in an interlocking manner. Because the bricks are composed of a fraction of cement, (reference) mortar is only required after every 4th course. The interlocking bricks also provide more lateral stability to the walls and ensure quick construction as bricks are self-aligning.

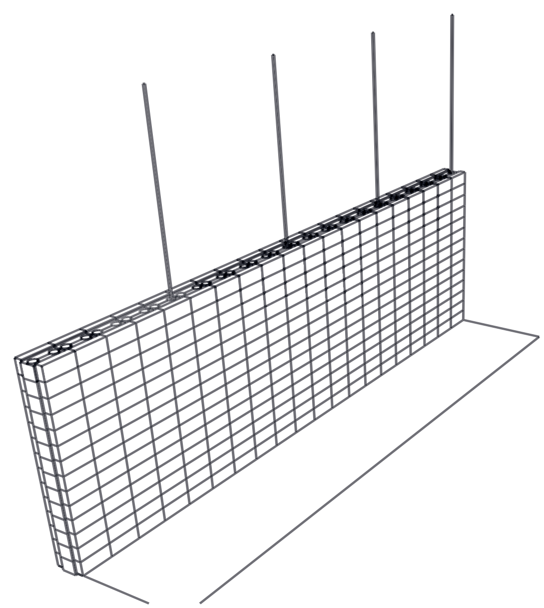


Figure42: Construction system of a compressed earth brick wall

Roof system

The roof is constructed using light weight corrugated metal sheeting over a timber roof framing. A ring beam lays along the walls to provide stability and the top plate sits on top of the ring beam. The roof is not sealed which gives a provision for flashing. Water will inevitably progress into the roof space during heavy storms but sufficient ventilation will enable the roof to dry off quickly. The timber roof framing is coated with used motor oil (preservative to prevent the timber from being attacked by insects such as termites.

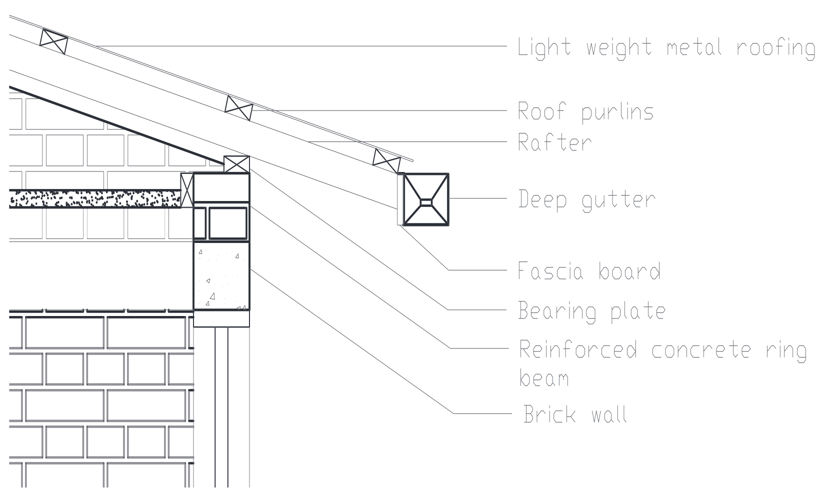


Figure43: Construction system of the proposed roof

Storm water management

In order to reduce flood risks on the site, surface water run off from the developments have to be managed (GBI: pg 10) Steep slopes are always exposed to soil erosion which is caused by surface run off which eventually damages the soil. Steep slopes also create uneven distribution of rainwater over the land, which naturally affects plant life more than it could if it were evenly distrubuted (Christopher Alexander: pg 835)

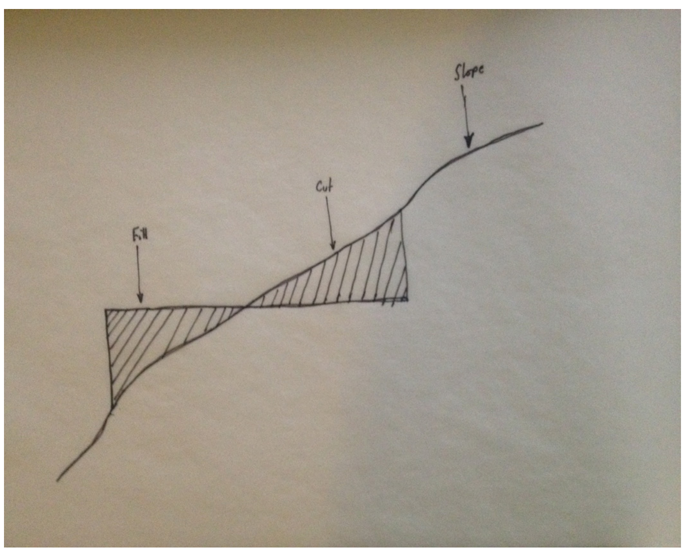


Figure44: Cut and fill of a steep slope

In order to address the issue of erosion on the proposed site, terraces are created evenly over the entire landscape in order to slow down the erosion. Terraces and bunds are built along contour lines.

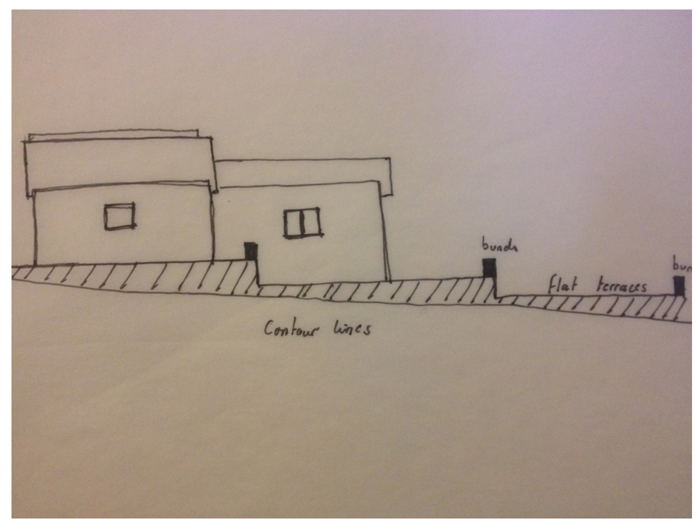


Figure45: Flat terraces and bunds

Water efficiency

Rain water harvesting

As a strategy to reduce portable water consumption, roof top rain water harvesting has been used as a point of departure in the project. The rainwater harvesting system consists of rainfall, a catchment area which is a roof surface in this case, a delivery system (gutters) to convey water from the collection surface to the collection point, a storage tank to store the water until its used and an extraction device (a tap)

This form of harvesting is common in rural areas and is used on small scales, mainly neighbourhoods like in homes. It is a simple low cost technique that requires minimum expertise to install (Sswm.info, 2015)

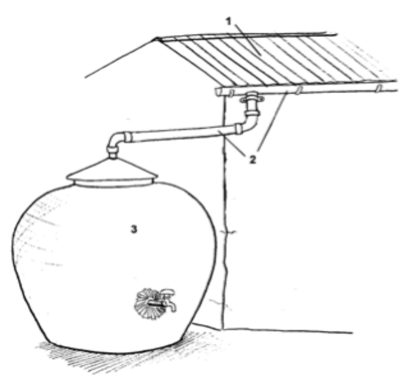


Figure 46: Three basic components of a rain water harvesting system (Sswm.info, 2015)

A system that does not require the use of portable water supply from the local authority has been integrated onto the roof structure of all the housing units.

