EVALUATING ENERGY EFFICIENCY IN THE DESIGN OF LARGE SCALE OFFICE BUILDING IN HOT-DRY CLIMATE OF NIGERIA.

BY

RUTH KAHU

DEPARTMENT OF ARCHITECTURE

AHMADU BELLO UNIVERSITY, ZARIA

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DEPARTMENT OF ARCHITECTURE,

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DECLARATION

I declare that the work carried out in this thesis entitled "EVALUATING ENERGY EFFICIENCY IN THE DESIGN OF LARGE SCALE OFFICE BUILDING IN HOT-DRY CLIMATE OF NIGERIA" has been carried out by me in the Department of Architecture. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree or diploma at this or any other institution.

RUTH KAHU	_____	_____
Name of Student	Signature	Date

CERTIFICATION

This thesis entitled "EVALUATING ENERGY EFFICIENCY IN THE DESIGN OF LARGE SCALE OFFICE BUILDING IN HOT-DRY CLIMATE OF NIGERIA" by RUTH KAHU, meets the requirements governing the award of Masters Degree in Architecture of the Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

Chairman, Supervisory Committee Dr. M.L Sagada	Signature	Date
Member, Supervisory Committee Arc. M.H. Mukhtar	Signature	Date
Head of Department Dr. M.D. Ahmed	Signature	Date
Dean, School of Postgraduate studies Prof. H.A. Zoaka	Signature	Date

DEDICATION

This research is dedicated to God Almighty, from whom grace and strength for all things are provided, and to my loving parents who allowed themselves to be used by God to provide all my needs from the beginning till this very moment, may God continue to bless you and may you eat the fruit of your labour.

Thank you very much Rev. Zachariah Katoh for also allowing yourself to be used by God to bless my life, may God bless you and your family abundantly. Thank you.

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ABSTRACT

This research sought to improve the level of energy consumption in large office buildings through improved technological installation of efficient appliances and passive design in order to reduce the negative impact of buildings to their physical environments. Energy efficiency during the buildings operational period may be achieved through passive means by incorporating natural features like day light, air circulation, and so on, this is because the main cause of energy consumption in a functional building are those building components used to ensure the comfort of the users and the functionality of the building in general. These components are strongly related to the natural features mentioned.

The methodology employed is computer simulation , case studies were carried out (in which one was simulated), and relevant information sourced from pertinent literature and the internet were done. In the course of the research, the building was designed to maximize the use of passive elements such as daylight, air flow, sun light, and so on. Based on computer simulation, the proposed design was able to achieve about 76% energy reduction as compared with the simulated case study. The principle of energy efficiency should be considered since it makes sure that greenhouse gas emission is reduced, this was achieved by more of soft landscape so as oxygen is increased around the site thereby creating a microclimate around the site.

Table of Contents

Contents **Page**

CHAPTER THREE:

CHAPTER FOUR:

CHAPTER SEVEN:

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

CHAPTER ONE

INTRODUCTION

1.1 Background of Study

Energy is a vital resource that helps in everything we do; it is one of the most important sources of every country's development. Energy empowers agricultural, commercial, industrial, domestic and official activities in both developing and developed countries of the world. To lessen the problem of poverty of a country, energy has to be provided to its citizens; this is the fundamental step when embarking on its growth and development.

The usage of energy mostly depends on what region or climate its being used and the appliances that use it. If the region is hot and dry, effort to achieve thermal comfort is a paramount issue. Designers often make sure that reasonable amount of indoor air quality are been attained to maintain user's comfort. But then some building sectors consume energy more than others. Sadrzadehrafiei et al (2012) asserted that office buildings consume a great deal of energy; they consume about 70-300KWh/m^2 of energy which is 10-20 times higher than residential sector.

Offices use-up energy mostly for lighting, air-conditioning, refrigerating, cooling and heating, computing, printing, photocopying, and so on. Mohsen (2011) highlighted a 2006 study by Centre for Environmental Technology and Development (CETDEM) Malaysia, He stated that, air-conditioning and refrigerator take up nearly 70% of the average electricity consumption and air-conditioning happens to be the largest consumer, see figure 1.1.

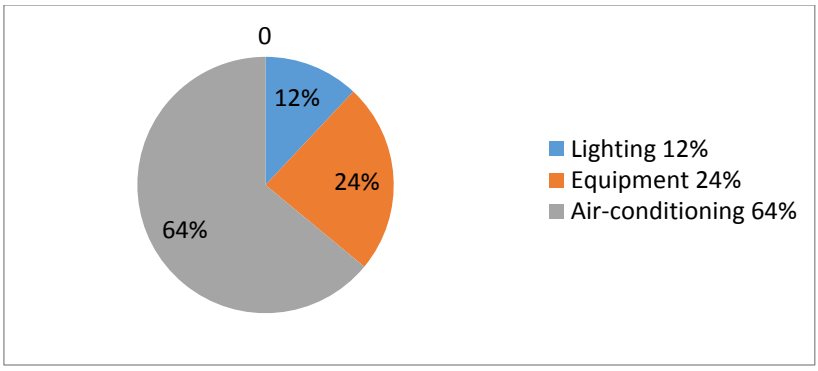


Figure 1.1: Office buildings electricity consumption – Source: CETDM, 2006

Energy performance of buildings is an important issue to building owners because it transmutes to cost. Energy efficiency does not mean that the use of energy is eliminated, it simply implies that the quantity of energy needed for the provision of services will be utilized in a way that minimizes its usage. Power-switch (2005) defined energy efficiency as the decrease of the specific energy consumption; it is the key to high thermal comfort as well as very low energy cost. This induces an excellent insulation that makes it possible not only to reduce the energy requirement just a little bit but to substitute the main part of the demand.

The supply of energy in Nigeria has not been able to meet up with the demand, hence the cost of providing alternative energy supply is an utmost concern; most organizations provide stand-by generators, uninterrupted power supply (UPS) and inverters because a lot of energy is needed to achieve a conducive environment for users in order to be productive.

The inadequate energy supply led to the need for alternative energy supply, its generation also led to the emission of greenhouse gases to the environment. Thus, the need to incorporate energy efficiency is a necessity since it reduces the need for fossil fuels (oil and gas) and would thereby improve not only environmental quality but also national security.

1.2 Problem Statement

The Power Holding Company of Nigeria (PHCN) has over the years provided its inhabitants with inadequate supply of electricity. This has made buildings especially offices to fall back on alternative sources of energy (such as generators and inverters) which increases their running cost. This also harbors other negative effect such as air pollution and noise pollution. Buildings in Nigeria are mostly poorly designed in terms of utilizing passive design strategies, for instance some office buildings lack enough illumination to be functional within the day and end up using artificial means, also offices becomes too hot due to excess solar heat gain and require alternative cooling method such as HVAC.

Energy efficient design strategies are a cost effective measure for buildings in respect to daylight and thermal comfort.

1.3 Aim and Objectives

This research aimed at evaluating the level of energy usage in existing large scale office buildings in the hot and dry tropical region of Nigeria, and to propose design strategies that can minimize energy consumption.

To achieve the aim, the following objectives were pursued:

i. Identification of the basic principles/strategies in achieving energy efficiency in office buildings.
ii. Assessment of the level of energy efficiency in office buildings in Nigeria particularly in the hot and dry climate.
iii. The use of computer simulation of a large scale office building in order to know the energy consumption as a means of comparison.

iv. The design proposal of an energy efficient large scale office building taking into consideration the principles that capture energy efficient designs for the hot-dry tropical climate.

1.4 Scope And Delimitation Of The Study

The research took place around the hot and dry tropical region of Nigeria, this is a climate that is portrayed by a long dry season (and subsequently a brief rainy season) accompanied with cold and dry harmattan wind, high temperature range (due to hot afternoons and cold nights) and intense sunlight. This region covers the savannah region (grassland), highland region (plateau) and semi-desert region. It comprises of towns like Abuja, Minna, Zaria, Yola, Maiduguri, Kano, Sokoto, Yelwa, Kaduna, Katsina, Nguru and other mountainous regions along the Cameroonian border. The areas are accompanied with cold nights and hot days alternate for six to ten months of the year, and characterized by moderate or low amount of rainfall. Hot and humid conditions are experienced during one or two months.

A large scale office building is a building that is 1000m^2 and above.

The research was delimited to the design of an energy efficient large scale offices for hot-dry tropical climate in Nigeria.

1.5 Justification

This research was able to identify the strategies to a cost effective office building in the tropics as a means to know the percentage reduction realized from intended cost of an office construction. This in so doing will serve as a means to help owners and design teams to consider energy efficient measures and sustainable strategies from the moment the decision to construct an office is made.

The need to reduce cost in office building's energy consumption rate is a big issue due to the fact that it helps reduce energy bills, it frees up money that can be spent elsewhere in the economy. Hence, this research is set to lay down standards for cost-effective measures and some major sustainable strategies to an advance office design. This was done to contribute to educational practice which can be revised, can extend and create new knowledge.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Nigeria is a developing country that aims at developing in sustainable manner. Sustainability allows to develop by meeting the needs of present and yet take into consideration and allowance of the needs of the future generations. (Kates et al., 2001; Lafferty, 2004). Therefore the utilization of energy is meant to be efficient, sensible and wise so that the purpose of sustainable development will become manifest.

The most appropriate approach is embraced by means of the application and understanding of thermal comfort, human behavior and energy utilization behavior of buildings. Recently, the level of energy consumption has increased owing to the substantial growth of the building industries; hence, it is important for Nigeria building industries to organize its development in a sustainable way.

Efficiency is a straightforward concept which can conceivably be summed up with the saying, "doing more with less," the term is normally associated with how energy is consumed at the point of end use, but the concept of efficiency can also be applied to how energy is produced and distributed.

Energy efficiency is a cost effective measure to achieving a design that saves a lot of money on energy bills, for example countries can reduce their dependency on fossil fuels, which are often imported and subject to price volatility. This chapter tends to review previous research work related to this research.

2.2 The Need for Energy Efficiency

Mohsen (2011) mentioned that buildings are accountable for 40% of energy consumption and 36% of CO_2 emissions. Enhancing the energy performance of buildings is a cost effective way of fighting against climate change and improving energy security while at the same time creating job opportunities especially in the building industry.

Community research and development centre CREDC (2009) assert that Energy efficiency has become an important aspect of sustainable development, the use of energy efficiency will lead to the saving of personal income; people will not have to spend so much money paying for energy. It will help to reduce the building of more power stations, thus the money for building power stations will then be spent on other sectors of the economy. In Nigeria, the inadequate supply of energy made it necessary for energy to be portioned/rationed, but with good energy management at the residential, public and private sector, there will be no need to ration electricity supply.

CREDC further assert that the energy been produced in Nigeria are from the combustion of fossil fuel such as oil and gas. For every kilowatt of electricity we consume; there is an equivalent emission of greenhouse gases (GHGs). Energy efficiency can help reduce the dependency on petroleum and also emission of greenhouse gases and reduce. The negative environmental impacts associated with the generation of energy will also be reduced if we use energy efficiently.

Many persons can be hired during intervention programs to change the behavior of people to use energy efficiently but then there are other methods ranging from retrofitting or employing energy efficient appliances to designing an energy efficient building to relate to the environment. In so doing there will be little or no use of energy. Companies involved in the manufacturing of

electrical appliances will experience competition among themselves; those who manufacture the most efficient appliances capture the patronage of consumers.

2.2.1 The benefits of energy efficiency

A 2012 study on the energy efficiency strategy, point out the benefits of energy efficiency as follows:

i. Economic growth: Energy efficiency measures when fixed often require local work force, and the venture has the possibility of enhancing employment and economic growth. There are long-term growth benefits, for example, it lowers domestic energy bills, this can lead to higher disposable incomes that can be spent elsewhere in the economy, while businesses can see a reduction in running costs and so an increase in productivity.

ii. Innovation of energy efficient technology: this offers a longer term investment in energy efficiency technology which can lead to a virtuous circle as innovation leads to cost reductions which can make it cheaper and easier to invest in energy efficiency in the future. Developing our innovative capacity in technology, materials or business models for energy efficiency opens up the potential for increasingly significant export opportunities for Nigeria as the global effort to combat climate change ramps up.

iii. Increase in productivity: Economic studies show that improved energy efficiency can encourage productivity, increases growth and reduces inflation. This provides additional jobs due to the cumulative impact of higher growth.

iv. Savings for domestic and business consumers: this is central to delivering a fair deal for the consumer. Most buildings are already benefitting from improvements in energy efficiency such as heating efficiency and insulation, if there had not been energy efficiency measures, energy use would be almost double the current level. Energy

efficiency will continue to have a role in driving long term reductions in a building's energy bills.

v. Increase in general well-being: good health can be improved through increased energy efficiency, e.g. a higher disposable income; due to lower energy bills can permit increased expenses on other needs. The health benefits from properly installed energy efficiency measures can be significant.

vi. Emission reductions: In order to fight against greenhouse gas emission which has been the targets over the coming decades in the most cost effective way, we need energy efficiency to improve significantly across all sectors because energy efficiency tends to be a cost-effective option.

vii. A sustainable and secure energy system: when energy consumption is reduced there is improvement in energy security. There can also be specific benefits to the energy system of decreasing demand as it reduces the long-term need for investment in additional infrastructure that would have otherwise been required. This has the potential to reduce the overall cost of energy generation framework in the future.

2.3 Basic Energy-Saving Techniques

A write-up by federal energy management program on "low energy building design guidelines (2001) indicated that for a particular project, the distinctive energy-saving techniques, strategies, and mechanisms to be used will vary greatly, depending on building and space type. Their choice and conformation will also be influenced by:

i. Climate

ii. Internal heat gains from occupants and their activities, lights, and electrical equipment

iii. Building size and massing

iv. Illumination (lighting) requirements

v. Hours of operation

vi. Costs for electricity and other energy sources.

Therefore, the basic energy-saving techniques below should be used to reduce building energy use.

- Siting and organizing the building configuration and massing to reduce loads.
- Reducing cooling loads by eliminating undesirable solar heat gain.
- Reducing heating loads by using desirable solar heat gain.
- Using natural light as a substitute for (or complement to) electrical lighting.
- Using natural ventilation whenever possible.
- Using more efficient heating and cooling equipment to satisfy reduced loads.
- Using computerized building control systems.

2.4 Energy Efficiency Strategies for a New Project

A manual on sustainable design and energy efficiency measures arranged the strategies for achieving energy efficiency into three groups:

i. Strategies that reduces the whole energy load within the building

ii. Strategies that improves the efficiency of the systems

iii. Strategies that involves on-site generation of electricity via the use of renewable resources.

The energy efficient strategies helps to improve whole sustainable performance of a building especially in improved access to daylight and views, improved indoor air quality, improved occupant comfort.

The manual further mentions that the cost-effectiveness of an energy efficiency measures differs by region and climate, there is no single amalgamation of measures that will offer the ideal energy efficiency and therefore, project teams are to continuously evaluate completely the conceivable and suitable actions so as to make sure that the most cost-effective solutions are acquired.

2.4.1 Building load reduction strategies

2.4.1.1*Fenestration*

This has to do with the use of high performance glazing products for window design. The use of Sun shading/light shelves, operable windows, fritted glass, and for skylights and other appropriate locations, insulated translucent composite panel. These are all part of window design strategies to achieving building load reduction.

It will present considerable operational cost savings in reduced energy. Additionally, these strategies can improve the interior environment through better access to daylight, views, and outdoor ventilation.

2.4.1.2*Air barriers*

The out-come of air infiltration caused by temperature differential, wind and stack effectare heat loss/gain. The placement of air barriers accurately inside the unclear wall construction or, in suitable climatic zones, presents a combined air and vapor barrier, considerable energy can be recovered that would normally escape through the building enclosure.

The extremely meaningful costs related with enhancing the thermal performance of the envelope come from removing thermal bridging and reducing the degree of air infiltration through the façade.

2.4.1.3*Walls, Roof and Slab*

In any plan or strategy, trying to lessen the use of energy in order to take advantage of thermal performance of envelope construction by minimizing heat transfer according to climate needs is a very important thing to embark on. More insulation is usually beneficial but there is a point at which additional insulation is not justified.

2.4.1.4*Daylight Dimming Controls for Perimeter Areas*

The Daylight dimming lighting controls depend on photocells to maintain the essential lighting levels in the space by decreasing the lighting output from electric lighting based on the amount of daylight in the space. The photocell is placed in such a way that makes it read exterior walls. It monitors the lighting level in the space and dims the electronic lights accordingly to maintain the required foot candles, based on the natural daylight available at any given time in the space.

The cost for integrating daylight dimming controls at perimeter areas includes both the cost of the control system and the additional cost associated with dimmable fixtures. Typically the cost increase is in the range of 1 to 2 percent of the overall lighting budget. Nevertheless by limiting artificial light, the heat load is also reduced, which reduces both the initial system size and long term energy costs.

2.4.1.5*Variable Ach (Air Changes per Hour) Ventilation Rates*

The degrees of ventilation are reduced based on occupancy and or time clock. For the occupancy sensor based controls, a space occupancy sensor identifies if the space is unoccupied, similar to lighting controls but with a longer time delay to prevent HVAC cycling. When the space is detected to be empty for 30 minutes (either by sensor or time clock) the ventilation rates to the space are reduced by 50 percent, and the fan regulated down. This in effect forces VAV

(Variable Air Volume) operation for these spaces, thereby saving significant fan, cooling and reheat energy.

The potential energy reductions are substantial with reductions in fan energy, heating, and cooling loads

2.4.1.6*Lighting and Occupancy Sensor Lighting Controls*

Artificial lighting contributes to energy consumption, selecting the type of lighting wisely is important. Energy efficient fixtures and lamp types such as compact florescent lighting (CFL) and other highly efficient types, should be selected for their energy efficiency in addition to their suitability in color rendition, functional use, cost, longevity, and so on.

Occupancy sensors turn off the space lights when no movement is detected (therefore the space is assumed unoccupied) for a period of time, the occupancy sensors are assumed to reduce the space lighting load by 15 percent, which can translate into an overall energy cost reduction of 2 – 3%.

2.4.2 High efficiency systems

To a great extent, high efficiency systems have a higher first cost; on the other deliver improved long-term operating costs. More efficient systems can also lead to downsizing of equipment or systems, which will provide some offsetting initial cost savings.

2.4.2.1*High Efficiency Chiller Systems*

Using chiller with efficiency of 0.50 kW/metric ton for the central plant saves energy by using less electricity to produce the same quantity of chilled water. In areas where cooling loads are a

significant contributor to the energy usage, high efficiency chillers can provide significant energy savings, and are very cost effective.

2.4.2.2*Increased Chilled Water Delta-T*

Increasing the temperature rise (delta T) on the chilled water system to 16°F can produce modest energy savings, particularly in areas where cooling loads are significant contributors to the energy cost. The delta T increase has a very slight effect on the construction costs as it requires slightly larger cooling coils on the Air Handling equipment. The cost increase would typically be less than 1 percent of the overall cost of the heating, ventilation and air conditioning (HVAC) system.

2.4.2.3*Cogeneration – Combined Heat and Power (CHP)*

Incorporating cogeneration with combined heat and power for some or the entire electrical load of the facility provides several energy efficiencies, some of which extend beyond the simple reduction in energy demand at the facility.

Cogeneration systems normally have a very high first cost, and their cost effectiveness depends greatly on the electricity rate structure and the local utility's policies related to zero net metering or electricity resale. The cost effectiveness can be greatly enhanced where the cogeneration can be fueled in whole or in part through the use of reject or non-commercial fuels, such as medical waste, biomass, methane, etc.

2.4.2.4*Energy recovery*

The most effective energy recovery approach is a Total Energy Recovery Wheel, although heat pipes and run around coils can also be utilized.

Total Energy Recovery Wheels are particularly effective in humid climates since both sensible (heat) and latent (humidity) energy are exchanged, which in effect pre-heats the outside air during the heating season and pre-cools the outside air during the cooling season.

2.4.2.5*Condensing boilers*

Condensing boilers are widely available and widely used, and are very economical. They can provide very good energy cost efficiency. The most significant limitation is that they are typically limited in size range, and not available at the size required by very large facilities, particularly those with high heating loads.

2.4.2.6*Ground source heat pumps*

Ground source heat pumps use the ground or ground water as a sink for heat rejection. Ground temperatures are usually very favorable for heat rejection, being generally consistently cooler than the design temperature of spaces. Ground source can also be used for heating, but with less energy efficiency. Another advantage is that ground temperatures are usually very stable, and so heat pumps can be designed more efficiently.

2.4.3 Renewable Systems

The use of renewable energy either off site or on site, will contribute in the reduction of greenhouse gas emissions by reducing non-renewable energy demand.

There are several advantages to generating energy on site, such as increasing electrical reliability and providing an emergency backup system. In addition, every kilowatt hour(kWh) provides a renewable energy credit (REC) which may be exchanged with the local utility for credits, or used as a part of an Energy Savings Performance Contract (ESPC) arrangement.

2.4.3.1 *Offsite*

Purchasing green power (power derived from solar, wind, geothermal, biomass or low-impact hydro sources), by selecting a Green-e certified power provider for a portion of electric purchases, purchasing a portion of electric power through a Green-e accredited utility program, or by purchasing Green-e accredited Tradable Renewable Certificates (RECs).

2.4.3.2*On Site*

Photovoltaic (PV): PVs are placed on building's exterior so as to generate electricity through collection of solar energy. Light shining on a PV cell, which is a solid-state semiconductor device, liberates electrons that are collected by a wire grid to produce direct current electricity which is then converted to alternating current for use by the facility.

Photovoltaic window or glazing modules can be integrated into a building as non-view windows, skylights, greenhouse windows, curtain walls, facades, and so on.

Wind Energy**:** Wind energy are mostly harnessed by wind turbines, it is usually located either on the building or at an adjacent site. The Wind rotation of the turbine converts the mechanical movement into electric power.

Biomass**:** The use of Biomass systems can be fed from a variety of sources, and can directly use gasses emitted from the decomposition of biomass, or can use the biomass in high temperature reformers to generate hydrogen, which is then fed into fuel cells. Some biomass can also be converted to biodiesel for use in diesel generators.

2.5 Energy Conservation verses Energy Efficiency

This two concepts may be taken to be alike but differ in strategies, the common idea is that both are important ways to reducing overall energy use. A write-up by AK energy smart on energy conservation and energy efficiency differentiates the terms as follows

2.5.1 Energy conservation

Energy conservation simply means reducing energy use by means of a behavioral adjustment that results in not using energy at a time when one might normally make use of it. For example, unplugging computers and other electronics at night or when not in use, or turning off the lights when you leave a room.

2.5.2 Energy efficiency

Energy efficiency means reducing energy use by installing appliances, equipment or lighting that use less energy, i.e. allows us to do more with less. Examples of energy efficiency include replacing incandescent light bulbs with compact fluorescents (CFLs) or LEDs, adding extra insulation to a house, or using Energy Star appliances that have power-saving measures installed.

Energy consumption is not just about electricity used in the building, it also has to do with the material used for its construction. Building an environmentally friendly and energy conscious architecture helps to lessen energy consumption and also reduces environmental degradation. Adopting the concept of embodied energy is a way to compare the performance of building materials. The embodied energy of a building material is the energy that has been required to extract, process, and manufacture it and then to transport it to the building site. The embodied energy in the structure of a new building is considerable, exceeding the total energy required to heat that building for the next twenty years (Umar, 2010).

During the manufacture of materials, the highest embodied energy is found in metals (steel requires 57,000kWh/m^3 or 251200MJ/m^3), and highly processed industrial products (hardboard and MDF require 2,000 kWh/m^3). The middle ranges of materials are simpler to make but require lot of energy in their manufacture (bricks needs 5170 and concrete blocks need

2350/m3). The lowest embodied energy is in materials that require only simple processing (building timber needs 180kWh/m3) or those made from salvaged materials or local natural materials (for example, straw bale, aggregates) which require little or no energy (Umar, 2010).Table 2.1 shows different building materials and their embodied energy in MJ/kg and MJ/m3.The lower the embodied energy the higher its insulation properties and vice-versa, the lower embodied energy materials have high insulation but lacks strength and durability.

Table 2.1: Embodied energy of materials - source: www.boralna.com.

	EMBODIED ENERGY	
MATERIAL	MJ/kg	MJ/m3
Aggregate	0.10	150
Straw bale	0.24	31
Soil-cement	0.42	819
Stone (local)	0.79	2030
Concrete block	0.94	2350
Concrete (30 Mpa)	1.3	3180
Concrete precast	2.0	2780
Lumber	2.5	1380
Brick	2.5	5170
Cellulose insulation	3.3	112
Gypsum wallboard	6.1	5890
Particle board	8.0	4400
Aluminum (recycled)	8.1	21870
Steel (recycled)	8.9	37210
Shingles (asphalt)	9.0	4930
Plywood	10.4	5720
Mineral wool insulation	14.6	139
Glass	15.9	37550
Fiberglass insulation	30.3	970
Steel	32.0	251200
Zinc	51.0	371280
Brass	62.0	519560
PVC	70.0	93620
Copper	70.6	631164
Paint	93.3	117500
Linoleum	116	150930
Polystyrene Insulation	117	3770
Carpet (synthetic)	148	84900
Aluminum	227	515700
NOTE: Embodied energy values based on several international sources - local values may vary.		

2.6 Principle of Energy Efficiency

According to Kornels, B. et al, in order to achieve an energy efficient building, an integrated design approach is a prerequisite to guarantee that the architectural elements and the engineering systems work effectively together. The following are the principles of energy efficiency;

i. Reduce heating, cooling and lighting loads. **Strategy**: -use the building as filter to selectively accept or reject solar radiation and outside air depending on the need for HVAC.

ii. Utilize active solar energy and other environmental heat sources and sinks. **Strategy**: - generate electricity (renewable energy) and apply space cooling methods that dissipate heat directly to natural heat sink without the use of refrigeration cycles (evaporative cooling, radiative cooling to the night sky, earth pipe cooling can be used).

iii. Increase the efficiency of appliances, heating and cooling equipment and ventilation. **Strategy**: - increase the efficiency and where possible reduce the number and size of appliances.

iv. Implement commissioning and improve operations and maintenance

v. Utilize system approaches to building design. **Strategy**: -1.Select a high performance envelop and high efficient equipment. 2. Incorporate a building energy management system that optimizes the equipment operation and human behavior. 3. Fully commission and maintain the equipment.

vi. Consider building form, orientation and other related attributes. **Strategy**: - employ strategies to improve passive ventilation and cooling.

vii. Minimize greenhouse gas emissions

A write up on development and land use policy simply summarizes the principle of energy efficiency as follows;

a. building orientation
b. orientation, size and shading of windows
c. roof and wall insulation
d. use of thermal mass (heat absorbing) material
e. cross ventilation
f. landscaping
g. energy efficient appliances

2.7 Sustainable and Energy Efficiency Strategies for Retrofitting of Buildings

Whole building design guide WBDG (2012), wrote on the essential sustainable and energy efficient strategies for the retrofitting of existing buildings, they are:

- Re-commission all energy and water systems to verify if they are functioning at optimum performance; then renovate energy and water systems to minimize consumption.
- Work-out a plan to enhance the recycling and re-use of demolition remains and waste from construction to minimize the waste sent to landfills.
- Assess occupancy patterns, and then apply daylight, HVAC and lighting sensors where suitable. Integrate energy into the project suitable for the tasks and functions of the spaces.
- Find out if natural ventilation and fresh air intake are possible substitutes to lessen heating and cooling loads.

