KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF ARCHITECTURE AND BUILDING TECHNOLOGY

COLLEGE OF ARCHITECTURE AND PLANNING

ENERGY EFFICIENT AFFORDABLE HOUSING,

KROBO ODUMASE, Greater Accra Region

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In partial fulfilment of the requirements for the degree

Of

MASTER OF ARCHITECTURE

By:

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DECLARATION

I hereby declare that, this submission is my own work towards the Masters in Architecture and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the university, except where due acknowledgement has been made in the text.

Signature……. Date……..

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Signature…… Date…….

Mr Samuel Amos –Abanyie

(Supervisor)

Signature…… Date…….

Mr. S.O Afram

(Head of Department)

DEDICATION

This design thesis is first and foremost dedicated to the Almighty God who gave me strength to go through the six years of architectural education and to my parents Madam Marian Grant and Mr. W. Sam-Awortwi for their support throughout my stay in the university.

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It is not by might neither is it by power but by His Grace and Mercies and Glory be to His name infinitely for without the Creator we humans are nothing.

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ABSTRACT

Housing is a basic human need and is thus addressed or confronted by people from all walks of life. In recent times, convenient or descent housing has become a prerogative of the rich and wealthy in society. This class form the minority with respect to the middle and the low income group. Governments worldwide always have housing on their development plans to address this unending need of man. The only obstacle faced is the issue of affordability. This spills out into many dimensions, from the cost of construction to its energy consumption which mainly constitute the running cost of the building. This has thus necessitated the need for a house that is inexpensive to acquire and has a low running cost, hence an energy efficient and affordable housing project. This design thesis addresses the issues involved in achieving an energy efficient affordable neighbourhood, through architectural and scientific interventions. It starts with the study of the target group and the site and the appropriate architectural intervention is employed. The issue of affordability is first tackled from the acquisition point of view which includes the cost of the building itself. Here, the judicious use of space is paramount as well as the type and qualities of the materials used. The energy efficiency which also cuts down on the running cost of the building is also first tackled with the use of passive lighting and ventilation. The physical and thermal properties of materials were also considered in selecting the most appropriate materials to best insulate or conduct heat into the building as required. A flexible mode of acquisition or payment has also been engineered to crown the whole project to make it a success.

CHAPTER ONE

1.0 INTRODUCTION

Ghana like most developing countries, is faced with rapid population growth and its associate increasing or uncontrolled urbanization. This has made housing one of the most critical socio-economic issues facing the country. This situation is very eminent in the big towns and cities such as Accra and Kumasi where there is a fast growing urban sprawl mainly due to rural- urban migration.

Until recent times housing in Ghana has always been the prerogative of the government with the support of organizations such as the Cocoa Marketing Board, the Social Security and National Insurance Trust (SNNIT), the Home Finance Company (HFC) and other private investors. During the reign of Dr. Kwame Nkrumah, the government established the State Housing Construction Company to help supply low-cost dwelling units for the general populace and particularly the urban worker. (The *Statesman news paper* January 2007) The Bank for Housing and Construction financed private housing schemes on mortgage basis. Whiles under another housing ownership scheme, civil servants acquired accommodations on purchase-lease terms.

The issue of **affordability and energy efficiency** has always been a very debatable and controversial subject. This is because the use of this word is generic and will therefore have to be narrowed down to a specific target group of people. For example what would be considered to be affordable for an engineer or architect might not be seen as such for a petty trader. Affordability in this case would not only refer to the initial cost of purchasing but also the running cost of the building. This would be achieved by the use of low cost but most efficient building materials,

optimization of the use of space and efficiency of design in terms of ventilation and lighting.

Electricity is the main source of energy for lighting and cooling our buildings both in the home and at work place. This therefore necessitates the need for energy efficient buildings to cut down the need to supplement with artificial lighting and ventilation which will in turn save the user and the nation as a whole some amount of money. The concept of green architecture will be employed in this case since it deals with ecologically friendly environments and is in accordance with sustainable development principles and using renewable resources and techniques.

As of today the problem of affordable energy efficient housing still persist and the government is acquiring sites in Accra to address these problems. To this extent the housing project should have a unique character and a sense of place. It must be environmentally responsive, economically feasible and also be marketable.

1.1 PROBLEM STATEMENT.

Provision of affordable housing is an issue that confronts governments of all nations worldwide irrespective of their level of development or economic strength. This thus alludes to the fact that housing (shelter) is a basic need of man and constantly needs attention. In every society however, we have the high class, middle class and low class people. This middle and low class form the majority in the society and are poor and often find it difficult or impossible to meet their basic housing needs. The resolution of this problem often falls in the hands of the government, who have been given the mandate and has the capital power to address this issue best.

1.8 AIM OF STUDY

- To design affordable houses that will be responsive to the needs of the average Ghanaian.
- To provide buildings that will have a low running cost with respect to the payment of utility bills.
- To maximize the use of local building materials as an example to be followed by similar projects in the future.

1.2 JUSTIFICATION

- In view of Ghana's current energy crisis, it is appropriate to design buildings which will reduce the strain on its limited energy resource as well as save money.
- Studies have shown that between 2000 and 2015, the urban population of Ghana is likely to reach 50 percent and the country's ability to prepare and adequately plan for this imminent growth is nagging. (Daily graphic, 2002.)
- The current estimates of housing needs by the Ministry of Works and Housing indicate that the country needs at least seventy thousand (70,000) housing units annually. Presently, the national supply is about 35% of this figure. *(GPRS II, 2006-2009).*

1.2 SCOPE

The project will be a planning and design scheme with housing types designed to suit persons ranging from the single or unmarried to a maximum family size of six (6). It will also comprise ancillary facilities to enhance good communal living such as parks and gardens and a shopping centre. In line with the attainment of affordability and energy efficiency in all possible respects, the following will be employed;

- **Architectural interventions**
    - Effective design of spaces, their disposition and relationships.
    - Techniques to utilise natural ventilation and lighting.
- **Construction technology**
    - Use of innovative construction methods.
- **Scientific interventions**
    - Study on the structural and thermal propertied of selected local building materials.

1.3 CLIENT

Ghana Government, under the Ministry of Water Resources, Works and Housing.

1.4 CLIENTS BREIF

The client desires a residential neighbourhood comprising the following:

- Bedsitter, single bedroom, two bedroom and three bedroom housing units
- Commercial centre or mini-market
- Recreational Areas
- Basic School (Nursery and Primary)
- Community health centre(clinic)
- Petrol filling station
- Police post

1.5 FUNDING AGENCY

Home Financing Company (HFC)

The home financing company is a Banking institution in the West African sub-region, which has evolved from an institution whose main scope of operation was mortgage financing, investment management and savings mobilization services into a bank that is primarily committed to broadening the scope of financial products and services offered to its customers.

The principal activities of HFC include the following;

- Provides a comprehensive range of mortgage financing, commercial banking and investment banking services.

- Offers mortgage loans to enable qualifying individuals to purchase and own houses. Special packages are available for recognized groups, associations and institutions to meet the home ownership goals of their employees and/or members.

- Through its banking and investment management operations, a wide range of financial and investment services are offered to individuals and corporate entities. Funds management, Brokerage, Property management, Current and Deposit accounts and all forms of credit facilities are available.

Under mortgage banking, the following services are provided

- Home Equity Mortgage (HEM)
- Completion Mortgage (HCM)
- Home Purchase Mortgage (HPM)
- Estate Developers in Ghana
- Home Improvement Mortgage (HIM)
- Buy, Build & Own a Home (BHOME)
- Non Resident Ghanaian

The requirements and other conditions for the Home Purchase Mortgage Loan (HPM) can be found in the appendix.

(Source: www.hfcbankgh.com, 2009)

1.6 TARGET GROUP

The target group for this housing development is the middle and low income Ghanaian worker. This is with particular reference to those in the government sector,

level 15 and levels 5 and 8. It is also for the unmarried person and those with a maximum family size of six (6)

Those in level 15 are the Assistant Directors, CEO's and General Officers and earn between GH¢ 4,388.8331per annum to GH¢ 5,560.8570per annum. Their monthly salary range from GH¢ 743.4661 - GH¢ 867.7740. *(Source: Office of the Head of Civil Service, Ministry of Local Government))*

Levels 5 comprise the Clerk and 8 comprise the Junior Officer and Executive Officer. Their annual income range from GH¢ 1,558.7184 to GH¢ 1,976.2362 and monthly salary GH¢ 365.7360 to GH¢ 463.4047 *(Source: Office of the Head of Civil Service, Ministry of Local Government)*

1.7 SITE LOCATION

The site for the project is Krobo Odumase Nsakina. It is near Amasaman in the Ga West District and is 24 kilometres from Accra central. According to the 2000 national population Census, this District has a population density of 491 persons per sq. km, which is much higher than the national density (79.3) and a little lower than that of Greater Accra Region (895.5). The population is however concentrated in areas like Gbawe, Awoshie and Ofankor, which happen to be areas with many economic activities as well as social infrastructural facilities.

(Source; www.christiancouncilofghana.org)

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 A BRIEF HISTORY OF THE HOUSING INDUSTRY IN GHANA

2.1.1 Post-Independence Era

The emphasis on developing the housing industry in Ghana probably commenced in the late fifties to early sixties as Ghana attained independence from colonial rule. As part of the 1960-65 National Development Plan, provision of housing was central as two main state bodies were formed to address housing issues: the State Housing Corporation (SHC) and the Tema Development Corporation (TDC). TDC was created with the special purpose of creating residential units in the rapidly growing Tema area as part of a major industrialization drive that saw the construction of a second sea port to serve Accra, the capital and the eastern parts of the country. This also led to the development of the Volta River project to provide energy to support the economic ventures associated with the establishment of the port. While TDC focused on providing residential housing in Tema, SHC worked in the regions across Ghana, providing real estate countrywide. Unfortunately, the resources allocated in the form of subventions, loans or grants for these ventures began to dwindle as Ghana's economic difficulties began to take a toll. Indeed, housing policy in Ghana has been fragmented instead of a holistic and comprehensive vision to deal with the complexities of housing a nation. Thus the housing sector began to experience a disjointed growth accompanied by urban sprawl as individuals built their own houses in an uncontrolled manner.

(Source: The Housing Market in Ghana, Bank of Ghana, 2007)

2.1.2 The National Shelter Strategy

In 1986, a National Housing Policy Committee was formed by the Ministry of Works and Housing (MOWH) to examine the housing situation in Ghana. This was geared towards an appropriate Government Policy and Action Plan that seeks to provide adequate and decent housing units in order to improve the quality of life of people in urban and rural areas. The focus of the said Committee was on constraints in housing delivery, especially in the area of housing finance, land, physical planning, infrastructure, building materials, design and construction and coordination delivery efforts. The report culminated in a National Housing Policy and Action Plan covering the period 1987 through to 1990. Prior to the Action Plan, the MOWH had identified the need for a comprehensive National Shelter Strategy (NSS) and an enhancement of the Ministry's planning capacity to implement housing policies. The strategy sought to: Implement a revised national shelter sector policy and action plan for short, medium and long-term strategies for Ghana with emphasis on rural communities in order to assist them to improve their existing shelter or improve access to the means for providing their own shelter; Develop non-conventional shelter delivery systems which encourages community participation at all levels and with emphasis on local authorities playing a substantial role in the management and development of shelter; Establish guidelines and procedures to facilitate administration, monitoring and coordination of shelter programmes and projects at the grassroots level; Rationalize land tenure and land title regulations to enhance access to land for shelter; Improve delivery of housing finance and improved access to credit for the construction of shelter by individuals; Promote a cost effective construction industry and programmes to promote local building materials; Ensure

greater involvement of women in planning, implementation and management of shelter programmes.

(Source: The Housing Market in Ghana, Bank of Ghana, 2007)

2.1.3 The Ghana Vision 2020

The First Medium-Term Development Plan of Ghana's Vision 2020, 1997–2000, targeted the provision of low-income housing units, which is affordable and within purview of the poor to improve their living conditions. The Plan introduced a new facility under the social security (or provident) scheme which would permit contributors to withdraw part of their contributions to purchase houses. Unfortunately, none of the housing strategies under the Medium-Term-Development-Plan were implemented due to lack of funds, private sector participation and political will. *(Source: The Housing Market in Ghana, Bank of Ghana, 2007)*

2.1.4 The Ghana Poverty Reduction Strategy (GPRS I)

In 2001, a new party took over the reign of government. Like others, the focus has been on attracting foreign capital to fund housing development. This quest was boosted by Ghana's participation in the Highly Indebted Poor Country debt relief program of the World Bank which allocated some funds for the housing sector. The GPRS II (2006-2009) also has a special program targeted at the vulnerable and excluded, to upgrade slums for the benefit of urban slum dwellers most of whom are poor. Also, the Ministry of Water Resources, Works and Housing is currently pursuing various affordable housing programmes through agencies such as the Tema Development Company (TDC), and the State Housing Company (SHC). Under the

National Housing Programme, apartments and unit flats are currently being constructed in Accra, Tema, Cape coast, Sekondi-Takoradi and Tamale.

(Source: The Housing Market in Ghana, Bank of Ghana, 2007)

2.2 AFFORDABLE HOUSING PROJECTS IN GHANA.

The then government, New Patriotic Party (NPP) in 2001, under the leadership of Mr. John Adjekum Kuffour took over the mantle to provide affordable housing for the people of Ghana.

The first phase of the affordable housing project had in its programme to produce 100,000 housing units. This was at the state of the nation address to Parliament in 2005 by the President.

As of the year 2008, the government had committed over $300 billion in all the six sites namely;

- Borteyman and Kpone — Greater Accra region
- Asokore Mampong — Ashanti region
- Koforidua — Eastern region
- Tamale — Northern region
- Wa — Upper East region

Lack of low income housing compared to demand, the absence of private sector participation and deficiencies in financial arrangements have made it difficult for ordinary Ghanaians to access the affordable housing. Various data on housing disclose a backlog of about 500,000 housing units while supply figures are between

25,000 and 40,000 units per annum, as annual requirement of 100,000. *(Source: Daily graphic, 2007)*

At the beginning of the project, one bedroom flat was estimated to cost 8,500 cedis and a two bedroom flat about 11,000 cedis. The one bedroom flat was intended to be further reduced to 5,000 cedis. However, these prices changed to reflect the economy as at the time the buildings were ready for sale.

A company that was to maintain the site and ensure that the place was neat was to be put in place on behalf of the government and also to prevent it from becoming a slum. Local service providers including contractors, construction specialists, architects and engineers were contracted for the various phases of the project.

(Source: National Agenda newspaper, 2007)

2.3 AFFORDABLE HOUSING CONCEPTS

2.3.1 Optimisation of the use of space

This starts with the high cost of land and this necessitates the need to account for each square metre of space. There is also a direct cost implication or relation to the area of space occupied by a building as proven by the per square area method of calculating the estimated cost of a project. This method is based on historical data and takes into account the quality and quantity of materials used and the area over which they are applied. A module is derived from this information to produce a cost per unit area. With this, the cost of a given project with a known floor area can be estimated.

(Source: National Academies Press, 1990)

Table 2.1 Housing - minimum spatial requirement.

Spaces	**Minimum standard sizes were provided for**
Floor to ceiling heights	This should not be less than 2.5m
Living rooms	13.47m2
Bedrooms	At least one should be 11.1m2, all others can be 8.47m2
Kitchen-	In combination with dinning space can be at least 7.43m2 in which kitchen portion should be at least 3.72 m2
Private Bathrooms	Space should be at 3m2
Shower	Front space between wall and shower should not be less than 530mm and space between shower and other objects should not be less than 400mm
Toilet	Space in front should be at least 460mm and space from the center of the pot to a wall should be 400mm
Wash basins	Space in front should be 530mm and space from center of the basin to a wall should be 400mm
Road to building	Building should be at least 3m away from road
Courtyard/building spacing	Space between two opposite parts of a building or two separate buildings on the same plot should be at least 5m

(Source: Ghana National Building Regulation, 1996 page nos. 16,17 and 18)

2.3.2 Modular design

modular design — or "modularity in design" — is an approach aimed at subdividing a system into smaller parts (modules) that can be independently created and then used in different systems to drive multiple functionalities. Besides reduction in cost (due to lesser customization, and less learning time), and flexibility in design, modularity offers other benefits such as augmentation (adding new solution by merely plugging in a new module), and exclusion Modular design is an attempt to combine the advantages of standardization (high volume normally equals low manufacturing costs) with those of customization. In modular design, the use of standard sizes or modules also brings about uniformity. *(Source: en.wikipedia.org/wiki/Modular design,2007)*

2.3.3 Choice of building materials

The choice of building materials is very critical when it comes to the issue of affordable housing. After the structural integrity of the building has been assured, the rest will be a matter of choice and this has a very wide range cost implication. For example one could use marble for walls and another would just do with plastering and paint and each has a different cost implication. However, in the affordable housing programme, it will be best suited to go for less expensive but reasonably durable materials. In our case we must not also forget that we are also dealing with energy efficiency.

2.3.4 Mode of acquisition

At this stage, one would have accepted the conditions of purchase. The conditions of purchase generally spell out the rules that will govern the

neighbourhood; for instance sanitation rules and those that will protect the architectural integrity of the place.

Different Real Estate agencies in Ghana have different terms of payment. However, the use of mortgage financing cuts across. Payment is often done between 1-5 years depending on the real estate agency and the customer. There are now a growing number of financial institutions in Ghana and overseas which have available mortgage financing schemes providing the individual with a lot of options to explore. The real estate agencies actively cooperate with these institutions to facilitate the payment process. This may however seem more expensive but at the time of purchase, it is the most affordable.

(Source: Comet Properties Ltd and Regimanuel Gray Ltd, 2007)

2.4 ENERGY EFFICIENT PRINCIPLES

2.4.1 Passive design.

Passive design is design that does not require mechanical heating or cooling. Homes that are passively designed take advantage of natural energy flows to maintain thermal comfort in buildings.

(Source: http://www.makeyourhomegreen.vic.gov.au/www/default.asp.)

Thus passive design as mentioned in this thesis refers to the attainment of natural ventilation and natural lighting.

Making good use of passive design includes:

- **Building orientation** – positioning the house to allow minimum solar ingress. In this case a situation whereby the building is a long rectangular

block with its longest side facing the sun is avoided. This includes deciding which rooms you want to be the sunniest depending on the intended use of the space.

- **Use of structural elements** – for example, wide eaves protect the facade of the building from the sun especially that containing openings. In short, there is increased protection against the negative effects of the weather.
- **Placement and glazing of windows** – sun facing facades are best left blank or otherwise windows are given due attention and designed to allow minimum solar ingress. Larger windows and openings should face the north or south (in the tropics) since they offer the best diffused light (skylight). Placement of windows must also be so as to ensure cross ventilation.
- **Ventilation of roof space** – the roof of a building always has direct contact with the sun. It is therefore appropriate to check the transmission of radiant heat into the interior of the building. This virtually means insulating the roof and one way is by coating the roof with an insulating material and another would be by ensuring that there is a constant air change rate in the roof space. A perforated ceiling could be used or a vented eave.

2.4.2 Thermal resistance(R) or transmittance(C) of Materials.

This is the property of a material that indicates its ability to conduct heat . *(Source: http://en.wikipedia.org/wiki/Thermal_conductivity)* This ability shows how fast a material of a given thickness would transfer heat into or from a space. This information is very vital in material selection for a building in order to attain a desirable room temperature.

Table 2.2 R-VALUE FOR TYPICAL BUILDING MATERIALS

THERMAL RESISTANCE	h ft2 oF / Btu [R / inch]	THERMAL RESISTANCE	h ft2 oF / Btu [R / inch]
Concrete	0.10	Energy plus double glass	4.50
Stone	0.05...0.10	Insulating double glass	1.89
Brick	0.10...0.35	Single glass window	0.89
Hardwood	0.90	Solid wood door	1.56
Softwood / plywood	1.25	Bonded urethane cushion	3.96
Particle board	0.85...1.85	Rippled rubber cushion	1.82
Insulating board	2.30...2.60	Fibre / hair / jute cushion	3.88
Sidings	0.80...1.00	Wool carpet	4.50
Asphalt shingles	0.44	Stucco / plaster	0.20
Wood shingles	0.94	Gypsum / plaster board	0.90
Built-up roofing	0.70...0.90	Fiberglas	3.16
Rock wool	3.20...3.70	Fibreboard	3.45
Mineral wool or fibre batt	2.90	Polystyrene extruded	5.00...5.40
Cellulose	3.20...3.70	Polystyrene expanded	3.85...4.35
Lightweight aggregate concrete	1.00...2.00	Polyurethane foam	5.80...7.70
Cement board	1.50...2.30	Building paper / felt	0.06
Cork	2.00	Vinyl / linoleum /	0.64

		rubber tile	
Ceramic tile	0.15	Synthetic carpet (level loop)	3.50...5.90
Synthetic carpet (plush)	2.40...4.50		

THERMAL TRANSMISSION Imperial: 1/R = Btu/h ft2 oF

Metric: 1/R x 5.678 = W/m2 oC

(Source: Step Warm Floor, 2007)

From the t**able 2.2 above**, we can calculate how much heat a given surface area of a material with a given thickness would be transmitted within a given time. The higher a materials resistance(R value), the less heat it would transmit. Higher R values of materials are thus preferred in the tropics since our concern is keeping heat out when it comes to thermal comfort.