The water can then be used for domestic use. The deep gutter has a wire gauze placed inside it that collects and prevents rubbish from getting into the collection point. In most cases, rainwater is contaminated by air pollution, bird droppings and organic matter therefore the water requires treatment like filteration, boiling and disinfection before consumption.

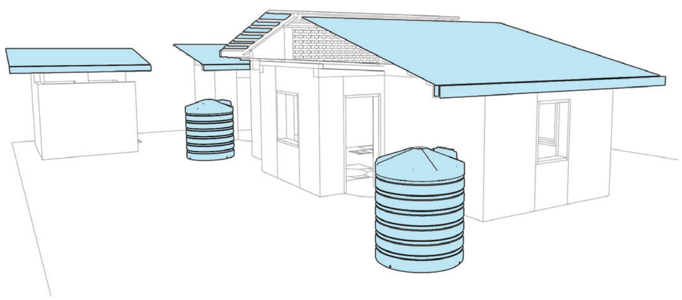


Figure 47: Rain water harvesting system for a single user's unit

Waste water management

Because of the cost incurred to establish a waste water recycling system, the project does not intend to reuse waste water or grey water. Therefore a strategy has to be set up in order to tackle the issue of waste water managment. Soak pits have been identified as cost effective ways for partial treatment of waste water and a relatively safe way for dischaarging it into the environemnt (Sswm.info, 2015).

A soak pit is basically a simple pit, approximately 1.5-4m deep normally filled with a porous material like hardcore or gravel that prevents the soak pit walls from collapsing in and also provide space for waste water as well. Because a soak pit doesnot provide treatment for raw waste water and the pit will quickly clog (Sswm.info, 2015), the project intends to use the soak pits to soak away waste water from the bathrooms and kitchen sinks. The soak pits are also situated in such a way that they are not accessed by high traffic in order to prevent the soil around and ontop of the soak pit from being compacted. The reason as to why the project has approached the aspect of waste water management by integrating soak pits is because soak pits can be built and repaired with locally raw materials, the technique can be applied and used by anyone, they require low costs to operate and they are a great way of recharging ground water bodies.

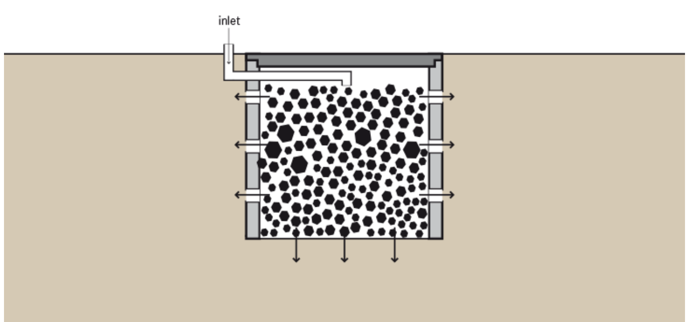


Figure 48: Schematic of a soak pit (Sswm.info, 2015)

Figure 49: Open soak pit with installed PVC pipe (Sswm.info, 2015)

Materials and resources

Reused and recycled materials

The project has taken a step to address the issue reuse and recycling materials through the following strategies;
During the construction of the development,designated areas should be established to facilitate the storage and collection of non-hazardous materials like timber for the purpose of recycling, this should be carried out side by side with the reduction of waste generated by construction that is disposed off in landfills..
The project also tends to encourage the reuse of building materials (soil and timber) in order to reduce the demand for fresh materials and to reduce waste thereby tackling the issue associated with with the extraction and processing of raw materials.
As a strategy to lower the carbon content and improving the building life cycle, the project has carefully selected materials that integrate the building design and its buildability in relation with embodied energy and durability.

Sustainable resources

The project looks at building materials and products that are extracted and manufactured within the region, preferably within 500km of the project site thereby supporting the use of indigenous resources and reducing the environmental impacts resulting from transportation of materials.

Indoor environment quality

Solar studies

The three different house plans were modelled in ecotect software in order to study the impact of solar radiation on each facade of the buildings. According to the East African design guide, it is recommended that the building are oriented along the east-west axis. This helps to avoid unnecessary glare and over heating. Over hangs are also provided along the north and south facing facades to provide shade from the mid day sun.
The models in ecotect were at the same time used to determine the most optimum orientation for the different buildings.
Simulations carried out in ecotect show that the west and east facing facades are affected most by solar radiation with the west facing facade receiving the biggest percentage of solar radiation per year. This is due to solar rays from the afternoon sun. The north and south facing facades are least affected by the solar radiation, however

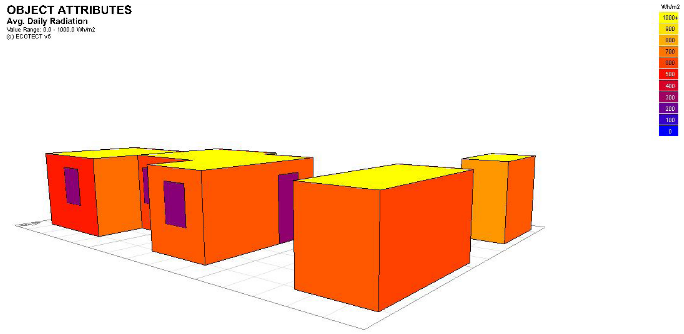


Figure 50: Solar radiation against the south and east facing facades (Ecotect Analysis)

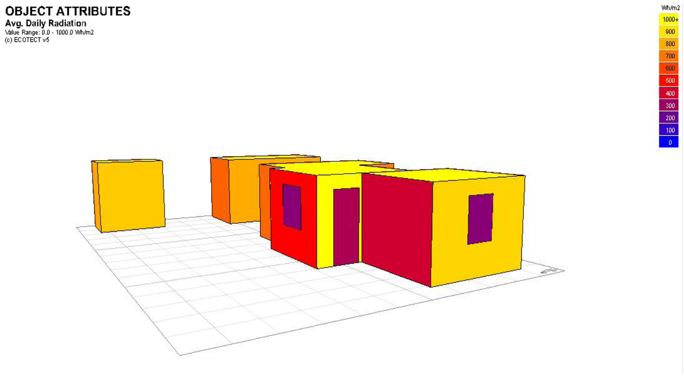


Figure 51: Solar radiation against the north and west facing facades(Ecotect Analysis)

these facades require shading/ over hangs in order to creat shading from the noon(over head) sun.
Studies from ecotect further reveal that the biggest area of openings should be situated on the north and south facing facades as these facades are least affected by unnecessary glare and over heating.
However, more studies in ecotect showed that the east-west- orientation of the buildings on site was not actually the best orientation with reference to over heated and under heated facades. In order to optimumly distribute the solar incidence on the facades, the buildings on site have to be oriented at 35^{o} N in order to obtain optimum orientation.