- Look into renewable options that can counter balance the purchase of fossil fuel-based energy.
- Consider solar shading devices for windows and doors, as well as those that generate electricity by photovoltaic (PV) devices.
- Change existing windows with windows suitable for climate and exposure.
- Examine the benefits of distributed generation if the building is in a campus cluster or can share the on-site energy produced with neighboring buildings.
- Some specific site can improve the energy performance of the building including reducing the heat island effect.
- Decide if a cool roof or green roofs are cost-effective ways to lessen heat island effect and storm water runoff.
- Employ Energy Star and/or a green building rating system for existing buildings like LEED for Existing Buildings: Operations and Maintenance (LEED EBOM) or Green Globes for Existing Buildings to gage the building's level of performance.
- Update systems appropriately to maintain a balance between the need for energy and water savings with the character of the original building fabric especially for historic buildings.
- Use the chance given by the building renovation to integrate sustainable practices and switch to green cleaning products and methods.
- In order to make sure that a newly renovated building continues to function as designed, measure the performance of the building frequently.

- If not already metered, plan on installing meters for electric, gas, water and other utilities. Smart meters and sub meters are preferable to monitor real-time usage, control demand and increase tenant accountability (cost control).

2.8 What is an Office?

An office is defined as a property that provides conducive environment to the performance of management and administrative activities, accounting, marketing, information, processing, consulting, human resources management, financial insurance services, educational and medical services and other professional services (BOMA Best, 2013).

2.9 Design Considerations for Office Buildings

Whole building design guide (2010) outlined the typical features of Office Buildings which include the list of applicable design objectives elements as outlined below.

2.9.1 Cost-Effective

High-performance office should be weighed-up by the use of life. Sometimes, owners need to be glad about the fact that optimizing building performance will involve the readiness to invest more initially to save on long-term operations and maintenance.

During design phase building development, appropriately applied value engineering considers alternative design solutions to enhance the expected cost/worth ratio of projects at completion. During the construction phase, contractors are encouraged by means of shared savings to draw on their special 'know-how' to suggest changes that cut costs while maintaining or improving quality, value, and functional performance.

2.9.2 Functional/Operational

2.9.2.1 *Tenant Requirements*

The design of the building must take into account the combined requirements of the proposed tenants. This consist of their desired image, degree of public access, operating hours, growth demands, security issues and vulnerability assessment results, organization and group sizes, growth potential, long-term consistency of need, group assembly requirements, electronic equipment and technology requirements, acoustical requirements, special floor loading and filing/storage requirements, special utility services, any material handling or operational process flows, special health hazards, use of vehicles and types of vehicles used, and economic objectives.

2.9.2.2*Flexibility*

The high-performance office must effortlessly and efficiently accommodate regular renovation and modifications. The modifications may be as a result of management restructuring, personnel shifts, changes in business models, or the advent of technological innovation, on the other hand, the office infrastructure, interior systems, and furnishings must be up to the task.

- Raised floors for easy access to cabling and power distribution should be taken into consideration, as well as developed air distribution capabilities to tackle individual occupant comfort.
- Features such as plug-and-play floor boxes for power, data, voice and fiber, modular and harnessed wiring and buses, and conferencing hubs should be integrated in order to allow for daily flexibility at work as well as future restructuring of office workstations.

2.9.3Urban Planning

The large concentration of workers within one building can have a substantial influence on the environs. Office organization can energize neighborhoods with the retail, food service, and interrelated business links. Transportation should be considered when developing office structures. Office buildings are often wedged by urban planning and municipal zoning, which try to promote compatible land use and exciting neighborhoods.

- When selecting office locations, Consideration should be given to the distance in which the majority of occupants will have to travel to reach the office. The developments of new office locations will habitually require relocation of employees, especially if the office is moved or opened in a new geographical area. When considering the resources of the community, it should include housing costs and availability, traffic congestion, school system quality, cultural resources such as museums, sports teams and institutions of higher education, natural attractions such as coastal areas, mountains and public parks, availability of educated labor, crime rate and law enforcement, and civic infrastructure capacity such as water, waste water and waste processing.
- As soon as a building has been built and occupied, it is precarious that long-term performance be confirmed through an aggressive process of metering, monitoring and reporting. The outcome of this feedback should notify maintenance and be available as input to new design efforts.

2.9.4Productive

Worker Satisfaction, Health, and Comfort: In office environments, the specific greatest cost to employers is the salaries of the employees occupying the space. It mostly exceeds the tenancy

and energy costs of a facility by a factor of ten on a square foot basis. Hence, the health, safety, and comfort of employees in a high-performance office are of utmost concern.

- Strategies such as increased fresh air ventilation rates, the specification of non-toxic and low-polluting materials and systems, and indoor air quality monitoring should be employed.
- Individualized climate control that permits users to set their own, localized temperature, ventilation rate, and air movement preferences should be provided.
- Although there is difficulty to quantify, it is generally acknowledged that worker satisfaction and performance is enhanced when office workers are provided with stimulating, dynamic working environments. Access to windows and view, the opportunity to interaction and control of one's immediate environment are some of the issues that contribute to enhance the satisfaction of a workplace.
- The use of natural light is important to the health and psychological well-being of office workers. While designing the office environments emphasis should be given to the provision of each occupant with access to natural light and views to the outside. A minimum of 30 foot candles per square foot of diffused indirect natural light is needed.
- The design of the acoustical environment of the office must integrate the other architectural systems and furnishings of the office. Exceptional importance must be given to noise control in open office settings, with absorptive finish materials, masking white noise, and enough separation of individual occupants.

2.9.5Technical Connectivity

Technology has turn out to be an essential tool for business, industry, and education. As long as technology is driving a variety of changes in the organizational and architectural forms of office

buildings, consider the following issues when integrating it, especially information technology (IT), into an office:

- Plan new office buildings to have an allocated, robust, and flexible IT infrastructure, which ought to permit technological access in virtually all the spaces.
- throughout the planning stage, it is required to identify all necessary technological systems (for example, voice/cable/data systems such as audio/visual systems, speaker systems, Internet access, and Local Area Networks [LAN] / Wide-Area Networks [WAN] / Wireless Fidelity [WI-FI]), and provide adequate equipment rooms and conduit runs for them.
- Consider and accommodate for wireless technologies, as appropriate.
- For existing office buildings, consider improving access to the IT infrastructure as renovations are undertaken.

2.9.6 Secure / Safe

There exist Terrorist attacks and design has focused on protection of occupants and assets against violent attack. During comprehensive threat assessment, vulnerability assessment, and risk analysis, security requirements for individual buildings and appropriate reasonable design responses are identified for integration into the office buildings design.

- Entrances that do not face uncontrolled vantage points with direct lines of sight to the entrance should be considered. Make use of site barriers and setbacks, perimeter barriers and blast resistances, access control and intrusion detection, entrance screening, package screening and control, open areas that allow for easy visual detection by occupants, and minimized glazing.

- Visitors that are unfamiliar with their surroundings may encounter difficulty in navigating to the safest exit route from the building. Consider using increased signage and/or providing safety information and a building directory in welcome brochures.

2.9.7 Sustainable

Energy Efficiency: Answerable to the office's size, local climate, use profile, and utility rates, strategies for minimizing energy consumption involve:

i. Reduction of load (by integrating the building with the site, optimizing the building envelope [decreasing infiltration, increasing insulation], and so on.)
ii. Sizing the heating, ventilating, and air-conditioning systems correctly.
iii. High-efficiency equipment, lighting, and appliances should be installed.

The application of renewable energy systems should be given due consideration, this include building that generate building electricity, solar thermal systems that produce hot water for domestic hot water (DHW) or space conditioning, or geothermal heat pump systems that draw on the thermal capacitance of the earth to improve HVAC system performance.

2.10 Characteristics of Hot and Dry Tropical Regions of Nigeria

Agboola (2011) asserts that the hot savannah zone of the middle belt and the northern Nigeria region has a climate that is portrayed by a long dry season (and subsequently a brief rainy season) accompanied with cold and dry harmattan wind, high temperature range (due to hot afternoons and cold nights) and intense sunlight. This region covers the savannah region (grassland), highland region (plateau) and semi-desert region. It comprises of towns like Abuja, Minna, Zaria, Yola, Maiduguri, Kano, Sokoto, Yelwa, Kaduna, Katsina, Nguru and other mountainous regions along the Cameroonian border. The areas are accompanied with cold nights

and hot days alternate for six to ten months of the year, and characterized by moderate or low amount of rainfall. Hot and humid conditions are experienced during one or two months.

The cool climate can be found around high altitudes of Jos Plateau, Manbilla Plateau and other mountainous regions, here; monthly rainfall exceeds 200mm for three or more months.

The vegetations in this region comprises of the Guinea, Sudan Savannah and Sahel Savannah. These come as a result of long dry season. The Guinea savannah has vegetation that is denser than the Sudan because the rain there is heavier. In both areas, the rain is just enough for fairly tall grasses and dispersed trees. At the North Eastern area around Lake Chad is the presence of Sahel Savannah due to few amount of rainfall. The rain is less than 500mm a year. The short grasses and few trees that are present here are thorny.

2.10.1 Climatic elements in focus

There exist the need to design architectural structures with climatic suitability parameters, this must be taken into cognizance in making sure that careful arrangement and sensible use of space, the comfort of the users, and the functionality of the total environment in meeting the physiological, protective and social needs. The physiological conditions of comfort that constitute criteria in design are as follows:

2.10.1.1 *Ventilation and Thermal Balance of Buildings*

Ventilation is the replacement of used inside air by the outside air. The ventilation condition inside building is among the leading factors that influences the health, comfort and well-being. However, Natural Ventilation is the ventilation attained without mechanical supports, but by stacks effect and wind pressure. Cross ventilation is the ventilation attained by positioning openings in opposite walls of an enclosure. Olotuah (2001) advised that the dwelling units should be designed so as to enable thorough ventilation as the deterioration in the physio-

chemical properties of the indoor atmosphere can unfavorably affect the comfort of the occupants. He further emphasizes on the fact that ventilation has three distinctly different functions as follows.

2.10.1.2 *Supply of Fresh Air*

Fresh air is essential for the removal of odor, too much heat and smoke from room interiors which may cause suffocation. The requirement is controlled by the type of occupancy, number and activity of the occupants and by the nature of activities being carried out in the space.

2.10.1.3 *Convective Cooling*

This is a practical suggestion in warm climates when the internal heat gain or solar heat gain through windows increases the indoor temperature greater than the outdoor air temperature. It is also referred to as structural ventilation. Indoor air, when exchanged with fresh out-door air can provide cooling if the latter is at a lower temperature than the indoor air

2.10.1.4 *Physiological Cooling*

Air movement over the skin surfaces hastens heat dissipation by intensifying convective heat loss and accelerating evaporation. This is to impart thermal comfort due to moist skin (thermal comfort ventilation).

2.10.1.5 *Thermal insulation*

Thermal insulation is a tool to make sure that the interior of rooms are kept at acceptable temperature for comfort. Olotuah (2001) itemizes factors to be considered in achieving thermal comfort to include:-

a. Appropriate use of building materials

b. The Volume of space enclosed

c. The number, type and size of window openings

2.10.1.6 *Wind Pressure*

Finding out the wind direction and wind speed is the duty of the designer so as to maximize the wind in the building. This is due to the following reasons:

i. Wind affects ventilation
ii. Wind causes driving drain
iii. Wind carries dust
iv. Wind can be used for cooling effects
v. It requires structure to be strengthened against wind-load.

Basically, the main aim of design is usually to make the best use of wind pressure for air movement, especially in the warm humid climate in the southern part of the country. The excluded situation is where the wind is dusty, cold and undesirable, such is experienced during the harmattan. There are where the wind causes destruction and tearing roofs off buildings for example in the Northern part of the country. The building ought to be designed in order to withstand the maximum probable wind-speeds.

2.10.2 Choice of appropriate construction materials

The requirements of the climate can be achieved through the use of appropriate construction materials and methods. Apart from the envelope, the materials within the internal space for example, floors, partitions, furniture, requirements, luggage and so on. Also modify the indoor temperatures by affecting their individual thermal properties. The materials affect the temperature of both indoor air and surfaces when the indoor thermal conditions are not controlled, thereby affecting the occupancy comfort drastically. The roofs should be light with a reflective surface and cavity. Wall should be adequately protected against driving rain.

2.10.2.1 *Hot Savannah of the Middle Belt and the Northern Nigeria*

This climate seeks solution through proper designs that can lower the effect of cold and cruel winds while delivering cool relieve from the intense heat of the mid-day sun.

In the meantime, the main design task here is to reduce the impact of solar radiation with reference to heat gain and glare. Adequate control of ingress of hot, dust and sand laden air into the built environment especially the building interior is equally important for comfort. The following are the main requirement in this zone.

Ventilation***:*** ventilation is needed this zone, but then it is not a primary design consideration when compared with the southern zone of the country. Careful effort should be made to reduce the inflow of air into the building because it introduces sand into the building interiors.

Thus, window areas should not be more than 40% of the floor area they serve. Window areas as small as 15% of floor areas they serve are considered adequate for indoor thermal comfort. Olotuah (2001) stresses that cross-ventilations not a design consideration in this zone because the air outside is rather hot and introducing this will lessen the advantage gained during the day from the massive heavy weight construction of the building. See figure 2.1.

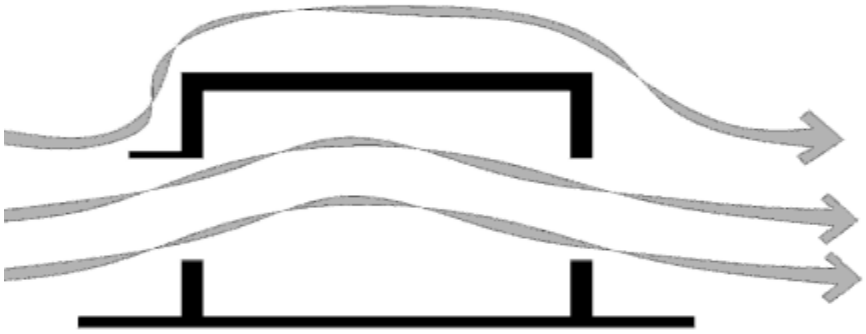


Figure 2.1: Cross ventilation achieved through openings – Source:Olotuah (2001)

But then, stack effect is more appropriate as cooler air is denser than warmer air, the cooler air enters through the lower opening; it ventilate the interior and moves out used air through the upper window as shown in figure 2.2.

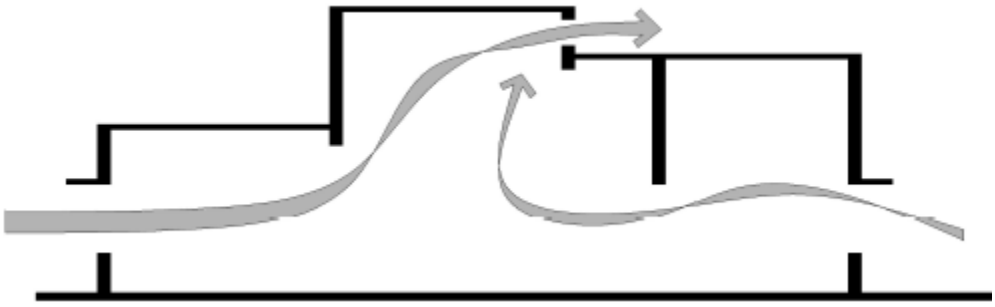


Figure 2.2: Stack ventilation – Source:Olotuah (2001)

Thermal Insulation***:*** Thermal conditions decree that openings should not go beyond the minimum size needed for good day-lighting. Consequently, the openings are usually small and situated high in the walls of the building. The size also helps in curtailing the incursion of dust and sand, in addition, the more the size of opening the greater the need for shading. Opoko (2001), while explaining the benefits of thermal insulation states that thermal storage is required for cooling interiors in the day and for providing warmth at night. Other essential features of houses in this zone which will make for thermal comfort include roof overhangs, verandahs and loggias. These will shield the building interior from direct sunlight and glare part from providing outdoor relaxation spots.

Site Planning (Forms and Orientation): The design of buildings should be compacted inward looking; provisions should be made for courtyards. These should be small in order to obtain maximum shading and retain coolness within the space. Air movement is not a prerequisite for comfort. So compact planning will economize land usage and help conserve heat. For the same reason double banking should be used. It is very important to provide shade trees, water bodies,

shrubs and so on. North-South orientation is recommended for buildings in this zone of Nigeria. Since the sun-path across this zone is East-West, this orientation reduces the amount of solar radiation which external walls are exposed to. Though in practice, it may not be feasible to achieve the North-South orientation due to other design considerations. In such instances, the best compromise orientation should be adopted.

Protection against Solar Radiation*:* Opening in this zone should also be protected against sun and rain penetrations. Hence this calls for sun-shading devices. Other areas that need to be shaded include all outdoor spaces like courtyard, verandah, patio and so on.

Choice of Appropriate Construction Materials: The selection of appropriate construction materials is essential in Architectural design. Opoko (2001) assert that a good understanding of thermal properties is required before selection of materials for this zone. What are required are materials which can minimize heat transfer into the building interior. These are essentially materials, which are poor conductors of heat or have good reflective capacities. Thermal properties of building materials can further be enhanced by coating them with white and other colors which possess high reflective qualities.

The above-mentioned had explained why mud has been used indigenously for walls in hot Northern Nigeria, because of its heat resisting properties. Mud is a dense (heavy weight) material and has a very high heat storage capacity. It takes considerable time to heat up and it takes long time as well to cool down again. It has a great advantage in hot dry regions, particularly because of temperature differences of the afternoon and the night. The heat absorbed slowly in the afternoon is dissipated slowly into the room interior warming it up at night. Walls, floors and roofs in this zone should be heavy with high thermal capacity and a time lag of over eight hours.

2.11 Checklist of Energy Efficient Office

According to Peter, S. et al (2011), to plan a resource efficient building, the following checklist can be used to ascertain the main points to be aware of;

Table 2.2: checklist – Source: Peter, S. et al (2011),

		ASPECT	YES/ NO	C0MMENT
PASSIVE ELEMENTS		The approximate basic area per inhabitant is around 30 square meters		
		Major window surfaces are oriented to the south		
		There is no big window surface to the north		
		The shape of the building is rather regular than irregular		
		There aren't any evergreens in front of the windows to the south		
		The roof is exceeding the building with at least 50 cm		
ACTIVE ELEMENTS	Building materials	Good heat absorbing and storing capacity of the walls		
		The windows triple glazed with an U-value of at least 0.8 W/m2K		
		The outside walls have an insulation of at least 15 cm		
		Insulation of floor plates is at least 10cm		
		Roof insulation is at least 30 cm		
	Heating system	The boiler is fueled with biomass or with natural gas		
		Condensing boiler is installed		
		Thermostatic valves are installed, the temperature can be regulated room by room		

	Renewable and rainwater	*At least one of the following renewable option is applied:*		
		solar panels for making hot water;		
		solar cells for making electricity;		
		biomass or biogas for heating;		
		heat pumps for heating;		
		small wind turbine for making electricity		
		Rainwater is collected and reused		

If the result is:

13-16 YES:

A lot has been saved in the environment and in a long term lots of energy and money will be saved.

7-12 YES:

A good planning has been achieved. But then in order to make the building more resource efficient, there will be a need to consult a good planner.

0-6 YES:

The plan needs to be revised. There is a need to reconsider some options with a planner.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This research was based on the strategies that will helped to meet the mandates for energy reduction, it is evaluative in nature, and this involves the retrospective assessment to determine the effectiveness of energy and demand savings in order to know how they have fared against specified accepted energy efficient measures or strategies. The study adopted both qualitative and quantitative type of research during the course of data collection and analysis.

3.2 Research Design/Approach

Case study approach is adopted whereby cases is examined, analyzed, categorized and tabulated. Zaidah (2009) highlighted past studies which mentioned the fact that case study research permits the exploration and understanding of complex issues and that it can be well thought out to be a straight forward research method particularly when it requires an all-inclusive and in-depth investigation.

According to Oluigbo (2011), case study application types that are relevant to architectural research include; illustrative, exploratory, explanatory, evaluative and critical instance. For the purpose of this research the evaluative case study is appropriate.

Evaluative case study**:** The evaluative case study is used in testing the effectiveness of policies or programs in order to suggest modifications and alternatives. Here, purposive sampling is used which may be typical or representative of diversity and best and worst cases.

This type of case study is chosen so as to assess the effectiveness of energy usage and demand reduction strategies that have been achieved so as to suggest relevant modifications and alternatives.

3.3 Sample and Sampling Techniques

This research involves the use of both qualitative and quantitative research, purposive sampling method is adopted, and this will involve the purposive selection of the case that falls within the hot-dry climate region of Nigeria.

3.3.1 Population of study

The population of study includes the office buildings located within the hot-dry climate of Nigeria and two is purposefully selected to represent the remaining.

3.4 Instrument of Data Collection

The tools or instrument of data collection to be used are;

i. Simulation of the case chosen to be studied
ii. Visual survey with the help of checklist

3.4.1 Simulation of the case

Pollock M. et al (2007) indicated that simulation of a case is an appropriate approach for the evaluation of an office building in other to assist in the delivery of a sustainable green office and with high rating of energy performance.

This tool is used because:

i. It will help in determining the energy consumption rate of the building
ii. It will help to optimize the building design in order to improve its overall performance.
iii. It will generate possible data for analysis

The analysis is based on the below variable:

3.4.1.1 *Energy consumption*

Determining the energy usage can help to propose possible energy efficient strategies to minimize its usage. This is in terms of day lighting and cooling /heating loads.

Daylighting: This is because natural daylight is vital within a building both for visual comfort of the occupants and to limit the dependency on artificial lighting.

Cooling/heating loads: the hot-dry climate acquires high temperature during the day, therefore internal heat gains has to be determined in order to mitigate overheating.

Other variables include;

- Climate
- Hours of operation
- Costs of electricity and other energy sources.

3.4.1.2 *Visual survey*

This involves looking out for elements that has to do with the requirement for an energy efficient design in the building.

3.5 Procedure for Data Collection

The office building (bank of industry) is simulated with the help of these softwares:

i. Revit 2011 for the building model
ii. VELUX daylight visualizer-2 for the analysis of day lighting
iii. Green building studio for the analysis of energy consumption, heating and cooling loads.

The building model is kept identical for all weather data sets with HVAC equipments sizing set by Consumer Electronics Association (CEA). The model is 3,199m^2, 8 storey medium rise building with a basement. For average lighting power (T-12 fluorescent) 10.87w/m^2 is imputed, exterior window ratio of 0.34 with single pane clear low iron 5mm glass in all locations, the area per person is 111m^2. Energy cost is calculated by Green Building studio based on local utility rate.

Actual hourly weather data (GBS-06M12-21-221068) year 2006, is used in the simulation software. The weather station is 7.42km away from Bank of industry corporate office building at lat 10.400 and long 7.433, it is used under cooling condition.

Table 3.1 shows the threshold temperatures of cooling in a day and heating in a day. Table 3.2 shows the temperatures for annual design conditions for cooling and heating.

Table 3.1:Temperatures of cooling and heating in degree day-Source: weather station; GBS-06M12-21-221068

Cooling Degree Day		Heating Degree Day	
Threshold	Value	Threshold	Value
18.3 °C	2492	18.3 °C	0
21.1 °C	1493	15.6 °C	0
23.9 °C	616	12.8 °C	0
26.7 °C	152	10 °C	0

The table below (table 3.2) are data on temperature gotten from the weather station, it is the temperature used for annual design conditions.

Table 3.2:Temperatures for annual design conditions-Source: weather station; GBS-06M12-21-221068

Annual Design Conditions				
Threshold	Cooling		Heating	
	Dry Bulb(°C)	MCWB(°C)	Dry Bulb(°C)	MCWB(°C)
0.1 %	39.8	17.2	8.7	4.0
0.2 %	39.3	17.5	9.0	4.4
0.4 %	38.8	17.4	9.5	4.9
0.5 %	38.7	17.3	9.8	5.2
1 %	38.2	17.6	10.9	6.0
2 %	37.2	19.1	12.2	6.9
2.5 %	36.9	19.2	12.7	7.1
5 %	35.2	19.0	14.5	7.9

The recent cost per unit of energy consumption gotten from utility bill is at 23.85naira/unit. The simulated software operates on default currency of USA dollar. It was converted at the rate of 160naira/dollar and it was imputed appropriately where needed.

After the imputation of all these information, the analysis is set out and it produced appropriate data for analysis.

Based on visual survey, passive and active elements are checked and inquiries were made by the help of checklist about the various appliances and equipment that consume most of the energy so as to propose alternative ways to minimize its usage.

3.6 Method of Data Analysis

The method for the analysis of data collected were tabulated and also represented in tables, bar charts and pie charts.

CHAPTER FOUR

DATA PRESENTATION AND ANALYSIS

4.1 Introduction

This chapter involves the presentation of data collected through the various instruments of data collection as well as analysis of the data collected. The research approach which is evaluative case study was conducted in order to check the effectiveness ofenergy efficient measures or strategies that has been applied to achieve energy efficiency in existing office buildings. Two case studies were conducted and one was chosen to be simulated to further evaluate its energy consumption.

4.2 Case Study One

Bank of Industry Ltd: Abuja, Nigeria

Plate 4.1: Bank of Industry ltd, Abuja - source: http://www.google.com.ng/imgres

Table 4.1. General characteristics of case study one.

General Characteristics	
Location	Plot 256 off Herbert Macaulay way, FCT-Abuja, Nigeria.
Building type	Commercial/Institutional (Corporate office)
When it was commissioned	22nd December 2011 by Dr. GoodluckEbele Jonathan
Architect	Shelter Design Partnership: Ikeja, Lagos State, Nigeria.
Building materials	Concrete, Steel, Glass
Number of floors	Twelve (12) floors
Time of operation	24hrs 7days weekly
Architectural style	Modern architecture
Energy efficient strategies applied	i. Strategies that reduce the whole energy load within the building, that is, fenestration running almost throughout the building and shaded by shading devices at strategic locations (east and west regions). ii. Strategies that improve the efficiency of the systems, that is, use of efficient chiller system, efficient lighting (CFL/BL2 fluorescent lamps). iii. Strategies that involves on-site generation of electricity, that is, street lights powered by solar cells
Present state	Functional

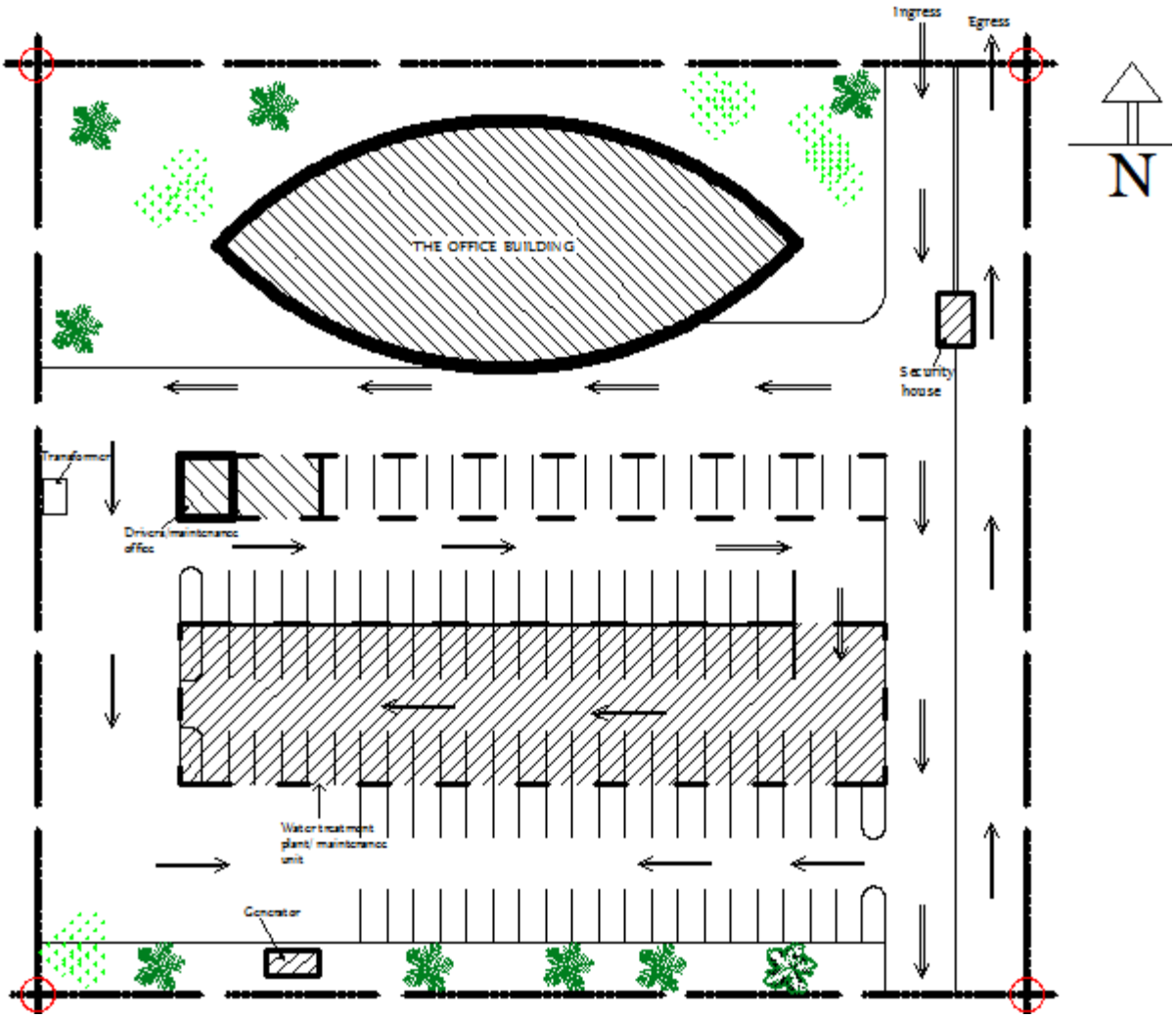


Figure 4.1: Site layout of case study one – source: Author's CAD sketch.