For instance comparing two materials of equal surface areas and thicknesses, say

Ceramic tile(R=**0.15** h ft2 oF / Btu [R / inch]) and Wool carpet (R=**4.50** h ft2 oF / Btu [R / inch]).

With the above mentioned materials, one can easily observe a big difference in their thermal resistance values and this directly relates to the vast difference in how they react to heat. The wool carpet with a higher R value is very slow to heat up unlike the Ceramic tile with a low R value which is very quick to heat up. Thus a room with its floor being woollen will radiate less heat into a room than that of the ceramic.

This applies to all parts of the building especially the components of the shell, which is the direct intermediary between outdoor and indoor temperatures.

Knowledge of this is beneficial in choosing appropriate materials to achieve a cooler interior space in a building.

2.4.3 UTILISATION OF A RENEWABLE ENERGY SOURCE-BIOGAS

With the current energy crisis facing the country, it is obvious that electricity tariffs would increase and for an energy efficient and affordable neighbourhood, it will be appropriate to have an alternative source of energy that is more reliable and also relatively cheap.

The main use of domestic energy in Ghana is basically for cooking and lighting. As such, biogas is the best suited as a source of domestic energy in this part of the world (tropics).Apart from it being readily usable as fuel for cooking, it is also fed in generators to provide electricity. It is also suited for this region because its warm humid climate facilitates the decomposition process of its raw materials. Biogas is a gas mixture which is generated when organic compounds like livestock manure is processed in the absence of air (anaerobic fermentation). This gas mixture is mainly made of methane gas, which is the energy source sought after in this conversion. In an airtight container, animal manure will change into digestive fluid and during that process biogas will be generated. There are three steps in this process. First step is the decomposition (hydrolysis) of organic matter contained in manure. Second step is synthesis of acetic acid out of decomposed matter. The final step is methane gas formation from acetic acid through the action of microorganism called methanogen.

Biogas contains carbon dioxide and a slight amount of hydrosulfide as well as methane gas. Hydrosulfide is an obstacle for utilization of biogas, because it is

corrosive. After desulfurised through biological method, biogas can be used for power generation.

The methane gas is then used to power a generator which in turn produces electricity.

(Source: Krieg &Fischer Ingenieure, 2002).

In a highly populated area such as an urban housing scheme, human excreta and organic waste from the kitchen could be used as fuel for the biogas plant.

2.5 GENERAL PLANNING OF RESIDENTIAL NEIGBOURHOODS

A neighbourhood design plan is a visual interpretation of the future development of an entire neighbourhood and shall, as a minimum, include:

- road alignments and standards
- sidewalks, trail systems and walkways
- potential cycling and transit routes
- potential lotting
- siting of schools, parks, open space lands, storm water management facilities and other community/utility uses.

Neighbourhood design plans will generally be prepared by development proponents and shall:

A. be undertaken in consultation with all landowners within the neighbourhood planning unit;
B. identify existing natural and cultural heritage features, hazard lands and regulatory shorelines;
C. indicate how the neighbourhood will provide the appropriate housing mix.
D. Be co-ordinated with all other required studies, including sub-watershed studies as required.

E. Indicate how transit supportive design principles such as minimum distance to transit stops and minimum densities, will be incorporated into neighbourhood development.

Residential neighbourhoods shall be developed in accordance with the following urban design principles:

2.5.1 Grid street layout; as the key element of the public realm providing a multiple use area for walking, cycling and motor vehicle use. Streets will be designed as high quality urban environments which encourage social interaction and provide multiple routes and connection to neighbourhood facilities. They will be utilized, wherever possible, to create view corridors and vistas of significant natural areas and public buildings. Street patterns should be oriented to provide for minimum passive solar gain;

2.5.2 Public buildings and spaces, including schools, parks and places of worship, will be located on prominent sites with significant street frontage. Public buildings will be oriented to the street incorporating massing, detailing and entrance features that reinforce its importance as a neighbourhood facility. Public buildings and spaces will generally be centrally located to minimize walking distances and will be designed to be accessible to the physically handicapped;

2.5.3 **Houses** should be sited with a consistent setback to provide a human scale to the street. The minimum set back should be 3metres (3m) from the edge of a minor road and 5metres (5m) from the edge of a major road.

(Source: National building regulations 1996)

House designs should incorporate features such as prominent entrances and front porches to encourage social interaction and allow for views along the street. Garages should be sited so that they are not the dominant feature of the streetscape or the house. Higher density housing will be strategically located near arterial and collector roads or within Neighbourhood Centres to create a transit supportive development pattern;

2.5.4 **Natural features** will be a key design consideration to ensure the protection of watercourses, valley lands, significant woodlots and wetlands and their ecological functions. Residential neighbourhoods will be "designed with nature" to minimize grade changes, preserve mature trees and enhance open space linkages. Opportunities to provide views of natural features and the waterfront should be incorporated, wherever possible;

2.5.5 **Cultural heritage features** will provide context for new development. In existing neighbourhoods, new development will be compatible with and complementary to its context with regard to siting, height, scale and design. In new areas, heritage buildings will be incorporated in a sensitive manner;

2.5.6 Public safety and security will be considered in all new development, including opportunities for visibility of public spaces in the design and siting of buildings, adequate lighting, multiple walking routes and opportunities to control potential speeding of motor vehicles; and

2.5.7 Development along arterial roads will be designed to provide a high quality urban environment with views of housing, street trees and landscape elements. Reverse lotting and acoustical fencing is generally not permitted.

The Municipality will review zoning and engineering standards, including alternative development standards, to achieve a sustainable, compact and healthy urban environment.

2.5.8 Neighbourhood safety and Crime Prevention Through Environmental Design (CPTED)

Neighbourhood Safety is a concern that is often raised during a planning process. Safety is a complex issue, one that varies from community to community. People feel safe and unsafe for many different reasons; however, a general definition of Neighbourhood Safety involves the idea of having plenty of people or “eyes” on the street. Sufficient lighting, crosswalks, traffic calming measures and other pedestrian amenities help residents in the community to feel comfortable and at ease during all times of the day.

CPTED helps to reduce opportunities for crime and nuisance activity by altering or enhancing the physical environment. This idea stems from the theory that careful design and effective use of space brings about certain behavioural effects in all

people. If a space is designed appropriately using the principles of CPTED, criminal incidences are reduced and people using the Space feel an increased level of safety.

7 CPTED Principles AT-A-GLANCE

- Surveillance
- Sense of ownership
- Defensibility
- Maintenance/Image
- Eyes on the Street
- Access control
- Target hardening

2.5.2 Transportation or communication.

Transportation is a very important factor to be considered in a residential neighbourhood. A properly designed street caters for problems that arise from over speeding vehicles, traffic congestions and also allows a walkable neighbourhood which will not only help residents exercise but also enhance a socially active neighbourhood.

During the design of roads, a positive attempt is made to check the speed of vehicles by not allowing roads to lead on several metres without a bend a bend. The concept here is that as long as the driver can see the way ahead and it's clear, he will speed up so his view is impeded to make him exercise caution. Junctions are also kept to a minimum to avoid unnecessary crossings of vehicles. After these measures have been taking, extra precaution could be taken by applying traffic calming strategies.

Speed hump: This is a raised hump (a pavement undulation) in the roadway with a parabolic (flattened curve) top, extending across the road at right angles to the direction of traffic flow. They are generally 10 to 14feet long (in the direction of travel), making them distinct from the shorter "speed bumps" found in many parking lots, and are 3 to 4 inches high. The profile of a speed hump can be circular, parabolic, or sinusoidal. They are often tapered as they reach the curb on each end to allow unimpeded drainage.

Raised crosswalks : These are flat-topped speed humps often constructed with brick or other textured materials on the flat section, outfitted with crosswalk markings and signage to channelize pedestrian crossings, providing pedestrians with a level street crossing. Also, by raising the level of the crossing, pedestrians are more visible to approaching motorists. They can be located at intersections or mid block if connecting to a significant pedestrian generator such as an elementary school. Speed humps and raised crosswalks are very effective in reducing speeds on neighbourhood streets, contributing to greater quality of life and fewer crashes. They are also very cost effective, at about $3,000 each. Chokers cost more at about $10-15,000 each. *(Neighbourhood Planning Toolkit.2004)*

- For speed humps - average of over 20% decrease in the 85th percentile travel speeds, average of over 40% decrease in accidents
- For raised crosswalks - average of 18% decrease in the 85th percentile travel speeds, average of 45% decrease in accidents Promote pedestrian, cycle and transit use.

(Source: Residential Neighborhoods, 2007)

Figure 2.0 Ocean side raised walk, California.

(Source; http://streetswiki.wikispaces.com/ Photo by Andy Hamilton.)

2.6 CASE STUDIES

Analyses of similar situations were used as bases to draw meaningful conclusions for the development of an energy efficient and affordable housing project.

Figure 2.1 Echlin Street Terrace Apartments

(Source: www.townsville.gld.gov.au/resources/1982.pdf)

FACILITY: Echlin Street Terrace Apartments

ARCHITECT: David Stefanovic

LOCATION: Echlin Street, Townsville, Australia.

CLIMATIC ZONE: Tropics

The project is the refurbishment of a warehouse into a sixteen contemporary 2 and 3 bedroom terrace apartment.

PURPOSE OF STUDY

- To analyse the climatic response of design
- To analyse its affordability
- To analyse its resource efficiency

CLIMATIC RESPONSE OF DESIGN

With this the key principle that was considered was keeping the heat out.

This was to be ensured by the following considerations;

- **Orientation**: this is the foremost factor to be considered since in keeping out the heat, our greatest adversary is the sun. The building if not properly oriented would have its longest side facing the rising and setting sun and as to whether or not there are openings, it will not mater because the building will heat up anyway. At Echlin street apartment, the buildings have a north south orientation and thus have less solar heat gain. Also, the placement of the windows is equally important. Majority of them are on the north and south facades and are easily shaded by overhangs. The first step in achieving energy efficiency has been achieved.

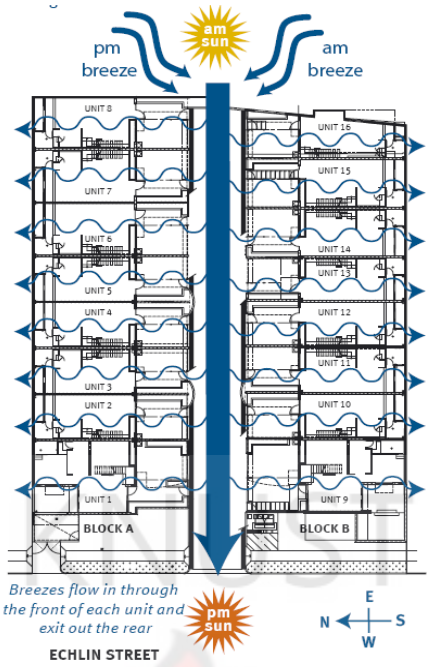

Figure 2.2 Floor Plan layout of Echlin apartments.

(Source: www.townsville.gld.gov.au/resources/1982.pdf)

- **Shading**: this when properly done prevents direct contact of surfaces (especially windows and other openings) with sunrays.
- **Reflection of radiant heat**: the part of the building that receives the largest amount of radiant heat is obviously the roof. It will thus be responsible for a considerable amount of heating that interior spaces might experience. To check this especially on the roof, a reflective solar paint known as **insulpro** has been used the coat the surface of the roofing sheets.
- **Insulation**: this deals with the ability of the material to resist the flow of heat from the surroundings into the building. In most cases, we may rely on the properties of the building materials used and in other cases too we may engineer combinations of materials in specific thicknesses to achieve an

overall higher heat resistance rating. In this peculiar case a combination of reflective and bulk insulation in the roof (reflective foil and polyester batts) achieves an insulation rating of R3.

- **The use of thermal mass**: during the day, high thermal mass materials absorb and store heat and slowly release it when the air temperature cools in the evening resulting in homes that remain warm long after its cooled off outside. Used appropriately, the negative aspects of high thermal mass can be minimised or even used to an advantage. The key for using concrete in the tropics is to prevent it from heating significantly in the first place. These terraces use a lot of high thermal mass materials specifically; concrete block walls, concrete floor slabs, ceramic floor tiles and concrete pavers. They are however catered for by allowing them a minimal opportunity to heat up. Most part of the concrete is kept out of direct sunlight and the walls are fully shaded by neighbouring terraces. The front and back walls are shaded by eaves and overhangs. The shaded driveway is an exception but within each property, sunshine of pavement is limited. The result here is that the concrete is used to an advantage with the temperature of concrete staying reasonably constant and fairly cool, the effect is a mass of material that is cool to touch and that cools the air around it.

(Source: Townsville City Council Planning and Development Services, 2006)

2.7 PRECEDENT STUDIES

A precedent study was taken on University Hall annex -B, popularly known as SHABA HOSTEL. It is located on the campus of K.N.U.S.T.

Figure2.3 Front View of University Hall Annex B -K.N.U.S.T. (SHABA)

(Source: Author's field survey).

Among others, the main objectives of this study were to analyse the building under the following:

- Modification of climate
  - Natural ventilation
  - Natural Lighting
- The innovative use of local building materials

2.7.1 MODIFICATION OF CLIMATE

This basically deals with keeping out the heat and improving the air change rate.

Orientation: The building is oriented in the north-south direction. Windows and other openings have been strategically placed on the north and south facades where there is no direct solar ingress.

Cross ventilation: This has been achieved by the placement of windows on opposite sides of the room perpendicular to the prevailing wind direction.

Shading devices: the building has made use of both horizontal and vertical shading devices to prevent direct contact of the sun to certain parts of the building envelope, to be specific windows and other openings.

Figure 2.4 Shading Devices, University Hall Annex B

(Source: Author's field survey).

Landscaping: soft landscaping has been used extensively around the building .this does not only beautify the environment but also absorbs the heat from the sun and minimises glare.

2.7.2 INNOVATIVE USE OF LOCAL BUILDING MATERIALS

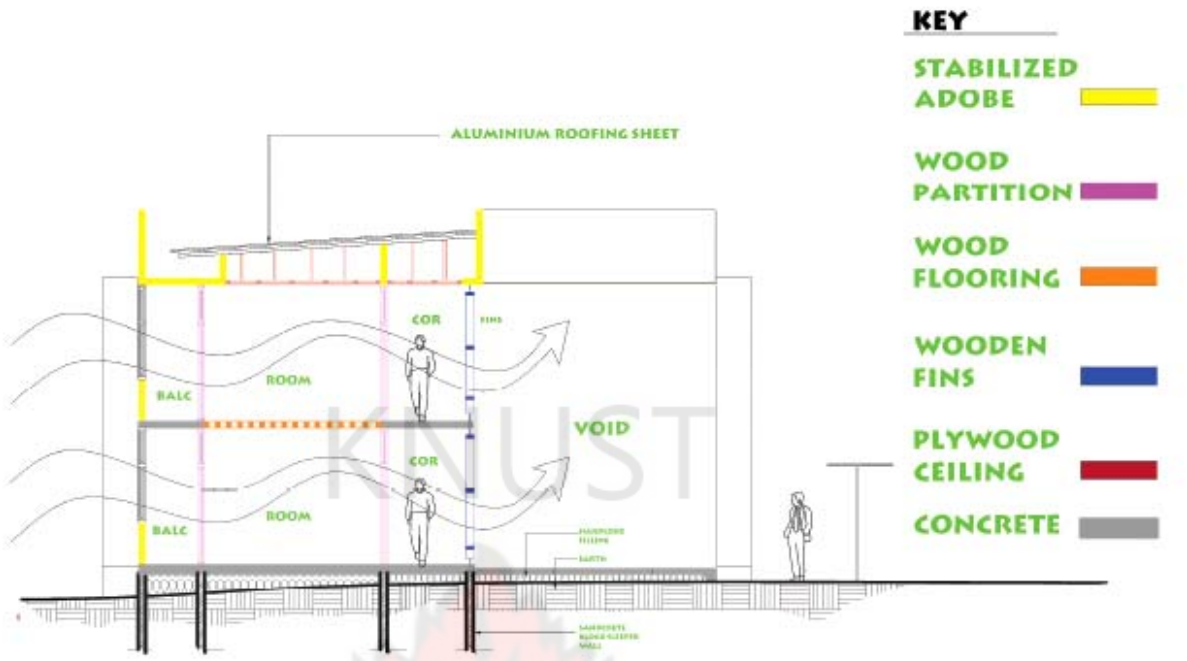

Figure 2.5 schematic section showing materials, University Hall Annex B

(Source: Author's field survey).

Stabilised adobe: this is a mixture of specific proportions of adobe (common earth with some amount of clay) and Portland cement which is the stabiliser and improves the structural integrity of the adobe block.

In this building, it has been used both structurally and as infilling .For its mortar joints, the cement-adobe mix is 1:1. The adobe walls are plastered with normal cement sand mix and this bond is facilitated by the presence of Portland cement in the adobe blocks.

The use of the stabilised adobe block is also known to have a considerable reduction in the total cost of the building.

(Source: Journal of Building and Road Research, 1994)

Figure 2.6 stabilized adobe wall, maintenance workshop K.N.U.S.T.

(Source: Author's field survey)

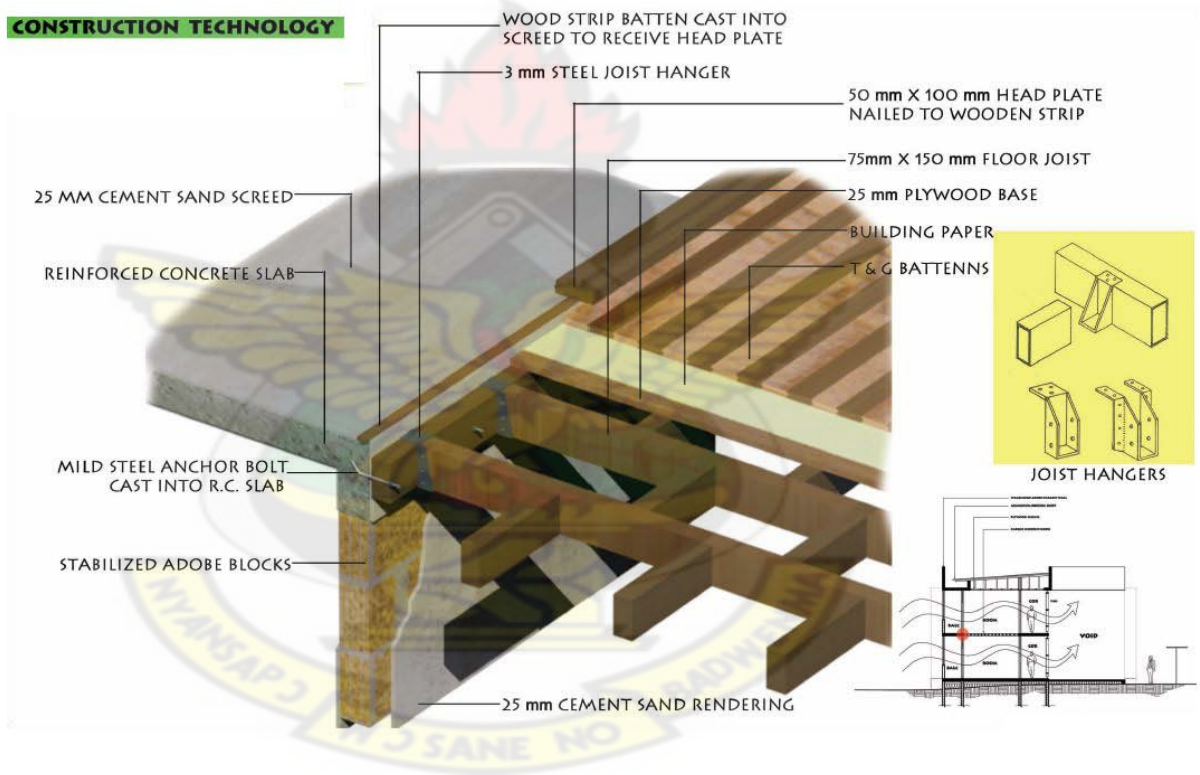

Figure 2.7 construction detail.