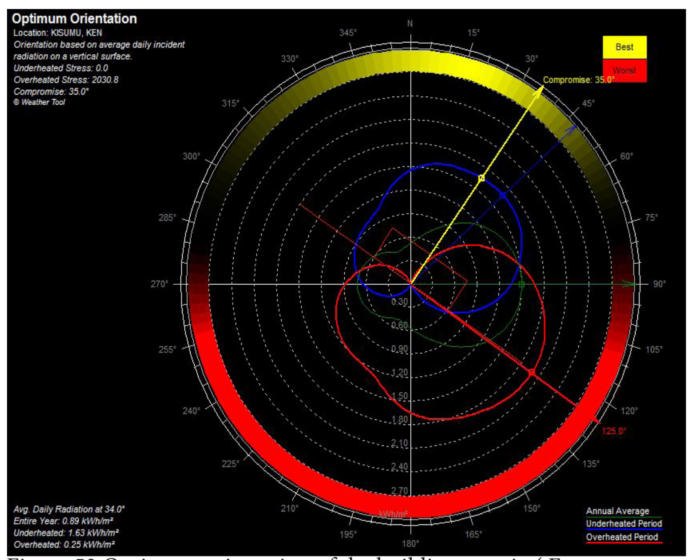


Figure 52:Optimum orientation of the buildings on site(Ecotect Analysis)

Day light studies

Daylight is a major factor that affects the quality of space. With a minimum average of 2% daylight factor as a point of departure, different window sizes for the different housing units were investigated in Velux daylight visualiser in order to establish an appropriate day light factor for each space. Taking into consideration the east-west axis and the solar radiation studies from ecotect, the window and door openings are maily limited to the north and south facing facades. The window openings create a linear horizontal connection on the facade. In order to optimize the distribution of light in the dwellings, each room is located in such a way that it has outdoor space outside it on at least two sides and a window placed on each of the walls so that natural light falls into every room from more than one direction.

Simulations from Velux Daylight visualizer show that the

Figure 53: Day light factor in a single's unit (Velux daylight visualizer 2)

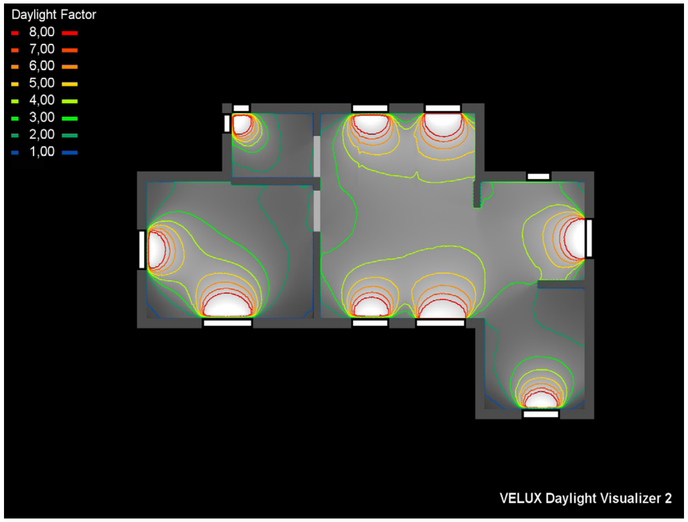


Figure 54: Day light factor in a couple's unit (Velux daylight visualizer 2)

day light factor in each of the bedrooms is greater than 2% and approximately 4-5% in the livinf spaces. (figure 4-4) From the results, the sizing of the windows is defined and tested in BSIM for indoor climate.

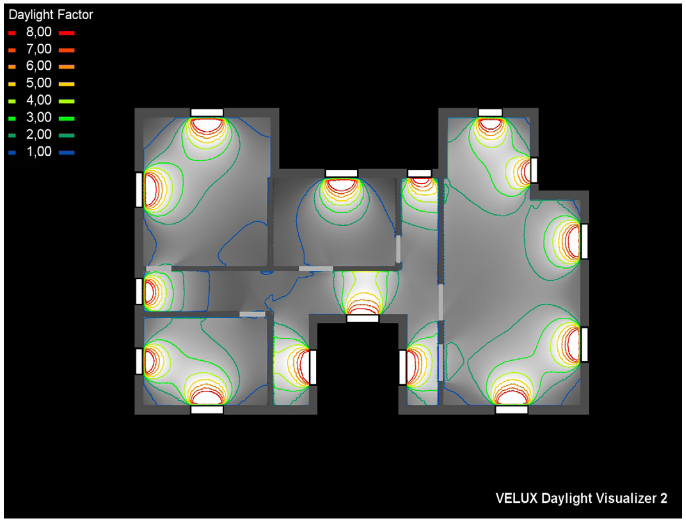


Figure 55: Day light factor in a family unit (Velux daylight visualizer 2)

Bsim

In order to investigate the indoor climate climate inside the three different typologies, the housing units were modelled separately in BSIM in order to obtain optimum results for each of the housing units. This is because the housing units are free standing and have no what so ever impact on each other with relation to indoor climate. The housing units are designed in such a way that completely excludes the use of active strategies but rather integrate passive strategies in order to address key issues with relation to the internal environment.
BSIM is therefore used to integrate an optimum design solution with a satisfactory thermal and air comfort. Because East Africa does not have set required indoor standards, the project will confirm with the set Danish Standards building class II (DS 15251, 2007) with temperatures between 23-26°C in summer periode and not exceeding 100 hours above 26°C and 25 hours above 27°C. And indoor CO_2 concentration not exceeding 850ppm.