The functional facilities provided based on the site layout in figure 4.1 are as follows;

a. The office block
b. Security house
c. drivers lounge
d. maintenance office
e. water treatment plant
f. Firefighting facilities

g. generator house

h. parking spaces

Plate 4.2: sloped and built terrain (packing on roof slab*)* – source: Author.

The site was well maximized to harbor the functional facilities; it was appropriately sloped in a way that permits roof slab (for maintenance unit) to also serve as parking space.

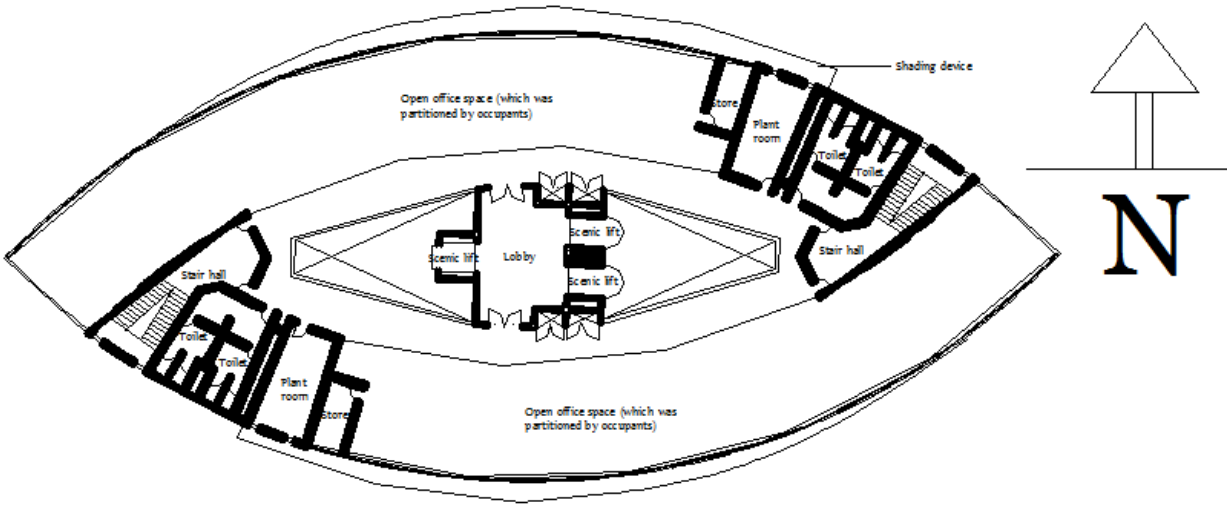


Figure 4.2: Floor plan, case study 1 – source: Author's CAD sketch.

The building was well oriented and shaded with netted steel shading device (plate 4.3) around east and west wings against intense solar radiation which in turn reduces heat gain into the building. The plan permits an open plan that allows occupants to design it to their specification (see fig 4.2).

Plate 4.3: North-west view - Source: Author.

The Plate above (plate 4.3) is the north-west view showing netted steel shading device and glazing used. The shading device help in reduction of heat gain from solar radiation.

Plate 4.4: Street lights powered by solar cells - source: Author.

The street lights are powered by solar cells; therefore there is no dependency on electricity (see plate 4.4).

Plate 4.5: Scenic lift (1) located around the atrium– source: Author.

Apart from the day lighting acquired from the external windows into the offices, the atrium (plate 4.5) harbors sufficient day light around the central part of the building where circulation takes place, therefore dependency on artificial lighting at this region of the building is reduced during the day.

Plate 4.6: Scenic lift (2 and 3) located around atrium– source: Author.

The lifts (plate 4.5 and 4.6) are highly dependent on electricity; therefore if power goes off, people are stocked up until the alternative power supply (generator) is on.

4.2.1 Inference

i. The use of medium ranged embodied energy material for construction (concrete, steel and glass did not efficiently reduce energy consumption).

ii. The implementation of atrium as a means to captivate daylight reduces the need for artificial light, whereas the little or no passive ventilation increases the cooling loads in the building.

iii. Little or no attempt was made to reduce energy consumption when the building was designed and constructed.

4.2.2 Summary of the Building's Features

Table 4.2: Summary of the building features- Source: Author.

Architectural expression	Building's relationship with site	Building material	Existing energy source	Energy efficient features	Provided facilities
Leaf-like shape portraying the features of modern architecture	The building was designed to fit the entire site, it was well oriented and shaded with netted steel shading device around east and west	Concrete Steel High performance glazing Aluminum internal partition	It is connected to the city's power grid Also uses alternative source (generator)	The use of efficient chiller system Incorporation of natural light through windows and skylight The use of	Main building/ offices Maintenance office/unit Security office Security stand

	wings against intense solar radiation which in turn reduces heat gain into the building.	solar panels on all street lights around the site Generation of on-site water for use.	Drivers office Transformers (1000KVA for AC and 500KVA for lighting) Generator house Parking spaces

4.2.3Visual Survey of the Case Study

According to Peter, S., et al 2011, to plan a resource efficient building, the following checklist can be used to determine the main point.

Table 4.3: Checklist result for case study 1- Source: Peter, S., Eva, C., (2011)

	ASPECT	YES/NO	C0MMENT
PASSIVE ELEMENTS	The approximate basic area per inhabitant is around 30 square meters	no	
	Major window surfaces are oriented to the south	yes	
	There is no big window surface to the north	no	
	The shape of the building is rather regular than irregular	yes	
	There are not any evergreens in front of the windows to the south	yes	

		The roof is exceeding the building with at least 50 cm	no	They are flat roofs
ACTIVE ELEMENTS	Building materials	Good heat absorbing and storing capacity of the walls	yes	The use of concrete
		The windows triple glazed with an U-value of at least 0.8 W/m2K	no	
		The outside walls have an insulation of at least 15 cm	no	
		Insulation of floor plates is at least 10cm	yes	
		Roof insulation is at least 30 cm	yes	
	Heating system	The boiler is fueled	no	
		with biomass or with natural gas	no	
		Condensing boiler is installed	no	
		Thermostatic valves are installed, the temperature can be regulated room by room	no	
	Renew-able and rainwater	***At least one of the following renewable option is applied:***		
		solar panels for making hot water;		
		solar cells for making electricity;	yes	
		biomass or biogas for heating;		
		heat pumps for heating;		
		small wind turbine for making electricity		
		Rainwater is collected and reused	yes	

13-16 YES:

A lot has been saved in the environment and in a long term, lots of energy and money will be saved.

7-12 YES:

A good planning has been achieved, but then in order to make the building more resource efficient; there will be a need to consult a good planner.

0-6 YES:

The plan needs to be revised. There is a need to reconsider some options with a planner.

The Case study falls under category 7-12 yes, this means that a good planning has been achieved. But then in order to make the building more resource efficient, there will be a need to consult a good planner.

4.3 Case Study Two

Bank of Industry Ltd: Kaduna, Nigeria

Plate 4.7: Bank of Industry ltd, Kaduna– source: Author.

Table 4.4: General characteristics for case study two – Source: Author.

General Characteristics	
Location	No 18, Warf Road, Kaduna, Kaduna State Nigeria.
Building type	Commercial/Institutional (Corporate office)
When it was commissioned	24th July 1984 by Dr. Mahmud Tukur
Building materials	Concrete, Glass, brick facing
Number of floors	Eight (8) floors and a basement
Time of operation	8hrs daily (7.00am-6.00pm), 5days a week
Architectural style	Modern architecture
Energy efficient strategies applied	i. Strategies that has to do with rejecting direct solar radiation in the building, that is shading device ii. Strategies that involve the use of good thermal mass material, that is concrete and glass.
Present state	Functional

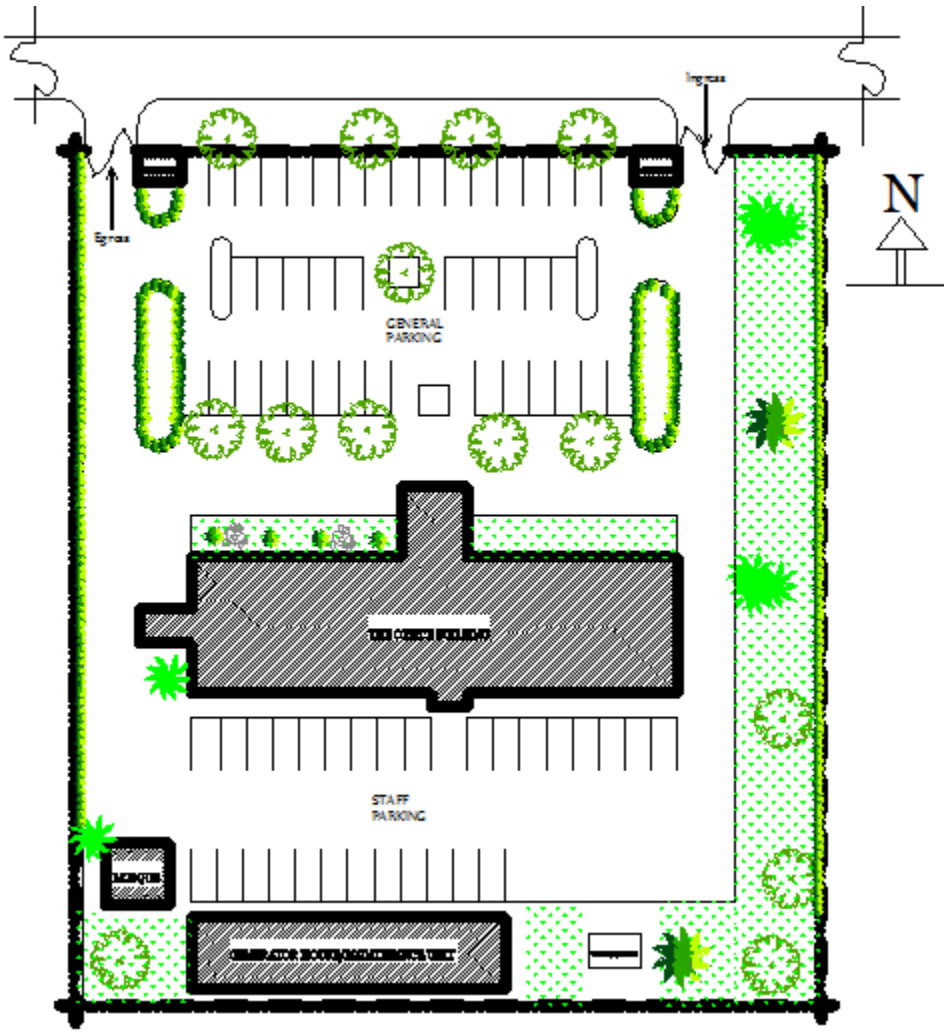


Figure 4.3: Site layout of case study 2 – source: Author's CAD sketch.

The functional facilities provided based on the site layout in figure 4.3 are as follows;

a. The office block
b. Security house
c. maintenance office
d. Firefighting facilities
e. generator house
f. parking spaces

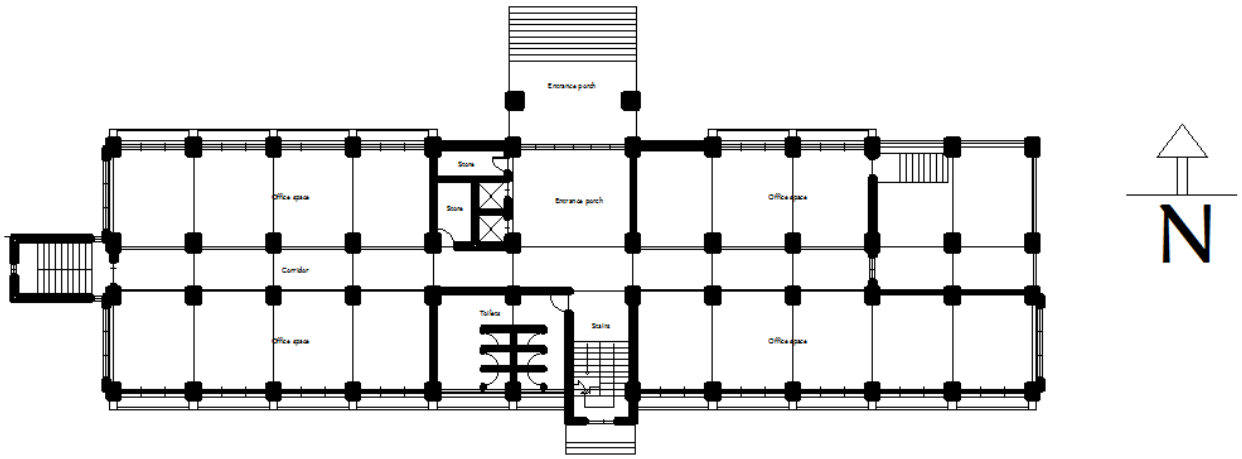


Figure 4.4: Floor plan, case study 2– source: Author's CAD sketch.

The floor plan (figure 4.4) is a rectangular shaped double banking of cooperate offices with flexible planned spaces that allows occupants to modify these spaces according to their specification. The orientation allows the longer sides to face north and south and shorter sides to face east and west with minimal openings around the east-west direction. This minimizes heat gain in the building.

Concrete shading device (see plate4.9) was constructed to help shade against solar radiation that causes excessive heat.

Plate 4.8: Corridor– source: Author

Plate 4.10 shows the corridor, the corridor depends on artificial light because it lacks day lighting therefore the corridor gets dark when there is fire outage.

4.3.1 Inference

i. The use of medium ranged embodied energy material for construction (concrete, steel and glass did not efficiently reduce energy consumption).
ii. Little or no attempt was made to reduce energy consumption when the building was designed and constructed
iii. Building conforms to the appropriate orientation for the region (longer axis facing the north-south direction) to minimize heat gain.

4.3.2 Summary of the Building's Features

Table 4.5: Summary of the building features in case study two – Source: Author.

Architectural expression	**Building's relationship with site**	**Building material**	**Existing energy source**	**Energy efficient features**	**Provided facilities**
Rectangular shaped double banking design	The building was designed to fit the entire site; it was well oriented and shaded with concrete shading device against intense solar radiation.	Concrete Glass Aluminum internal partition	It is connected to the city's power grid Also uses alternative source (generator)	The use of efficient chiller system Incorporation of natural light through The use of efficient lighting bulbs such as led	Main building/ offices Maintenance office Security office/ Security stand Mosque

			and fluorescent bulbs	Generator house Transformer (1000KVA) Parking spaces

4.3.3Visual Survey of case study two

According to Peter et al 2011, to plan a resource efficient building, the following checklist can be used to determine the main point.

Table 4.6: Checklist result for case study 2 – Source: Peter, S., Eva, C., (2011).

		ASPECT	**YES/NO**	**C0MMENT**
PASSIVE ELEMENTS		The approximate basic area per inhabitant is around 30 square meters	no	
		Major window surfaces are oriented to the south	yes	
		There is no big window surface to the north	no	
		The shape of the building is rather regular than irregular	yes	
		There aren't any evergreens in front of the windows to the south	yes	
		The roof is exceeding the building with at least 50 cm	no	They are flat roofs
ACTIVE ELEME	Building materials	Good heat absorbing and storing capacity of the walls	yes	The use of concrete
		The windows triple glazed with an U-value of at least 0.8 W/m2K	no	

NTS		The outside walls have an insulation of at least 15 cm	yes	
		Insulation of floor plates is at least 10cm	yes	
		Roof insulation is at least 30 cm	yes	
	Heating system	The boiler is fueled	no	
		with biomass or with natural gas	no	
		Condensing boiler is installed	no	
		Thermostatic valves are installed, the temperature can be regulated room by room	no	
	Renewable and rainwater	***At least one of the following renewable option is applied:***		
		solar panels for making hot water;		
		solar cells for making electricity;		
		biomass or biogas for heating;		
		heat pumps for heating;		
		small wind turbine for making electricity		
		Rainwater is collected and reused	yes	

13-16 YES:

A lot has been saved in the environment and in a long term, lots of energy and money will be saved.

7-12 YES:

A good planning has been achieved, but then in order to make the building more resource efficient; there will be a need to consult a good planner.

0-6 YES:

The plan needs to be revised. There is a need to reconsider some options with a planner.

The Case study falls under category 7-12 yes, this means that a good planning has been achieved. But then in order to make the building more resource efficient, there will be a need to consult a good planner.

4.4 Simulation of Case Study

In order to evaluate the data collected, the case study of Bank of industry limited, Kaduna (case study 2) was modeled and analyzed using three variables with the aid of Autodesk Revit architecture, VELUX daylight visualizer and Green Building Studio. Case study 2 was chosen amongst the two case studies conducted because its location is the same as the proposed office building, it will be a better ground for comparison.

In determining the energy consumption of the office above, the following variables were considered, they are:

i. Daylight: natural daylight is vital within a building both for visual comfort of the occupants and to limit the dependency on artificial lighting.
ii. Heating/Cooling loads: the hot-dry climate acquires high temperature during the day and low evening sand also depending on the season.
iii. Energy consumption.

4.4.1 Day Lighting

The illumination is set at sky conditions, sunny at 12pm, all weather data from weather station were made available, and the building was oriented with the longer sides facing the north and south direction.

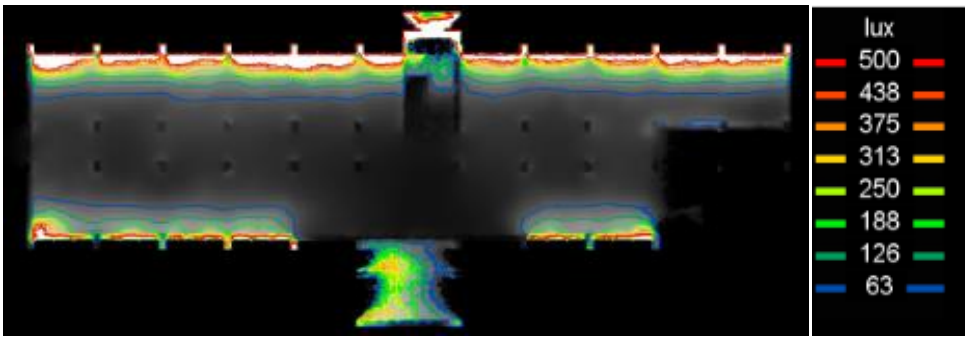


Figure 4.5: ISO contour daylight for basement – Source: Author's simulated result.

Above is the simulated daylight of the basement (figure 4.5), its luminance is low because it has high level windows and the whole building envelope shades it from receiving adequate luminance. There is high dependency on artificial lighting and cooling at this level.

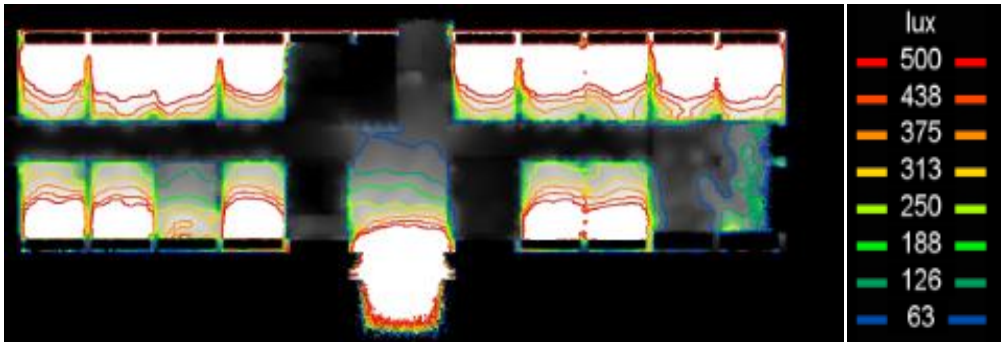


Figure 4.6: ISO contour daylight for ground floor– Source: Author's simulated result.

The ground floor (figure 4.6) is more illuminated more than the basement, this is because the windows are larger and the amount of light entering this floor reaches a wider surface area. Along the corridor, lift, toilet, stores and stairs, illumination is poorly achieved due to inadequate planning; for that reason, there is high dependency on artificial lighting to achieve visibility.

Day lighting analysis shows that the higher the floor levels the more illuminated they are and vice versa.

4.4.1.1 Result

According to an engineering tool box, the global outdoor luminance is about 10,000lux. The ratio between the luminance measured indoor at a reference point (for example, work plane) and the outdoor global luminance on an unobstructed horizontal surface (daylight factor) is used as a measure of light quantity. A normal office should be able to attain about 500lux (that is 5% daylight factor) light level in order to achieve a good working condition and visibility comfort.

The building has daylight factors at different luminance level as follows

Table 4.7: Day light factor table– Source: Author's simulated result.

LUX	DAY LIGHT FACTOR (%)
500	5.00
438	4.38
375	3.75
313	3.13
250	2.50
188	1.88
126	1.26
63	0.63

The areas that are illuminated with about 500lux have achieved the standard daylight factor for a normal working condition of an office. The regions ranging from 1.88-0.63% of daylight factor totally depends on artificial lights in anytime of the day thereby consumes a reasonable amount of energy.

4.4.2. Heating/Cooling Loads

Buildings in this region acquire internal heat gain through direct solar radiation, especially when there is no sky cover. The site where the building is located acquires the following (solar radiation, high temperature, little or no sky cover) and are what influences internal heat gains in the building.

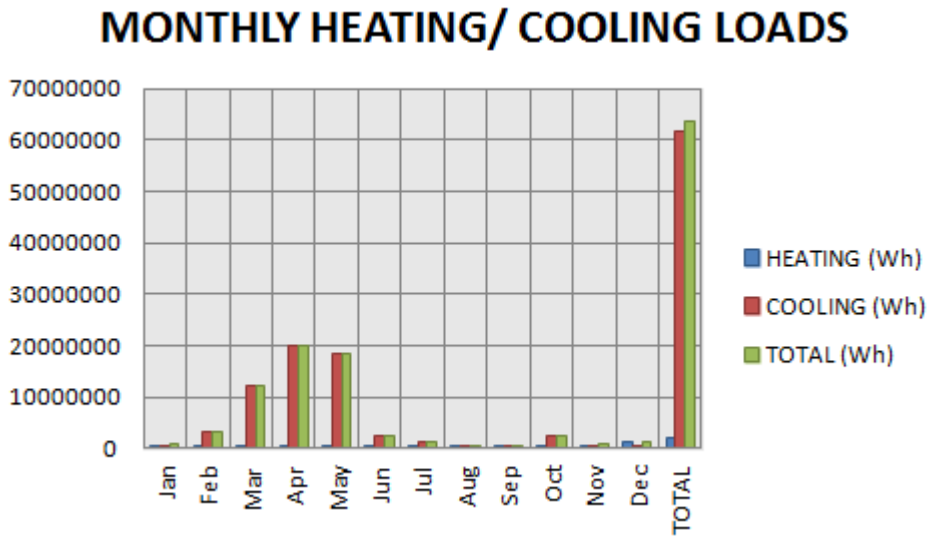


Figure 4.7: Monthly cooling and heating loads– Source: Author's simulated result.

Figure (4.7) is a breakdown showing the relative contribution of each space/zone displayed within each monthly heating and cooling band, this does not mean energy loads but simply mean the load required to heat or cool those zones or spaces.

4.4.2.1 Result

The figure above (Figure 4.7) shows that there is high energy consumption in the month of April due to cooling loads; this is mostly because during April the hot season is more prominent whereby the solar radiation is at its peak accompanied with high temperature. Therefore, there exists a high demand on the cooling system during that period. On the other hand, the demand

for heating loads is more prominent around January-December. August-Septembers' demands are neutral.

Energy is mostly consumed around the months that experiences maximum heating/cooling loads.

4.4.3 Energy Consumption

Since the main problem to be solved in this climate is mainly that of lighting and cooling, the energy is usually consumed by lighting fixtures, HVAC systems and other miscellaneous equipment. This sums it up to both monthly and annual energy consumption of the building.

KWh

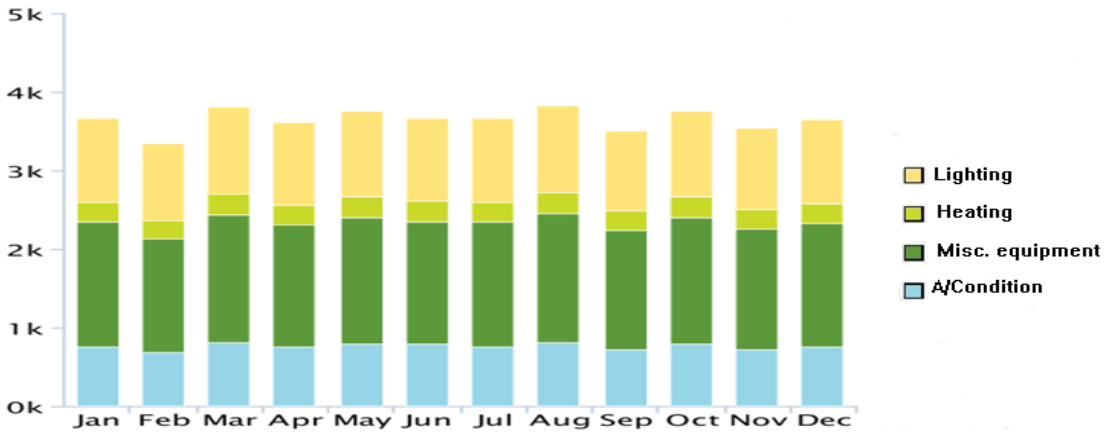


Figure 4.8: Monthly electricity data consumption for component end use– Source: Author's simulated result.

In Figures 4.8, the chart shows the component end-use (cooling, lighting, heating, and others) energy performance (in thousands of KWH/month) for each of the 12 months. This shows that the miscellaneous equipment (computers, photocopiers, printers, and so on.) consume the highest amount of energy.