(Source: Author's field survey).

2.8 SPECIAL STUDIES

Compressed earth building for affordable housing

"The utilisation of earth in housing construction is one of the oldest and the most common methods used by a larger percentage of the developing countries population. It is the cheapest material everywhere."

Joseph and Tariq (2007)

PURPOSE OF STUDY

This study seeks to address the possibility or feasibility of using adobe blocks for construction by the following criteria;

- That the blocks meet the technical requirements for constructional purposes
- That it is made durable to stand the test of time.

This study also seeks to promote the use of adobe as a sustainable tool for construction of affordable houses.

This study is an experiment that was carried out by Joseph and Tariq (2007) of the University of Maryland, U.S.A. The methodology and results have been discussed as follows.

The compositions of the blocks were: 6 parts of clay (mud slurry) to 1 part of Portland cement.

The compressed earth blocks were made using the HB520 block press manufactured by the Vermeer manufacturing company.

Figure 2.8 HB520 block press

(Source: Compressed building blocks for affordable housing, 2007)

The blocks were cured for 14 days and tested for their moisture content and compressive strengths. The modulus of rapture and the compressive strengths were tested with a weight of 90,000 pounds using the Tinius Olsen universal testing machine.

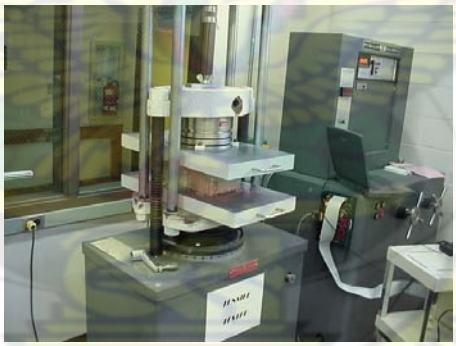

Figure 2.9 compression test set up – Tinius Olsen universal testing machine

(Source: Compressed building blocks for affordable housing, 2007)

The results were as follows

Table 2.3 COMPRESSION TEST FOR COMPRESSED EARTH BLOCKS

Type	Moisture content (%)	Density(pcf)	Compressive strengths	Modulus of rapture(psi)
Soil	10.54	129.46	178	33
Soil +5%fibre	11.2	127.72	189	38
Soil + 5% cement	14.76	134.56	260	53

(Source: Joseph and Tariq,2007)

Table 2.4 AVERAGE DENSITIES, COMPRESSIVE STRENGTHS AND MODULUS OF RAPTURE.

No. Of blocks	Maturity (days)	Average density (pcf)	Average compressive strengths (psi)	Average modulus of rapture (psi)
5	65	130.06	365.79	-
10	105	124.84	354.31	-
13	240	122.62	249.13	-
6	281	124.69	373.90	-
Average density=125 pcf Average compressive strengths = 349 psi				
15	205	130.93	-	65.34
6	281	128.31	-	72.57
Average density=129 pcf Average modulus of rapture = 69 psi				

(Source: Joseph and Tariq ,2007)

The New Mexico adobe rammed earth building code requires the following for a one storey building

- Average block compressive strength - 300 pounds per square inch
- Average modulus of rapture -50 pounds per square inch

(Source: Compressed building blocks for affordable housing, 2007)

It was also observed that

- Too much clay will cause the clay to crack whilst too little of it and more sand will cause the block to crumble.
- The addition of 5% Portland cement and kenaf fibres improved the properties of the blocks

  (Source: Joseph and Tariq, 2007)

Durability

One of the weaknesses of earth in building construction is its low resistance to moisture (water) destructive effect.

In another experiment, a partial wall was built and exposed to rain and snow. It was observed that the bottom blocks were crushed due to wetting and thawing of the blocks. This sensitivity of water and lack of durability in its untreated for m highlight the main reservation on the wide use of this building material. To solve this;

- The wall surface must be protected by the application of rain resisting plaster.
- Wall should be protected from rain driven rain by using an appropriate roof overhang

- For the plaster, the cement –clay ratio should be 1:1 to reduce cost(the compressive strength of this is 35psi)

Advantages of the stabilized adobe block

- It is abundant since its raw material is earth thus very cheap.
- Suitable soil on site eliminates the transportation cost
- Requires less skill and thus easy to work with
- Has high resistance to fire
- Sound resistant
- It is non toxic
- Has a high thermal insulation value thus provides a comfortable built environment.
- Specific strengths could be achieved by altering the quantity of Portland cement.
- Can be designed to be earth quake resistant.

(Source: Compressed building blocks for affordable housing, 2007)

GENERAL REQUIREMENTS FOR ADOBE BLOCK CONSTRUCTION

Soils

- Soil needs soaking for at least 12 hours before making blocks
- Clumps should be less than 10-12mm and the coarse grain should be 25mm.
- Moisture content should be between 13.85-14.62% for good workability.

Mortar

- Cement mortar should not be re-constituted once it has attained its initial set.
- Cement soil ratio shall be 1:6 and water is used to mix for proper consistency.
- The minimum moisture content is always maintained for good workability and proper bedding of compressed earth blocks.

(Source: Compressed building blocks for affordable housing, 2007)

Table 2.5 RATIO OF CONSTITUENTS OF ADAOBE BLOCKS, MORTAR MIXES AND PLASTER.

	Mix for blocks	Mix for mortar	plaster
Ordinary Portland cement	5	15	50
Clay	87	85	50
Sand	8	-	-

(Source: Joseph and Tariq,2007)

Different percentages of some agricultural fibres like rice husks, sugarcane bagasse, coconut fibres etc. and Portland cement increases its credentials as a durable building material.

(Source: Joseph and Tariq,2007)

CONCLUSION ON SPECIAL STUDY

The compressed earth blocks made had the following properties;

Density	-125 pcf
Compressive strength	- 343 psi
Modulus of rapture	-65psi

Recommended properties for building blocks

Compressive strength	300 psi
Modulus of rapture	50 psi

Comparing the above properties, the compressed earth blocks can be used for building and it will be more affordable.

2.9.0 TECHNICAL STUDIES

2.9.1 PLANNING STANDARDS FOR HOUSING

2.9.2 RECOMMENDED OCCUPANCY RATES BY THE DEPARTMENT OF PLANNING, K.N.U.S.T.

From 1.5 persons per room (PPR) in low density areas to 2.0 persons per room in high density areas.

2.9.3 RESIDENTIAL DENSITIES

a) Low density (or high class) area-30 persons (Min) per acre (PPA) to 40 PPA (Max)

b) Medium density (or middle class) area -40 PPA (Min) to 80 PPA (Max)

c) High density (with high rise apartments) 80PPA (Min) to 150PPA (Max)

2.9.4 RESIDENTIAL NEIGHBOURHOOD BOUNDARY DEFINITION

The boundaries of a residential neighbourhood will be determined by significant landmarks such as natural physical barrier e.g. a stream or by major roads and or by a catchment population of between 5000 persons and 15000 persons.

2.9.5 BASIC SUPPORTIVE FACILITIES TO BE PROVIDED IN A NEIGHBOURHOOD

A designated residential neighbourhood should have the following basic community facilities.

- A nursery
- A primary school
- A junior secondary school
- A neighbourhood shopping centre or a local market with attached retail shops adjacent to a parking space
- A health post, a postal agency, public refuse bin, a police post, a neighbourhood open space for out of door meetings, at least a football field and children's play area.

Table 2.6 EDUCATIONAL FACILITIES-SUMMARY OF PLANNING STANDARDS

Schools	Enrolment Per class		Average floorArea per pupil		Average classroom size	School Area		Sphere of influence		Population to be serviced	
	Min	Max	Min	Max		Min	Max	Min	Max	Min	Max
Nursery	40	50	15	20	30 X 25X 10	600Sqft	1000sqft		10min walking distance from house	1000	5000
Primary		40	14		30 x 25 x 13	3 acres		0.25	5 miles	1500	6000
JSS	33	40	16	-	30x 25 x 10	4 acres	6acres		2 miles	5000	10000

(Source: Department of Planning K.N.U.S.T.,2008)

Table 2.7 HEALTH FACILITIES-SUMMARY OF PLANNING STANDARDS

Status	Sphere Of Influence	Land Requirement		Population To Be Served		Number Of Beds		Basic Site Services
		Min	Max	Min	Max	Min	Max	
Regional Hospital	Whole Region	30 acres	50 acres	30000	50000	1000	1500	Water, Electricity, Parking Space, Telephone, Fire Fighting
District Hospital	Whole District	15 acres	30 acres	15000	30000	200	250	As above
Urban Health Centre Or Poly Clinic	Urban Neighbourhoods	2.5 acres	5 acres	10000	15000	-	5	As above
Health Centre	10 miles radius from sub-district	1.5 acres	2.5 acres	5000	10000	12	15	As above
Health Post	Village	-	0.5 acres	-	5000	-	-	As above
Clinic	In Urban And Rural Neighbourhoods	-	0.25 acres	-	5000	-	-	As above

(Source: Department of Planning K.N.U.S.T. 2008)

Table 2.8 TRANSPORT: GHANA HIGHWAY AUTHORITY - ROAD AND WALKWAY STANDARDS

ROAD	TARRED WIDTH ROAD	SHOULDER WIDTH (M)	WALKING WIDTH(M)	MEDIAN	RIGHT OF WAY(M)	REMARK
Motorway (Expressway)	7.0×2	3.0×2	-	5-10	90	
Primary	7.5	2.5×2	-	-	60	
Secondary	7.0	2.0×2	-	-	55	
Feeder	6.0	1.5×2	-	-	40	
Town ❖ freeway or duel carriage	7.0×2	-	-	1-4	60	Bus stop and service recommended
❖ Normal	7.0	-	2.0×2	-	40	
❖ Estate	6.0	-	2.0×2	-	30	

(Source: Department of Planning K.N.U.S.T. 2008)

Table 2.9 PARKING REQUIREMENTS

Description	**Number of vehicle parking space required**
1. Residential (one family) house and apartment	Class I-1 for each dwelling unit Class II-1 for every two dwelling unit Class III and IV- 1 for each building block
2. Shop (up to 50m^2 clear retail floor space)	1 for every shop
3. Shop (Over 50m^2 clear retail floor space)	1 for each 50m^2
4. Department store or shopping Center (Over 450m^2 clear retail floor space)	1 for each 25m^2 clear retail shop
5.Office	1 for each 150m net usable office floor area

	or least 1 per office
6.Public Halls, Community Centre , non residential	1 for each 30m^2 of public floor space
7.Theater and Cinemas	1 for each 15 fixed seat of public accommodation
8. Hotels and Guest House	1 for each 10 guest house
9. Hospitals	1for each 10 beds
10. Industry and or workshop	1 for each 80m^2usable floor space

(Source: Department of Planning K.N.U.S.T. 2008)

Household Refuse collection point

Location of refuse bins for household refuse should be determined by residential densities.

- In residential low density areas with maximum of 30 to 40 persons per acre, distance from one bin to another should not exceed 360m (1200ft.)
- In residential medium density areas with 40 to 50 persons per acre, distance between two bins should not exceed 270m (900ft.)
- In residential high density areas with over 150 persons per acre, distance between two bins should not exceed 150ft. (600ft.)

Refuse Depot.

- Catchment population - 5,000 to 30,000
- Site size - 5 ha per 10,000 people

- Location - Within 10km. radius of town site should be fairly f lat or a depression needing filling with a good vehicular access to a main road site should be free from visual pollution and ensure safety from seepage of water into nearby rivers.

WATER

Domestic Unit Demand

- Minimum of 60 litres per person per day } for low income group
  Maximum of 70 litres per person per day} ,, ,, ,, ,,
- Minimum of 115 litres per person per day } for medium income group
  Maximum of 125 litres per person per day } ,, ,, ,, ,,
- Minimum of 165 litres per person per day } for high income group
  Maximum of 175 litres per person per day } ,, ,, ,, ,,

Space Requirement

Domestic and Industrial water consumption

- For up to 5,000 persons space needed for maximum of 175,000 gallon water reservoir should be up to 450m2.
- For up to 35,000 persons space needed for 175,000 gallon water reservoir should be up to 2,000m2.
- Location of water treatment and storage facilities should ensure safety from contamination. Water treatment plant should normally be located at

least 1km. away from the nearest buildings or possible source of contamination.

- The location of public stand pipe should ensure easy access to user as well as safety normally be at least 3m (30ft.) from the adjoining roads and should be properly drained.

ELECTRICITY

Medium density housing (medium income group)

- Lighting - 240 watts

  Power for medium size cooker, electric iron,}

  Radio, light. }

  Small refrigerator }

  Air conditioner unit } -5900watts

  = **6140 watts**

7. Low density housing (high income group)

- Lighting - 480 watts
- Power for large size cooker, electric iron, radio, hifi and T.V, refrigerator, Air conditioner unit - 11000 watts

= 11480 watts

(Source: Department of Planning K.N.U.S.T. 2008)

2.10 ACCOMMODATION SCHEDULE

Based on the studies conducted and the planning standards, the brief was further expanded with the following approximate floor areas.

Table 2.10 ACCOMMODATION SCHEDULE FOR EDUCATIONAL FACILITIES.

	Enrolment per class	Population to be served	Land area required
Nursery	40 -50	1000 - 5000	55.7 m2-92.9 m2
Primary	40	1500 - 5000	8093.7 m2
JHS	33 -40	5000	12140 m2

TOTAL area = 20288 m^2

(Source: Department of Planning K.N.U.S.T. 2008)

Table 2.11 ACCOMMODATION SCHEDULE FOR HEALTH CENTRE

Population to be served	Number of beds	Land required	
5000 - 10000	12 – 15	1.5 – 2.5 acres	8093.7m2

TOTAL area = 8093.7 m^2

(Source: Department of Planning K.N.U.S.T. 2008)

NEIGHBOURHOOD SHOPPING CENTER

- Catchment population -From 5000 persons to 15000 persons
- Plot size -Minimum of **100sq.m**
- Commercial floor area -Minimum of **20sq.m.**

PLACES OF WORSHIP

- Catchment area -A neighbourhood or a small settlement.
- Population size - Up to 15,000
- Site size - 0.35ha to 0.7ha.

(Source: Department of Planning K.N.U.S.T. 2008)

Table 2.12 ACCOMMODATION SCHEDULE FOR BEDSITTER FLAT (ONE UNIT)

SPACE	DIMENSION	QUANTITY	AREA m2
BEDSIITER	6.5 X 2.8	1	18.36
KITCHEN	1.95 X 2.06	1	4.01
TOILET	1.95 X .40	1	3.60
TERRACE	1.95 X 1.40	1	2.37
CIRCULATION	10%		2.97
TOTAL			**28.70**

Table 2.13 ACCOMMODATION SCHEDULE FOR ONE BEDROOM FLAT (ONE UNIT)

SPACE	DIMENSION (m)	QUANTITY	AREA m2
BEDROOM	3.45 X 3.45	1	11.90
KITCHEN	2.35 X 2.45	1	5.75
LIV/DIN	3.85 X 5.55	1	21.36
TOIL	1.96 X 1.85	1	3.62
YARD	2.35 X 2.40	1	5.64
CIRCULATION	10%		4.83
TOTAL			**53.07**

Table 2.14 ACCOMMODATION SCHEDULE FOR TWO BEDROOM FLAT (ONE UNIT)

SPACE	DIMENSION (m)	QUANTITY	AREA m2
BEDROOM	3.45 X 4.65	1	16.04
BEDROOM	3.46 X 3.40		11.76
KITCHEN	3.46 X2.45	1	8.47
LIV/DIN	6.75 X 4.65	1	31.38
TOIL	2.37 X 3.48	1	8.24
YARD	2.80 X 3.31	1	9.26
CIRCULATION	17%		15.77
TOTAL			**85.11**

Table 2.15 ACCOMMODATION SCHEDULE FOR THREE BEDROOM FLAT, TYPE 1 (ONE UNIT)

I	DIMENSION (m)	QUANTITY	AREA m2
BEDROOM	3.45 X 3.45	3	35.71
UTILITY	2.0 X 3.45	1	11.76
KITCHEN	3.6 X 3.4	1	12.24
LIVING ROOM	3.4 X 4.4	1	14.49
DINNING	3.60X2.8	1	10.08
TOILET	2.35 X 3.45	1	8.10
YARD	4.6 X 3.6	1	16.56
CIRCULATION	15%		16.30
TOTAL			**124.9**

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter discusses how the research was carried out to design an energy efficient affordable housing community.

3.2 CASE STUDIES

Case studies were undertaken for specific reasons to address the issues pertaining to energy efficiency, affordability and functionality of the housing scheme. With each case study, its aims or objectives have been stated. Case studies of successfully designed housing development in Ghana and ongoing affordable housing projects were also undertaken.

The internet was also very helpful by exposing me to an ocean of knowledge amongst which I obtained information on my foreign case study.

3.3 FIELD PROCEDURES

Certain field procedures were necessary for thorough assessment of certain issues pertaining to this research.

Measured Drawings

With the case study on existing buildings, measured drawings had to be done since the existing drawings were not readily available. The dimension of spaces were needed to make a more meaningful statement on the optimisation of space.

Market Survey

A market survey was carried out on the cost of various building materials and the general costs of residential buildings in Ghana. It must be noted that all the prices are with respect to the time in which the survey was conducted.

Interviews

Interviews were conducted with architects and other stakeholders of affordable housing projects. These interviews were not formally structured but were conversational and the aim was to get opinions from both professionals and the general public alike.

Personal observation and visual survey.

In designing a neighbourhood, there is the need to observe the life styles, preferences, behavioural patterns and trends of the target occupants. This is necessary to make the design responsive to the preference of the people.

3.4 MAPS AND SITE PLANS

Maps and site plans were obtained from the Ministry of Water Works and Housing. They have been scanned and added to the write up..

3.5 LITERATURE REVIEW

Published and unpublished literature on the topic were reviewed. This involved the examination of written material such as books, journals, periodicals etc. and video

recordings. A lot of literature was also gathered from various web sites associated with housing, energy efficiency in buildings and cost reduction in design.

3.6 LIMITATIONS

Data collections through interviews were cumbersome since people had diverse views on housing and would more often be inclined towards a particular stance.