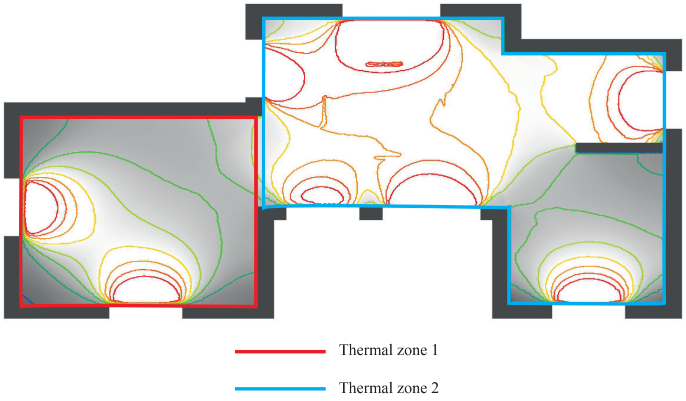


Figure 56: Thermal zones, single user's unit

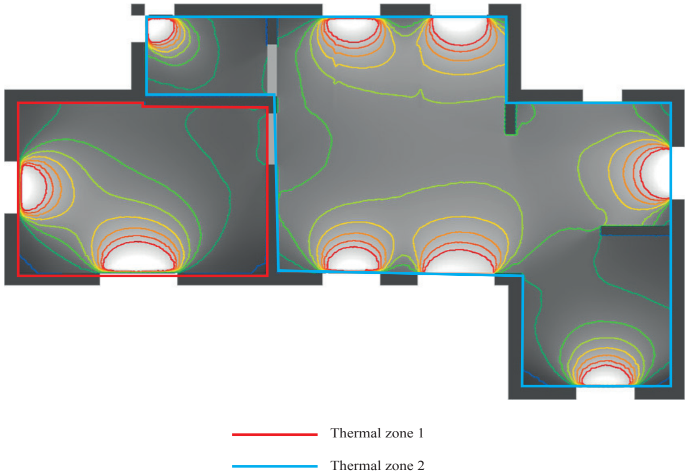


Figure 57: Thermal zones, couple's unit

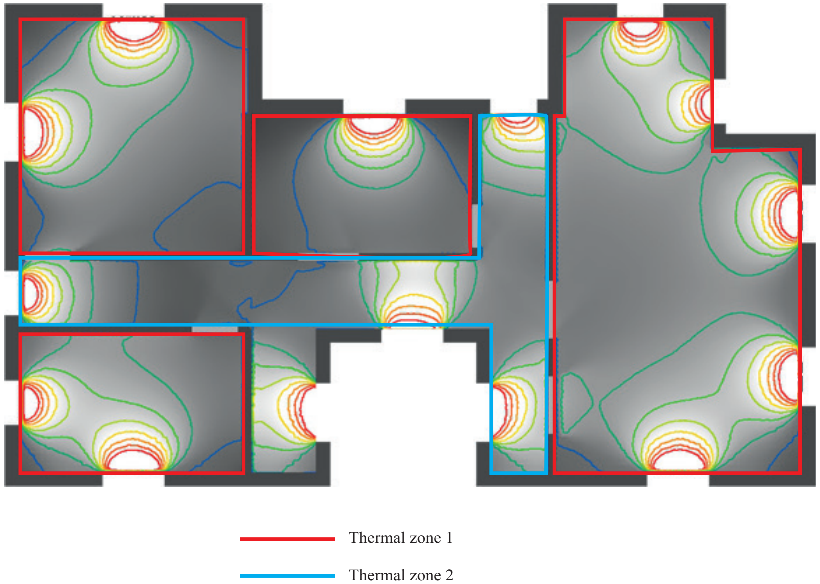


Figure 58: Thermal zones, family unit

Innitial investigations in BSIM show that the thermal comfort in each of the housing typologies was not satisfactory with very high temperatures over long hours during the lat quarter and and first quarter of the year. By investigating the occurance of the high temperatures in BSIM, it was only clear that they occur due to the very high temperatures outside. However the high temperatures are acceptable because they occur during the day when most people are not at home. In order to avoid over heating in the various housing typologies, shading strategies have been implemented into the design. Long over hangs of 600mm-1000mm have been integrated as part of the roof structure to control the amount of solar incidence on the facades of the buildings. Figure 59 shows the mean temperatures inside the single user's unit before shading strategy was integrated into the design while figure 60 shows the temperatures of the same house typology after integration of shading solutions.

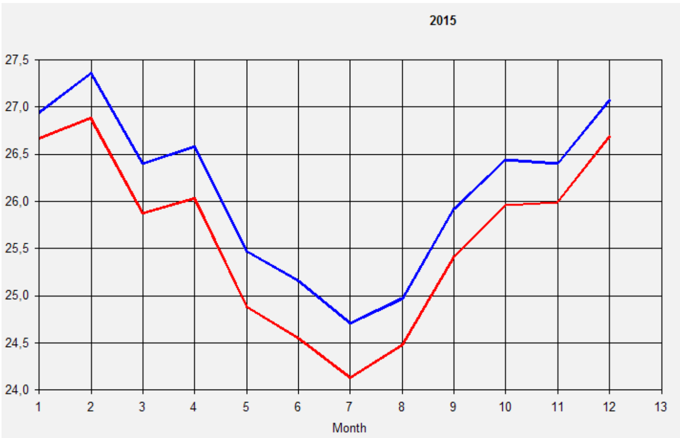


Figure 59: Temperatures before integrating shading solution, single user's unit (Bsim)

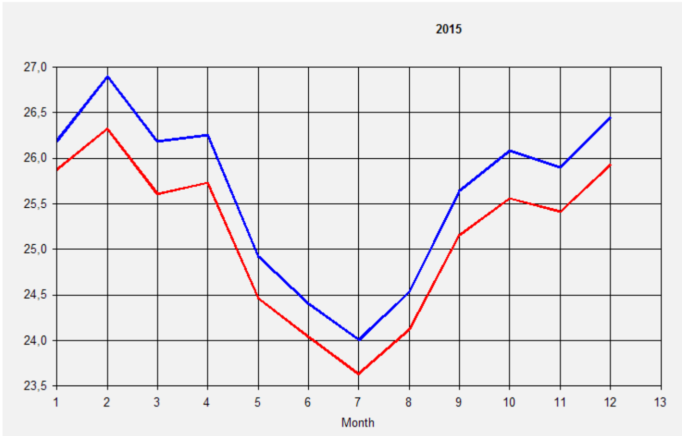


Figure 60: Temperatures after integrating shading solution ,Single user's unit (Bsim)

Figure 60 shows the simulated zones of a single user's house in relation to CO_2 conceteration. Results show that the carbon dioxide cumulation in the house is lower than 850ppm which is in accordance to design criteria of a class II building. The highest value of carbon dioxide cummulation is recorded in thermal zone two which comprises of the living areas. The CO2 in the living area raises up during April and September due to the low air flow in the housing unit during that particular time of the year (Figure 62). Mechanical systems are not integrated into the design in order to save energy and at the same time achieve a high level of atmospheric comfort.

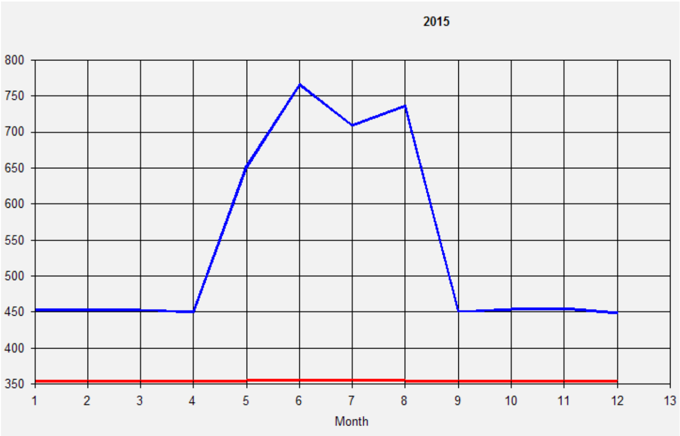


Figure 61: CO2 concenteration in the single user unit under 850ppm(Bsim)

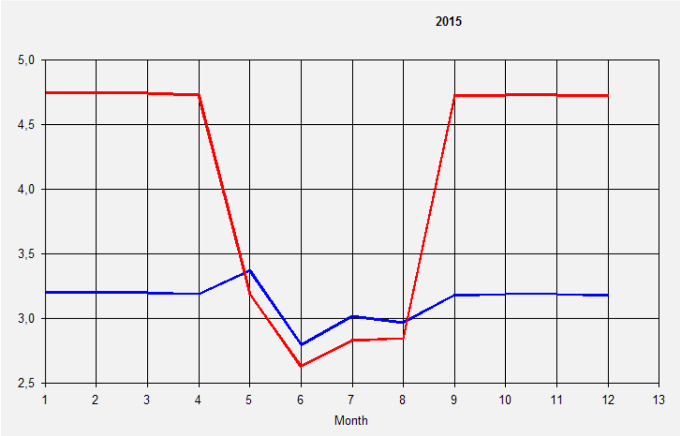


Figure 62: Rate of air flow in the single user's apartment (Bsim)

Energy efficiency

Renewable energy

Uganda has abandunt natural energy resources such as biomass, water and peat as well as favourable conditions for solar, wind and geothermal power generation. However, hydro power and biomass are the only energy resources that have been tapped to contribute to the country's energy demand (GmbH, 2015). Even though the country has a low electrification rate of 15%, the available energy is usually used wastefully which has been a negative impact on the already insufficient supply.