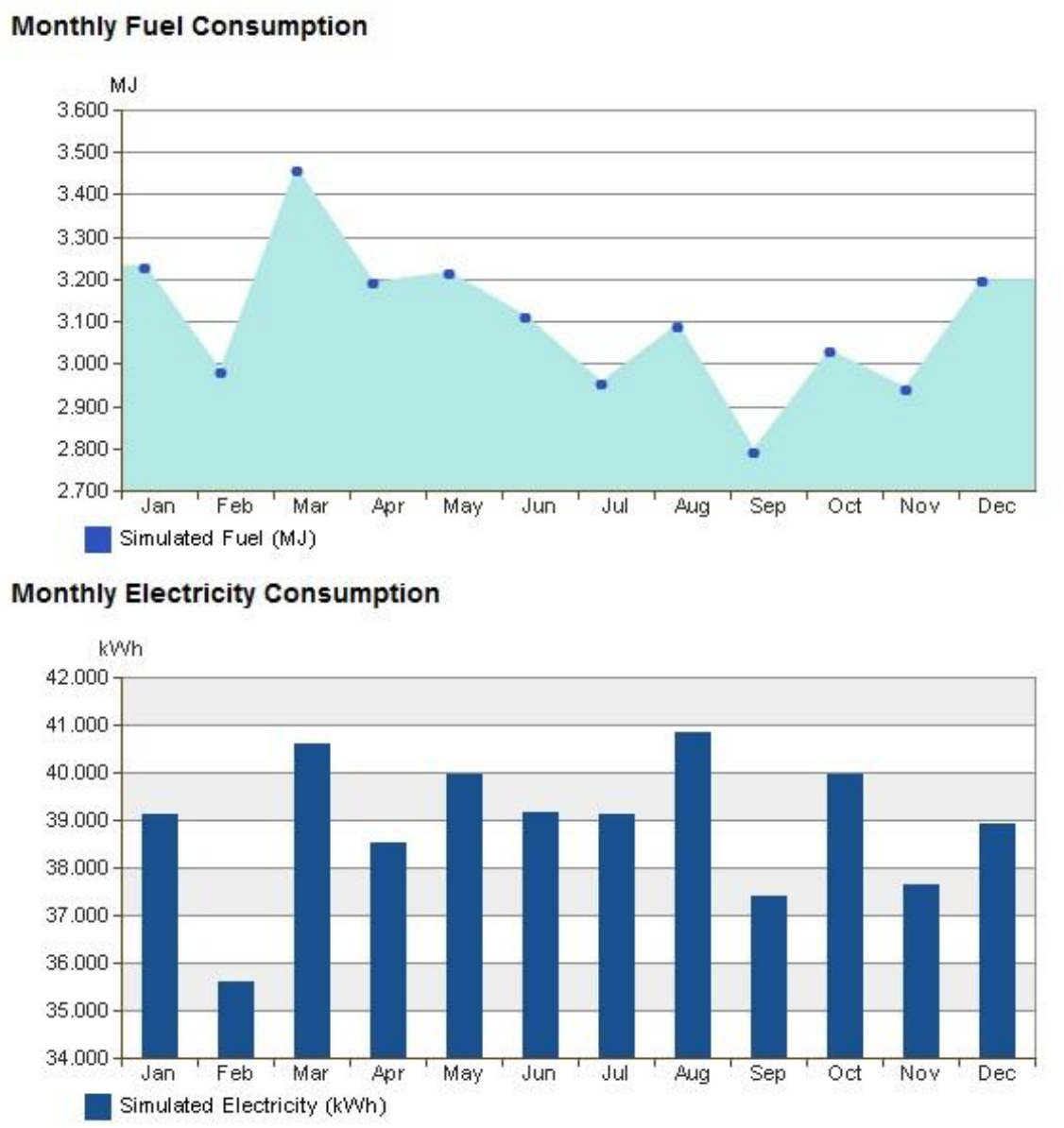


Figure 4.9: Simulated monthly fuel and electricity data consumption– Source: Author's simulated result.

Fig 4.9 shows the simulated value of monthly fuel and electricity consumption, it indicated that the month that consumes energy the most is August and February consumes the least.

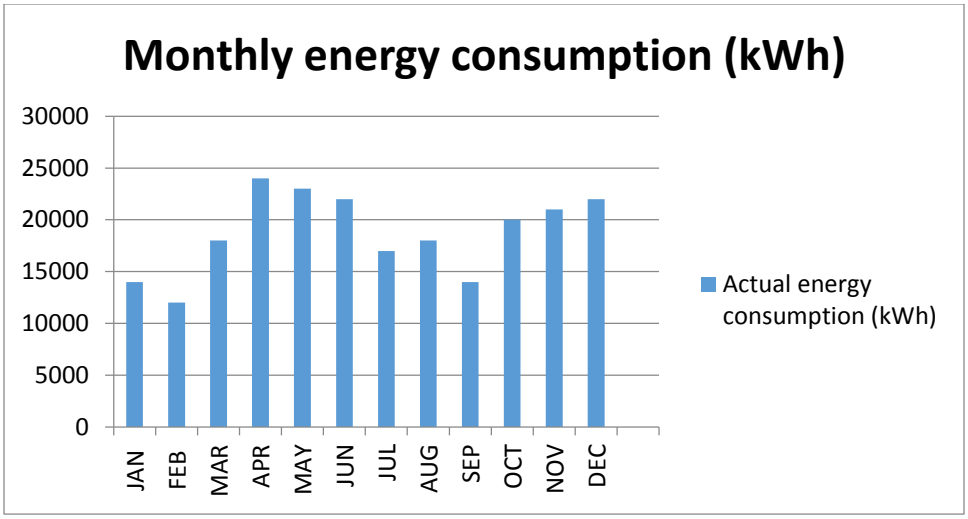


Figure 4.10: Monthly electricity consumption from utility bill – Source: Author's simulated result.

Fig 4.10 shows the actual monthly electricity consumption collected from utility bill dated from January 2013-December 2013. It indicated that the highest energy is consumed in April and the least is consumed in February.

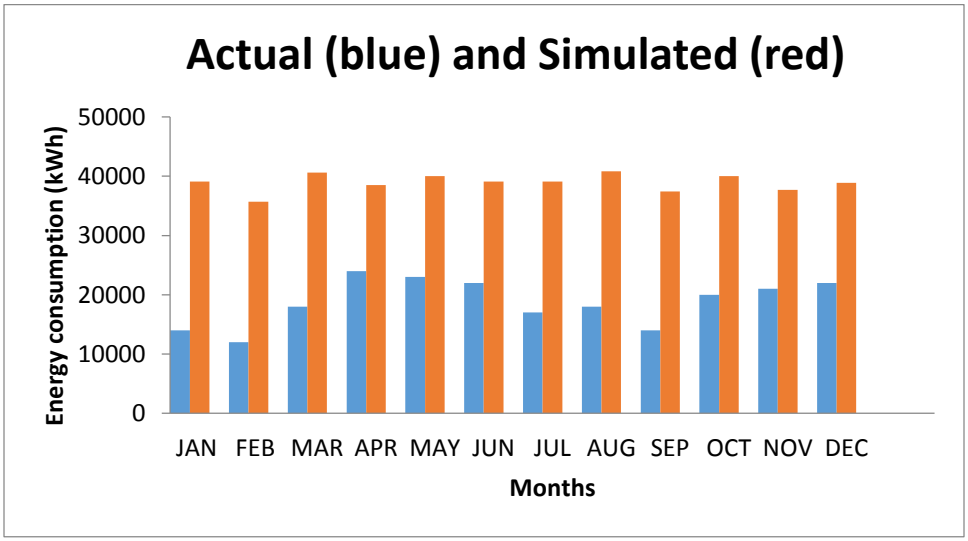


Figure 4.11: Comparison between the actual and the simulated monthly electricity consumption– Source: Author's simulated result.

From figure 4.11, the comparison between the actual and the simulated energy consumption, it shows that the simulated is 35% higher than the actual energy consumption.

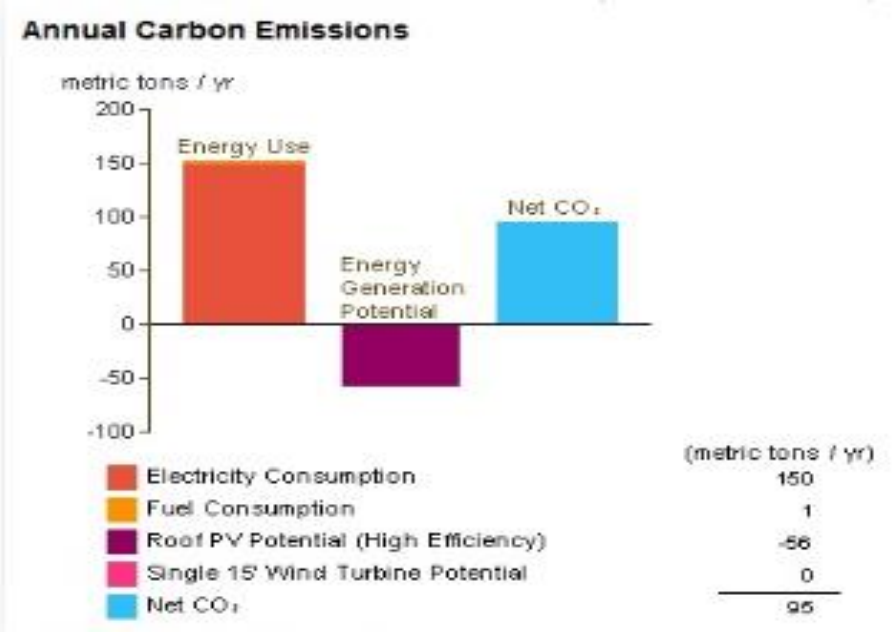


Figure 4.12: Annual carbon emissions (metric tons/yr.)– Source: Author's simulated result.

At the cause of energy use, the building emits about 150metric tons/yr. of CO2, while fuel consumption emits about 1metric tons/yr. but the building has the possibility of attaining -55metic ton/yr. of roof PV potential (see figure 4.12), thereby having a net CO2 emission of 95metric tons/yr. (this is very high).

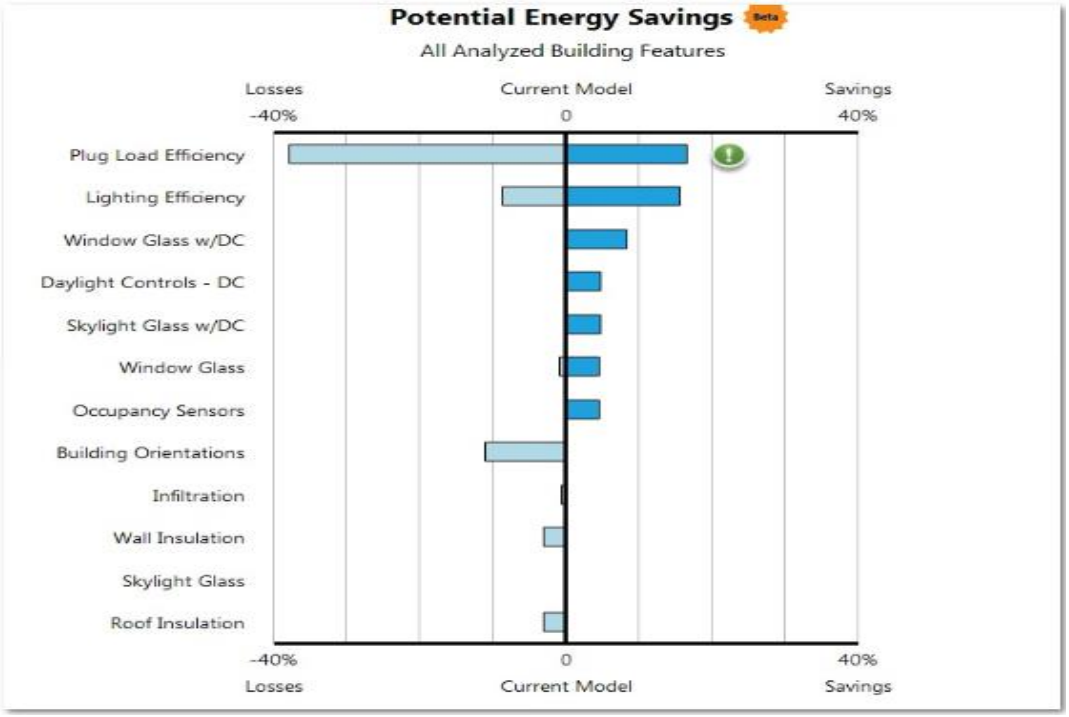


Figure 4.13: Potential energy savings– Source: Author's simulated result.

The building has the possibility of saving considerable energy in percentages which was achieved by analyzing all the building features as seen in fig 4.13.

4.4.3.1 Result

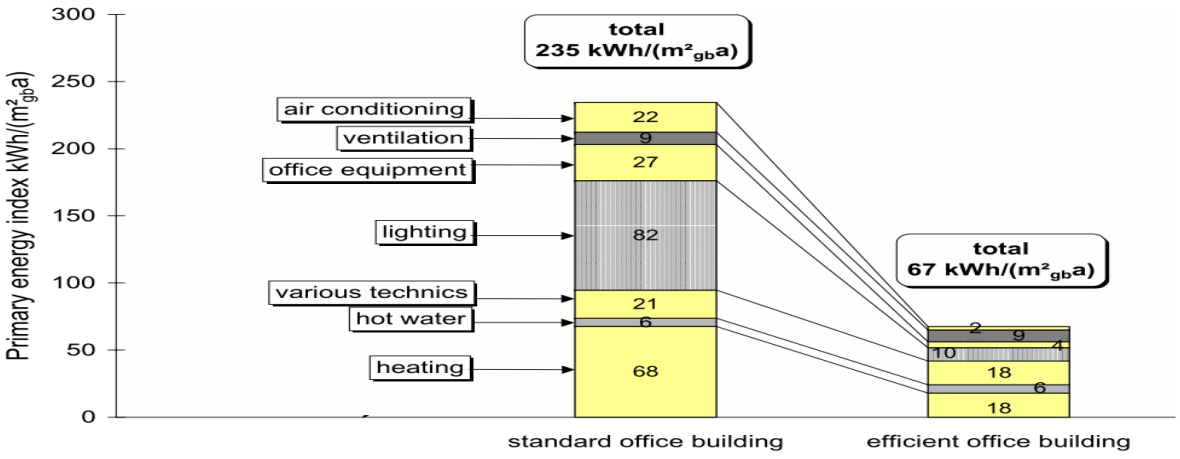


Figure 4.14: Primary energy index– Source: Author's sketch.

The figure above is the primary energy index of both the standard office building and an energy efficient office building, using figure 4.14 above and modifying the component end use to suit the component end use utilized in the case study will help to have a vague idea of how a standard and energy efficient primary index ranges. This will help to further know if the simulated Bank of Industry office building is within the range of a standard office or an energy efficient office. The index is gotten from a book by Knissel, J.

i. Standard office building: this entails the minimum requirement of HVAC system, lighting, equipment and so on.
ii. Efficient office: it involves the best efficiency standards available at the market today.

The primary energy index is calculated by dividing the primary energy consumption by the gross base of the building, it basically indicates that energy consumed is proportional to its overall area.

When modified to suit the component end use of the case study (in order to have a rough idea of how a standard and an energy efficient office entails), the figure when compared appears as this (see figure 4.15).

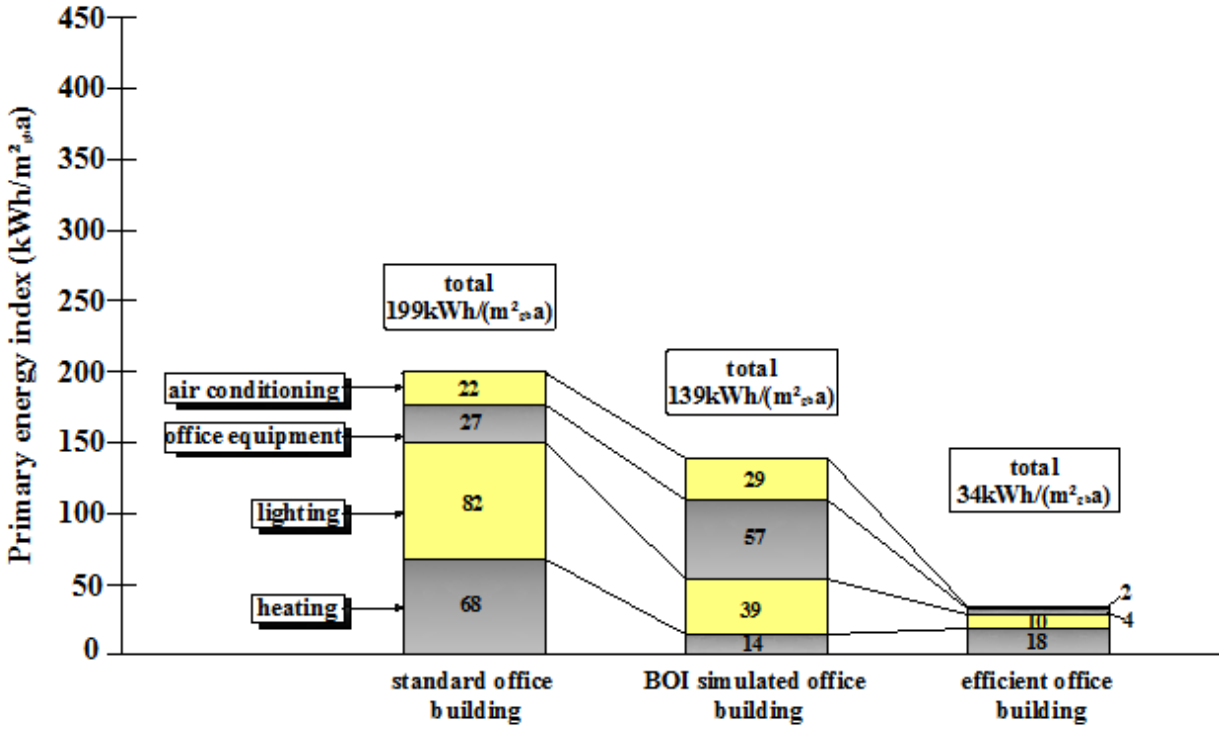


Figure 4.15: Primary energy index when compared with BOI simulated office building– Source: Author's sketch.

The figure above shows the comparison between the standard office, BOI (Bank of Industry) office building and efficient office building. The figure indicates that Bank of Industry office building is up to standard but not efficient.

This also agrees with the visual survey carried out in table 4.6 which also indicates that the building is up to standard and requires being more efficient.

CHAPTER FIVE

DESIGN CRITERIA

5.1 Introduction

This section discusses on the preliminary design proposal and exceptional characteristics that will form the bedrock for the proposed design. The design solution for the proposed design will be based on the client's requirement, space requirement, similar case studies, site location criteria and schematic designs while applying energy efficient principles which are aimed at minimizing energy consumption in the entire design project.

5.2 Brief Formulation

Chevron Corporation is an American multinational energy corporation that deals with every aspect of oil, gas and geothermal energy industries. They are also involved in alternative energy operations such as geothermal, solar, wind, bio-fuel, fuel cells and hydrogen. The corporation has interest to invest in an energy efficient facility, therefore by erecting a mixed corporate large office building, it will help explore their quest for a facility that not only acquire renewable power venture but can also minimize energy consumption.

5.3 The Site

The proposed mixed corporate large office building is to be located at Millennium city, Kaduna state. The center of learning (state slogan) is located at the central portion of the northern part of Nigeria. It is bounded by eight other states which are; N: Katsina, N-E: Kano, E: Bauchi, S-E: Plateau, S: Nassarawa, S-W: Abuja, W: Niger, N-W:Zamfara.

Latitude:+10.20 ($10^0$31'75"N)

Longitude:+7.45 ($7^0$29'41"E)

Total area: 46,053km^2

Time zone:WAT (UTC+01)

Country: Nigeria

Continent: Africa

Sub-region: west Africa

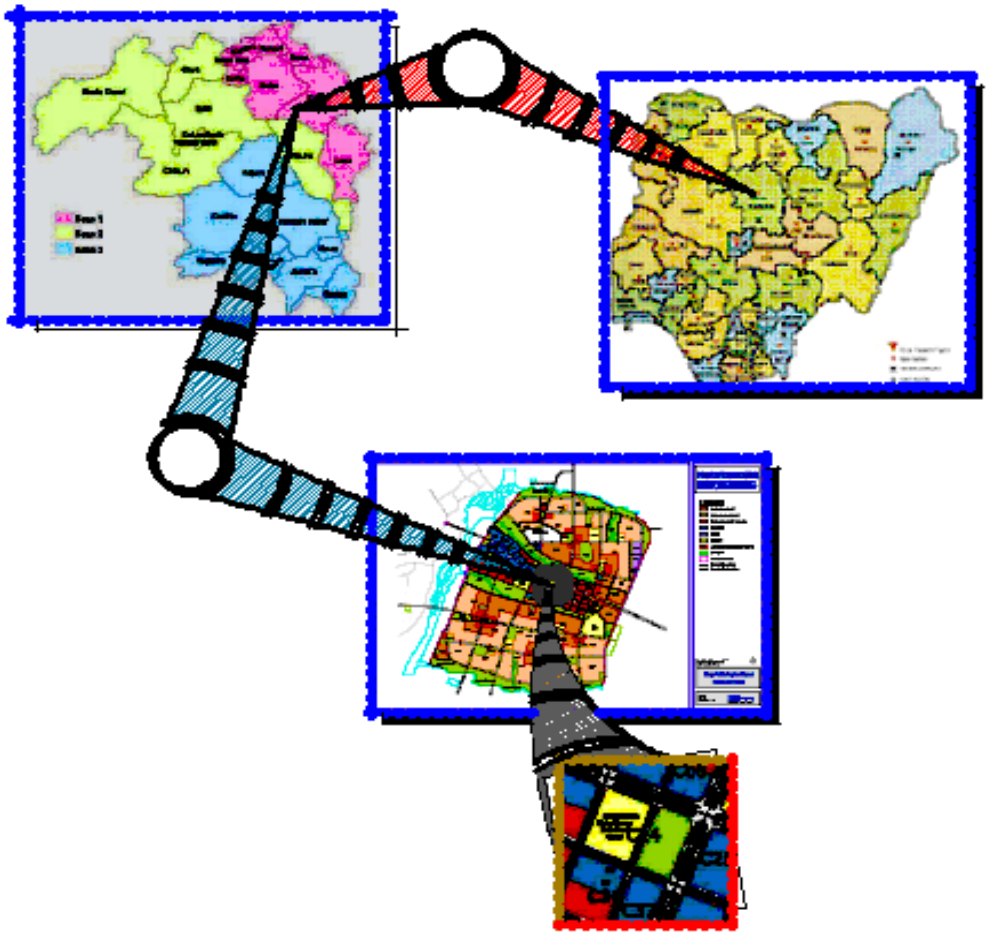


Figure 5.1: Site location– Source: Author's CAD sketch.

5.2.1. Site selection criteria

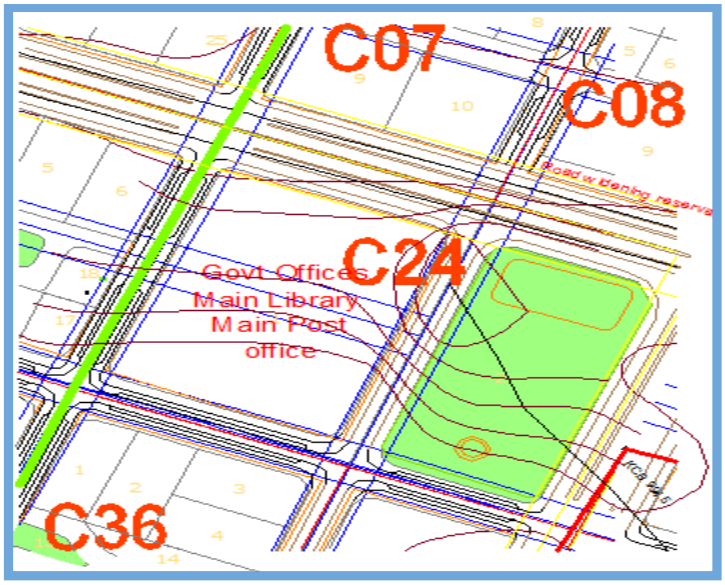


Figure 5.2: Site selection– Source: Author's CAD sketch.

The site selected is labeled C24; the main elements of this site can be described as follows:

1. Choice of site based on approved land use plan
2. Primary central location in the heart of the city
3. Accessible through major and minor road transportation routes
4. Potential of serving proposed and existing settlements
5. The site is characterized by even topography and average environmental conditions

The land principles/office location criteria employed to select this site include:

i. Located along the central belt of 'town center' activities.

ii. Primary frontage of retail/commercial zone along key east-west spine of city.

iii. The site is prominent (a corner site at a busy intersection where the office can easily be seen is preferred).

iv. The site permitted orientation of the front of the building to the north in order to minimize glare from the sun (if it was not possible, orientation to the east was the second choice. However, an otherwise excellent, centrally located site should not be eliminated for lack of appropriate orientation. Modern year around temperature control devices and artificial light can be used effectively to minimize sun exposure problems.

v. Ideally, a site should have uniform foundation conditions, either rock or soil. Test borings should be made, preferably before a site is purchased.

The opportunities and constraints inherent in the site include:

A. Constraints

1. Busy development of city center may impact negatively on noise levels and travel speeds along this busy route

2. Long walking distances from residential areas to the proposed location

3. Sharing of site with government offices and Post Office according to master plan

B. Opportunities

1. Good delineated location

2. 'Good address' on primary route of New City

3. Potential accessibility by residents of proposed and existing settlements

5.2.2 Site Analysis

Figure 5.3 shows the quantitative climatic data analysis. This was analyzed to determine wind speed, mean radiant temperature, rain fall, and so on. this were major considerations in the design.