CHAPTER 4

4.0 FINDINGS/DISCUSSIONS

4.1 SITE STUDY

4.1.0 SITE LOCATION AND PERIPHERAL STUDIES

The site is located in the outskirts of Accra, the capital city of Ghana. It is about 40 minutes drive from the city centre. To the north of it is Achiaman, to the east is Pokuase and to the south is Ofankor

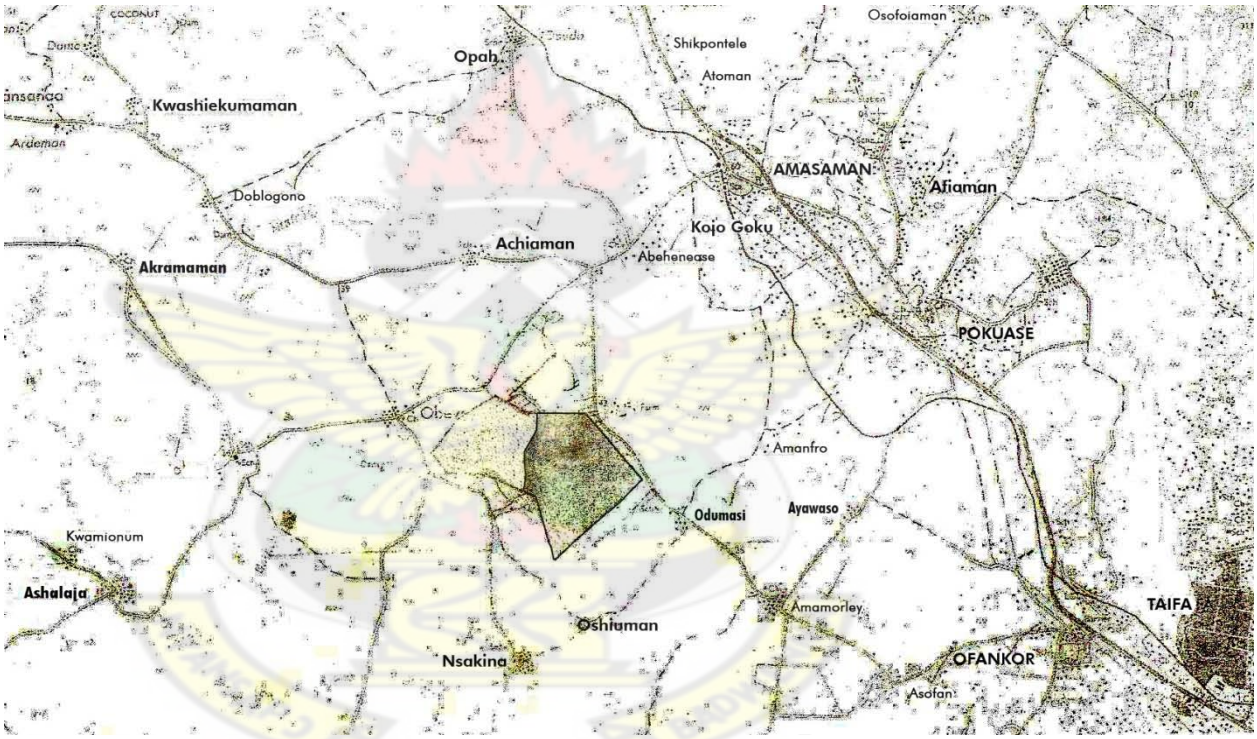

Figure 4.10 Site plan of Ga West District showing site to be developed

(Source: Ministry Of Water Works and Housing).

The site covers a total land area of 126.23 hectares or 312 acres

4.1.1 SITE JUSTIFICATION

This site was chosen for the following reasons;

- It is located in the capital of the country where housing needs are needed the most.
- Its strategic location on the outskirts of the city is in good line to help in the decongestion of the capital city.
- Odumase Nsakina is a semi-urban town and looking at the rate of urbanisation or development in the country, it will be in the right direction to plan it before it is too late.
- Among the features of the site are good soil for plant growth, interspersed water bodies and rock outcrops. These natural features could be utilised to create and ecologically sound environment.

4.1.2 SITE INVENTORY

Climate

Accra falls in the hot humid climatic zone. It has a daily average temperature of 31^{O}C. The coolest times are between July and September.

Vegetation

The vegetation is that of the guinea savannah woodland with a few shrubs scattered over it. There are however a few significant trees on the site which would be maintained.

Geology

The soil on the site is not consistent. It is a mixture of silt from the rocks and a rich sandy loam soil.

Topography

The central part of the site is fairly flat with highlands to the north and northwest of the site. Rocky outcrops are located at the extreme north western end of the site. A freshwater spring lies in the middle of the site and another lies to the eastern boundary of the site.

The site has a gradient of 8.4 metres but the slope is not a continuous one.

Electricity

There is electricity in the neighbouring village but around the site, there are only electric poles but no wires on them.

Pipe borne water

There is no pipe borne water in the immediate village by the site but it is present in the Odumase Township which is about 1.5 km from the site.

4.1.3 SITE ANALYSIS (SWOT)

Strengths

- Site is fairly flat in the middle area and can thus serve a lot of purposes.
- Interspersed water bodies and rocky outcrops presents a presents a very admirable landscape

Weakness

- The interspersed water bodies could obstruct the freedom or fluidity of planning
- Undulating nature of land restricts freedom of planning
- Inconsistencies of the soil could hamper the growth of plants at certain parts of the site.

Opportunities

- The presence of water bodies on the site suggests that the water table is high thus one can take advantage of it to create wells and boreholes.
- Site water is fresh and could be used for household chores or treated for consumption.
- Central part of the site is fairly flat and could be used for social gatherings or have communal facilities cited there.
- The abundance of rocks at the north western end of the site could be used for concrete works to cut down on the cost of construction.
- The water bodies on the site could also serve recreational purposes like picnicking or an edge definition of a park.
- Facilities to be sited near the water bodies could go for higher prices for the views and the serene environment to be enjoyed.

Threats

- The level of the water bodies in the dry season could go down during the dry season.

- Small pockets of water bodies on the site could breed mosquitoes if not treated.

4.2 DESIGN PHILOSOPHY

Preamble

"IN A GOOD NEIGHBOURHOOD, PEOPLE HAVE A SENSE OF BELONGING.RESIDENTS RECOGNISES ONE ANOTHER AND COUNT FRIENDS AND FAMILY AMONG THEIR NEIGBOURS"

The design philosophy for this thesis could be summed up in the following phrase "**GOOD COMMUNAL LIVING**"

4.3 DESIGN CONCEPT

In line with the design philosophy of good communal living, the **courtyard concept** has been employed.

In the simplest term, the courtyard is a central space which is more often than not open to the sky and bound by walls or buildings that define this space.

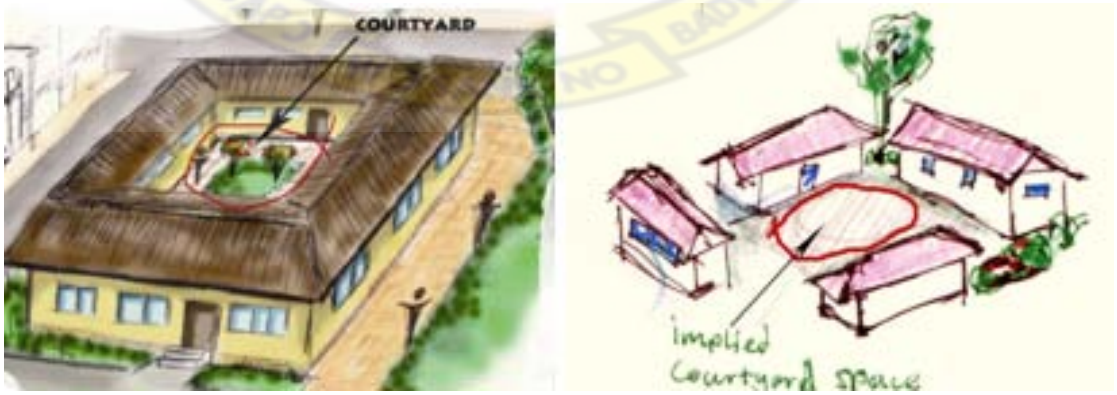

Figure 4.11 The courtyard concept

(Source: Author's field survey)

ATTRIBUTES OF THE COURTYARD HOUSE

- *SAFETY*

  This is by virtue of its inward looking nature and controlled access

- *SECURITY*

  The space is always overlooked. This is due to the fact that most of the rooms open into the courtyard thus once there is someone in the house, there is an eye over the courtyard.

- *THERE IS PROVISION FOR PASSIVE VENTILATION AND LIGHTING*

  It s open to the sky and thus allows in daylight and fresh air and this falls in line with the energy efficiency.

- *OPTIMISATION OF SPACE*

  The central space is shared by all and this also falls in line with affordability.

- *SEMI-PRIVATE*

  Though the space is enclosed, it is semi-private because it is also accessible by other tenants in the block

The attributes of the courtyard shall apply to the housing scheme from the general planning of its layout, the actual design of the building blocks and their overall arrangement.

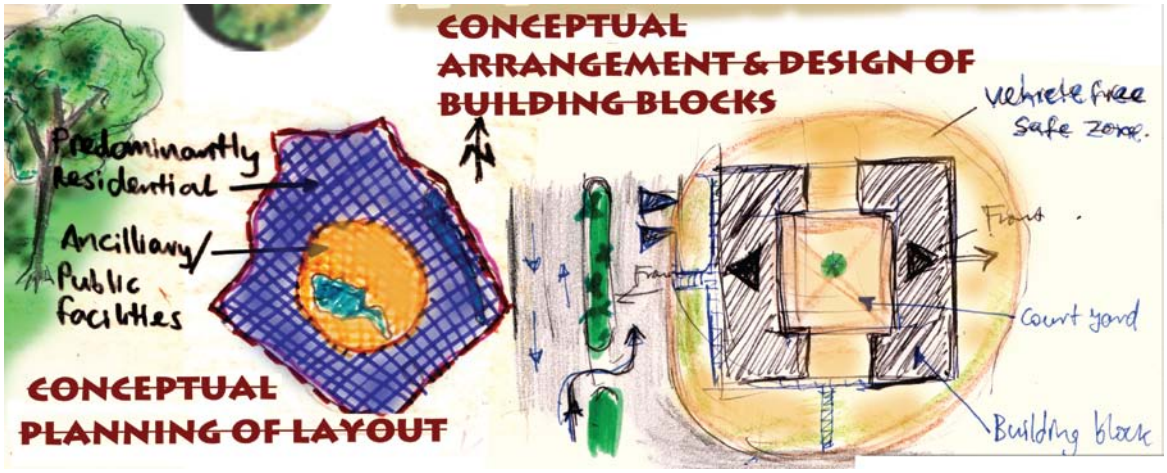

Figure 4.12 Philosophy as is to be implemented

(Source: Author's field survey)

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4.4 CONCEPTUAL SITE PLANNING

STAGE 1

Figure 4.13 Conceptual site planning stage 1

(Source: Author's field survey)

As intended by the design philosophy, the planning of the neighbourhood is as to create a general communal space or points of attraction to foster good communal living.

The size of the site is 312 acres which will be for a target population of 21,280 people (medium density of 65 persons per acre). From the planning standards, a residential neighbourhood is to have a population between 5,000 and 15,000 people. With this in mind i had to further break the 'giant' neighbourhood into smaller units each with its own focal point. This was to ensure the even distribution of resources. I however maintained a central open space for the whole development

STAGE 2

Figure 4.14 Conceptual site planning stage 2

(Source: Author's field survey)

For an edge definition, I decided to use a green belt. This is to give the neighbourhood a character as I intend to move it towards green architecture. It is also to serve as a noise and air pollution filter for the site. On the north western end of the site, there is a rock quarry (granite) and a green belt buffer zone has been created around it to cut off its noise and air pollution from the rest of the site.

The land around the quarry is also worn out so the buffer zone which would be a forest, will allow the land to fallow and regain its natural richness.

Three (3) entry points have been strategically placed on the periphery of the site and this decision was based on the following factors;

- Avoiding the instance whereby the neighbourhood would be used as a thoroughfare by both commercial and private car drivers.
- The topography at these points was considered.

STAGE.3

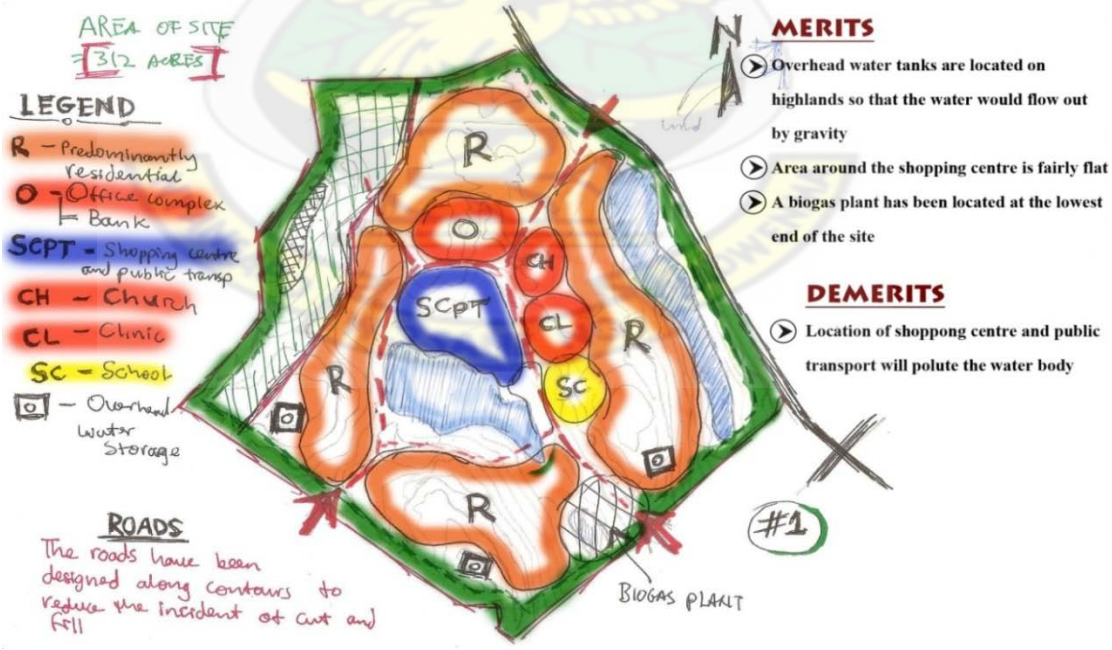


Figure 4.15 Conceptual site planning stage 3

(Source: Author's field survey)

From the developed brief assembled from the case studies and planning standards, the following zones were created and are represented by their corresponding colours and letters.

Residential --------- R

Educational----------

Civic or cultural----

Primary school - - - - - SC

Office complex - -**O**

Utility area ----------

Clinic - **CL**

Overhead water tank - - - - - - - - - - - **O**

Church - **CH**

Shopping Centre/public transport - - **SCPT**

The central part of the site is fairly flat and will be a good location for a shopping centre or other public or communal facility.

The water body in itself could be a pubic attraction and its central location is favourable. The residential areas have been so arranged around the other shared facilities so they would converge to use them.

Overhead water tanks have also been strategically zoned on highland to supply water to the various sectors of the site.

A biogas plant has been situated on the south eastern end of the site where the land is lowest. Surface water on the site will eventually find its way here so there would be a provision for it. A water treatment plant could also be located in this area. At this point the road network has also had its fair share of attention. The road network has been demarcated with a red broken line. Apart from the site not being used as a

thoroughfare, other considerations given to its design were the topography of the land and the issue of speed control.

The roads have been laid along the slopes to minimise cutting of the site which will go a long way to reduce the cost of construction. The road also meanders slightly every now and then within reasonable distances to reduce speeds of vehicles.

The shopping centre and public transport located by the water body poses a threat to the central water body in terms of sanitation.

STAGE 4

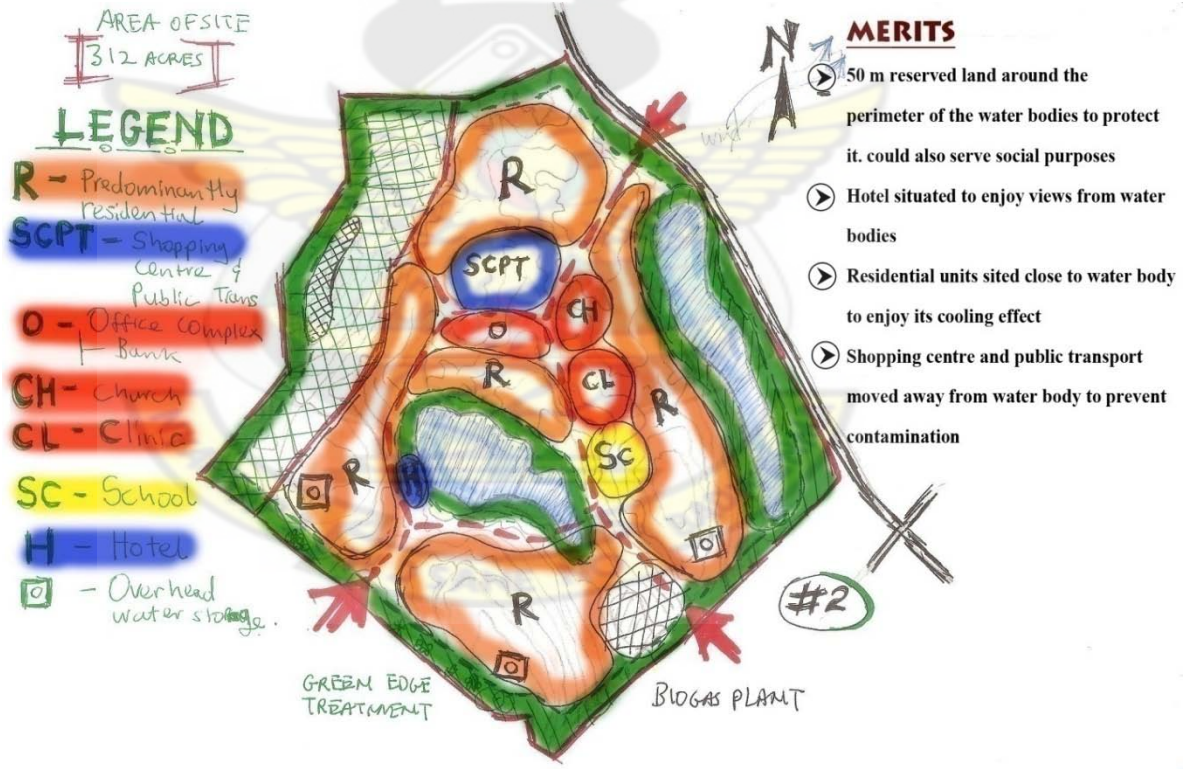


Figure 4.16 Conceptual site planning stage 4

(Source: Author's field survey)

The shopping centre and public transport yard has been moved further away from the water body to prevent its contamination. Instead, a hotel facility with a perceived recreational facility in the nature of a water sport would be sited near the water body. The hotel rooms can also utilise views from the water body. The hotel has been demarcated with the letter 'H' and has a blue background since it is a commercial facility.

A clearance space of about 50 metres has been demarcated around the water bodies as a protective measure. No construction is to take place in this zone.

A residential area has however been located near the northern bank of the central water body. Houses in this location will probably attract a higher prize by virtue of its location.

Between this residential area and the shopping centre and public transport yard which was moved further north is an office complex which would include banks, restaurants and other business facilities. This area is to serve as a transitional point between the predominantly residential area and a commercial area. It is intended to soften the noise and busy nature of the commercial area as you approach the residential area.

4.5 LAYOUT DESIGN

The design of the layout aims at creating an eco-friendly environment for people to live in. It does not stick to a strict zoning system since in modern times, towards urbanisation; spaces are becoming more and more mixed used in nature.

Among residential areas are pockets of open spaces or play grounds and corner shops interspersed appropriately within the settlement. There is however a central shopping centre or mini-market to cater for the wider varied needs of residents.

In line with the concept of good communal living, the layout has been designed to create vehicle free spaces which serve as focal points and also brings people together.

These spaces are fully pedestrianised and have a hierarchy whereby there are smaller open spaces in and around the buildings and large open spaces where people can meet.

The least in the hierarchy of open spaces is the **courtyard** which is located in the actual buildings. Its main purpose is for lighting and ventilation but on the smaller scale for social interaction.

Next to the court yard is a **common compound or quadrangle** which is as a result of the arrangement of the building blocks. This space is vehicle free and it is here that actual socialising takes place. Children can also play in this space under the watchful eye of their parents. Corner shops are located not far from this space, preferably near a secure parking lot.

In other instances, a portion of the ground floor of one of the building blocks forming the quadrangle is converted into a shop to be assessed from the compound.

Next to the quadrangle is the **play grounds or public open spaces**. These are fewer in number and are located centrally at vantage points where necessary.

The last in the hierarchy of spaces is the **parks and the shopping centre**. These facilities are located centrally on the site.

The talk about energy efficient and affordable housing brings to mind the word sustainability. In this line there is provision for the generation of electricity through the use of a biogas plant and the supply of portable drinking water on the site. The water shall be obtained from boreholes, rain water harvesting and from a spring in the centre of the site.

Hierarchy of spaces

Figure 4.17 Diagram showing hierarchy of spaces as proposed.

(Source: Author's field survey)

4.6 BUILDING DESIGN

The design of energy efficient affordable houses had quite a number of controversial issues at hand. In cases where the design was very affordable, it was not very energy efficient and vice-versa.

Since energy efficiency in itself contributed to affordability in terms of running cost, I took a stance to design for energy efficiency but not forgetting the issue of affordability. Passive design concepts were considered. At that stage the affordability issues considered were basically the floor areas. Minimum requirements were considered. Nevertheless every detail of the building was designed with the aim of attaining energy efficiency and affordability.