The situation has foreseen the uprise of organisations set out to promote the use of renewable energy resources and energy efficiency programmes. PREEP a Germany based programme is one of such programmes that have been set up in the country to address the issues of renewable energy consumption and energy efficiency.
As one of the innovations, the programme has developed improved stoves that use improved biomass technology.

Figure 63: The improved jeep rocket stove (Jeepfolkecenter.org, 2015)

Figure 64: Solar PV being installed on a house : (Sunlabob.com, 2015)

Mud firewood stoves have also been developed in order to address the issues of energy efficiency. These have been found to have less impact on the income of the local people and the forest coverage as well (Anon, 2015)
On the other hand, EnDev Uganda has set up a market development for improved cook stoves in the rural areas. The focus mainly lies on the clay rocket stoves that are suitable for firewood (Energyprogramme.or.ug, 2015)
A number of grid densification projects have also been setup over the last couple of years to provide electricity to homesteds in villages that do not have access to hydro power grids. EnDev Uganda has managed to do this through the support of solar PV markets which inturn have an impact on the outcome of the entire programme.
The majority of people in villages largely rely of lighting mechanisms such as candles and kerosene lamps which in the long run are harzedous to the people due to the toxin gasses that are produced by these mechaanisms (Energyprogramme.or.ug, 2015)
It is therefore a goal to establish a densification grid within the project through the integration of solar PV on all housing units in order to implement the use of renewable energy within the homes. The estimated amount of energy required per homestead based on the requirements is calculated and later used to derive the numver PV solar cells required to provide energy to a home (See Appendix) . The project has further integrated the requirements and qualities of rural realms into the design through the fragmentation of the building volumes to enable efficient use of the newly developed technologies.

PRESENTATION

MASTER PLAN

The master plan takes its point of departure from the meandering street structure that gradually follows the terrain of the site. Part of the street structure forms the edge of the site thereby giving identity to the entire community. The master plan comprises of 1 storey free standing building volumes that are placed on cut terraces along contour lines and constitute of different mixed functions. The buildings are arranged and clustered in subcultures that are defined by the street structure on the site thereby giving different spartial qualities to the outside spaces.
The user profile is distributed on the site based on the targeted user groups. The different homesteads are arranged along the edges of the site with an accessible public space situated at the centre of the the site. The central public space constitutes of public entities such as the proposed kindergarten, community hall, playing court and open green spaces.The lower edge of the site is characterised by the family units and commercial units. The commercial units are located along the intersection nodes or junctions. The commercial units are also situated within the public space's vicinity for easy access.
The single and couple's homesteads are arranged on the more bustling edges of the site towards the north end of the site.
The master plan also constitutes of farm land on the northern end of the site where the occupants of the community can carry out farming activities like growing of cash crops.

key figures

Single housing units: 14 units- 40sqm
Couple's units: 38 units- 60sqm
Family units: 22 units- 110sqm

Figure 65: Site section 1:500

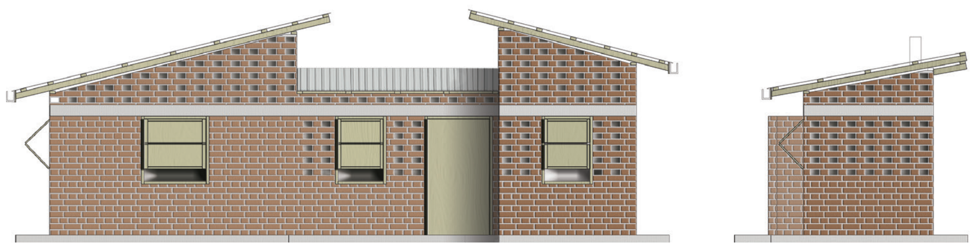


Figure 66: Couple's unit, front elevation 1:200

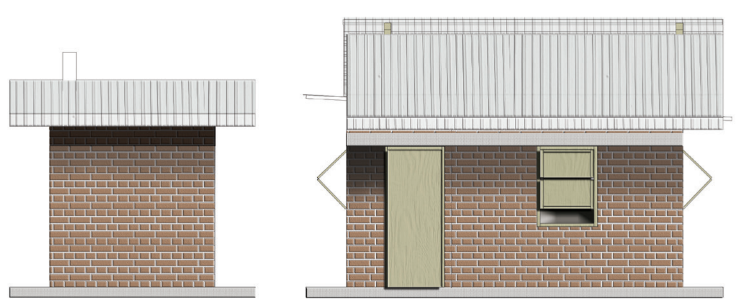


Figure 67: Single's unit, West elevation 1:200

HOUSING TYPOLOGIES

The apartments are planned based on the different realms according to the user profile. The different realms are distributed amongst three volumes; the main house, kitchen and the washrooms. The main house comprises of the living areas such as the bedrooms, study areas, dining rooms and living room. The private spaces such as the bedrooms are situated towards the western end and the common spaces are situated towards the eastern end of the main house. The common spaces act as a point of transition between the private spaces and the outside detached spaces.
As different families have different spartial needs, the building layouts are planned so that the different housing units vary in size.
All housing units are characterised by semi private spaces around the homesteads