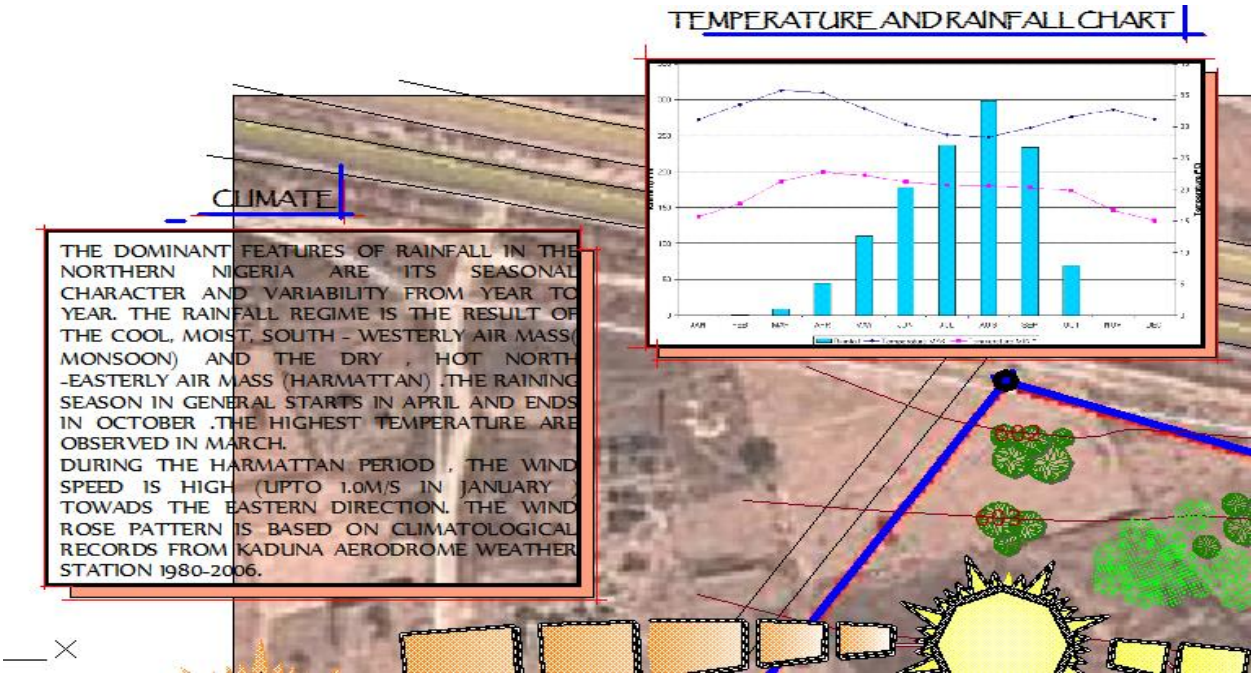
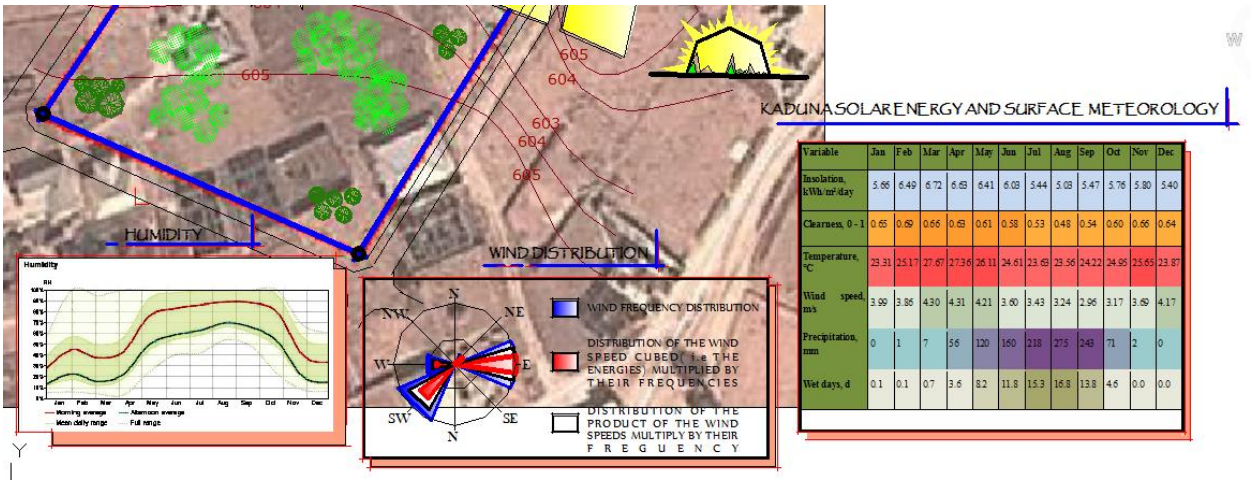


Figure.5.3a: Climatic data analysis – Source: Author's CAD sketch.



Variable	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Insolation, kWh/m²/day	5.66	6.49	6.72	6.63	6.41	6.03	5.44	5.03	5.47	5.76	5.80	5.40
Clearness, 0 - 1	0.65	0.69	0.66	0.63	0.61	0.58	0.53	0.48	0.54	0.60	0.66	0.64
Temperature, °C	23.31	25.17	27.67	27.36	26.11	24.61	23.63	23.56	24.22	24.95	25.65	23.87
Wind speed m/s	3.99	3.86	4.30	4.31	4.21	3.60	3.43	3.24	2.96	3.17	3.69	4.17
Precipitation, mm	0	1	7	56	120	160	218	275	243	71	2	0
Wet days, d	0.1	0.1	0.7	3.6	8.2	11.8	15.3	16.8	13.8	4.6	0.0	0.0

Figure.5.3b: Climatic data analysis – Source: Author's CAD sketch.

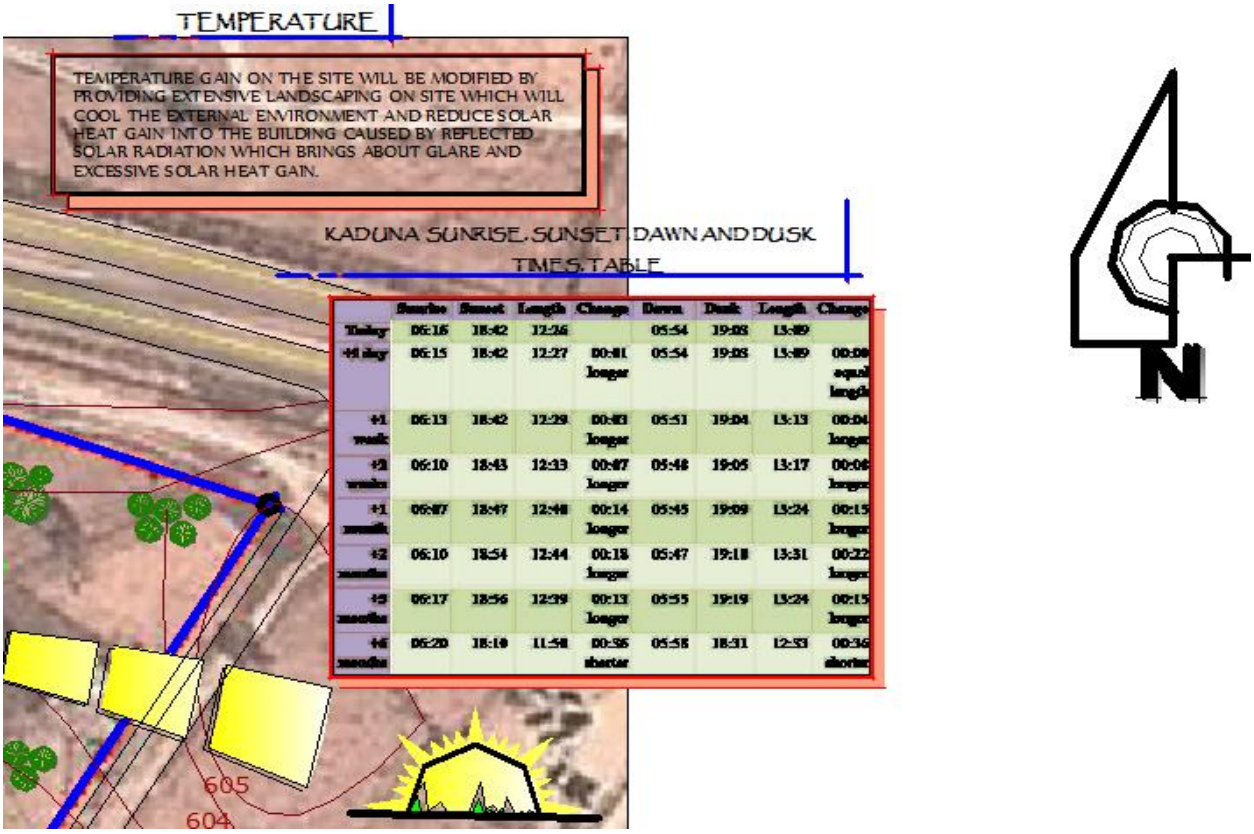


Figure.5.3c: Climatic data analysis – Source: Author's CAD sketch.

The figure below (Figure 5.4) is site analysis showing views around the site. Front view (North-east) of the site is the primary road there is provision for sidewalk and storm drainage. South-east of the site shows a pedestrian pathway running from north-western part of the site to the south-eastern part. Along south-western part of the site is characterized by tall trees and grasses and around the western part of the site is occupied by illegal block manufactures.

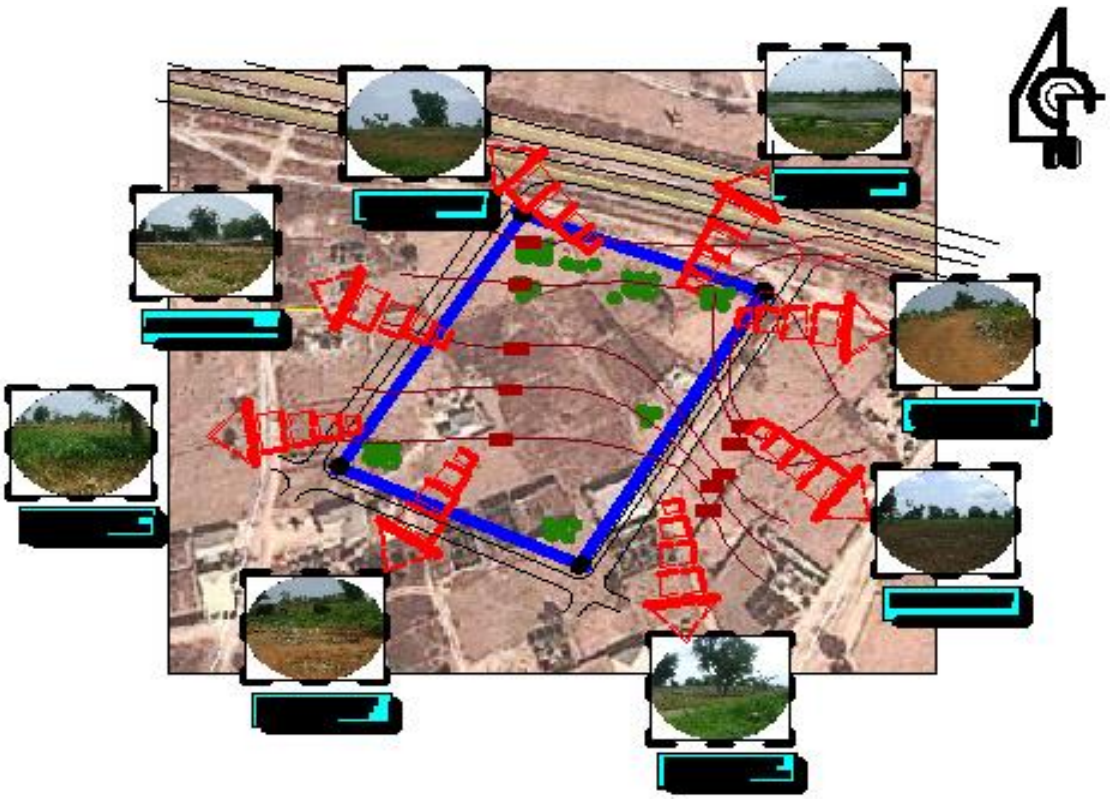


Figure 5.4: Visual analysis– Source: Author's CAD sketch.

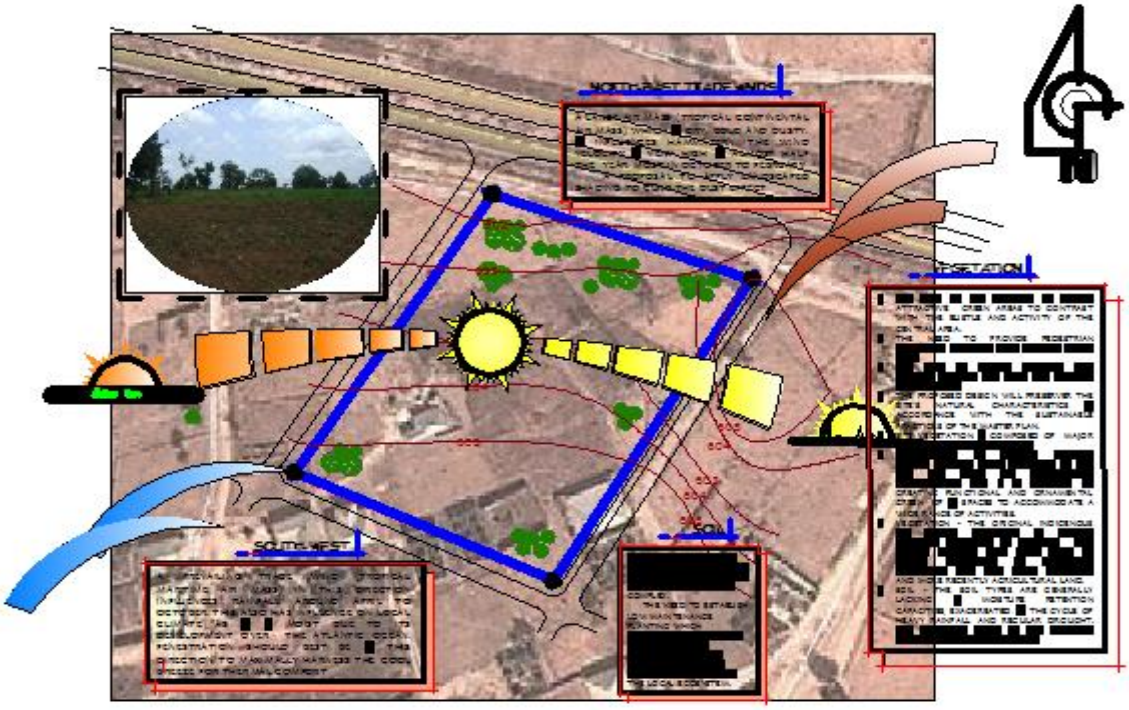


Figure5.5: Site character – Source: Author's CAD sketch.

Figure 5.5 shows the site character in terms of soil and vegetation. The type of soil here is laterite, it has loose and moisture retention abilities, the need to establish low maintenance planting which complements the urban structure while improving moisture retention, reducing erosion and supporting the local ecosystem. The site is characterized by tall trees and grasses, trees like parkia clappertonia (commonly called Dorowa in Hausa) and mangifera indica (mango).

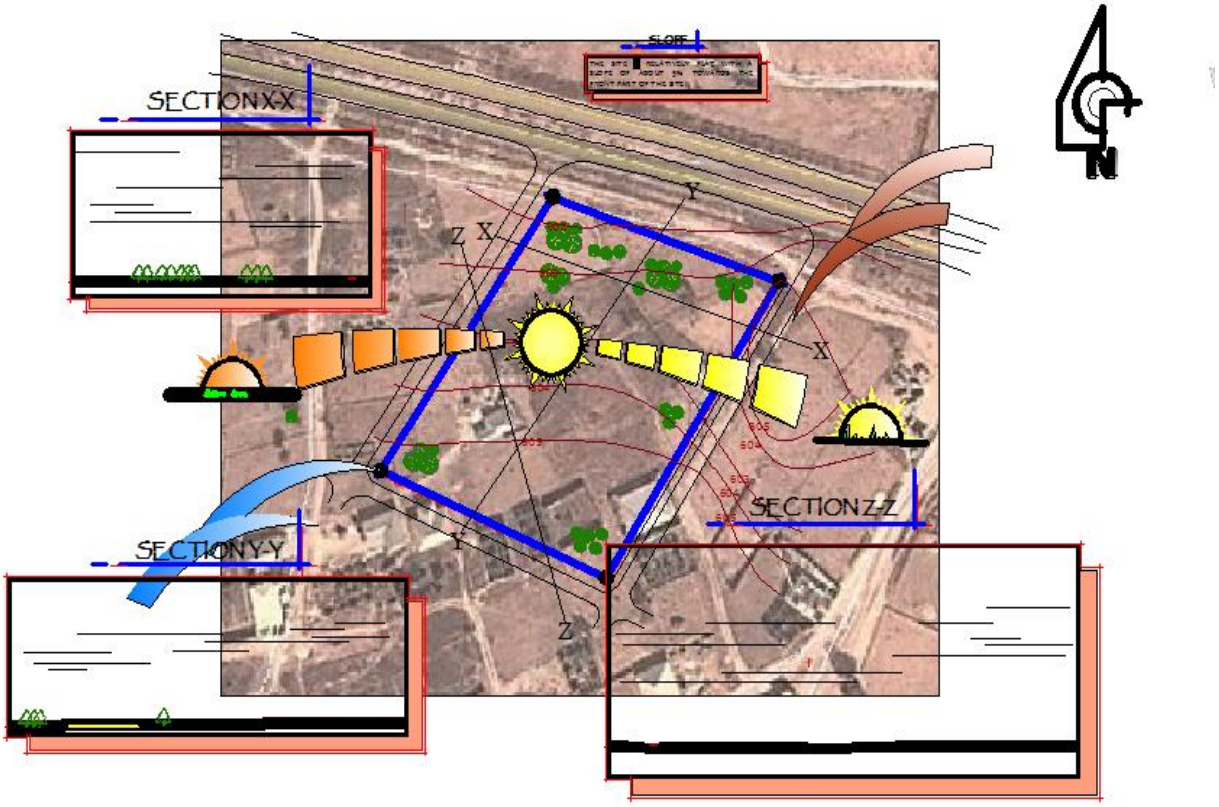


Figure5.6: Topography– Source: Author's CAD sketch.

The site is relatively flat with a slope of about 5% towards the north-eastern part of the site (see figure 5.6).

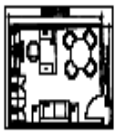
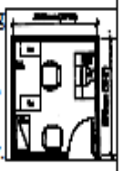
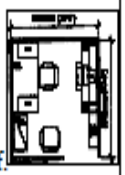
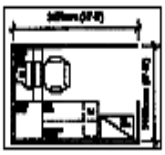
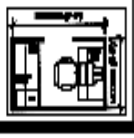
5.4 Schedule of Accommodation

Allocation of spaces was based on standard floor area requirement for each work station and employee in an organization. The facility is meant to lease about four (4) different categories of corporate organizations and they were zoned vertically based on the privacy they require.

The categories are listed below;

- The commercial/retail zone (for example, banks, telecommunications, cyber café, e-library, book club and so on.)
- Consultancy/service oriented firms (for example, architectural firms, pharmaceutical firms, and so on.)
- Consultancy firms (for example, real estate firms, law firms, and so on.)
- High profile consultancy firms

Table.5.7: Schedule of Accommodation (workstation spaces) – Source: Author's CAD sketch.

SPACE TYPE	FUNCTIONAL ASSIGNMENT	SPACE ALLOCATION	
		m^2	ft^2
Enclosed Type A	Frequent meetings with up to four others and/or requiring confidentiality, security, visual and acoustical privacy. Typical assignment for Deputy Minister or equivalent. 	22.5	240
Enclosed Type **B**	Frequent meetings with up to two others and/or requiring confidentiality, security,visual and acoustical privacy. Typical assignment for assistant Deputy Minister, Director, senior position in charge of a regional or district office or equivalent 	13.9	150
Enclosed Type **C**	Frequent meetings with up to two others and/or requiring confidentiality, security,visual and acoustical privacy. Typical assignment for position involved with counseling, human resources management or other sensitive situations requiring ongoing visual and acoustical privacy. 	9.3	100
Open Type **D**	Concentrated multi-source paper work: compiling information, reading, writing, analysing,calculating and referencing multiple sources of material; allows for manual and automated drafting functions. Typical assignment for managerial, professional or technical staff. 	9.3	100
Open Type **E**	Multi-task intensive work: telephone work, keyboarding, filing, sorting documents, handling mail, editing, operating equipment, scheduling, receiving visitors. Typical assignment for secretary and administrative support staff. 	6.5	70
Open Type **F**	Specific, task-oriented work, focusing on data input into electronic media. Typical assignment for clerical and data entry staff. 	4.5	50

25% of the actual space required was added as circulation space

Table.5.8: Schedule of Accommodation (support spaces) – Source: Author's CAD sketch.

SUPPORT SPACE	TYPICAL SPACE ALLOCATION AND FUNCTIONAL ASSIGNMENT
Filing Cabinet	Allow 1.0m² (10ft²) per filing cabinet.
Plan Cabinets	Allow 1.5m² (15ft²) per plan storage cabinet.
Storage Shelf Units, Storage Rooms	Allow up to 1.0m² (10ft²) per shelving unit either free-standing or within storage rooms
Photocopier Area	Allow up to 5.0m² (50ft²) for standard photocopying requirements to include paper storage and work surface.
General Work Area	Allow up to 5.0m² (50ft²) for common/shared workstation for functions such as mail sorting, computer equipment facsimile machine, etc.
Reference Library	• Allow up to 1.0m² (10ft²) per shelving unit. • Allow 5.0m² (50ft²) per reading and work table.
Local Area Network (LAN) Computer Room	Space allocation determined on a case by case basis taking into account equipment footprint and other functional requirements.
First Aid Room	First Aid Room will be provided based on reputations under the Safety Act for buildings with multiple department.
Reception Area	Space allocation based on functional needs; e.g, visitor/customer traffic, security requirements, reception activities, etc.
Quiet rooms	Allow 1 quiet room of 9.3m² (100ft²) for every 10 open workstations.
Meeting Rooms	• Meeting of 4-5 people, allow 11.15m² (120ft²) • Meeting of 6-7 people, allow 13.90m² (150ft²) • Meeting of 12 people allow 22.30m² (240ft²)
Coffee Counter/Nook	Allow 1 counter/nook of 1.16m² (12.5ft²) • per 30-FTE department; or • per floor, where departments each have less than30 FTEs

FTE means Full Time Equivalent

5.5 Functional Flow Diagram

The relationship between spaces within the proposed office building includes circulation, working spaces and support spaces. The major access to these facilities are lifts and lifts all accessed through the circulation/core. This is essential to ensure accessibility and easy servicing.

The figures below (figure 5.7 and 5.8) show the spatial and functional relationship between spaces provided in the proposed office building.

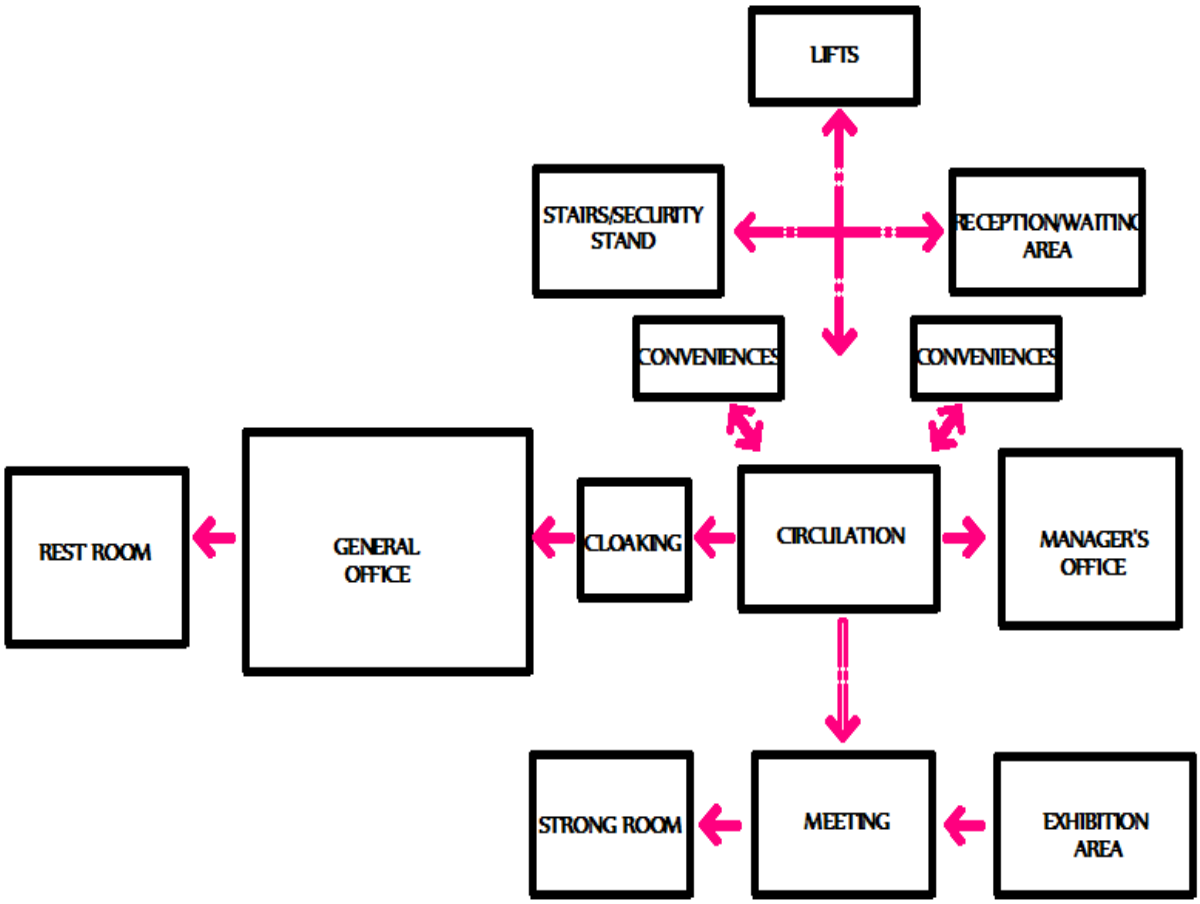


Figure 5.7: Functional Flow around Commercial and Retail Zone – Source: Author's CAD sketch.

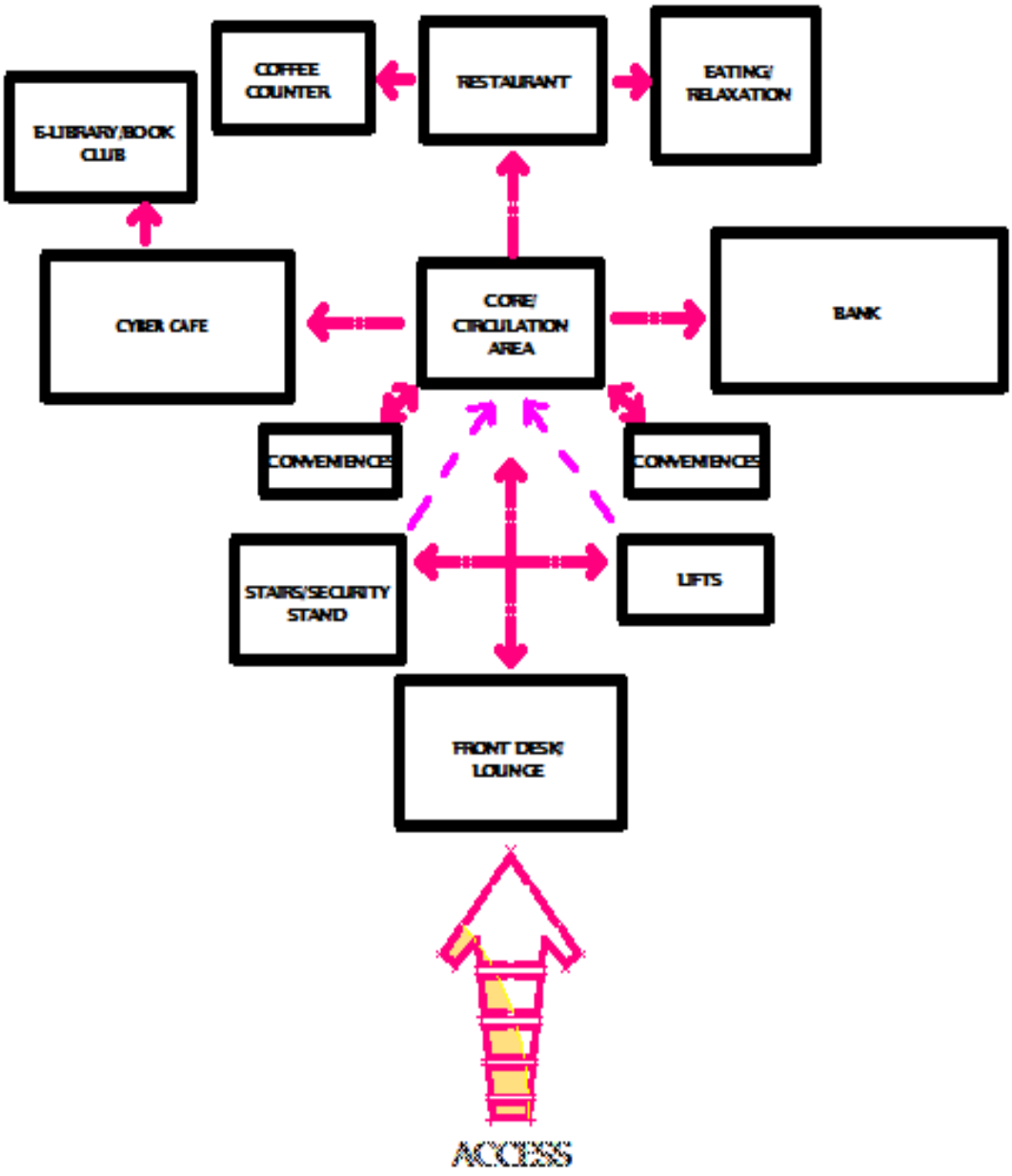


Figure 5.8: Administrative functional flow diagram – Source: Author's CAD sketch.