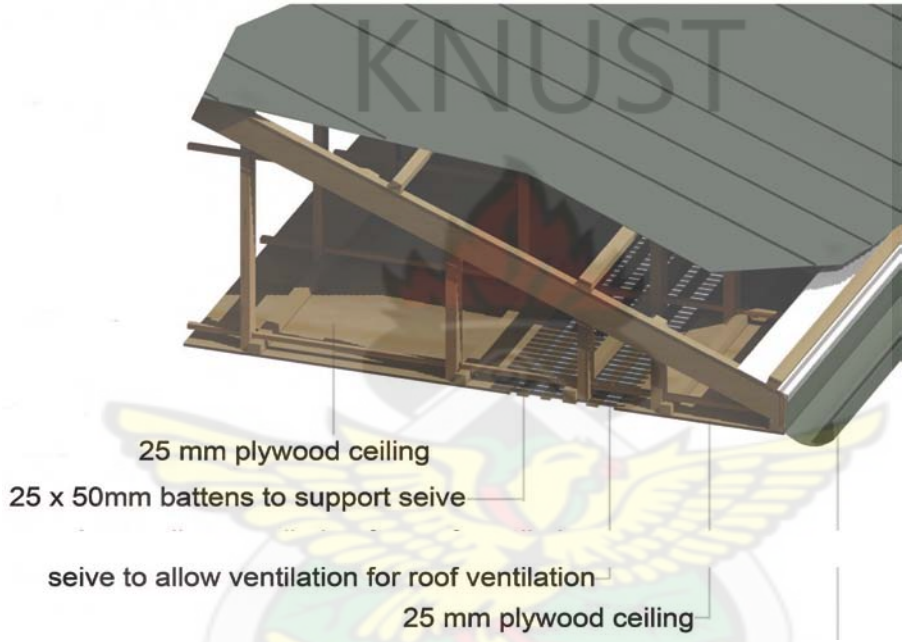


Figure 4.18 Roof detail for energy efficiency and rain water harvesting

(Source: Author's field survey)

The above figure shows a detail of an eave where provision has been made for ventilation in the roof space. Heat gain through the roof or ceiling is greatly reduced this way. This has been done with the use of a net or nets intermittently or entirely on the soffit of the facia.

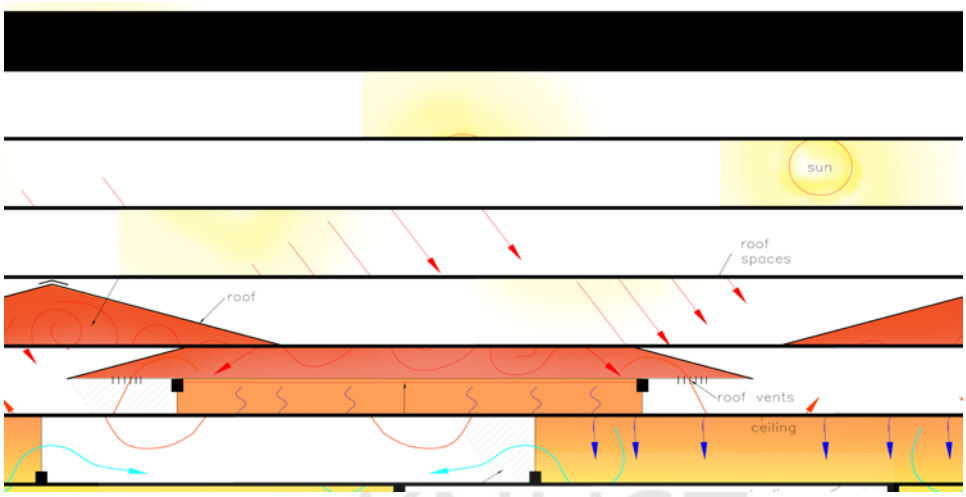


Figure 4.19 Ventilating through the vents under eaves and other openings

(Source: Author's field survey)

The figure above further explains the role or contribution the eave vents to the overall cooling of the building.

Detailed floor plans of individual house types, elevations, sections and perspectives can be found in the appendix. It must also be noted that concepts and strategies to achieve energy efficiency and affordability run through the whole scheme.

4.7.0 ORIENTATION

Talking about energy efficiency, all the buildings on the site have a strict north – south orientation. In this respect, the shorter side of the building faces towards the sun with little or no openings at all. This is a key design consideration for the attainment of an energy efficient building.

4.8.0 VENTILATION

The designs are such that mechanical ventilation will only serve as a back up in unusual conditions. Passive ventilation has been achieved by the strategic placement of windows and openings.

4.9.0 FLOOR PLANS

To cater for a wider target group, five different energy efficient affordable residential designs have been provided. Namely

- Bedsitter flat
- 1 bedroom flat
- 2 bedroom flats
- 3 bedroom flats (2 types)

4.10.0 STRUCTURE/FORM

As has been the case from the onset, the project seeks to be energy efficient and affordable. This idea has also been translated into the structure/form of the buildings, not forgetting the issue of durability.

The structural system used is the post and beam. In this case regular reinforced concrete columns are used with pre-stressed concrete floor slabs and stabilised adobe is used for infilling as shown in the figure 4.21 below.

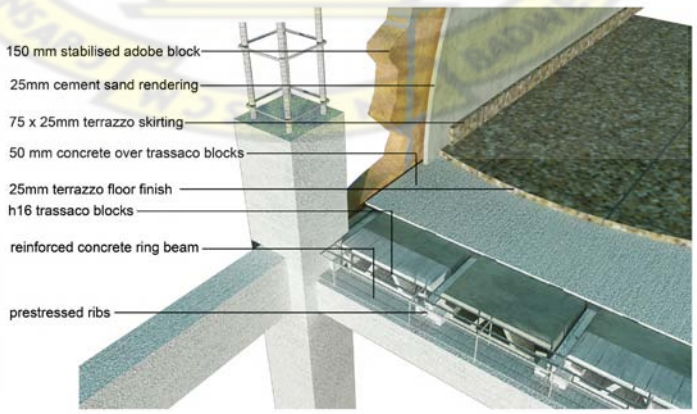


Figure 4.20 Typical structural detail

(Source: Author's field survey)

4.11.0 ELEVATIONS

The architecture employed for the housing scheme is a combination of the neo-classical style and modernism, to be precise cubism. The later mentioned style would have dominated the design and would have been very obvious if it wasn't for the simple gable roofs which bring about some sort of symmetry.

For the sake of energy efficiency some facades which face the rising and setting sun have been left blank and that also emphasises the beauty of plane surfaces. Where appropriate, windows and other openings have been recessed and shadows formed by this during the day are a delight to watch. Also in other semi –private or public spaces such as stair cases and shared lobbies or corridors, fins which have been designed to suit the various elevations have been used to break the monotony of solid walls or windows as well as enhance natural ventilation.

The elevations have been carefully designed to cater for affordability, energy efficiency as well as giving some meaning and delight to the neighbourhood.

4.12.0 MATERIALS

The materials for this project were chosen with the ultimate aim of energy efficiency and affordability in mind. Their durability of the building was also considered.

Building element ***Materials***

Floors

General internal spaces---------- Screed

Living area/bedrooms----------Polished terrazzo floor finish

Walls----------Plastered stabilised adobe blocks with emulsion paint

Doors----------Flush door type

Windows----------Furnished timber frames with glass Louvre blade infill.

Balustrades----------Metal balusters and railings with wooden handrails

Roofs----------Aluminium roofing sheets coated with insulpro Timber fascias.

4.13.0 MARKET SURVEY

A random market survey was carried out to see the current trends in the housing sector and the results were as follows.

Table 4.16 Market survey

COMPANY		HOUSE TYPE & PRICE-CEDIS				STANDARD FEATURES
		BEDSITTER	1 BEDROOM	2 BEDROOM	3 BEDROOM	
COMET PROPERTIES LIMITED		16,250	32,500	60,000	70,000	-plaster board ceiling -ceramic tiles for floors -naco window blades -panel doors outside -flush doors inside -galvaluminium roofing
DAMAX CONSTRUCTION CO. LTD.		10,635	21,270	42,555	63,832	-coloured roofing tiles -ceramic wall -floor tiles for bathroom & ki tchen. -terazzo floors
LAKESIDE ESTATE		8,625	17,250	34,500	51,750	———
REGIMANUEL GRAY CO. LTD.		11,535	23,070	49,750	63,800	-ceramic floor tiles throughout - fibre cement roofing tiles -ceramic floor tiles for wet walls of toilet and shower -painted plywood ceiling -aluminium louvre frame window -flash door type -standard plumbing fittings
DEVTRACO COURT		10,833	21,666	43,333	65,000	———

(Source: National Building Exhibition-2008)

Note: all prices are in cedis

Using a cost calculation by floor area at 250 cedis per square metre, the following prices were arrived at:

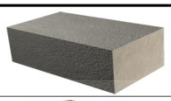
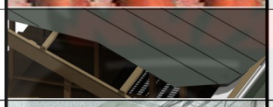
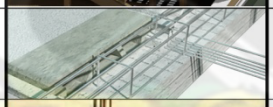
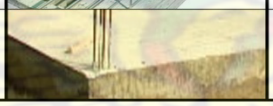
Table 4.17 Cost of houses at Krobo Odumase

COMPANY		HOUSE TYPE & PRICE-CEDIS				STANDARD FEATURES
		BEDSITTER	1 BEDROOM	2 BEDROOM	3 BEDROOM	
KROBO ODUMASE		7,917.5	17,285	26,662	34,150	-SCREED FOR GENERAL INTERNAL SPACES - TERRAZZO FOR LIVING/BEDROOMS -ceramic floor tiles for wet walls of toilet and shower -painted plywood ceiling -aluminium louvre frame window -flash door typE -standard plumbing fittings - TRASSACO FAST FLOORS -STABILISED ADOBE MASONRY

(Source: Author's field survey)

This drop in price is basically due to the composition of its building materials and some affordable housing principles used both in design and construction.

Table 4.18 Material Cost Analysis and U-values

MATERIAL		COST (CEDIS) PER UNIT *or* PER m^2	U - VALUE
SOLID BLOCK 6"		1.31	1.1
HOLLOW BLOCK 6"		1.01	.43
STABILIZED ADOBE 6"		.78	0.41
CONCRETE ROOF TILES (ACP)		96.92	1.25
CORRUGATED ALUMINIUM RF SHEET		15/ SHEET	1.6
PRE CAST, PRESTRESSED HOLLOW CORE FLOOR SLABS		32.22/ m^2	0.36
RC CONCRETE FLOOR (INSITU)		100/m^3	0.83

(Source: Author's field survey)

For the table 4.18 above, the two considerations made were how affordable or relatively cheap a material is and also how easily they can transfer or dissipate heat from or into a building.

4.14.0 SERVICES

4.14.1 Electricity

Electricity will be generated on the site by generators that will be fuelled by methane from the biogas plant. Transformers will be placed appropriately to cater for the large number of people in the area.

4.14.2 Lighting and Ventilation

Natural lighting has been will be used to light space for the full twelve hours that the sun is out. Artificial lighting will be provided to light space both indoors and outdoors when it is dark.

4.14.3 Security Control

Security is catered for with presence of the police station and the use of compound system where people can keep a watch on each other's property.

4.14.4 Fire

Hydrants have been placed at 45m intervals to cater for fire situations that may occur.

4.14.5 Water Supply

A water reservoir has been provided for the individual communities and can store water for supply up to two weeks in case the mains cease to flow. Individual

compound housing units will have underground storage facilities within compounds to store rain water. The size of tanks can store water to last up to two weeks.

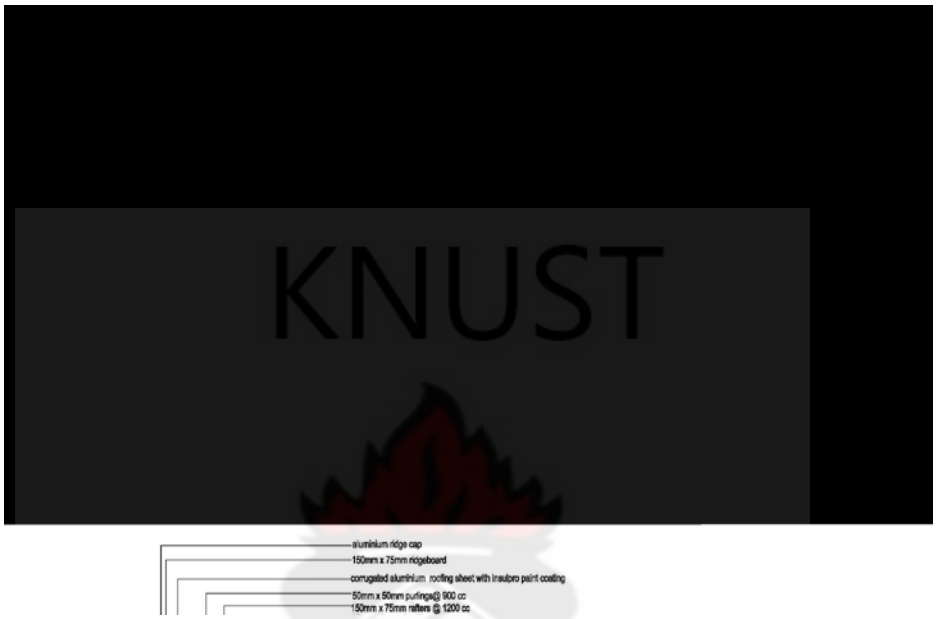


Figure 4.21 Section through two (2) bedroom flat

(Source: Author's field survey)

The above figure is a section through a two (2) bedroom flat showing provision made for overhead water tanks of capacity 6720 litres each to cater for a family of four (4) for two weeks. This calculation is based on the average water consumption for the middle class as provided in the technical studies. *(Source : Planning standards for young Planners, K.U.S.T. 2008)*

4.14.6 Telecommunication

Mobile telecommunication exits in the area with good reception.

4.14.7 Sewage

This will be channel to the central sewage plant located at southern end of the site. Water will be treated and channelled to various stand pipes in the neighbourhood for landscaping. Solid waste will be used in the production of biogas.

4.14.8 Refuse Disposal

Refuse collection vehicles will be dispersed to collect household refuse that will be placed close to the car park for collection. Refuse is then sent to the depot which has a recycling plant for sorting into bio-degradable (for compost and biogas production) non- biodegradable. Families will be encouraged to sort out refuse according to paper, plastics, glass and biodegradable for easy use by the recycling plant. Families will be offer money for sorting and the bringing of non-biodegradable rubbish to the depot. Biodegradable will still be collected from the various homes.

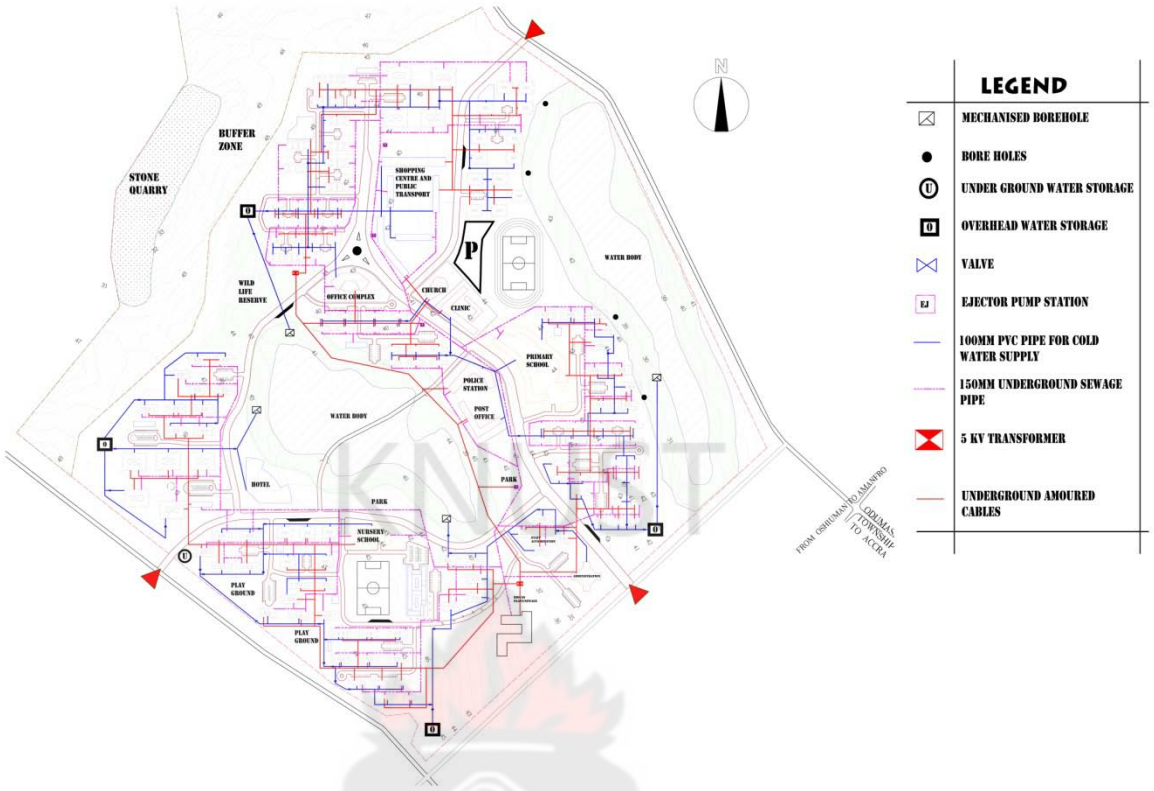


Figure 4.22 Services Layout

(Source: Author's field survey)

The figure above shows the disposition of service lines as proposed on the site.

4.15.0 LANDSCAPING

Ghanaians generally have an outdoor oriented lifestyle and would be very inappropriate to let landscaping go unattended to. For the purpose in trying to attain energy efficiency it is important to create an environment that does not encourage the radiation of heat into the atmosphere. Hence several systems of soft landscaping will be employed**.** However it is inevitable that to maintain proper soft landscape the introduction of hard landscape is also necessary

4.15.1 Soft Landscaping

i. Shade Trees

The use of the almond tree within courtyard spaces provided shading outdoors to allow occupants the chance of enjoying the outdoors without suffering under the hot tropical sun.

The Collector streets and sidewalks are also planted with almond trees but are specially tree to ensure proper growth to provide canopies of street shading.

The weeping willow trees are placed on the eastern and western side to reduce the sun's rays have direct contact with walls to keep buildings cool.

ii. Hedges

To provide boundary between private open spaces for a number of grouping of buildings the duranta yellow was used as a hedge. This will be allowed to grow to a height of 1.2. This will provide sufficient boundary without cutting away air movement and light

iii. Lawn/ open space

This will allow for social interactions on a larger scale between both children and adults. Theses will be provided manly for activities such as durbars, football funerals and others.

4.15.2 Hard Landscape

i. **Side Walks**

ii. These will provide authorized pedestrian movements to prevent treading along lawns. It will also provide shorter routes to various destinations within and around the community

iii. **Car parks**

These provide safe zones for which homes with vehicles and park. Long parking areas will have flowerbeds with shade trees in the middle to break the monotony and also to provide shade for the cars. They shall also be fixed with external lighting to ensure security at night.

4.15.3 External lighting

This is very essential for night time activities. It will be very necessary for ensuring the security of the neighbourhood. In the normal residential areas that are connected to the national electricity grid, there is an amount of money that is paid for street lights. In the energy efficient affordable housing, street lights shall be connected to solar panels that will be attached to each pole to provide it with energy. In this case when a light becomes faulty, it will not affect the rest.

4.16.0 COSTING

This costing is an estimate to give the client an idea of the financial investment the project will need.

The cost per square meter of construction is GH¢250. This amount was arrived at after an economic analysis of the cost of the components of the adobe block.

The bedsitter and the one bedroom flat will be for rent and the two and the three bedroom flat could be for sale or for rent.

Table 4.19 COST OF HOUSES AT KROBO ODUMASE

	FLOOR AREAS PER UNIT	COST AT 250 CEDIS/m2
Bedsitter flat	31.6	7,197
One bedroom flat	69.14	17,285
Two bedroom flat	106.65	26,662
Three bedroom flat	134.60	34,150

(Source: Author's field survey)

This amount does not include the cost of servicing and landscaping.