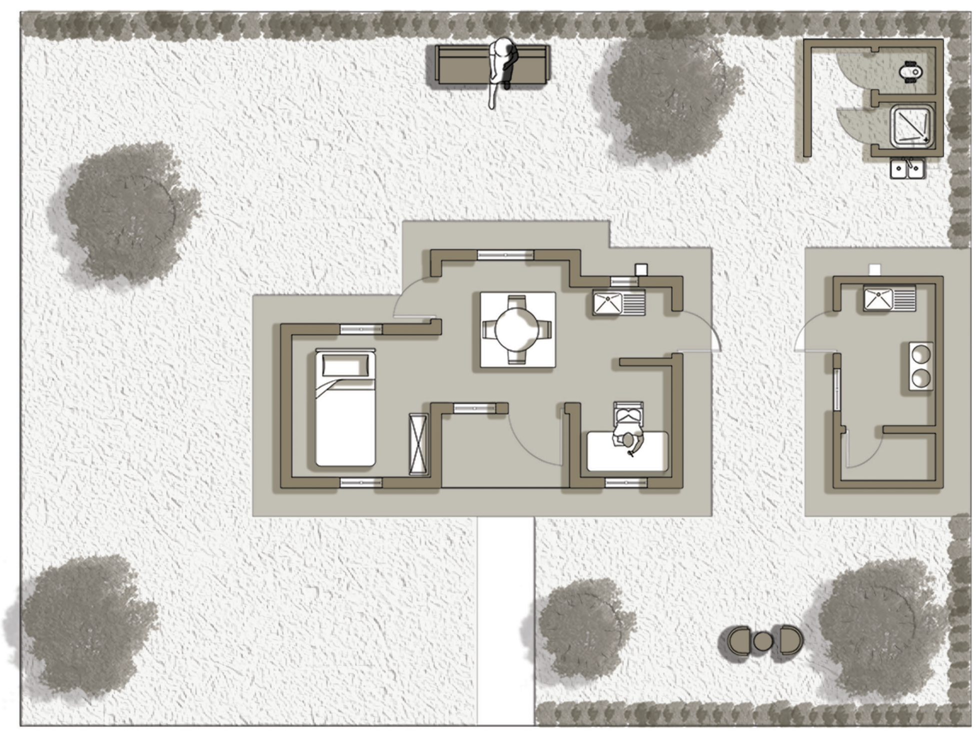


Figure 68: Single user's unit 1:200

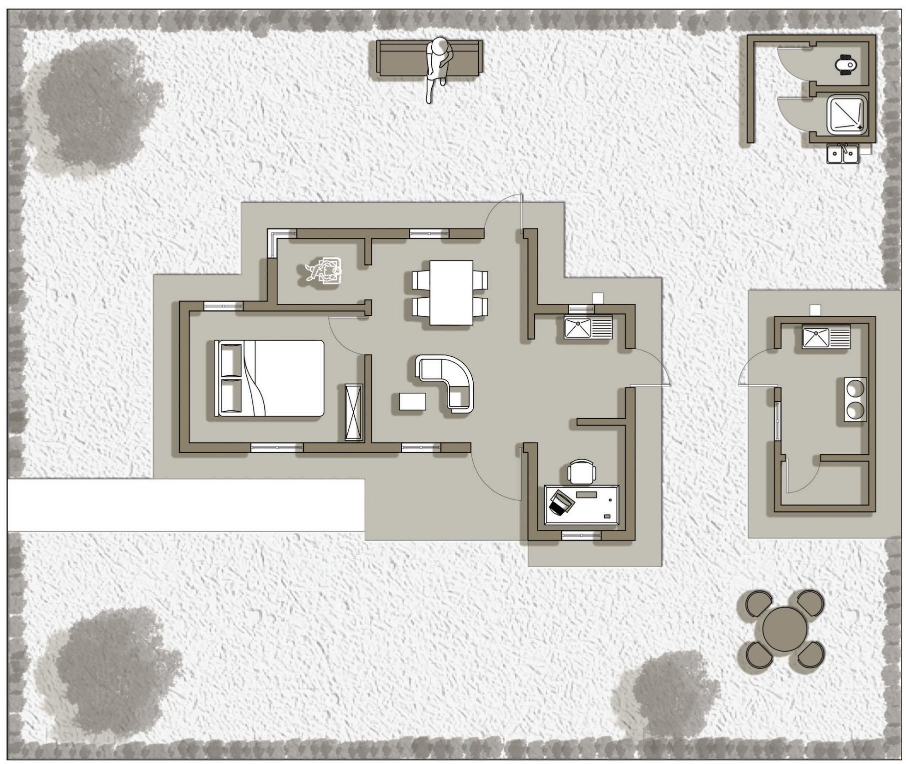


Figure 69: Couple's unit 1:200

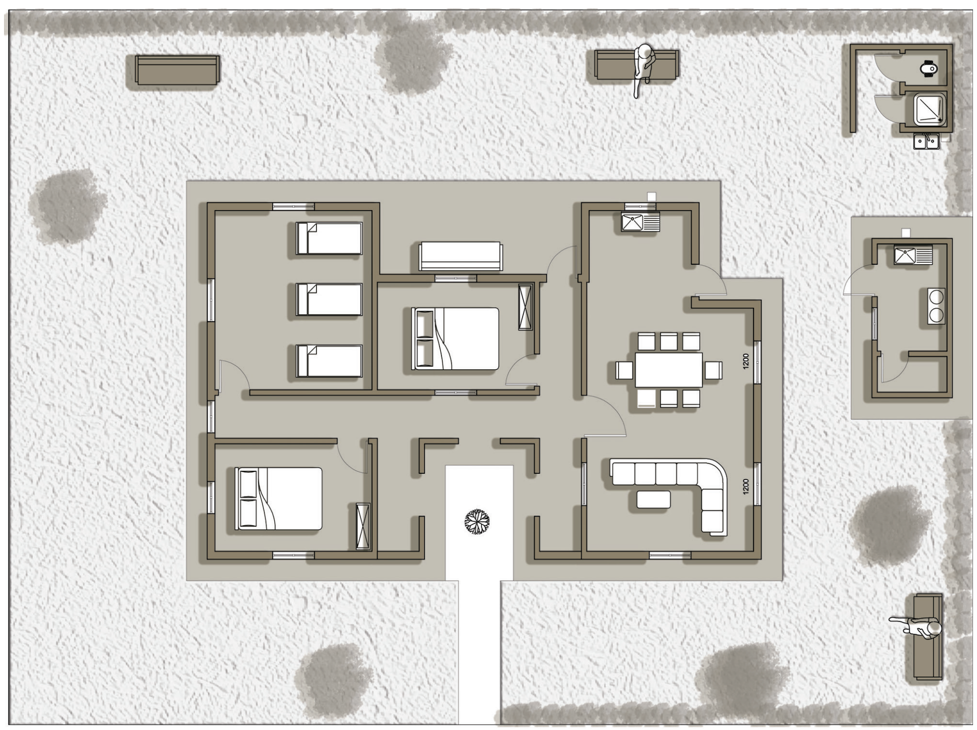


Figure 70: Family unit 1:200

DETAILING

CONSTRUCTION DETAILS

Calculation of U-values carried out according to Danish Standard (DS418 : 23)
The contruction layers of the building individually have an impact on the design and the energy performance of the building. To ensure an optimum solution both aesthetically and technically, the calculation is implemented early in the