CHAPTER SIX

DESIGN REPORT

6.1 Preliminary Proposal

This design aimed at providing a facility that will consume energy at a rate that minimizes its usage, thereby applying the principles of energy efficiency to achieve this goal. The design also considers the basic design characteristics of the hot and dry climate by focusing on the climatic suitability parameters so as to achieve ventilation, thermal balance and visual comfortability. The deign provided the follow facilities;

i. Administrative facilities
ii. Commercial/retail facilities
iii. Plant rooms (electrical control room)
iv. Security stands
v. Drivers lounge
vi. Maintenance office
vii. Generator house
viii. Recreational/relaxation facility
ix. Mosque
x. Parking spaces

6.2 Sketch Design

The design is a mixed corporate office, it is a square form, and 6m grid office building that is made up of 10 floors in a tower and podium setting. It is vertically zoned into commercial/retail zone, consultancy/service oriented zone, consultancy firms' zone and high profile consultancy firms' zone.

Space allocation were based on standard floor area requirements for each functional space (workstations, equipment and circulation area inclusive) for the achievement of energy efficiency.Rentable office was based on the number of employees (say between 3-6 employees) will have to share the same printer, photocopier, and scanner.

The ground floor (see fig 6.1) is categorized under the commercial/retail zone, it has facilities such as main reception, banks, café and offices that operates under this category. The facilities in this zone are more of public oriented activities and are placed here foreasy accessibility. This zone (ground and first floor) can be easily accessed by two staircases located around the core of the design. Two lifts can be seen located at the northern part of the design; each is an 8 passenger car lift.

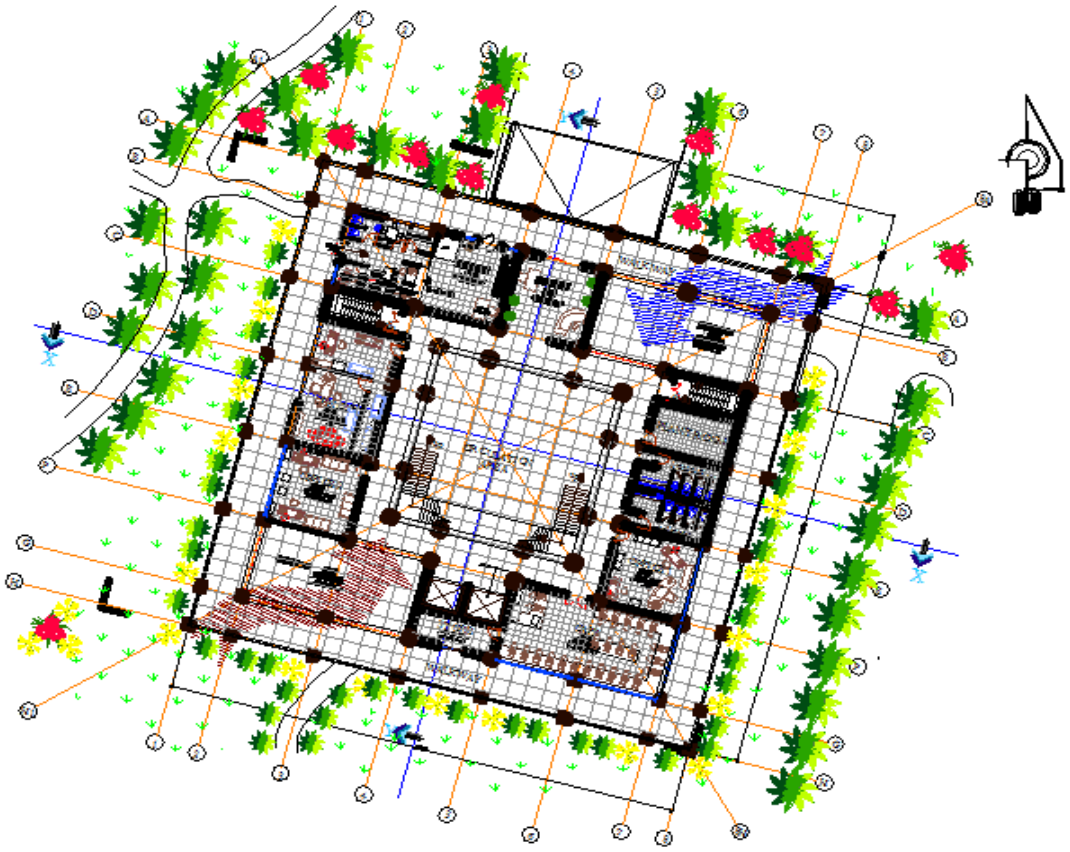


Figure 6.1: Ground floor plan – Source: Author's CAD sketch.

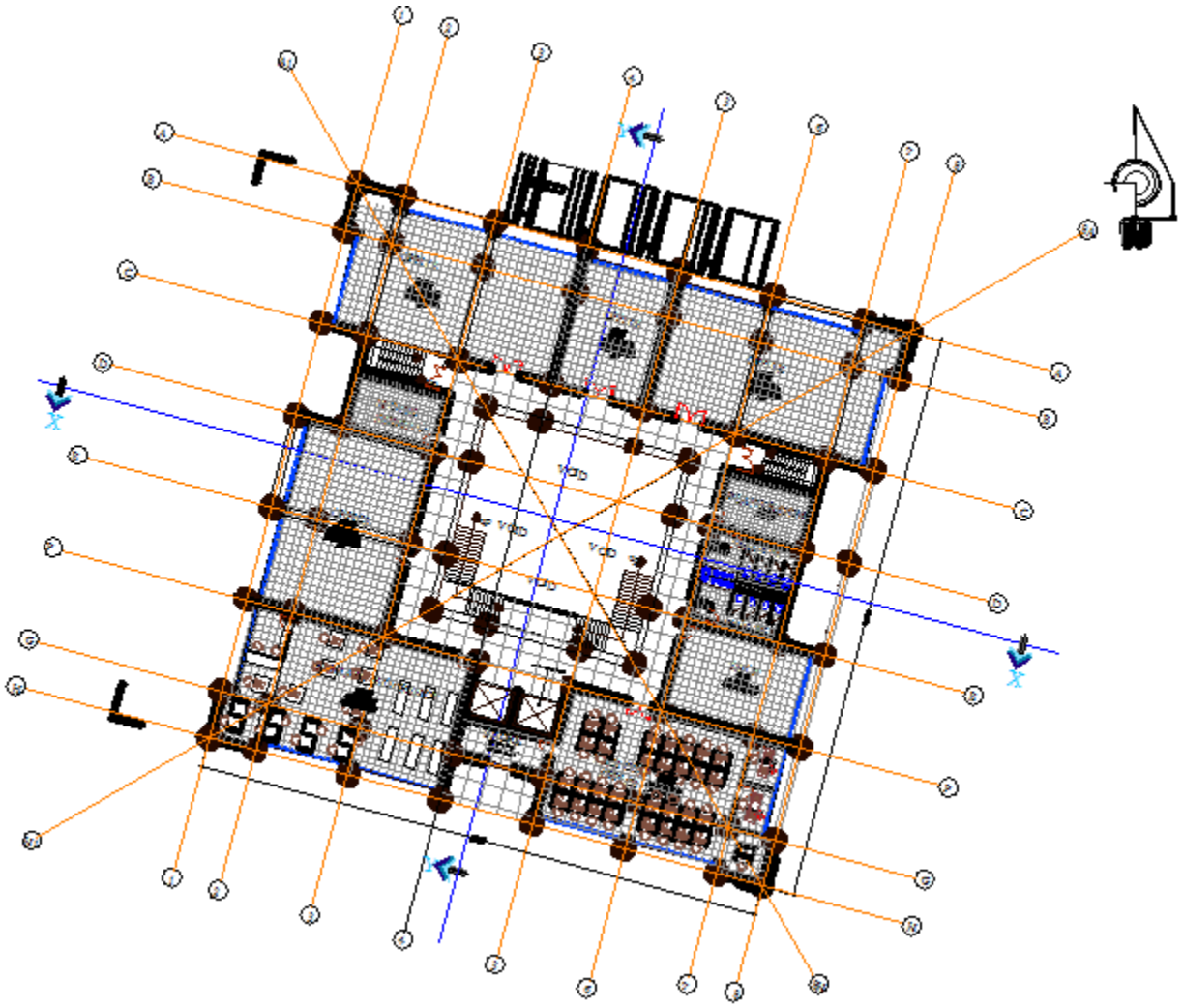


Figure 6.2: First floor plan – Source: Author's CAD sketch.

Figure 6.2 is the first floor plan, it's also under the commercial/retail zone, it has facilities such as telecommunication office, e-library/book club, shop, and offices that fits into this category.

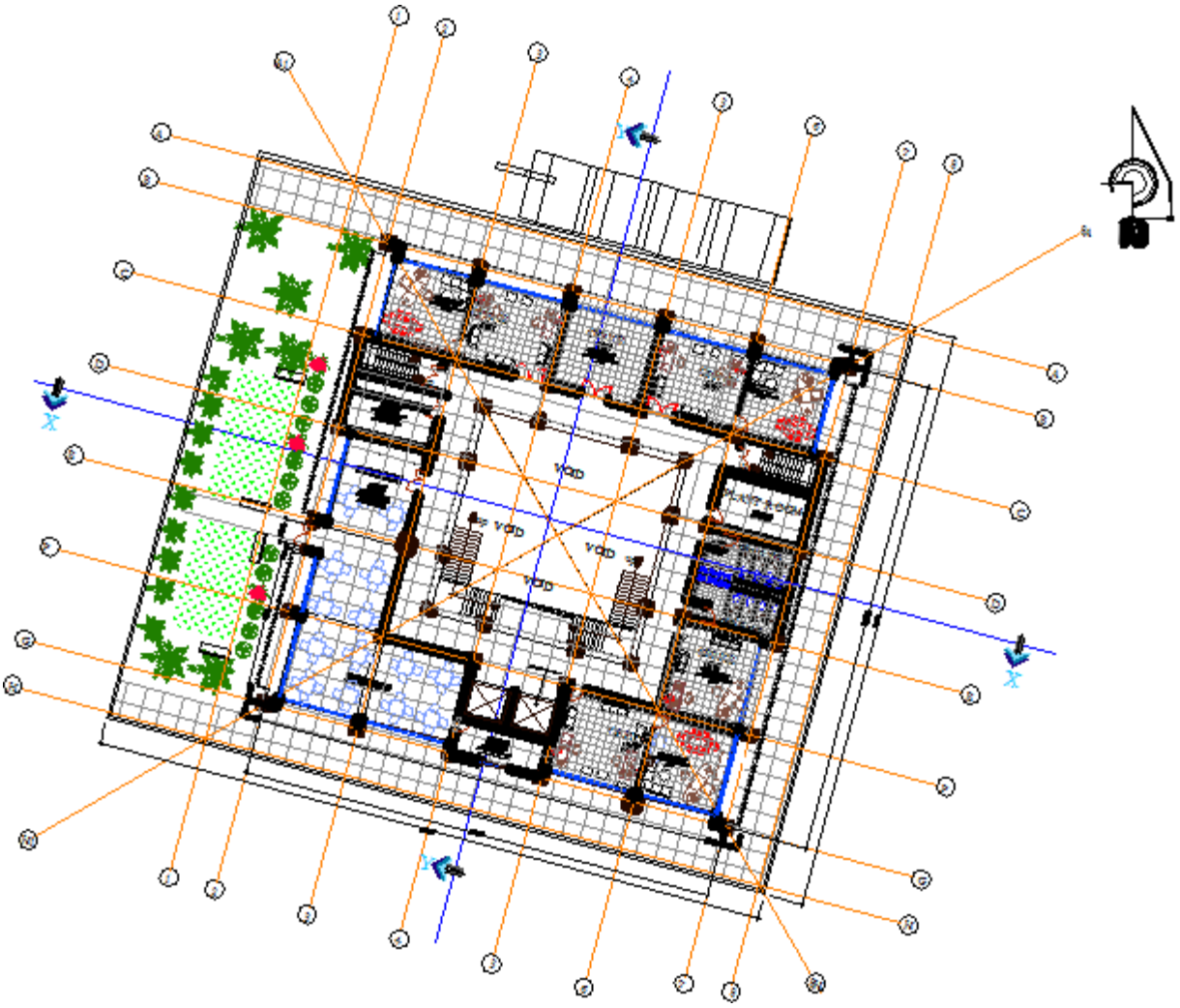


Figure 6.3: Second floor plan – Source: Author's CAD sketch.

Second floor plan (fig 6.3) is under consultancy/service oriented zone, this zone has to do with facilities that consult and at the same time offer some basic services related to the type of activities they do. Offices like architectural firms, pharmaceutical firms etc. this floor has administrative facilities (offices) and restaurant is also placed here so that employees in this building wouldn't go out of the building to get food during break period. The floor also has a roof garden that helps in creating a micro climate by sieving the area in terms of oxygen supply and CO_2 reduction. This zone covers from second to fourth floor.

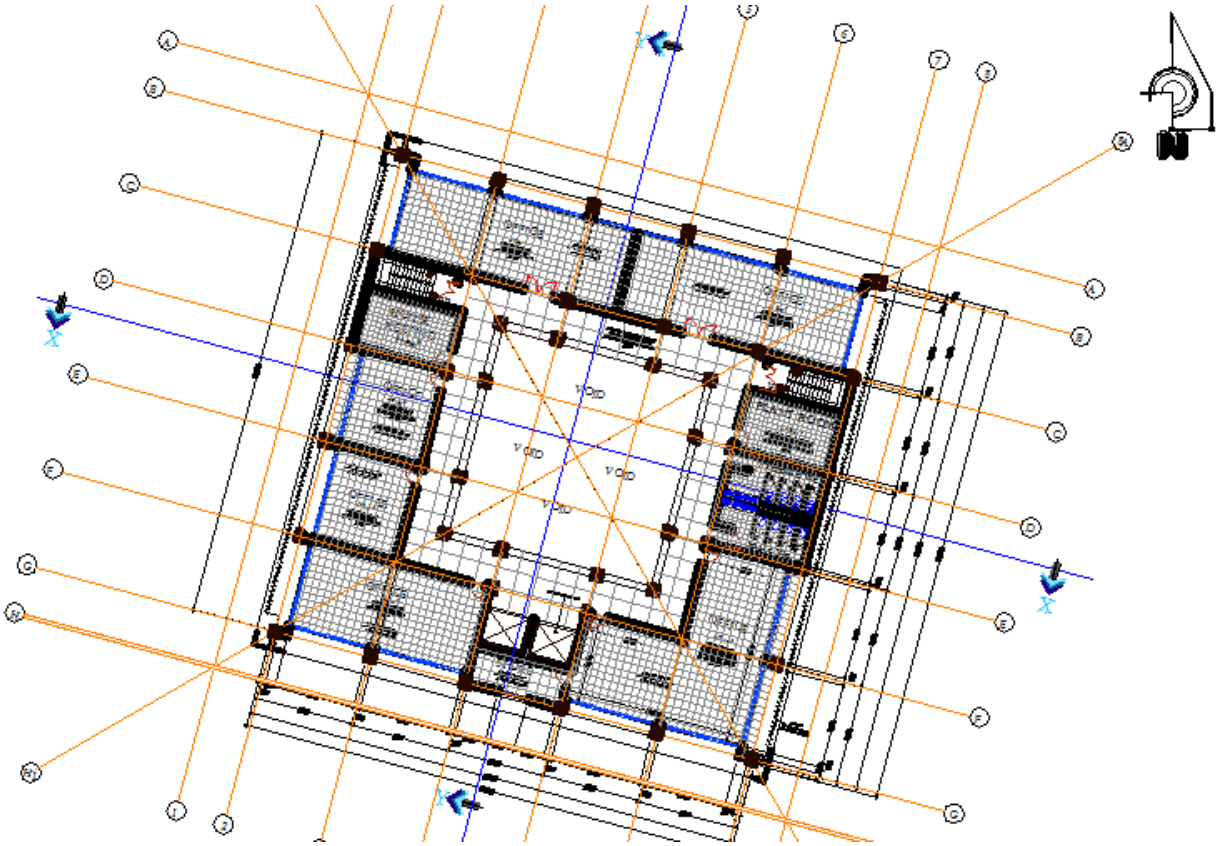


Figure 6.4: Fifth-seventh floor plan – Source: Author's CAD sketch.

Fig 6.4 is the 5th-7th floor plan, it is zoned as the consultancy firm zone, it basically involves firms that strictly deals with consultation, firms like law firms, real estate firms etc. leasable floor area is based on the size of the firm and number of employees.

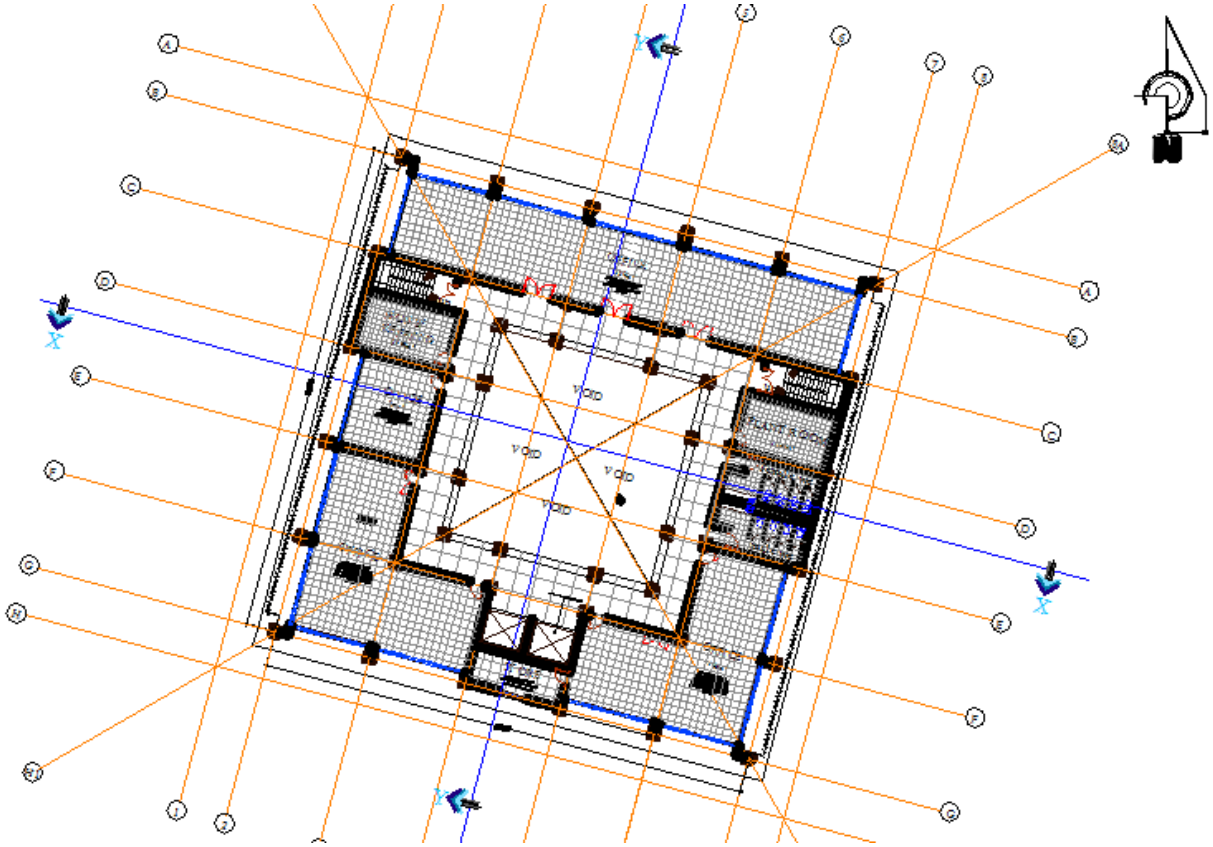


Figure 6.5: Eighth-ninth floor plan – Source: Author's CAD sketch.

Fig 6.5 is zoned under high profile firms, it is a private zone, and people come here only when they are given appointments. A firm can lease a whole floor or part of it depending on the need.

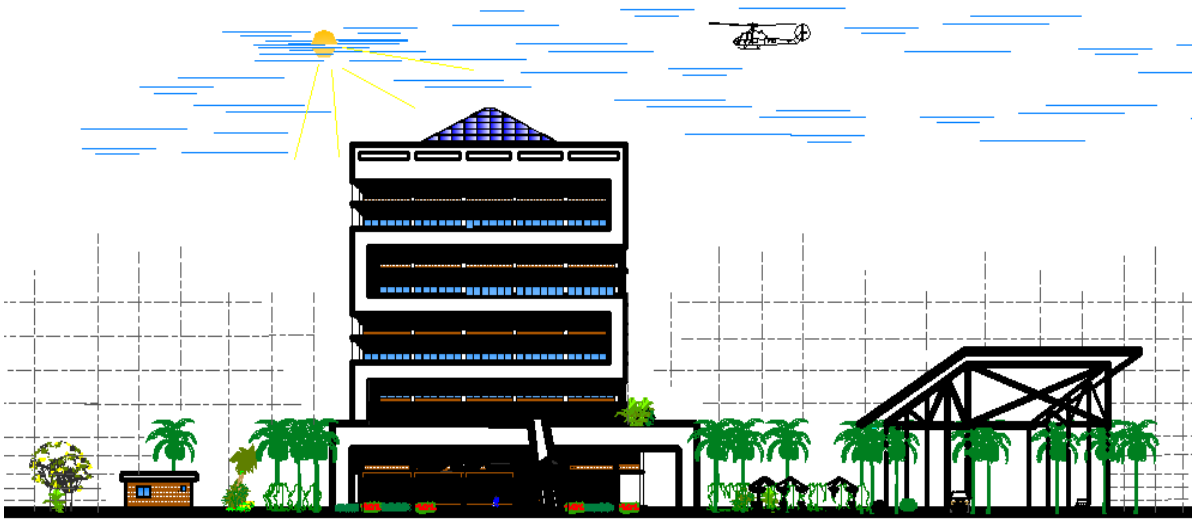


Figure 6.6: Approach elevation – Source: Author's CAD sketch.

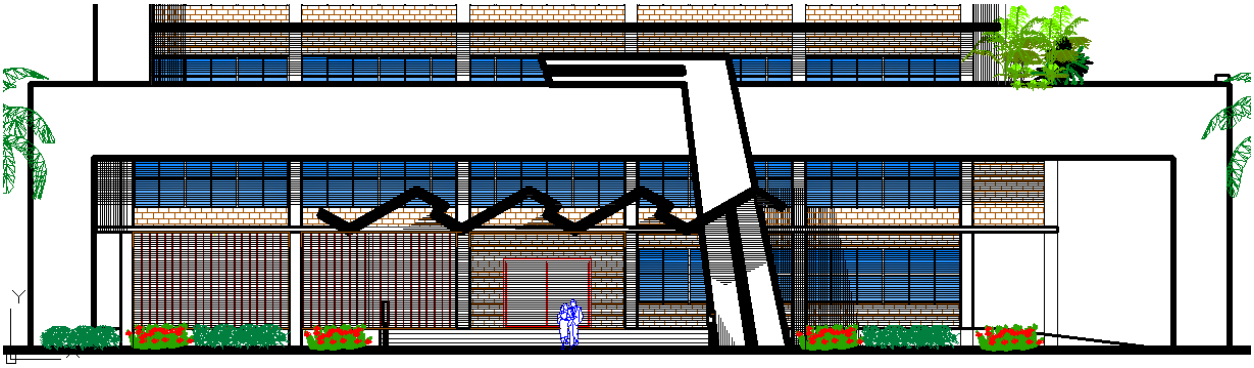


Figure 6.7: Approach entrance – Source: Author's CAD sketch.

Fig. 6.6 is the approach elevation; it shows a defined and celebrated entrance. It is reinforced concrete folded plate anchored on first floor slab and also supported by the prominent slanted column shown in figure 6.7. The elevation shows extensive overhang (1800mm) that help in the shading of the building from direct solar radiation, therefore reduces excessive heat gain.

6.3 Adopted Principles of Energy Efficiency and how it was applied in the Design

The principles of energy efficiency that the design adopted are as follows and how it's been applied will be discussed appropriately. The principles are as follows;

i. Reduce heating, cooling and lighting loads.

Strategy used: - 1. Medium ranged embodied energy material (bricks and concrete) was used, they are characterized by high insulation capabilities and good thermal mass, and they also have strength and durability and will stand the test of time.

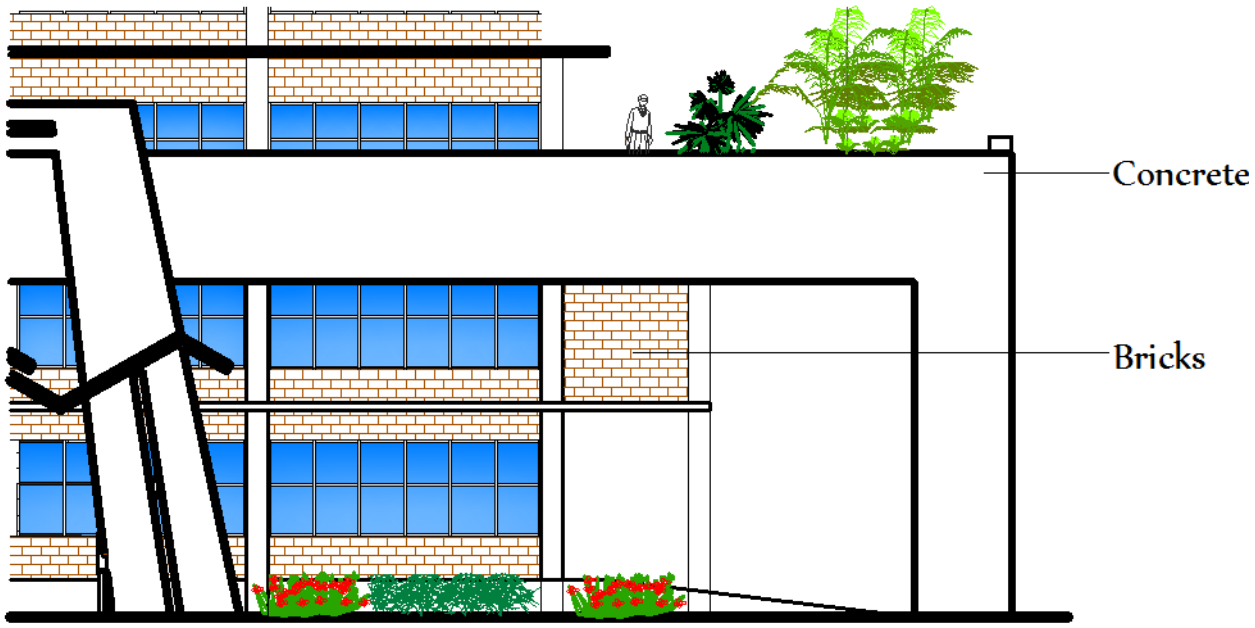


Figure 6.8:The use of bricks and concrete – Source: Author's CAD sketch.

The embodied energy of brick is 2.5MJ/Kg and 5170MJ/m^3, concrete has embodied energy of 1.3MJ/Kg and 3180MJ/M^3.the fig above (figure 6.8) shows how these material are used, they help to reduce the cooling load of the building by absorbing heat, store it for a long time and dissipate it during the cold evening when it is needed, therefore these materials has a good thermal mass.

2. Ventilation – the principle of stack effect was introduced, cool air enters through the external window and the used air goes out through the upper window.