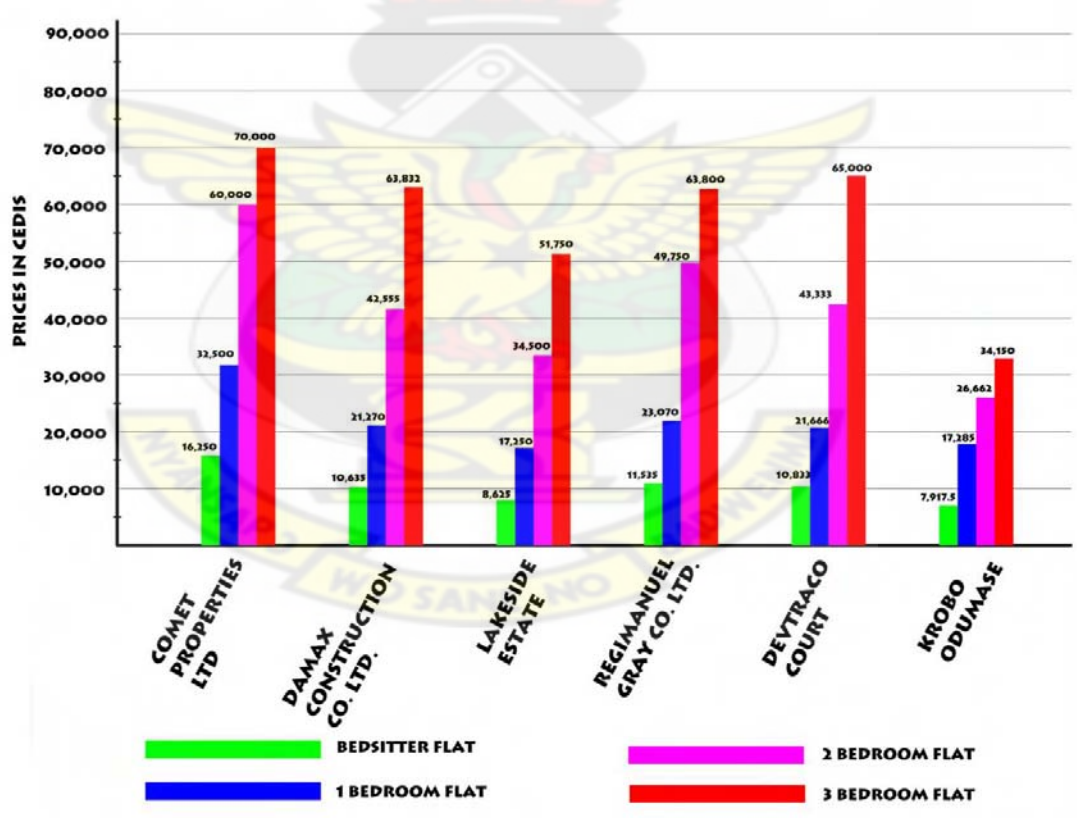


Figure 4.23 A Chart Comparing prices obtained from a market survey.

(Source: Author's field survey)

The above figure presents a chart in which in which Krobo Odumase house types emerge as the cheapest. This is not only due to good construction practices but also due to innovative use of local cheap but efficient materials.

CHAPTER 5
RECOMMENDATION AND CONCLUSION

5.0 RECOMMENDATION

Considering the wide scope of an energy efficient and affordable neighbourhood or housing project, the recommendations would be broken down into two main parts; that pertaining to

- The design of the layout and
- The actual design of the individual housing units.

Thus under each of the above mentioned, there would be recommendations to achieve energy efficiency and affordability.

5.0.1 ENERGY EFFICIENCY OF LAYOUT

The issue of energy efficiency as mentioned previously in the report is basically about passive cooling and lighting. At this stage passive cooling will be more relevant to us with respect to the contribution of the surroundings to the cooling of spaces in and around buildings. For the achievement of this, the following will have to be considered.

5.0.1.0 SOFT LANDSCAPING

This is a general term but in this case we will be referring to the use of vegetation and water as ground cover. The main purpose of this will not only be for aesthetic purposes but also to create a convenient micro climate for the neighbourhood. When the sun shines on hard surfaces such as concrete or other stone products, it absorbs

the heat quickly and radiates it into its immediate environment. This is because of their high thermal conductivities. Vegetation (grasses, shrubs, trees etc.) and water however, have lower thermal conductivities and thus take a longer time to gain and give off heat. Thus;

- All unbuilt areas (excluding pavements) shall have a surface cover of lawns, shrubs, trees or any other form of vegetation where appropriate. In other instances, for example our site which is blessed with water bodies will be incorporated into the design as ponds, pools etc. This will also greatly enhance the aesthetic character of the site.

- All roads have walkways or pavements at their sides which are shaded by trees. This creates an avenue and encourages walking especially within short distances. In effect money could be saved on fuel.

- For the edge definition of the neighbourhood, hedges have been used instead of a solid masonry wall. This also enhances the quality of air.

5.0.1.1 UTILISATION OF ORGANIC WASTE ON SITE FOR BIOGAS

For a medium density medium class residential area, one would expect quite a lot of organic waste mainly from human excreta and kitchen waste. This waste could be treated and used to feed a biogas plant which at the end of the production chain would provide energy (electricity and cooking gas) to serve the neighbourhood. Excess energy could be sold out.

Depending on the output capacities and the energy requirements, a biogas plant/(s) would be situated at vantage points to provide energy for the neighbourhood.

5.0.2 AFFORDABILITY ISSUES IN LAYOUT DESIGN

The road network of the neighbourhood was designed with the contours of the land in mind. Roads have been designed to run along the slopes as much as possible rather than across the slopes. This is to minimise the cost of cutting and filling during road construction.

Also the overall mileage of the road network has been kept to the barest minimum through the use of general/public parking lots.

In terms of planning, the use of courtyards or communal spaces avoids the need to create pockets of open spaces for social activities.

5.0.3 ENERGY EFFICIENCY OF DESIGN

As stated earlier, the energy consumption of buildings in our part of the world, is basically due to ventilation or cooling and lighting needs. Depending on the intended use of the building or nature (lifestyle) of its occupants, other electrical gadgets may be required which will increase the energy requirement for running the building.

This however does not fall in the domain of the architect/ designer. His contribution to the energy efficiency of a building is at the design stage. At this stage he makes use of the natural light and breeze when they are available and only need to be supplemented when they are not. In this case the building is not fully dependent on the use of energy for lighting and ventilation. The following are guides to how the energy efficiency of the design was achieved at Krobo Odumase.

Orientation

This usually refers to the position or placement of the building with respect to the cardinal points. For example if the longer side of a building which is rectangular in shape is made to face the east or west(sunrise and sunset),more surface area is exposed for heating .Just as the sun moves from the east to the west, so does the win also have a predominant direction of flow. In Ghana for instance, the predominant wind direction is from the south west to north east. Thus, a building which is oriented such that its longest side faces the south west would often have the wind blowing across it giving it a more effective natural ventilation.

Considering the orientation of a building during the design stage ensures the following

- maximum use of natural lighting,
- natural ventilation
- And the building would not be unnecessarily heated since a smaller surface area of wall would be made to face the sun.

Sizes and placement of windows and openings

Bigger sizes of windows and openings would enhance the air change rate of the room. This could also bring in direct sunlight or glare into the room, thus appropriate measures should be taken in considering their location. Also, an appropriate shading device could also be used to avoid direct contact with sun light.

Cross ventilation is the most effective form of natural ventilation where by windows of approximately the same size and position are placed on opposite walls of a room.

In this case, the air that enters the room is made to move across the room before it is replaced.

The stack effect is also another means of ventilation which is based on the following principle

- Hot air rises and cold air sinks.
- Air flows from a region of higher pressure to a region of lower pressure.

Thus in a room, one would realise that there are different strata of temperature from the floor level to the ceiling. This is however more significant when the ceilings are higher.

Now the temperature of the air further away from the floor is higher than that which is closer to the ground, this implies the following;

- The air above which is of a higher temperature is less dense than the air below.
- The air below also keeps gaining heat and it also moves up forcing the air above to come down again forming a cycle.

In this cycle however, there is no air change. Eventually the whole room gets hot/ humid and becomes uncomfortable. Proper ventilation is thus ensured when the air is allowed to escape at the top and a fresh supply is allowed in from the sides. This is ventilation using the stack effect. It does not work properly when there are no lower openings to let in a fresh supply of air.

The type of windows also matter in determining the quality of natural ventilation in a building. For example in a two bay sliding window, only one bay would be useful for

ventilation when it is fully opened. Also for a three bay sliding window, only two bays would be available for ventilation when opened fully.

With the louvered window, they can be described as having many bays but this time horizontal. They allow in more air since they don't slide behind one another but rather rotate about their pivots to open up more space for ventilation. The efficiency of the louvered window with respect to ventilation is 90% thus it is recommended for more effective natural ventilation.

Depth of building.

Natural lighting in a room loses its effectiveness beyond a distance of 5metres from the opening through which light is being emitted. Likewise there are cases where a building is so deep that there are inner rooms which do not receive direct ventilation or lighting from outside the building. In these rooms or spaces, there is great discomfort if the lighting and ventilation is not supplemented which would further increase the running cost of the building.

There are however, several creative ways of solving this problem and it comes down to a matter of design. The most commonly used approach is the use of the **courtyard**, which can either be opened at one side or closed on all sides. Over here, the courtyard which is open to the sky ventilates and lights the core of the building whilst the perimeter rooms are naturally catered for by virtue of their location.

The **light well** is also another way of solving problems associated with deep buildings. This is very similar to the courtyard but in this case, the space left in the core is not as big as that of the courtyard. The light well is often purposely for lighting and ventilation without any dual use of being a place for any social activity.

An example of this has been illustrated in the Echlin Street Terrace Apartment in chapter four.

Alternatively, one may use a plan shape like the “plus” sign or the “L” shape since they avail a lot of the building to the immediate environment. They allow more of the building access to natural light and fresh air. Modules of these shapes could be used in many creative ways to do away with the effects of deep buildings as well as achieving an aesthetic masterpiece.

Thermal properties of materials for construction.

The thermal properties of a material describes how a material behaves when it is subjected to heat. It talks about how they gain, retain or give off heat.

In our effort to produce cooler rooms, it will be in our interest to use materials that don’t easily transmit heat into the room or in other words materials with a high heat resistance. The list of some common building materials has been listed in Table 2.2 R-VALUE FOR TYPICAL BUILDING MATERIALS. This table gives information on the thermal properties of building materials and thus helping to make inform decisions with respect to an expected temperature condition in a room.

5.0.4 AFFORDABILITY OR COST REDUCTION OF BUILDING DESIGN

Optimisation of the use of space

With respect to cost reduction in construction, every unit area is accounted for financially. The larger the area, the more material and labour to be used. Thus all spatial dimensions are the barest minimum that provides ***comfort***. The minimum spatial requirements for residential buildings are spelt out in the

National Building Regulations of Ghana 1996,

Shape of building

Generally, simpler shapes cost less to build than more complex shapes, this is because, the longer, narrower or more complicated or irregular a shape gets, the higher the perimeter/floor ratio and in effect the higher the unit cost.

Irregular outlines yield increased costs for the other reasons such as increased setting out costs, increased cost for site works, drainage works which tend to be more complicated and thus more expensive. The wall to floor ratio gives an indication of the planning efficiency of buildings. This is calculated by dividing the external wall area (with windows and doors) by the gross floor area. This ratio can be used to compare different plans. In general, the lower the wall /floor ratio, the more economical a design proposal is.

Standardisation or dimensional and modular –co-ordination

There are standard sizes of prefabricated building components on the market and due to their mass production, there is a cost benefit. It will be very costly if every component of the building has to be customised or purposely made for that particular design. The prefabricated building component come in regular sizes and shapes such that, they are easily manipulated to suit almost every design situation. For example floor tiles come in standard sizes, so multiples of these sizes must inform the area of the floor to ensure that most of the tiles would fit on the floor with minimum cutting and wastage.

Also, there are standard window sizes, doors etc. . and when these are used , it reduces the number of skilled operatives needed on site, improves the quality of the

product, and reduces the time taken to complete operations. This however has financial implications which have to be taken advantage of.

Storey heights

Although variations in storey heights do not change the floor area, they alter the cost of buildings. The major elements in the building affected by changes in storey height are walls and partitions and their related finishes and decorations. Other possible changes arising variations in storey height include:

- An increase in volume to be heated or cooled which would require larger heat/cooling sources and increased pipe work or cables.
- Longer service pipes and waste pipes to sanitary appliances.
- Costs to hoist roof members into place may be increased.
- Staircases and lifts (where available) will cost more to build.
- Ceiling finishing and decorations may cost more to apply.
- In some cases, substantial increase in storey height may result in increased foundation costs to support the additional load.

5.1 CONCLUSION

The housing scheme will create a vision for housing development in Ghana so that government and corporate bodies will find it worthwhile to invest in housing development in Ghana.

It is also to improve the quality of life of the average Ghanaian since it does not only cater for his spatial needs only but also his economic, socio-cultural and mental well

being. This will in effect enable the average Ghanaian to give out his maximum output as a contribution to the development of mother Ghana.

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APPENDICES

APPENIX A

HFC REQUIREMENTS,TERMS AND CONDITIONS

REQUIREMENTS FOR HOME PURCHASE MORTGAGE LOAN (FCL)

APPLICATION

- A completed and signed HFC Bank Mortgage Application form
- Processing Fee ($250.00 OR £150.00)
- Offer Letter from Real Estate Developer or Vendor

IDENTITY

- 1 passport size photograph
- Personal Reference Form
- Proof of Relationship(If Joint application)
- Power of Attorney (must be witnessed by a Notary Public)

INCOME VERIFICATION

SALARIED EMPLOYEES

- Confirmation of Income and employment from your employers
- The latest three (3) salary slips/pay stubs showing all deductions.

SELF-EMPLOYED APPLICANTS

- Last 3 years certified audited accounts or last 3 years copies of individual income tax returns.
- Business profile
- Last 12 months Bank Statements if not an HFC Bank Customer.

CREDIT HISTORY

- Credit report from a recognized credit bureau or credit reporting agency.
- 12 months copy of Bank Statements if not HFC Customer.
- May open a Homesave Account with a minimum of USD500 or GBP200.

DOWN PAYMENT

- Minimum deposit or down payment of 20% of the total cost of the property.

IF BUYING FROM A PRIVATE VENDOR

- Add a Valuation Report (to be done by an HFC Bank recommended Valuer)

HFC BANK HPM-FCL - Updated December 15, 2009

CONDITIONS TO BE FULFILLED AFTER APPROVAL

1. Submission of signed facility letter (indicating acceptance of our terms and conditions)
2. Mortgage Protection or Life policy (to cover loan amount granted)
3. Hazard policy (to cover the value of the property)
4. Submission of original title documents if buying from a private vendor.
5. Payment of facility fee (1% of loan amount)
6. Payment of a legal deposit (GH¢1,500.00)
7. Payment of Stamp Duty on title document (1% of property price)
8. Payment of Stamp Duty on Mortgage Deed (0.05% of loan amount)
9. Payment of a title search fee of GH¢100.00
10. Property valuation fee of GH¢225.00
11. Pre-disbursement meeting with HFC Home Loans Advisor and the signing of the mortgage deed.
12. Disbursement of approved loan amount
13. Commencement of mortgage loan repayment (by the 25th day of the month after disbursement)

HFC BANK HPM-FCL - Updated December 15, 2009

EMPLOYER'S CERTIFICATION OF INCOME

Please return to: [ ]

HFC BANK (GH) LTD
P. O. BOX CT 4603
CANTONMENTS
ACCRA

[Affix Certificate & Seal of Notary Public Here]

Date:

Dear Sirs:

Your employee named herein has applied to us for financial assistance. In order to facilitate his/her getting a loan from us, you are kindly requested to complete PART II of this form and return it to us.

PART I: REQUEST (TO BE FILLED BY APPLICANT)

I have applied for a loan from HFC Bank (Gh) Ltd and have stated that I am now employed by you. My signature below authorises verification of information in respect of my employment.

Name of Applicant	Employee No. (if any)	Department	Signature of Applicant
.....	.....	.....	.....

PART II: VERIFICATION OF PRESENT EMPLOYMENT (TO BE FILLED BY EMPLOYER)

EMPLOYMENT DATA		ANNUAL PAY DATA	
1. Applicant's		1. Basic Pay:	
(a) Date of birth:		2. Other Income:	
(b) Qualification:		Commission:	
(c) Date of joining:		Mortgage Subsidy:	
2. Present Designation		Sub-Total	
3. Is employment permanent?		Deductions	
4. Does Applicant qualify for mortgage subsidy?		1. Tax:	
		2. Social Security:	
		3. National Insurance:	
		4. Other:	
		Net Salary	

DECLARATION:

1. We the employers of the above named..... certify that the above details relating to employment and the emoluments thereof are correct and accurate.

2. We consider..... to be honest and trustworthy and do not think he/she will enter into any obligation, which he/she cannot keep.

Signature and Stamp of Employer **Date**

HFC BANK (GHANA) LIMITED
MORTGAGE APPLICANT'S PERSONAL REFERENCE FORM

NAME OF APPLICANT (S): _____ **CONTACT TEL. NO._____**
Please provide at least three relatives and two friends Resident in Ghana **E- MAIL: _____**

NAME	ADDRESS (Please provide complete location address with popular landmarks)	OCCUPATION	RELATIONSHIP	PHONE & FAX NUMBERS
	Home:			
	Business:			
	Home:			
	Business:			
	Home:			
	Business:			
	Home:			
	Business:			
	Home:			
	Business:			

I/We do hereby certify that the information given above is true and accurate.