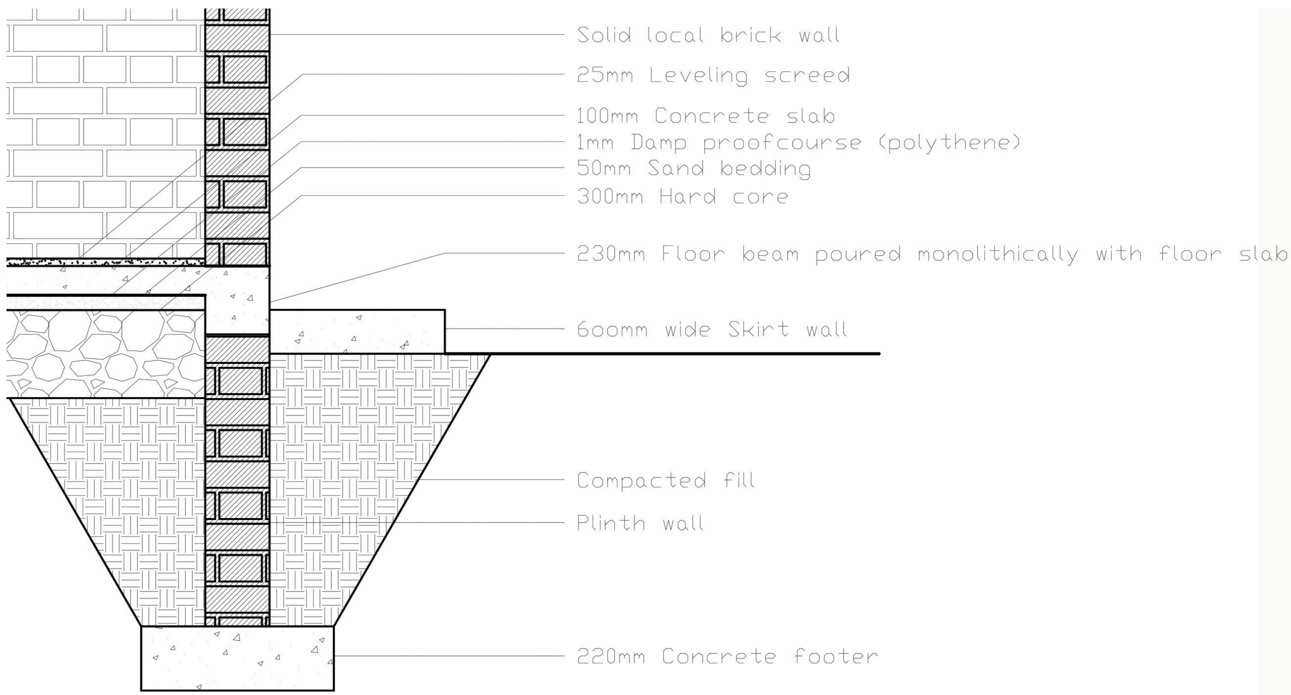


Figure 71 : Foundation detail 1:20

process to ensure satisfactory results.The results of the different U-values are later used in Bsim simulation(u-value.xlsx).