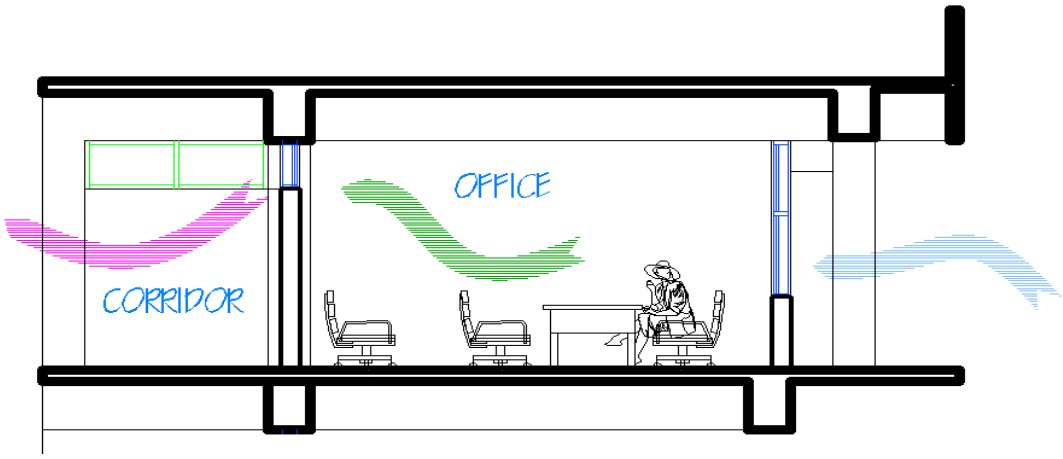


Figure. 6.9: The use of stack effect – Source: Author's CAD sketch.

Fig 6.9 shows how the stack effect was achieved in each office, the used/hot air passes through the upper window and through the corridor and escapes around the atrium. The use of extensive overhang (about 1800mm) is also seen in figure 6.9, the walls and windows are not in direct contact with solar radiation. This helps to reduce the cooling load.

3. Day lighting – the building is well day lighted at individual offices and at the same time around the atrium.

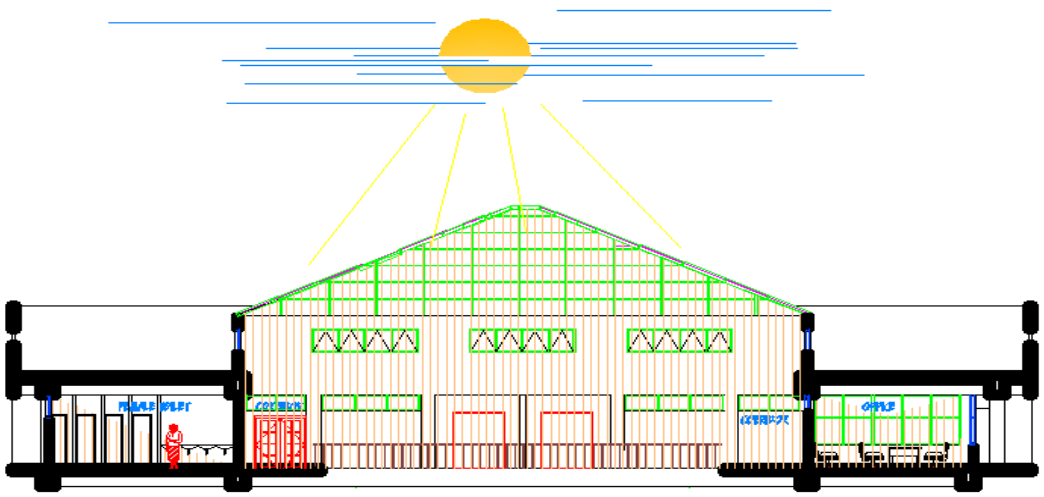


Figure 6.10:Day lighting – Source: Author's CAD sketch.

Fig 6.10 shows how day lighting enters the building, the material used for the atrium is low-e translucent glass (Danpalon), it allows light pass through diffusely and does not allow heat pass through. This helps to reduce the lighting load in the building.

This climate is usually hot, harmattan is experienced in just few months, and therefore there is little or no need for heating the building.

ii. Utilize active solar energy. **Strategy**: - generation of electricity on site (PV panels) as a means of renewable energy. There are other source of renewable energy such as wind energy and biomass. The research basically chose solar energy because the site location has solar energy in abundant compare to other form of renewable energy.

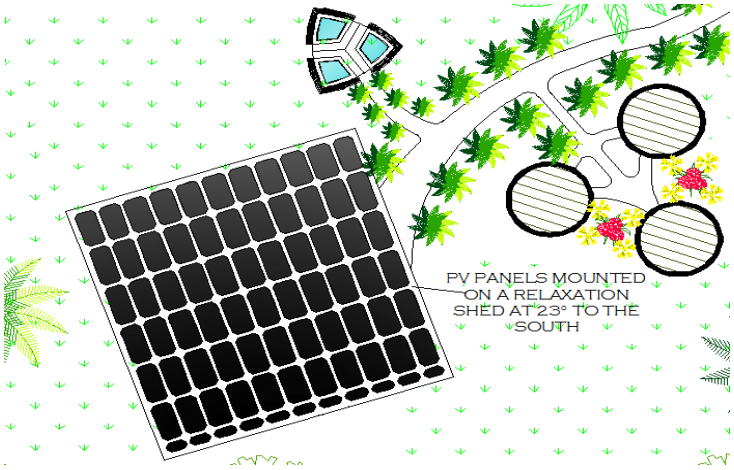


Figure 6.11: Photovoltaic panel – Source: Author's CAD sketch.

Figure 6.11 shows the photovoltaic panel placed on a shed for relaxation for the generation of electricity on site, it is placed at 23^0 to the south (this is where solar radiation is intense irrespective of sunrise and sunset). Photovoltaic means they convert sunlight into electricity, many cells link up to form photovoltaic/solar panel. Photovoltaic cells are made of conducting material usually silicon. When sunlight shines on the cell it creates electrical field across the layers. The stronger the sunshine, the more the electricity it produced, it is measured in kilowatts

peak (kWp). The figure below (figure 6.12) shows the flow from when sunlight is been converted to electricity to its end use.

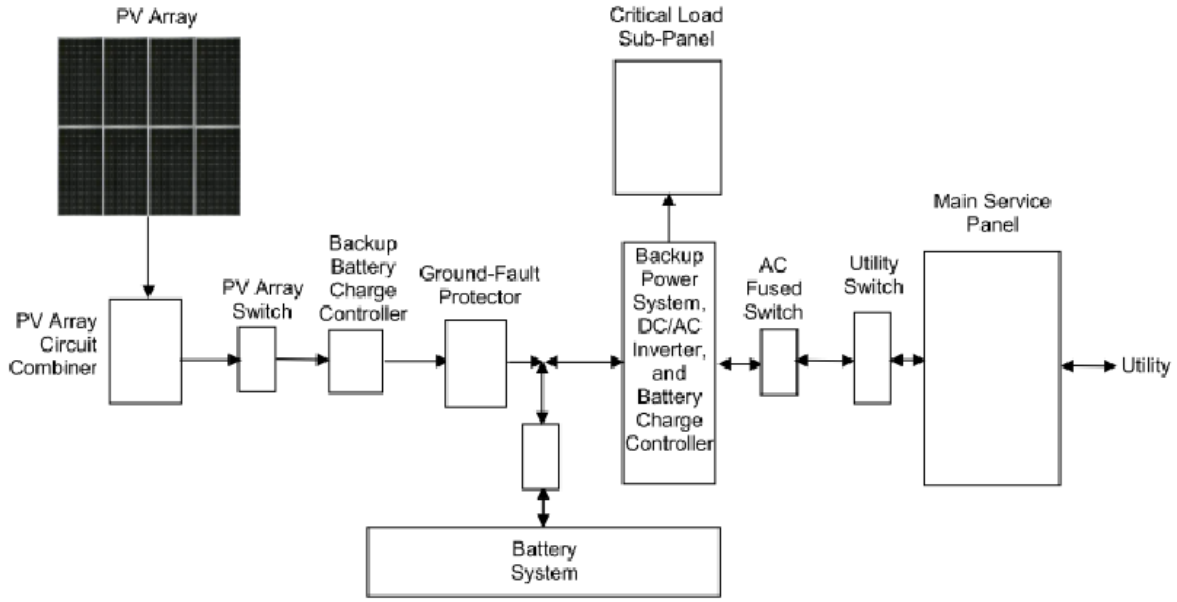


Figure 6.12: Photovoltaic panel flow chart – Source: Author's CAD sketch.

iii. Increase the efficiency of appliances, heating and cooling equipment and ventilation.

Strategy: - energy efficient appliances and equipment were used and where possible the number and size of appliances were reduced.

Energy star rated (6.0) appliances and equipment that consumes less energy are used so that the energy will be consumed at a rate that minimizes its usage.

Table 6.1: Floor area, calculated number of users and number of equipment per facility – Source: Author's CAD sketch.

Facility	**Floor Area**	**No of Employees**	**Energy star 6.0 rated Equipment and amount/facility**				
			Desktop 30w	Printer 35w	Photocopier 500w	Scanner 12w	Projector 15w
Reception	$36m^2$	4	-	-	-	-	-
Bank	$72m^2$	10	5	1	1	1	1
Cafe	$72m^2$	5	25	1	1	1	1
Office (1&2)	(2)$36m^2$	(2)3	(2)3	(2)1	(2)1	(2)1	(2)1
Office 3	$54m^2$	6	4	1	1	1	1
Exhibition	(2)$72m^2$	(2)4	-	-	-	-	-

Table 6.1 shows energy star rated appliances that consumes less energy and the numberof people that uses it, this helps to monitor the number of equipment used in the building. This calculation was based on facilities in ground floor.

iv. Utilize system approaches to building design. **Strategy**: -1. Daylight diming control will be placed in open/flexible office where the amount of daylight entering the space controls the dimming ability of the lighting appliance. It saves about 15-30 percent energy

2. Occupancy sensorswhile programmed, time-clock-based control, turn lights on and off based on whether the monitored area is occupied, the result is 35-45 percent energy savings. It will be placed in private office.

3. Full commissioning and maintenance of the equipment will be given due consideration.

v. Minimize greenhouse gas emissions. **Strategy**: - this was achieved by landscaping, landscaping reduces CO_2 in the atmosphere, thereby purifying the atmosphere by releasing sufficient oxygen.

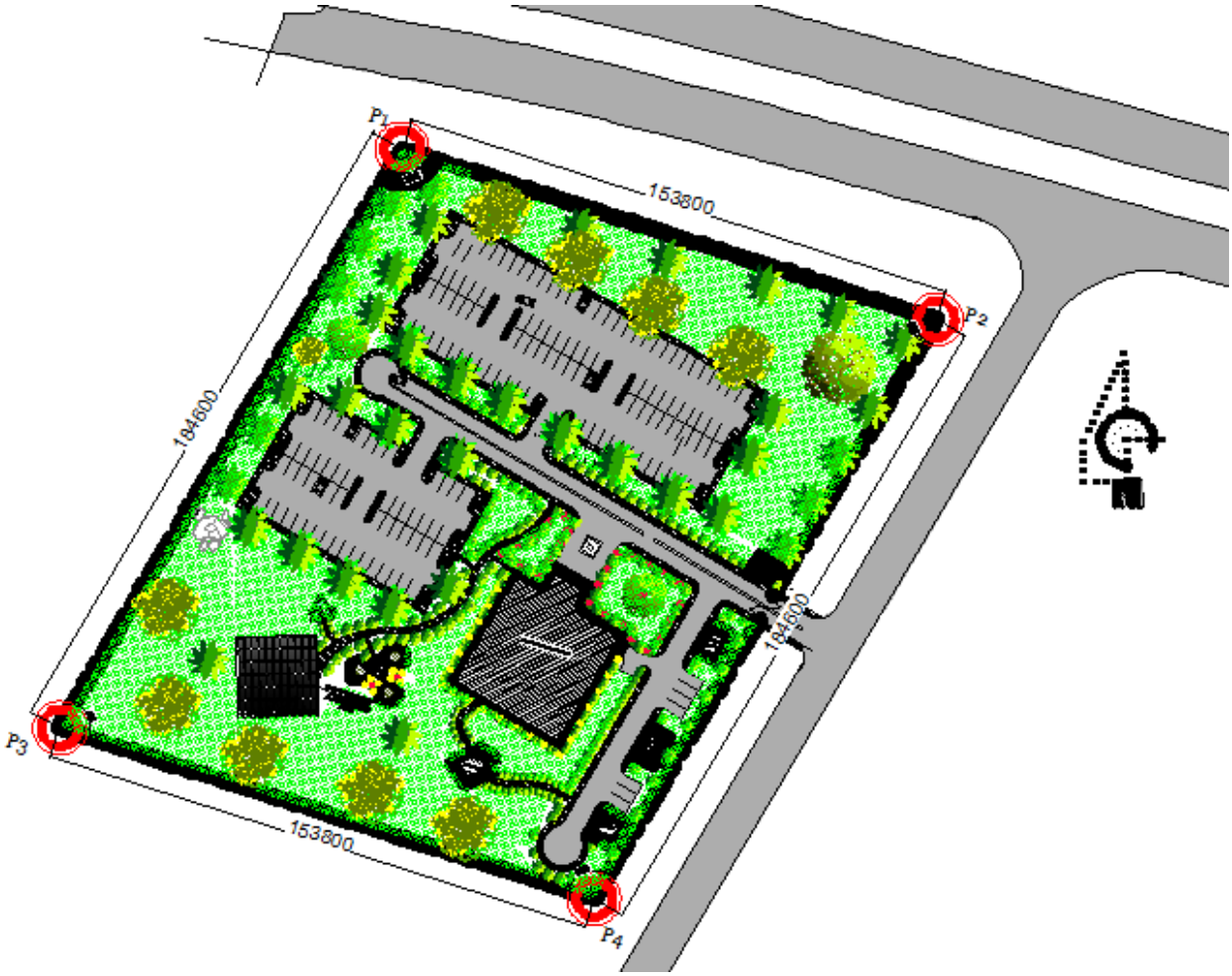


Figure 6.13: Landscaped site plan – Source: Author's CAD sketch.

The figure above (figure 6.13) shows how the planting of trees will create a micro climate around the site; it will help to reduce the CO_2 content around the site.

6.4 The Effect of Climate on the Design

This climate seeks solution through proper designs that can lower the effect of cold and cruel winds while delivering cool relieve from the intense heat of the mid-day sun.

The main design task here is to reduce the impact of solar radiation with reference to heat gain and glare. Adequate control of ingress of hot, dust and sand laden air into the built environment especially the building interior is equally important for comfort. The following are the main requirement in this zone.

i. Ventilation

This was achieved through stack effect as cooler air is denser than warmer air, the cooler air enters through the lower opening; it ventilate the interior and moves out used air through the upper window as shown in figure 6.9.

ii. Thermal insulation

The essential features of buildings in this zone to enable thermal comfort include roof overhangs, verandahs and loggias. These will shield the building interior from direct sunlight and glare part from providing outdoor relaxation spots. Extensive overhangs is introduced, it is about 1800mm deep (see fig 6.14). Shading devices is seen in figure 6.15, it is place around the west and east region so as to minimize glare and reduce overheating.

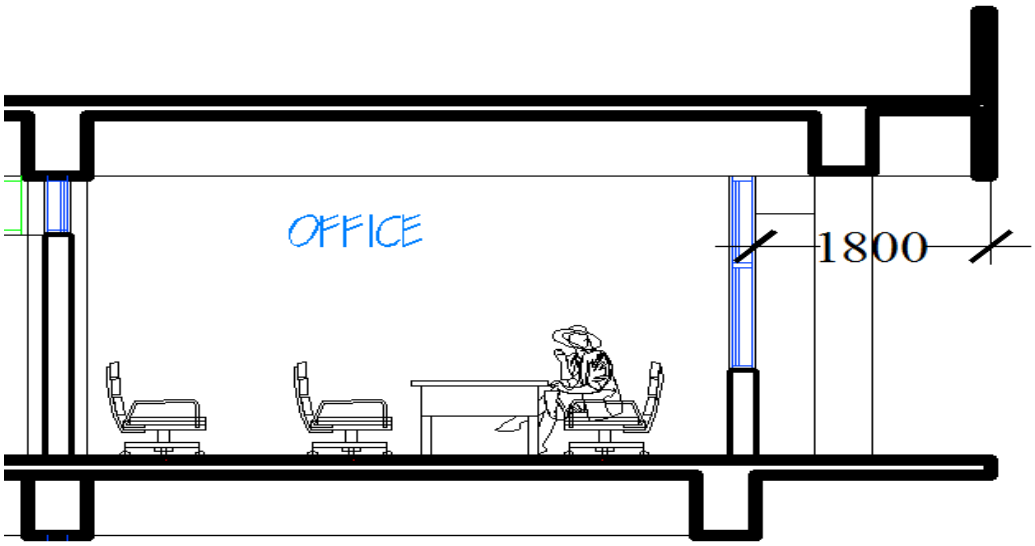


Figure 6.14: Overhang – Source: Author's CAD sketch.

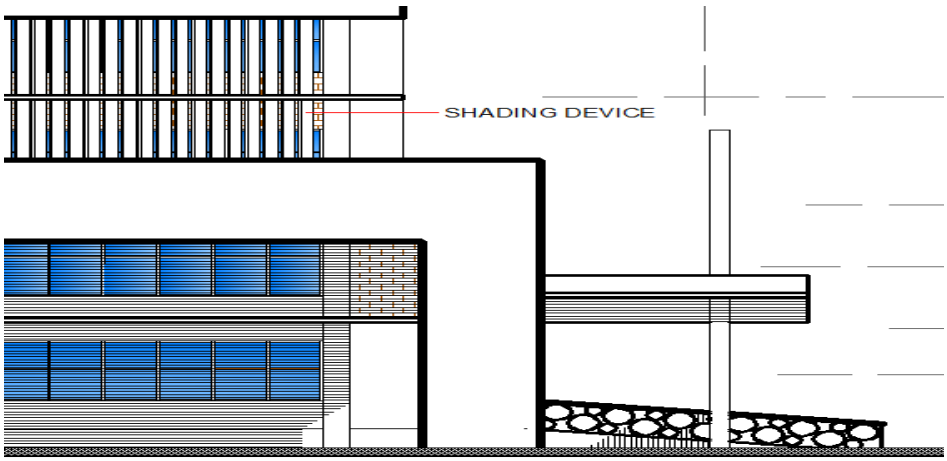


Figure 6.15: Shading device – Source: Author's CAD sketch.

iii. Site planning (form and orientation)

The design of buildings should be compacted inward looking; provisions should be made for courtyards, in this case an atrium was provided instead. Air movement is not a prerequisite for comfort. So compact planning will economize land usage and help conserve heat. North-South orientation is recommended for buildings in this zone of Nigeria. Since the sun-path across this

zone is East-West, this orientation reduces the amount of solar radiation which external walls are exposed to. Though in practice, it may not be feasible to achieve the North-South orientation due to other design considerations. In such instances, the best compromise orientation should be adopted. The proposed design is a square form and therefore has no orientation because all sides are equal.

iv. Protection against solar radiation

Since the reason for orientation is avoidance of the east-west radiation, windows were been recessed to about 1800mm to avoid direct solar radiation and the heat that accompany it. (See fig 6.14)

v. Choice of appropriate construction materials

Building materials play an important role when talking about designing with climate, its choice is dependent on its thermal mass, materials that can absorb and store heat and then dissipate it when needed is an appropriate properties when it comes to hot and dry climate. The proposed design made use of brick and concrete which has very good thermal mass. (See fig 6.7).

6.5 Simulation of the Building

Simulation of the proposed facility was done to confirm it's extending of energy efficiency based on the delineated principles that has been applied during the course of the design.

The softwares used are;

i. Autodesk Revit architecture 2014 for modeling, setting of materials, lighting, and location of site on the internet.

ii. Green Building Studio for energy analysis

The imputations for the analysis of equipment and appliances were based on energy rated types. The materials are also the bedrock for this analysis to be achieved. The calculated spaces (person/m^2) and the allocated equipment per office were determined. The average number of employees/users was calculated to be 40persons per floor. The office was set to operate for maximum of12hrs (6am-6pm) in five working days.

This is a typical calculation undergone floor by floor for the achievement of the simulated results (especially table 6.1).

Table 6.2: Simulation imputes for the analysis based on performances – Source: Autodesk Revit architecture 2014.

Building Performance Factors

Location:	, Kaduna
Weather Station:	1581464
Outdoor Temperature:	Max: 40°C/Min: 7°C
Floor Area:	9,792 m²
Exterior Wall Area:	9,021 m²
Average Lighting Power:	10.87 W / m²
People:	400 people
Exterior Window Ratio:	0.40
Electrical Cost:	$0.15 / kWh
Fuel Cost:	$0.61 / Therm

Energy Use Intensity

Electricity EUI:	33 kWh / sm / yr
Fuel EUI:	26 MJ / sm / yr
Total EUI:	323 MJ / sm / yr

Life Cycle Energy Use/Cost

Life Cycle Electricity Use:	13,866,603 kWh
Life Cycle Fuel Use:	3,590,547 MJ
Life Cycle Energy Cost:	$603,250

*30-year life and 6.1% discount rate for costs

Renewable Energy Potential

Roof Mounted PV System (Low efficiency):	95,942 kWh / yr
Roof Mounted PV System (Medium efficiency):	191,884 kWh / yr
Roof Mounted PV System (High efficiency):	287,826 kWh / yr
Single 15' Wind Turbine Potential:	430 kWh / yr

*PV efficiencies are assumed to be 5%, 10% and 15% for low, medium and high efficiency systems

The table above shows imputes based on the building performance factors, energy use intensity, life cycle energy use/cost and renewable energy potential.

Table 6.3: Simulation imputes for the analysis based on concrete material properties – Source: Autodesk Revit architecture 2014

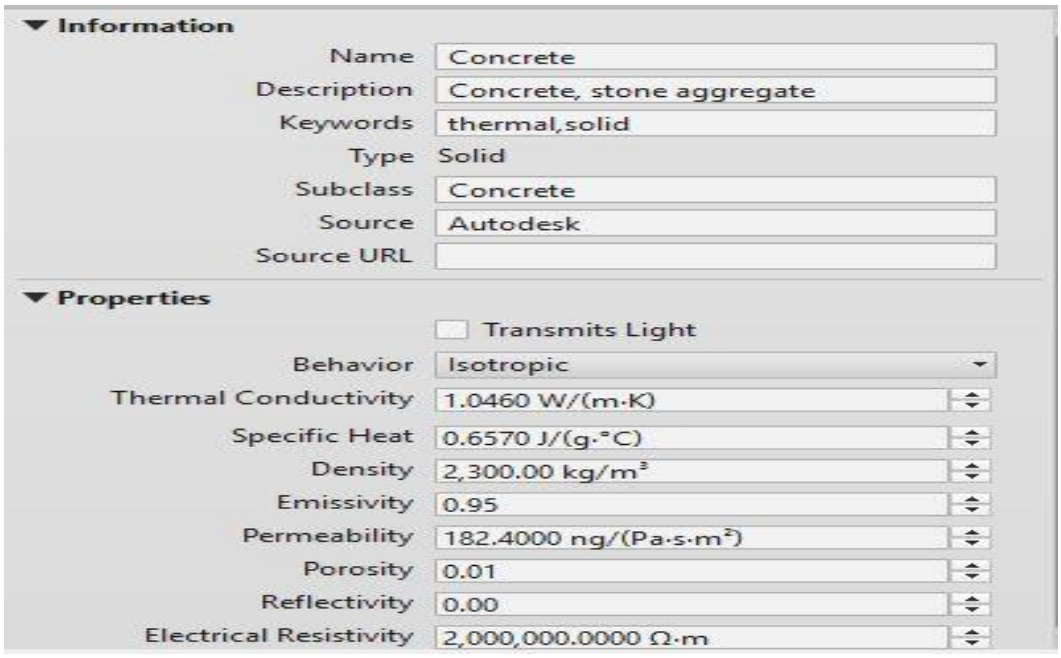


Table 6.3 shows the information and properties of concrete that was imputed, it was set not to transmit light i.e. not to allow radiation pass through and its behavior was set at isotropic (having physical properties that is independent on direction), other properties are shown above.

Table 6.4: Simulation imputes for the analysis based on material brick properties– Source:Autodesk Revit architecture 2014

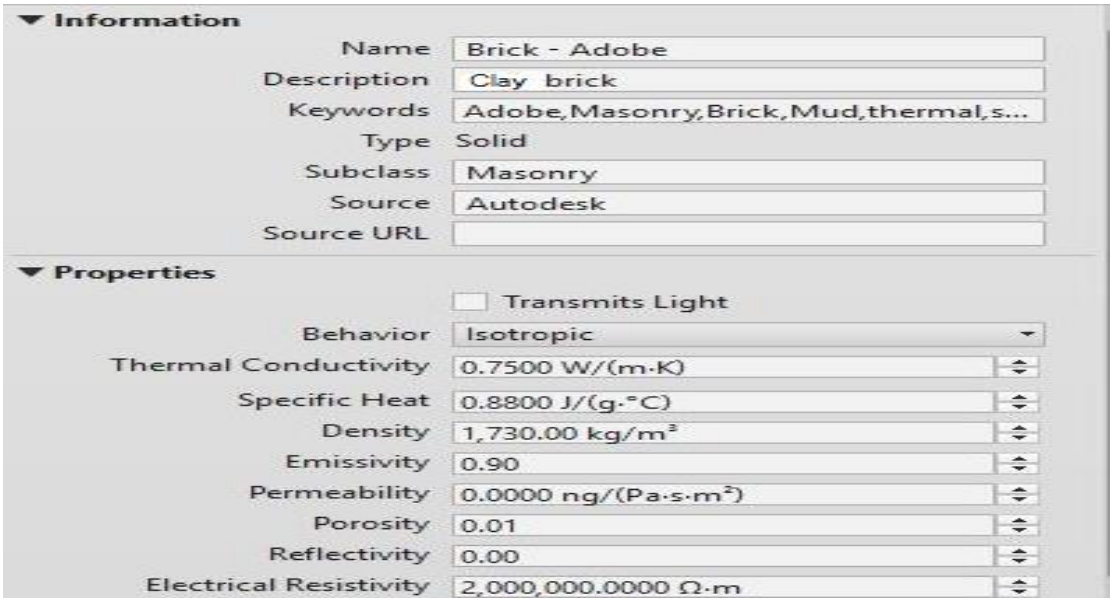


Table 6.4 shows the information and properties of brick that was imputed, it was set not to transmit light i.e. not to allow radiation pass through and its behavior was set at isotropic (having physical properties that is independent on direction), other properties are shown above.