Signature: _____

POWER OF ATTORNEY given on_____day of _____2010, by

_____(hereinafter called "the Principal (s)")_____

WHEREAS:

1. I/We have been in purchase/refinance/completion/remodeling etc., of a house payment of which shall be made by a loan facility granted me/us by **HFC BANK (GHANA) LIMITED** (hereinafter called "HFC") secured by way of legal mortgage of the said House-----

2. I/We, the said Principal(s) living and working in _____appoint

_____as my/our Lawful Attorney

of Post Office Box _____Tel: _____(Office),

_____(Res), (hereinafter called "the Attorney") to conclude the said contract to purchase a house or refinance/complete/remodel it etc., through a mortgage, execute all title documents, execute a mortgage and charge thereon to HFC and take charge, manage and improve the said property-----

NOW THIS DEED WITNESSETH that I the said Principal hereby appoint the said

to be my/our lawful attorney to do and execute for me/us and in my/our name all acts matters and things that may be necessary in order to complete the said mortgage loan facility and mortgage charge on the property and in particular the following:

1. To enter into any undertaking subject to contract for the finance of the purchase/ refinancing/completion/re-modelling etc. of the said property----

2. To sign on behalf of the Principal(s) the contract and all undertakings for such Mortgage Loan----

3. To sign and seal as my/our act and deed deliver any deed or instrument in writing and to do every other thing whatsoever which may be necessary or proper for carrying the contract or any agreement necessary to complete the purchase/refinancing/completion/remodeling etc. of the property-----

4. To raise and borrow from HFC Bank (Ghana) Limited upon such terms as to repayment and payment of interest and generally as my/our Attorney shall think fit all monies necessary to effect the purchase of the property upon the security of the said premises and to give valid receipt for the same----

5. For the purpose of security repayment of the sum as borrowed with interest as aforesaid to sign and seal and as my/our act and deed deliver such mortgage of or charge upon the said premises and with and subject to all such covenants powers and stipulations as my/our Attorney shall think necessary or proper----

6. To pay all taxes rates charges expenses and other outgoings whatsoever payable by me/us for or on account of my/our said property or any part thereof and to insure any building thereon against loss or damage by fire and to pay all premia for such insurances---

7. At the request of **HFC** to do all such acts and deeds and effect all such payment as may be required to more perfectly secure my/our property to **HFC**----

AND I/WE the said Principal(s) hereby declare that all and every receipt deed matters and things which shall be given made executed or done by the said Attorney for the aforesaid purposes shall be as good valid and effectual to all intents and purposes whatsoever as if the same had been signed sealed delivered given or made or done by me/us in my/our goodself/goodselves----

AND I/WE hereby undertake at all times to ratify whatsoever my/our said attorney shall lawfully do or cause to be done in or concerning the purchase, refinance/completion/remodeling etc., and mortgage and management of the property by virtue of this POWER of Attorney-----

IN WITNESS WHEREOF the said has executed this Power of Attorney the day and year first above written-----

SIGNED SEALED AND DELIVERED }
by the within named } .....
in the presence of : }

Notary Public:- Name:

Signature:

Approved Seal:

HFC BANK (GHANA) LTD

MORTGAGE APPLICATION FORM

HFC BANK
'EBANKESE' #. 35, SIXTHTH AVENUE,
NORTH RIDGE, ACCRA
P. O. BOX CT4603, CANTONMENTS,
ACCRA, GHANA

T: 233 0302 242090-4
F: 233 0302 242095
e: hfcomp@hfcbankgh.com
www.hfcbank.com.gh

AFFIX RECENT PHOTOGHRAPH OF APPLICANT WITH SIGNATURE	AFFIX RECENT PHOTOGHRAPH OF CO-APPLICANT WITH SIGNATURE

CURRENCY	
CEDI/GH¢	❒
DOLLAR/$	❒
OTHERS:	❒

HFC INVESTMENT ❒ Unit Trust ❒ Equity Trust ❒ Other

HFC ACCOUNT NO:

TYPE OF MORTGAGE REQUESTED, PLEASE CHECK ONE

1. Home Purchase ❒ 2. Home Completion ❒ 3. Home Equity ❒ 4. Home Improvement ❒ 5. Other ❒

PERSONAL INFORMATION OF APPLICANT (S)

Applicant				Joint Applicant			
Surname		First Name		Surname		First Name	
Other Name				Other Name			
Marital Status	❒ Married	❒ Single	❒ Separated	Marital Status	❒ Married	❒ Single	❒ Separated
	❒ Divorced	❒ Widow	❒ Widower		❒ Divorced	❒ Widow	❒ Widower
Identitication Document:				Identitication Document:			
Identitication Number:				Identitication Number:			
Residential Address :				Residential Address :			
Mailing Address :				Mailing Address			
Educational Qualification:				Educational Qualification:			
Tel No.(Residence)		Fax:		Tel No.(Residence)		Fax:	
Mobile Phone No:		Office No.		Mobile Phone No:		Office No.	
E-mail:				E-mail:			

Business Telephone No.		
Shareholding in Business	%	%
Nature of Business		
Length Of Current Employment/Business		
Name and Address of Accountant if Self-Employed		
Telephone Number		
Please Provide Employment/ Business History over last 3 years (use separate sheet if necessary)		

	Applicant	Joint Applicant
Previous Employment		
Previous Occupation		
Previous Employment/Business name		
Telephone Number		
Shareholding in Business		
Nature of Business		
Length of Previous Employment/Business		

BANK DETAILS

Applicant	Joint Applicant
Name and Address of Bank (If not HFC Bank)	
Branch	
Telephone Number	
Account Number	
How long has account been at this bank	

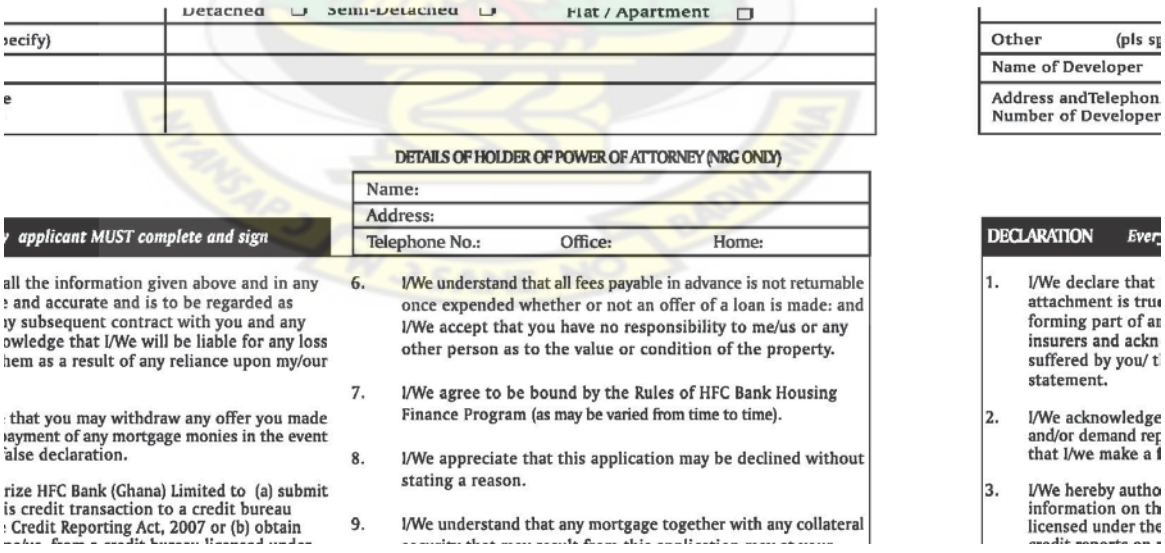
FINANCIAL INFORMATION

Monthly Income:	Applicant	Joint Applicant
Basic Wage/Salary		
Commission / Allowances		
Mortgage /Rent subsidy		
Other income		
Sub Total		
Deduction: Tax		
Social security / provident fund		
Net Salary		

STATEMENT OF NETWORTH

ASSETS		LIABILITIES	
Tpye of Asset (including investmems)	Value (in Cedis)	Type of Liability	Value (in Cedis)

DETAILS OF PROPERTY UNDER THIS APPLICATION	
Location of Property (Address)	
Region	District :
Purchase price / Open Market Value	Loan Amount Required :
Down Payment Amount	If no down Payment Specify Sheme :
Is Property	Freehold ❐ Leasehold ❐ in the course of construction (new) ❐
	Owner Occupied ❐ Investment Purposes ❐
No. of Unexpired Years:	Yrs. Plot Size: 80 x 100 ❐ 70 x 80 ❐ Other ((specify) :
Property Type	
One Storey	2-bedroom ❐ 3-bedroom ❐ 4-bedroom ❐ Other ((specify) :
	Detached ❐ Semi-Detached ❐ Flat / Apartment ❐
Two Storey	2-bedroom ❐ 3-bedroom ❐ 4-bedroom ❐ Other ((specify) :



Detached ❐ Semi-Detached ❐ Flat / Apartment ❐

ecify)

e

Other (pls sp

Name of Developer

Address andTelephon
Number of Developer

DETAILS OF HOLDER OF POWER OF ATTORNEY (NRG ONLY)

Name:

Address:

Telephone No.: Office: Home:

applicant MUST complete and sign

all the information given above and in any
and accurate and is to be regarded as
y subsequent contract with you and any
owledge that I/We will be liable for any loss
hem as a result of any reliance upon my/our

that you may withdraw any offer you made
ayment of any mortgage monies in the event
alse declaration.

rize HFC Bank (Ghana) Limited to (a) submit
is credit transaction to a credit bureau
Credit Reporting Act, 2007 or (b) obtain

6. I/We understand that all fees payable in advance is not returnable once expended whether or not an offer of a loan is made: and I/We accept that you have no responsibility to me/us or any other person as to the value or condition of the property.

7. I/We agree to be bound by the Rules of HFC Bank Housing Finance Program (as may be varied from time to time).

8. I/We appreciate that this application may be declined without stating a reason.

9. I/We understand that any mortgage together with any collateral

DECLARATION Ever

1. I/We declare that attachment is tru forming part of a insurers and ackn suffered by you/ t statement.

2. I/We acknowledge and/or demand rep that I/we make a

3. I/We hereby autho information on th licensed under the

Source: HFC BANK GHANA LIITED, Ebankese,Accra

APPENDIX B

DESIGN THESIS-ENERGY EFFICIENT AFFORDABLE HOUSING,KROBO ODUMASE – ACCRA.

Figure 5.24 Layout of neighbourhood

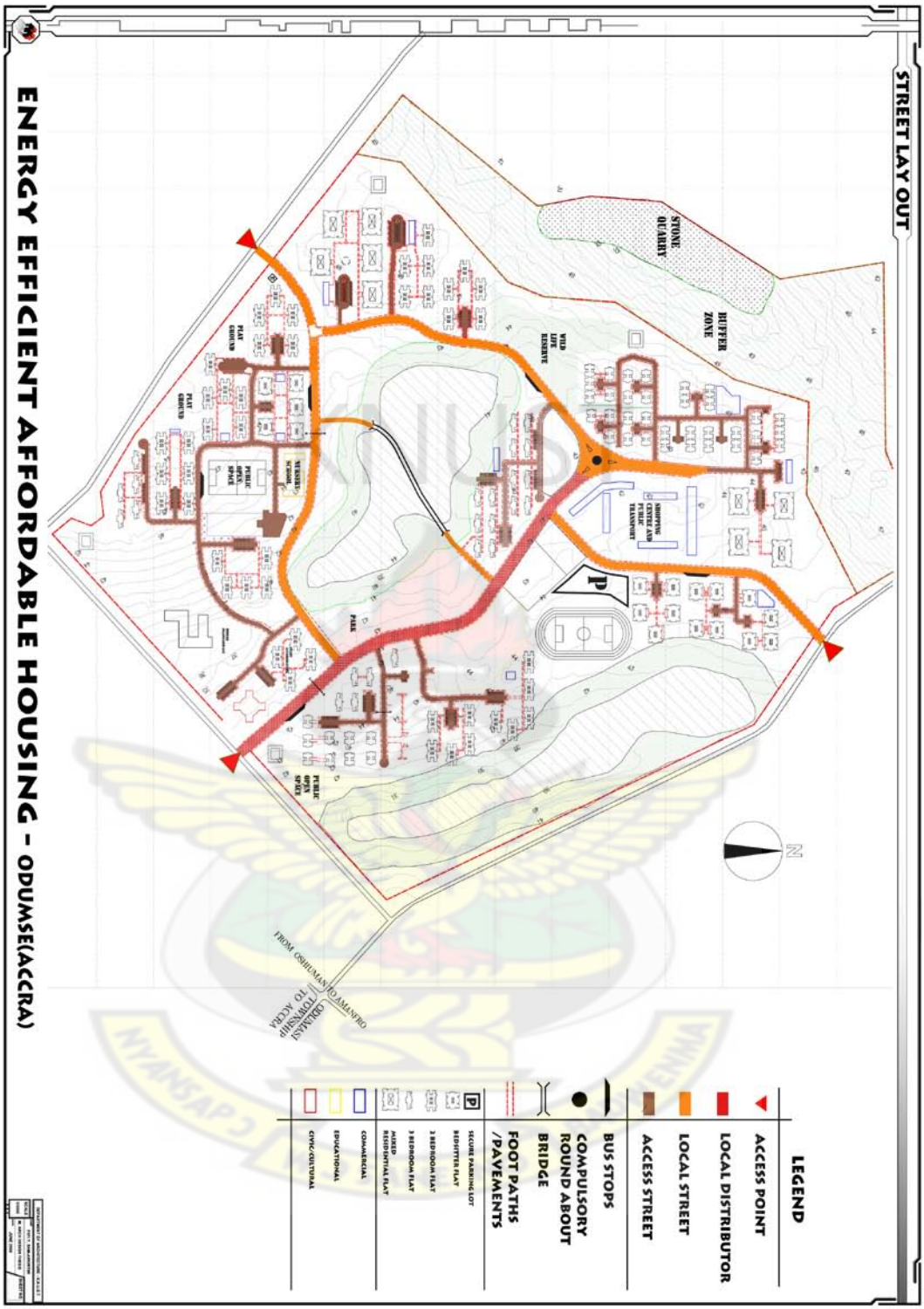


Figure 5.25 Street Layout of Neighbourhood.