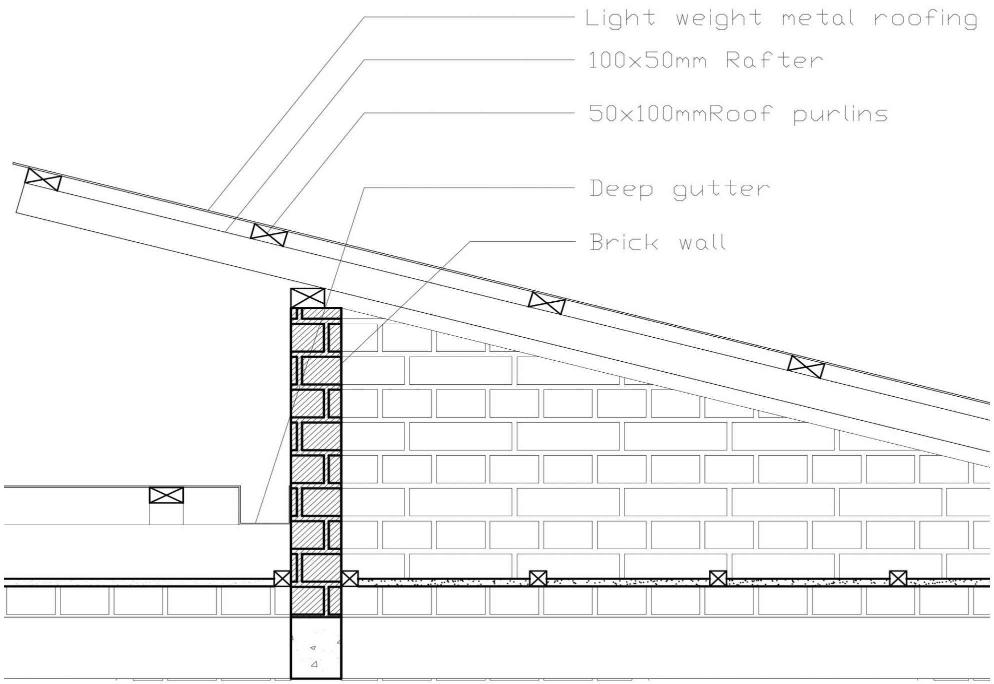


Figure 72 : Roof detail 1:20

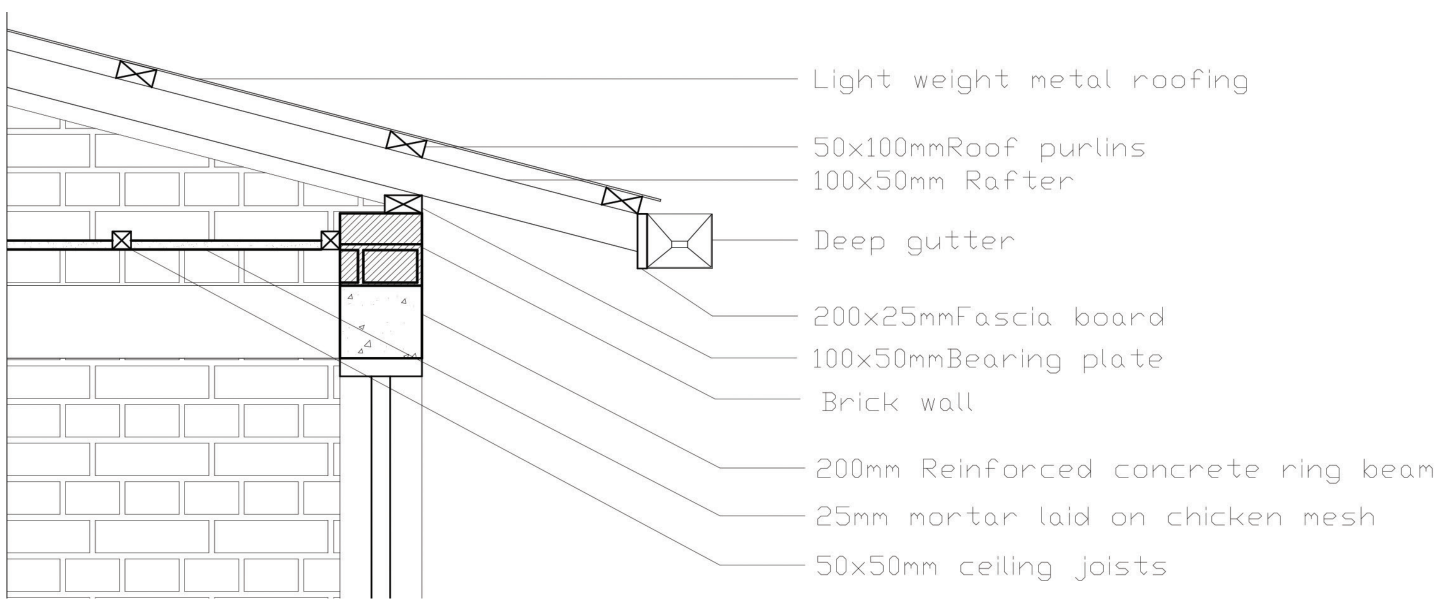


Figure 73 : Roof and open eave detail 1:20

EPILOGUE

CONCLUSION

During the execution of the project, emphasis was made on the aspects of social and environmental sustainability. The two aspects were incorporated into the project using the integrated design process in order to develop a design that was responsive to both the environment and essential housing principles. The environmental aspect was mainly addressed technically through the use of passive strategies in order to enhance the performance of the design as a whole whereas the social aspect was addressed through the use of tangible and intangible strategies that directly had an impact on the general behavioural sustainable patterns of people.
As a means to define the different groups of the user profile of the design, measures were taken in order to give identity to the different targeted users. This was made possible by strategically creating subcultures that had diferent spartial qualities and were boldly defined by artificial boundaries in form of streets. However, a common public space is integrated into the design and acts as the common space amongst the different subcultures on site.
On a neighbourhood scale, each homestead is availed with a private space that is defined by artificial boundaries in form of shrubs. The strategy however maintains the coherence of the homesteads with the master plan while creating an embracing configuration that rather creates the possibility of inviting people.
The different houses are arranged along the contour lines and placed on terraced surfaces in order to maintain their structural integrity. The housing units are programmed in such a way that the family units occupy the less steep areas and the single and couple's units occupy the more bustling areas of the site. However, all the housing units have access to the public entities like the public open space, kindergarten, and coummunity hall. The housing units have been designed in such a way that they meet the requirements of good indoor environment through the careful integration of active design solutions. The sun and wind have been optimally used for their passive strategies, that is, remarkable day light, natural ventilation e.t.c
The project therefore positions sustainability principles as core issues and parameters as a means to creating an environment sensitive design with rather efficient design solutions.

REFLECTIONS

The project is composed of 3 typologies, however, this has been articulated as a risk with no thought given to the repercussions. Homesteads in Ugandan villages are comprised of extended families which are usually very big in number. When children grow up into adults, they usually leave their parental homes but in most cases, they leave for the city to find a better life thereby resulting into the problems that arise as a result of rural urban migration. The project proposes a user profile that addresses the fact that childrene eventually grow up and leave their homes, however, it does not assess the fact that village homesteads are mainly comprised of extended families. Further more, the creation of different sub cultures with different identities blocks the synergy amongst the different homesteads as each user group is contained within a specific subculture. This tends to reduce the interaction and engagement of people in the society which is quite contradictory to the norms of social sustainability. However, this problem could have been solved by further integrating the different typologies in order to create a closer relationship and to encourage interaction between the user groups of the design.

During the facade study, simulations were carried out in Bsim to find out the results of the different facade expressions, however, Bsim does not have a provision for perforated or open facades therefore it was quite problematic to achieve the required design solution using Bsim as an integrated design tool.

LIST OF FIGURES

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APPENDIX

Air comfort

In order to achieve an optimum quality of air in a room, the following calculations are carried out in order to establish the rate of flow of air inside a room then integrated into the design process in order to achieve an optimum design. The calculations are carried out for the various rooms and spaces and later used in Bsim to simulate the indoor air quality.

Assumption: Danish standards of building are used as a basis to carry out the calculations.

Category B building design criteria:
PD ≤ 20%, decipol≤1,4 and PPD<10%

At stationary balance, the input of pollution = the removal of pollution.
The needed air rate can then be calculated using following the
formulas (GKB, 1997)

$q + ci * VL = c * VL$

$c = 10 * q / VL + ci$
$VL = -10 * q / (ci - c)$

$$n = \frac{VL[m3 / h]}{VR[m3]}$$

c is the indoor air quality (decipol)
ci is the outdoor air quality (decipol)
q is the pollution in the room (olf)
VL is the outdoor airflow (l/s)
VR is the room volume

Olf values from polluting sources(GKB,1997:40)

Polluting sources in OLF:	olf
Sedentary person	1
Active person	5
Person (one pr 10 m2)	0,1olf/m2
Low polluting building	0,1
Air quality	
Outdoor air quality, ci	0,1
Air quality in room, c	1,4

The pollution in the bedroom of 10 m2 with 2 persons can then be define as:
q = 1 olf * 2 person + (0,1olf/m2* 10 m2) +0,1 olf
= 3,1 olf

The air change needed will then be:
VL=-10*q/(ci-c)
= (-10 *3,1 olf) /(0,1-1,4) = 23,8 l/s

The air rate per hour is then:

$$n = \frac{VL(m3 / h)}{VR(m3)}$$

where VR= 10 m2 * 2.5m =25 m3
n= (23,8 l/s * (3600 /1000))/25 m3 =3,4 h-1

As the air comfort depends on the volume of the room and amount of occupants, the calculation is done separately for all the other rooms in an excel sheet [airquality.xls]

Calculation following CO2,

Design criteria for Category II building:
The CO2 concentration must not exceed 500ppm above outdoor concentration, which in Denmark is assumed to be 350ppm in most case.
A person is asumed to exhale 10 l/min with a CO2 concentration
of 4%.
co=850ppm
ci=350 ppm
VR= 25 m3
lung ventilation 10 liter/min.
CO2 concentration 4%
The pollution source, q is then:

$$q = \frac{(CO2concetration * xPeople) / 100)}{(10l / min*60) / 1000}$$

q= ((4% /100)*2 people)* ((10 l/min * 60) /1000)
q= 0,048 m3/h

The air rate needed for the CO2 concentration, co=850 ppm, can be expressed as:

co = (q *1000/n*VR)1000 + ci
n = (q*1000000) /(VR*(co-ci))

If there are two people (q=0,048m3/h) in room volume VR=25 m3 the air rate needed will be:

n= (0,048m3/h * 1000000) /(25m3 *(850ppm-350ppm) = 3,83 h-1

Solar cells

Uganda does not have an established energy consumption frame for the villages of Uganda therefore, in order to calculate the amount of PV cells required in order to provide energy to the house hold, assumptions are made regarding the estimated appliances that could be found in a village house hold.

Looking at the single user's household, assuming;

6 Philips energy savers bulbs each with a power rating of 11W. Let's say they are used for 6 hours a day.

1 Philips flat iron of a power rating of 1,000W, used for half an hour a day

1 Samsung UN32EH4000 LED 21 inch Flat screen TV with power of 20 Watt. You watch TV for 4 hours a day.

Appliance	Number	Power rating (W)	Total power	Hours per day	Total energy per day(kWh)	No. of days usage per month	Total energy per month(kWh)
Philips energy saver bulbs	6	11	66	6	0.396	30	11.88
Philips flat iron	1	1000	1000	0.5	0.5	30	15
Samsung TV	1	20	20	4	0.08	30	2.4
Total							29.28

Total energy requirement for single user's house per month;
= 29.28 kWh

Therefore, in order to determine the amount of solar cells required for the single user's house;
User's consumption= solar energy production.

Solar energy production =351.36kWh/year

The calculation is based on solar cells with efficiency of 18%, the performance is 143kWh/sqm [pv.xlxs]. This means that the area of pv needed should be;
(351.36 kWh) /(143 kWh/m2) = 2.457m2