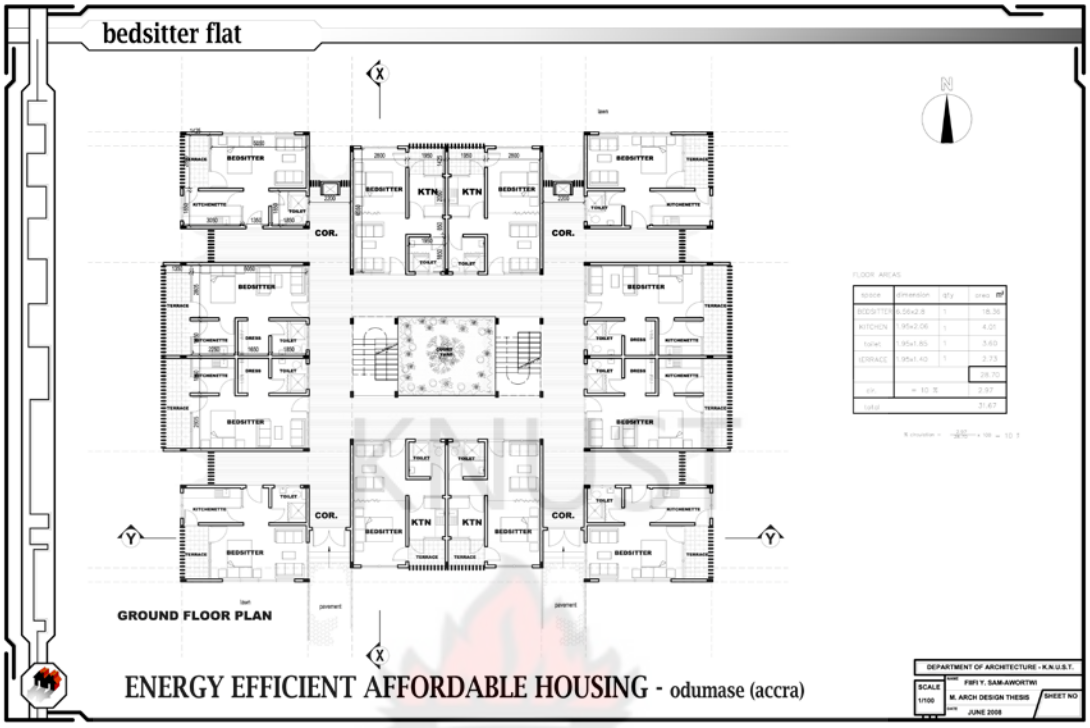


Figure 5.26 Floor Plan of Bedsitter Flat

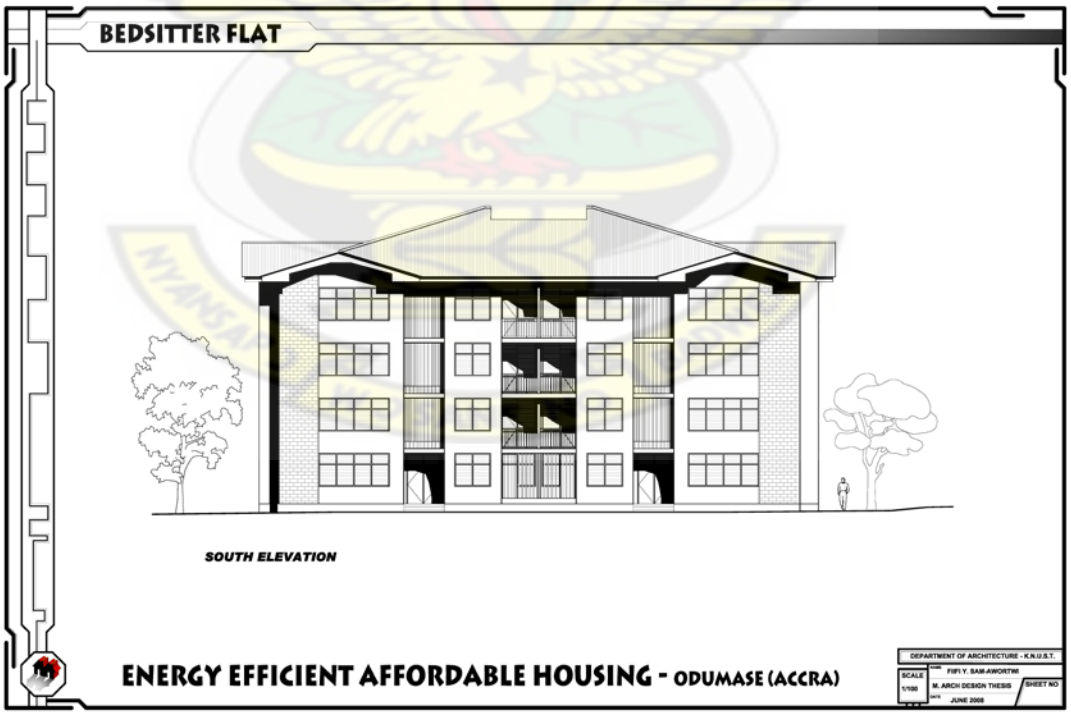


Figure 5.27 Elevation of Bedsitter Flat

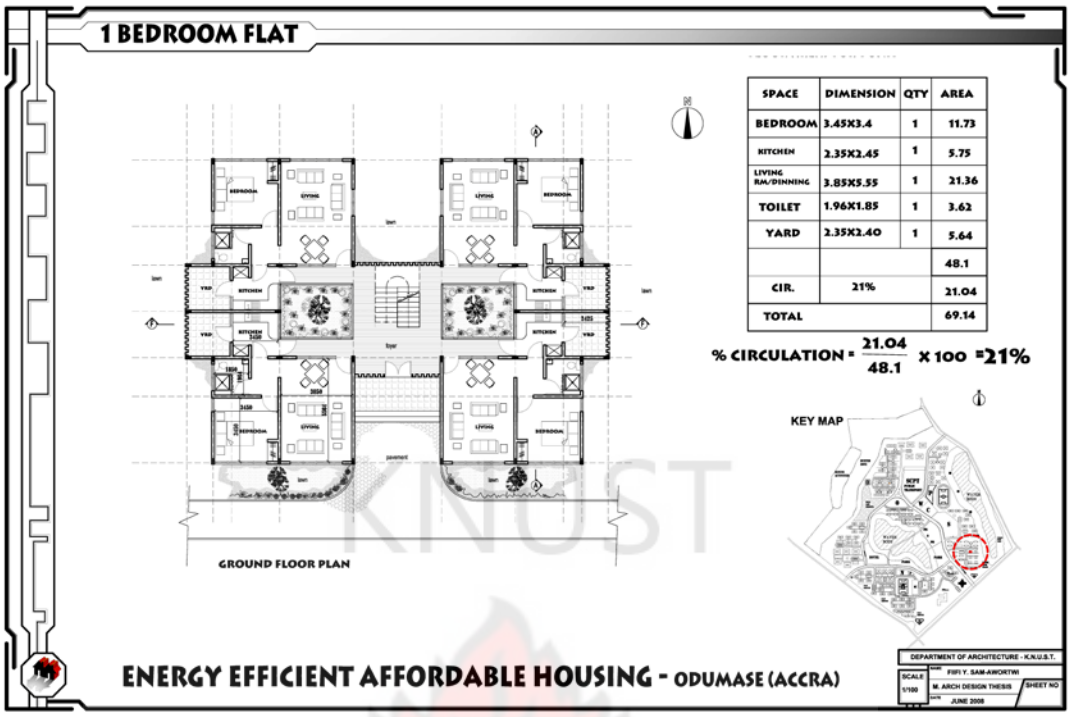


Figure 5.28 Ground Floor Plan of 1Bedroom Flat

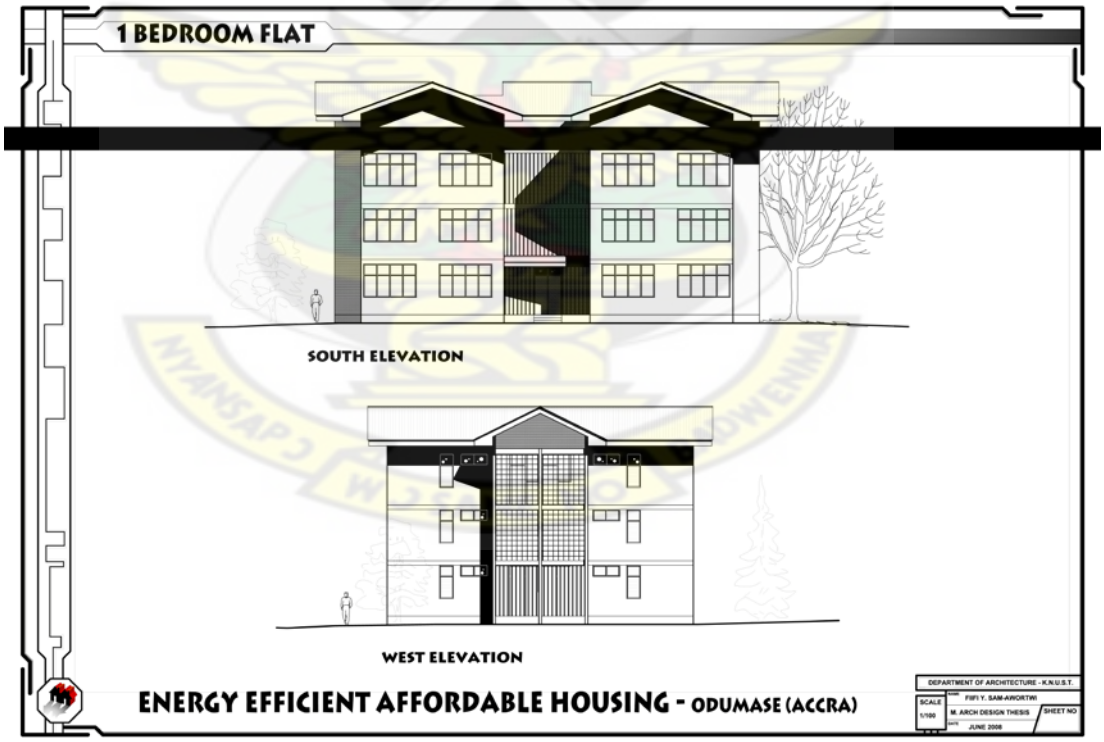


Figure 5.29 Elevations of 1 Bedroom Flat

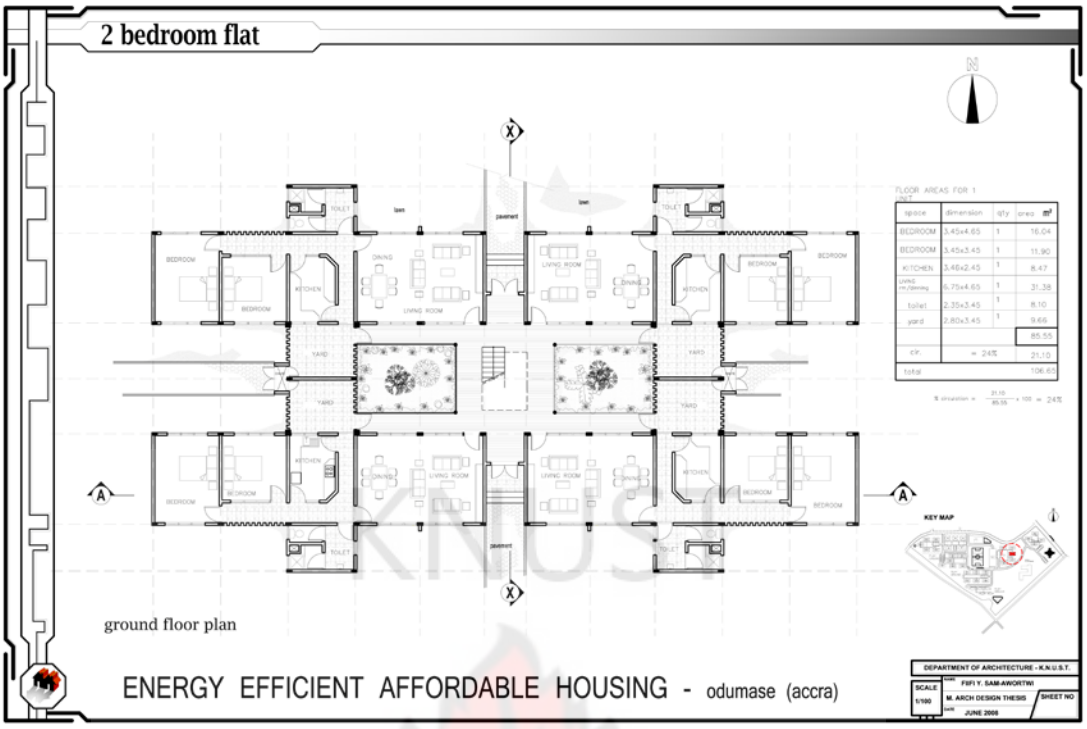


Figure 5.30 Floor plan of 2 Bedroom Flat

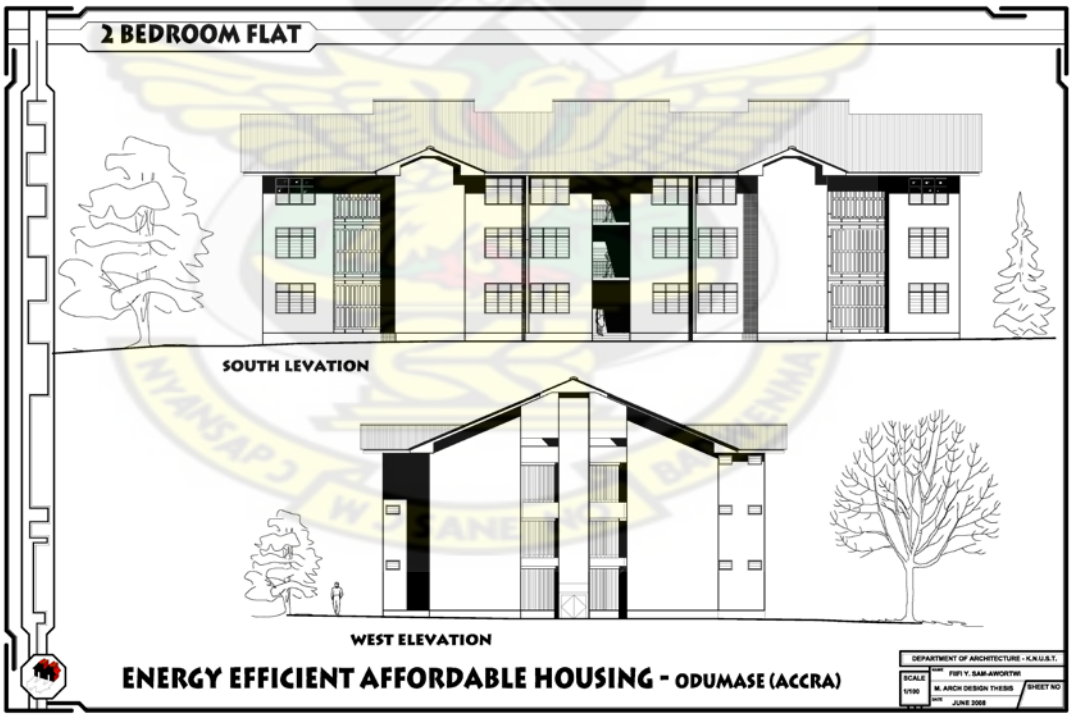


Figure 5.31 Elevations of 2 Bedroom Flat

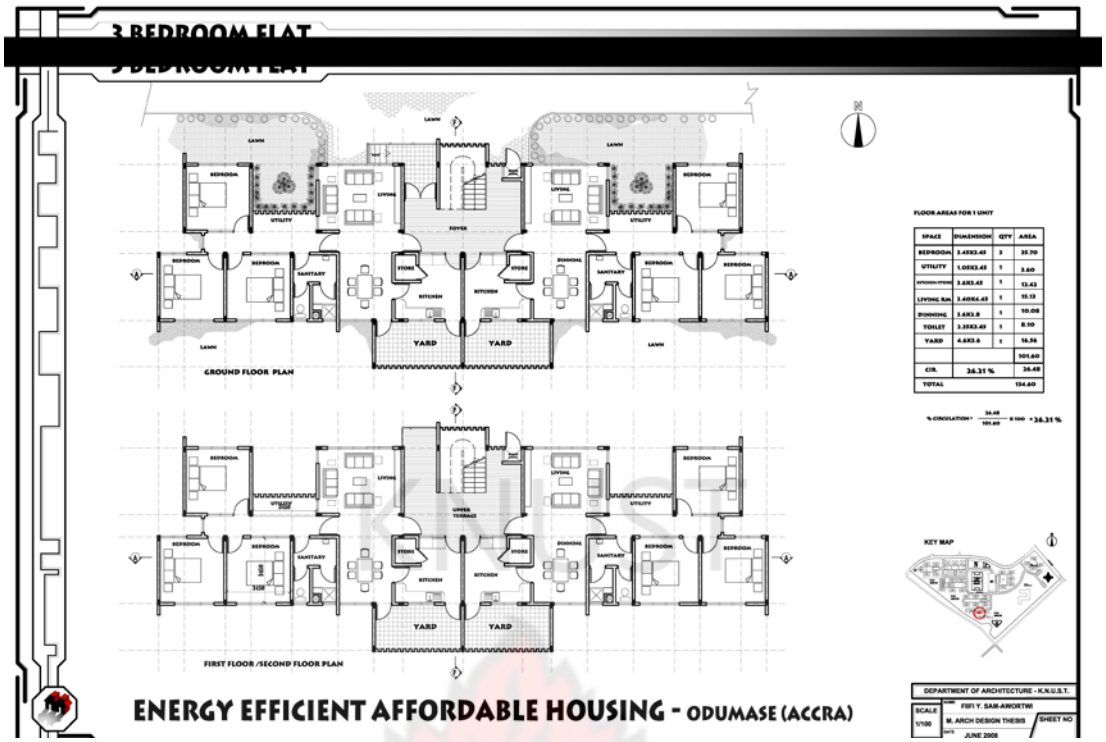


Figure 5.32 Floor Plans of 3 Bedroom Flat

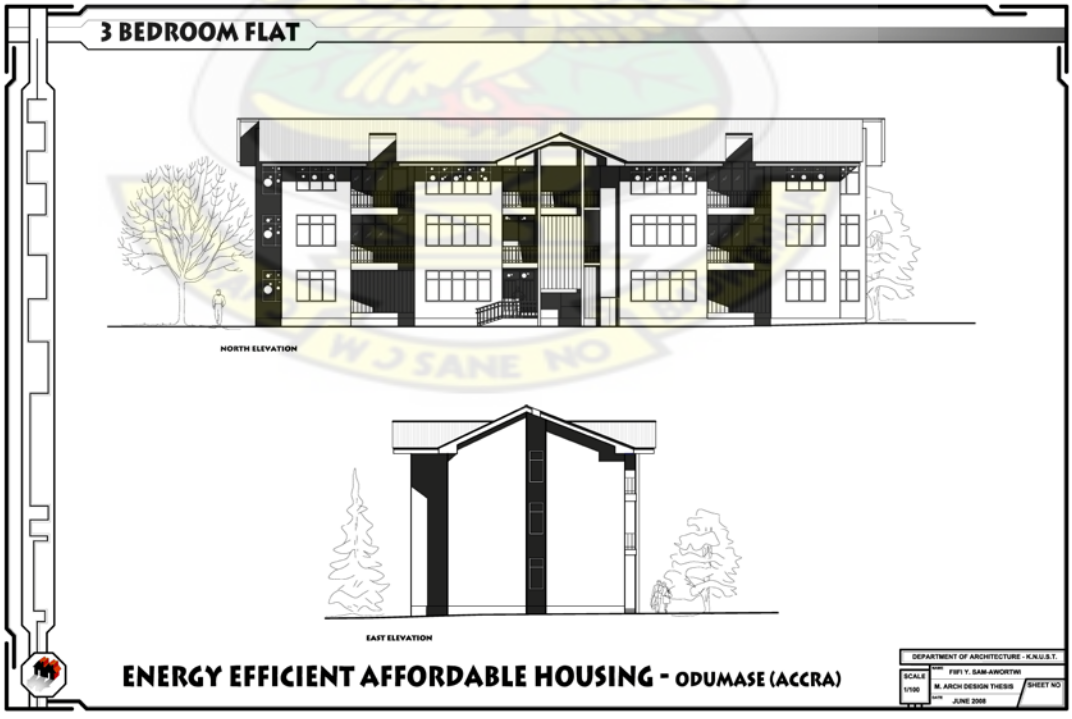


Figure 5.33 Elevations of 3 Bedroom Flat

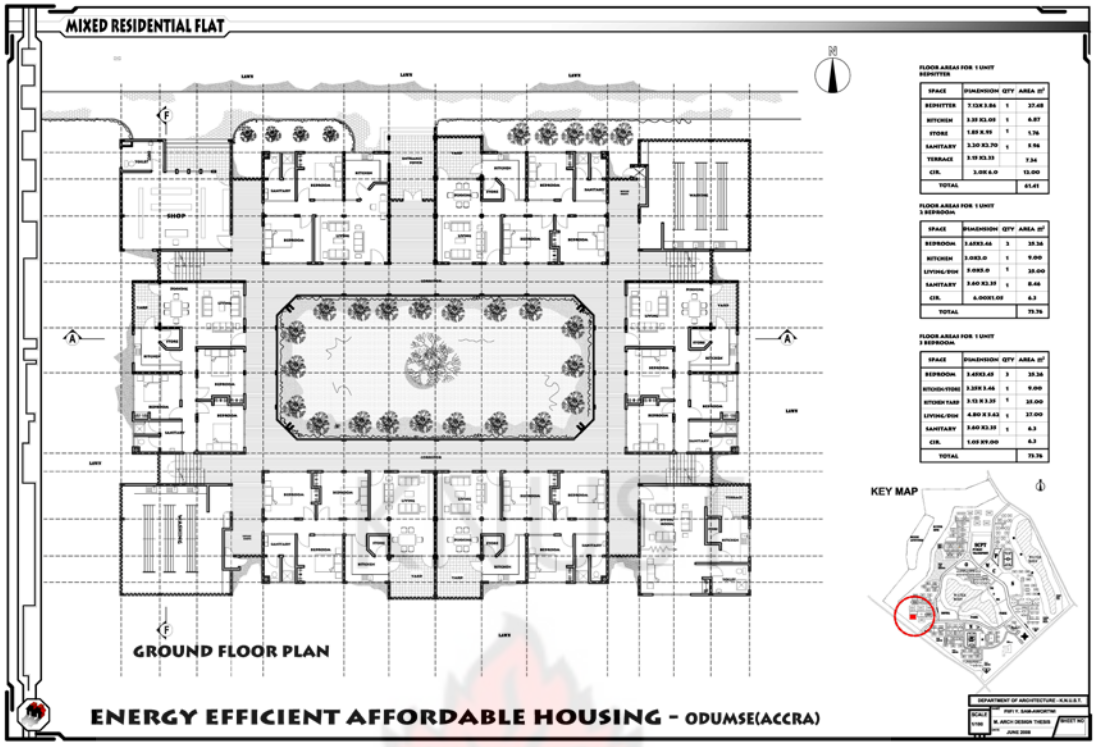


Figure 5.34 Floor Plan of Mixed Residential Flat

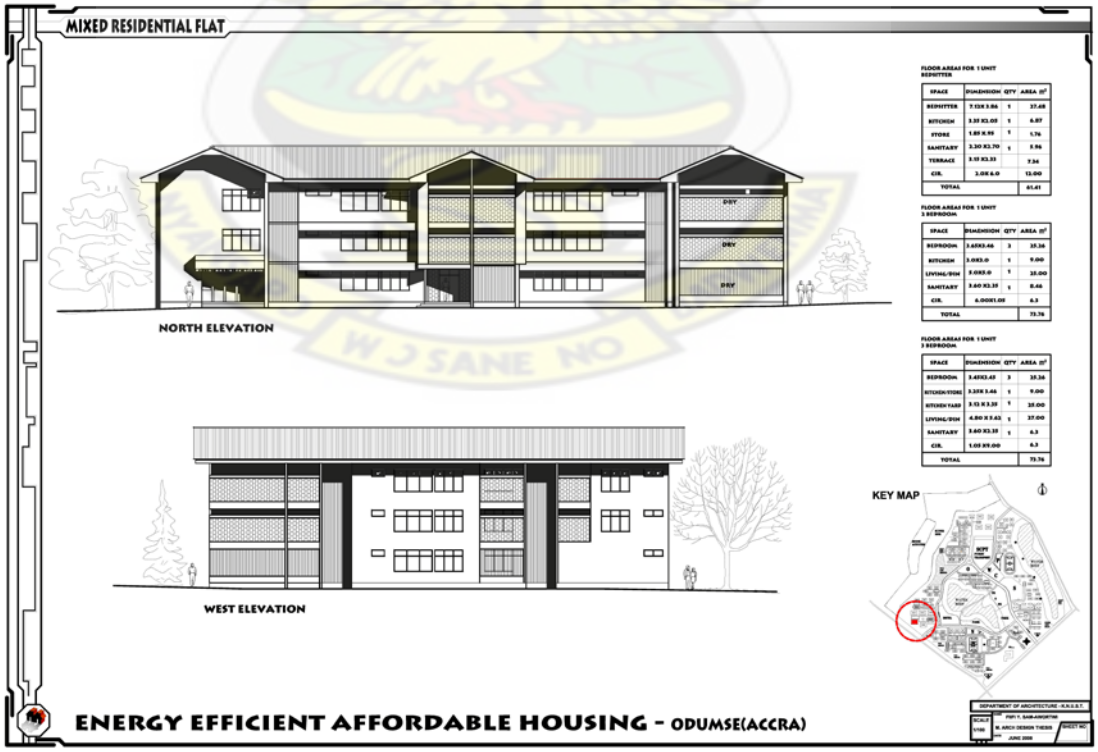


Figure 5.35 Elevations of Mixed Residential Flat

Figure 5.36 View from quadrangle-bedsitter flat

Figure 5.37 View from parking area- 3 bedroom flat

Figure 5.38- View from courtyard- mixed residential

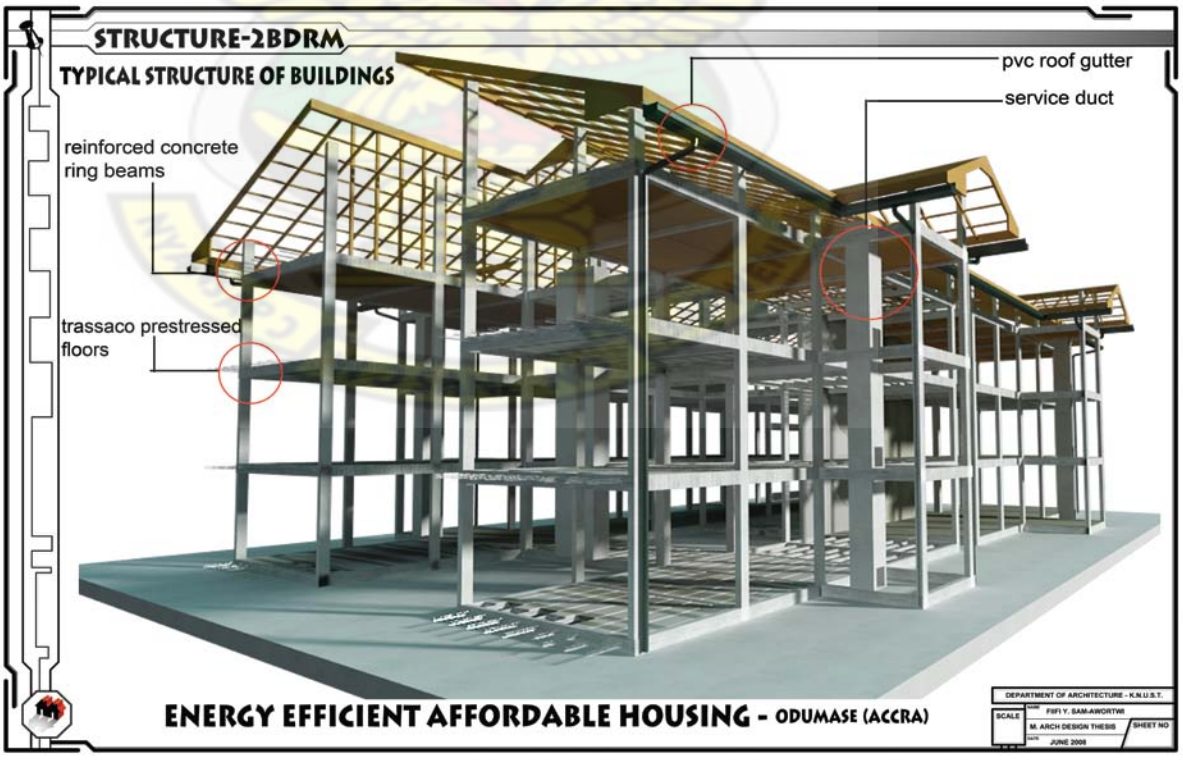


Figure 5.39 Typical structure of building

Figure 5.40 Typical detail of floors and walls

Figure 5.41 3D impression of site layout