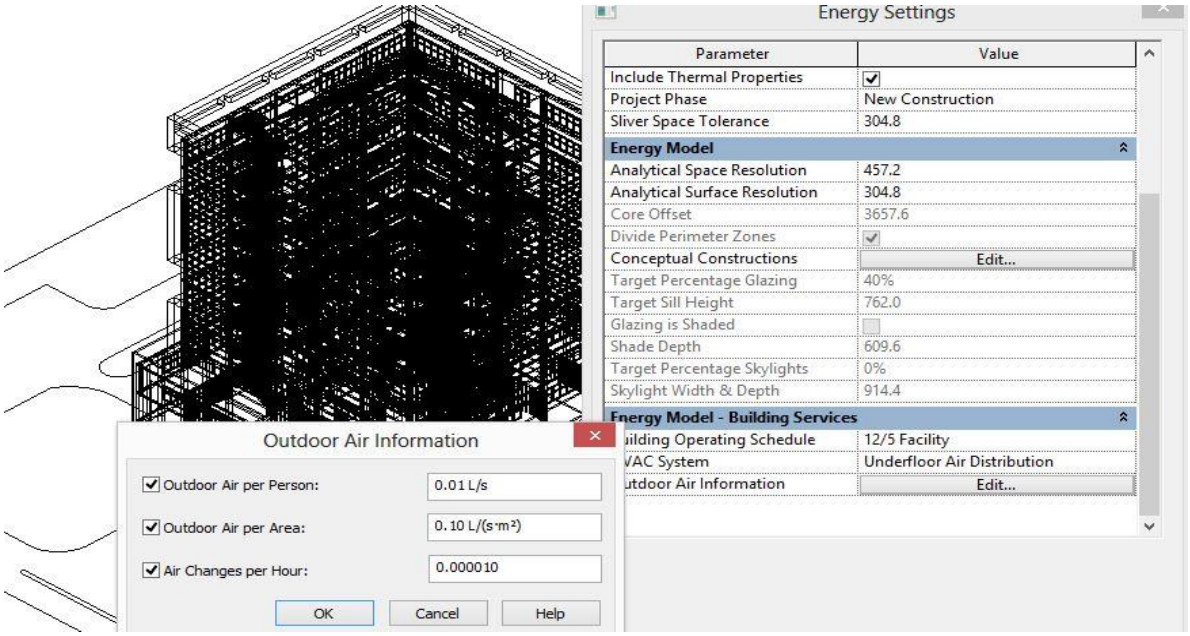


Figure 6.16: Simulation energy setting1 – Source: Autodesk Revit architecture 2014.

The figure above (Figure6.16) shows energy setting, it further shows the information on the building services which indicates that the building operates 12hrs for 5days and various outdoor air information.

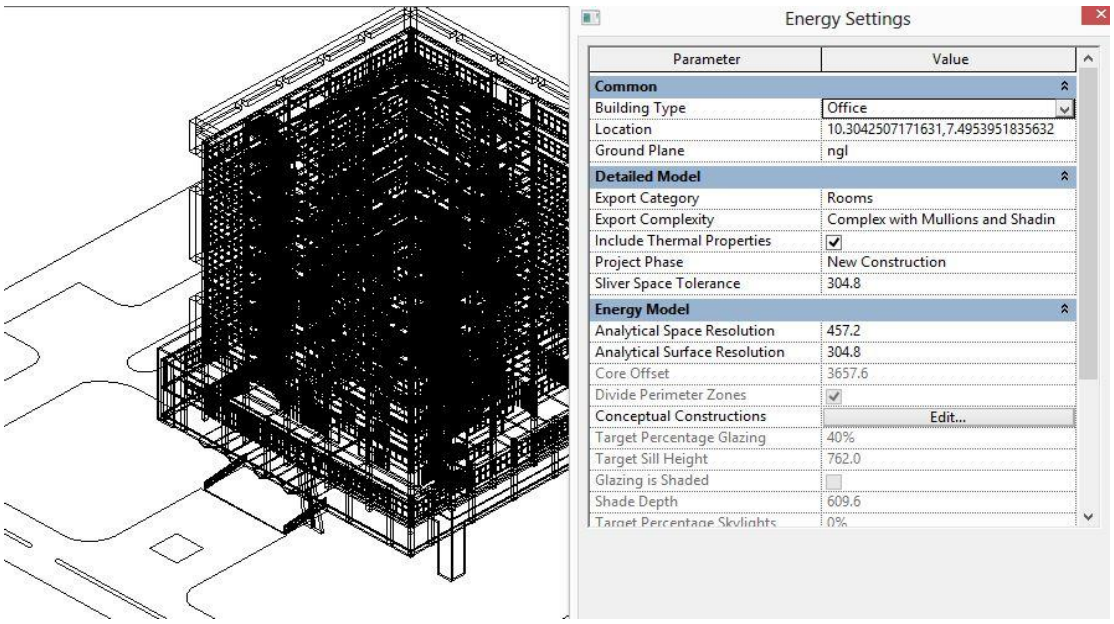


Figure 6.17: Simulation energy setting2 – Source: Autodesk Revit architecture 2014.

Figure 6.17 shows the latitudinal location of the proposed office building at natural ground level plane.

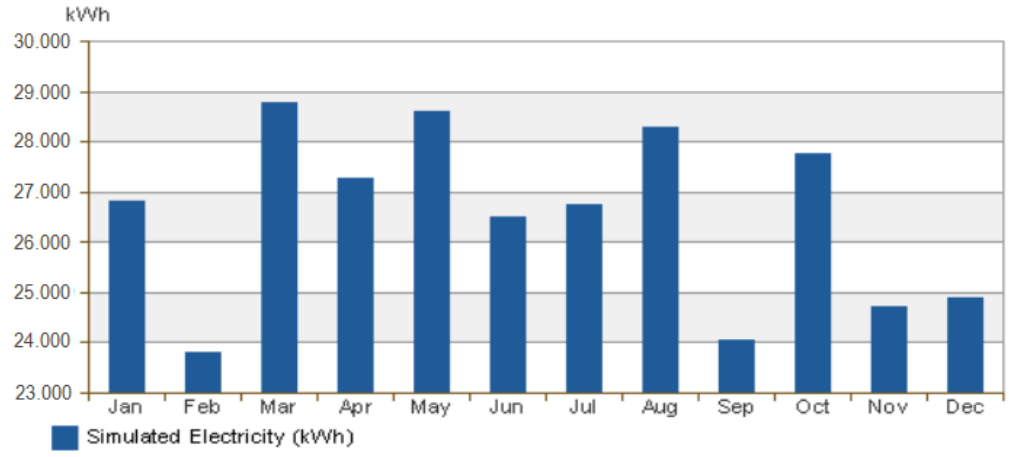


Figure 6.18: Simulated electricity consumption – Source: analysis result from Green Building Studio.

Figure6.18 shows the simulated value of monthly electricity consumption, it indicated that the month that consumes energy the most is March and February being the least.

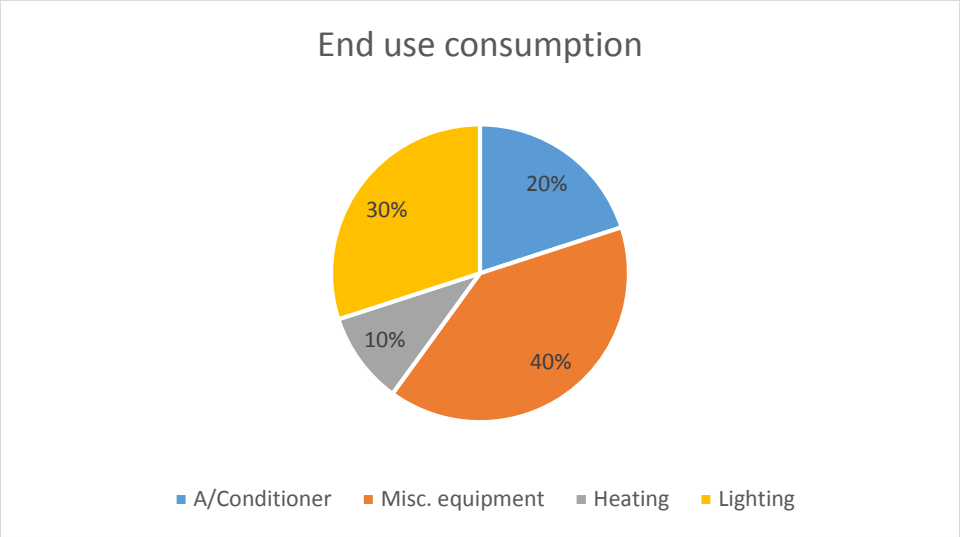


Figure 6.19:End use electricity consumption – Source: analysis result from Green Building Studio.

Fig 6.19 shows the component end-use (cooling, lighting, heating, and others) energy performance in percentage.

This indicates that miscellaneous equipment (computers, photocopiers, printers, and so on.) consume the highest amount of energy. Heating load consumes least because little is needed for heating in hot dry climate (it is only needed during the cold harmattan season)

PV panel was introduced and the following is the process in which the array was sized;

Table 6.2: Characteristics of PV panels at Standard test conditions (STC) - source: Kogi, 2007

	PST/ASE panel	EPV panel
Model	PM6008A36N Opak	EPV40
Supplier	ASE GmbH, Germany, (also known as RWE Solar GmbH)	Energy Photovoltaic, USA
Dimension	1000mm X 670mm	1250mm X 640mm
P-peak (peak power)	40W	40W
Voc (voltage at open circuit)	50.2V	62.2V
V- peak (peak voltage)	40.6V	44.8V
Isc (short-circuit current)	1.18A	1.16A
I -peak (peak current)	0.99A	0.9A

To calculate the capacity for the PV panels for this design, one needs to know the;

- Average energy consumption per month
- Annual energy consumption
- Energy consumption per day
- Average peak sun hours per day for a south facing array (Kaduna has 4 peak sun hours)
- Over all system efficiency

The average consumption based on simulated data is 26500KWh/month

Annual consumption = 318000KWh

Therefore energy consumption per day is 318000KWh ÷ 365days/yr. = 871.2KWh/day

871.2KWh/day ÷ 4 sun-hrs. /day = 217.8KW

217.8KW ÷ 0.72 efficiency factor = 303kw array

From the table above, a panel model of 0.67m^2generate 40w

So, 303KW array ÷ 40W × 0.67m^2=5075m^2space required for the array

Therefore, the PV panel will contribute to the total energy by about 37%.

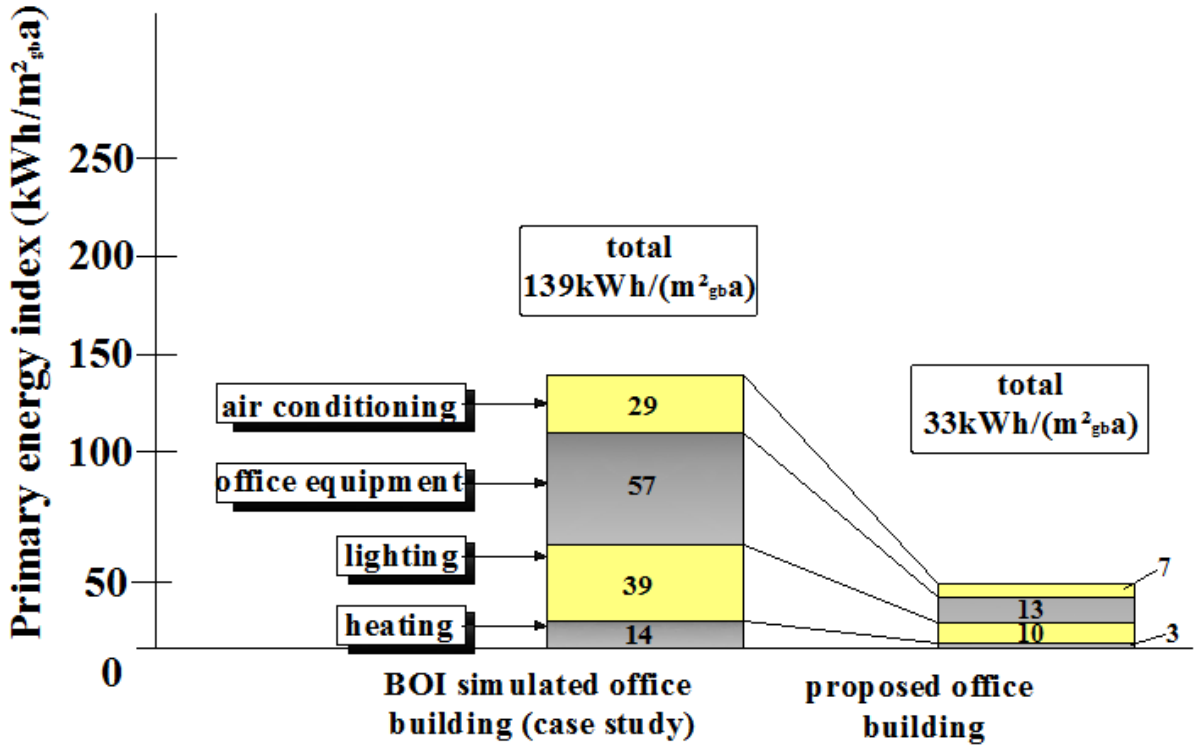


Figure 6.20: Primary energy index in comparison – Source: analysis result from Green Building Studio.

The figure above shows the primary energy index of simulated case study office building and the simulated value of the proposed office building. The figure indicates that the proposed office building is energy efficient. This is due to the imputed energy efficient equipment, appliances, and lighting fixtures. The materials used for the building model also help in terms of cooling load reduction. Another aspect that contributes in the reduction of cooling load is the window

material; insulated translucent panels were selectively specified so that it can allow light pass through diffusely but not heat.

The simulated proposed building is more efficient, therefore, there is about 76% energy saving achieved compared to the simulated case study.

CHAPTER SEVEN

CONCLUSION

8.1 Summary

Energy efficiency has three basic strategies to achieving minimized energy consumption in buildings (whole energy load reduction, efficiency of the systems, and on-site generation of electricity). But this is achievable depending on the scale of the facility and hours of operation, the use of advanced technology and mechanisms is more effective in enhancing energy efficiency during the buildings operational stage. The research work is built on the energy efficient principles which provided the essential tools needed to achieve low energy consumption in large scale office building.

Inferring from various literatures and gathering information from the case studies indicated energy a major problem and reducing its consumption is a paramount concern. Energy efficient buildings are beneficial in terms of economic growth, increased productivity, emission reduction and so on. It is expected that providing a large office building which is capable of reducing the amount of energy it consumes through provision of advanced technological means would act as an example of how the building industry can contribute to the economic growth of a country by saving money and using it elsewhere.

The general anticipation of this research is that, it will provide a model for the application of principles of energy efficiency not just in office buildings, but in any existing and every proposed building.

8.2 Conclusion

The elements that comprise energy efficiency which should be applied in a building design to minimized energy consumption are as followings;

i. Reduce heating, cooling and lighting loads.

Strategy used: - 1. Medium ranged embodied energy material (bricks and concrete) should be used, they are characterized by high insulation capabilities and great thermal mass, and they also have strength and durability and will stand the test of time.

2. Ventilation – the principle of stack effect should be considered because cool air enters through a window and the used air goes out through the upper window.

iv. Utilize active solar energy. **Strategy**: - generation of electricity on site (PV panels) as a renewable energy

viii. Increase the efficiency of appliances, heating and cooling equipment and ventilation. **Strategy**: - energy efficient appliances and equipment should be considered and where possible the number and size of appliances should be reduced.

ix. Utilize system approaches to building design. **Strategy**: -1. Daylight diming control should be employed to reduce lighting loads especially for open/flexible office. 2. Occupancy sensors should also be considered especially for private offices. 3. Full commissioning and maintenance of the equipment will be given due consideration.

x. Minimize greenhouse gas emissions. **Strategy**: - landscaping reduces CO2in the atmosphere, thereby purifying the atmosphere by releasing sufficient oxygen. This should be given due consideration when designing any building.

Generally, energy efficiency tries to emphasize on reducing energy use by installing appliances, equipment or lighting that use less energy, i.e. allows us to do more with less.

8.3 Recommendation

i. The application of the principles of energy efficiency in the design of a large office building can help reduce the energy consumed by about 76% compared to a standard building. This in due course reduces the operation cost of the building.

ii. To maximize the application of energy efficiency principles, the building material plays an important role. This emphasizes the insulation properties for the reduction of cooling loads of the building, this in turn help save energy.

iii. The principle of energy efficiency should be considered since it makes sure that greenhouse gas emission is reduced, this was achieved by more of soft landscape so as oxygen is increased around the site thereby creating a microclimate around the site.

iv. Locating the office building (with energy efficient features) in Kaduna will influence future development towards being efficient due to the amount of energy that have been saved thereby improving economic growth and other benefits.

8.4. Contribution to Knowledge

i. The principles of energy efficiency can positively reduce energy consumption, as this research has enumerated the best way to achieve this is by installing low energy rated appliances and equipment and monitoring its usage. The building materials is another important aspect.

ii. Energy conscious strategy in buildings reduces cost, improves the environment, and redefines architectural forms. This is because the project draws the designer's attention to how a building consumes energy throughout its life span so that designers will understand the implication of every component he inserts into the design from inception to completion thereby making designers more environmental and energy

conscious in their designs so that the building industry would make a positive impact in the nearest future. The designers will reduce cost either in the initial stages (using low embodied energy materials), or in the long run (through the building's operation).

iii. Achieving a conducive and comfortable working condition within a building is the primary reason why a lot of energy is consumed during the building's operation stage. This is because most electrical and mechanical devices within the building are usually used for adjusting interior conditions to suite the users.

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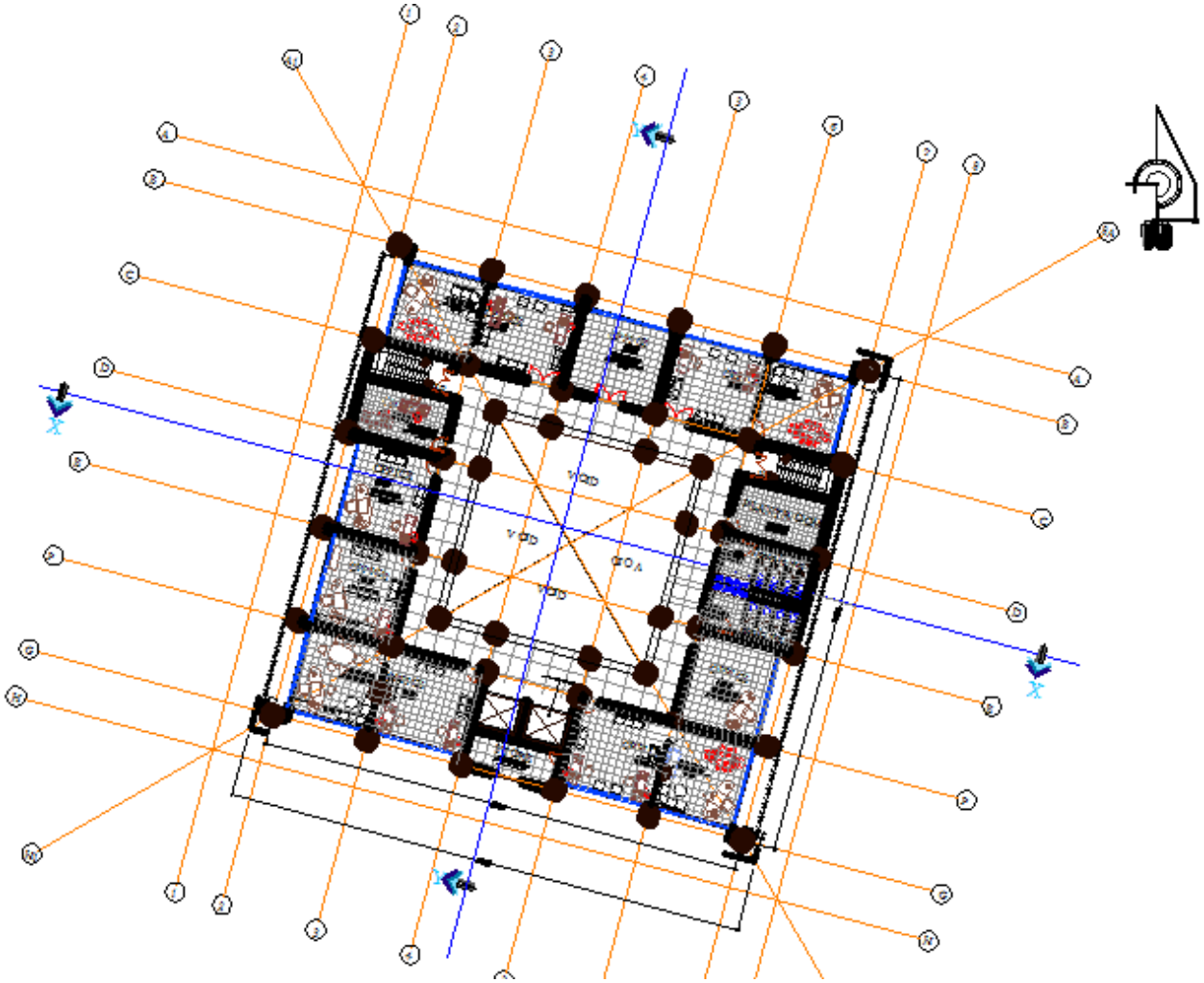
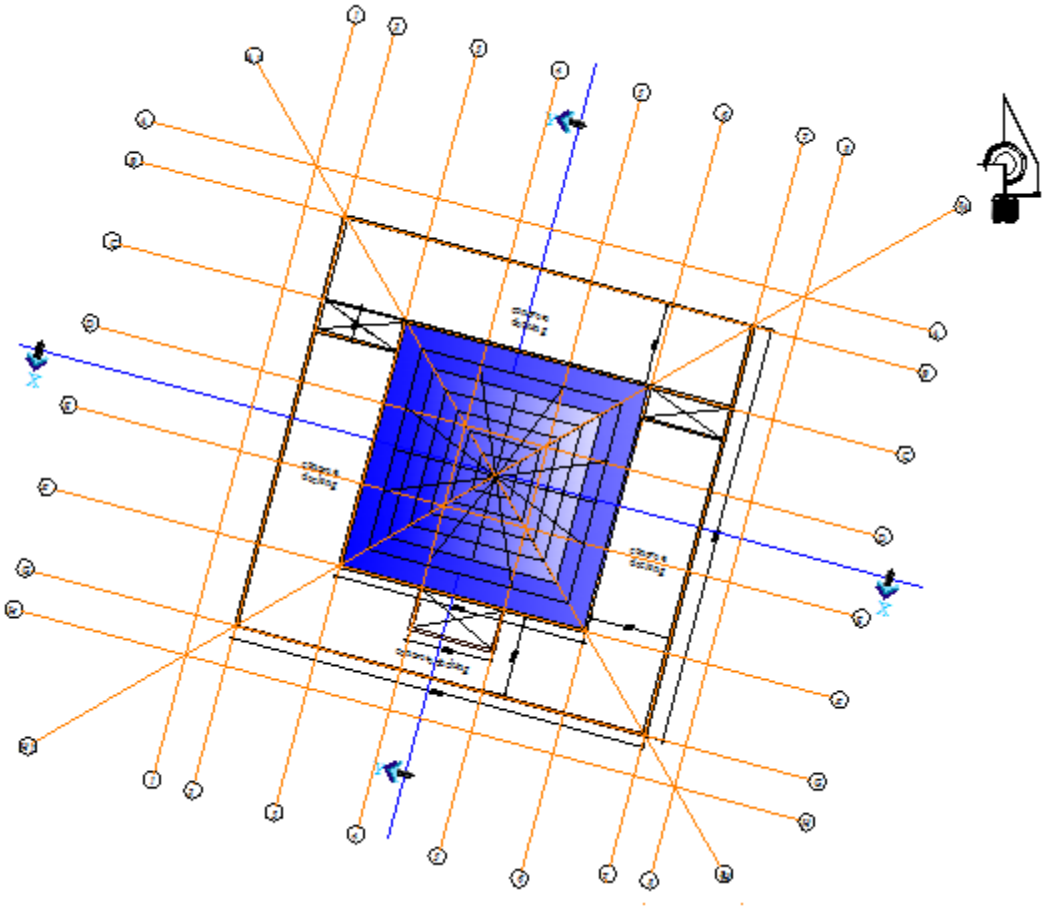
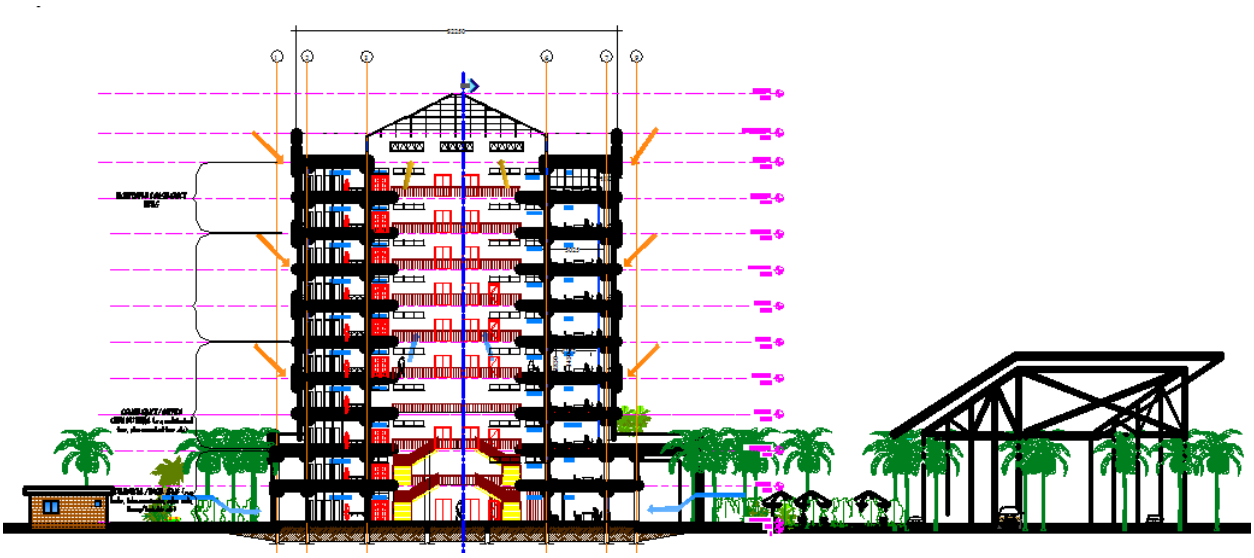
APPENDICES



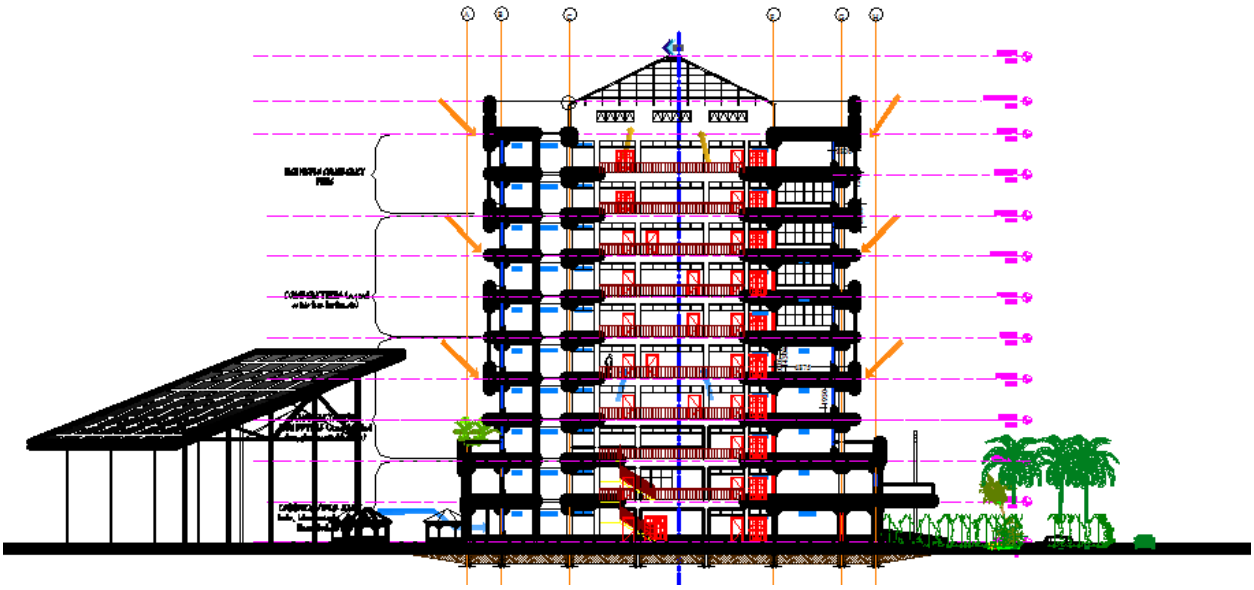
Appendix 1: 3rd and 4th floor plan



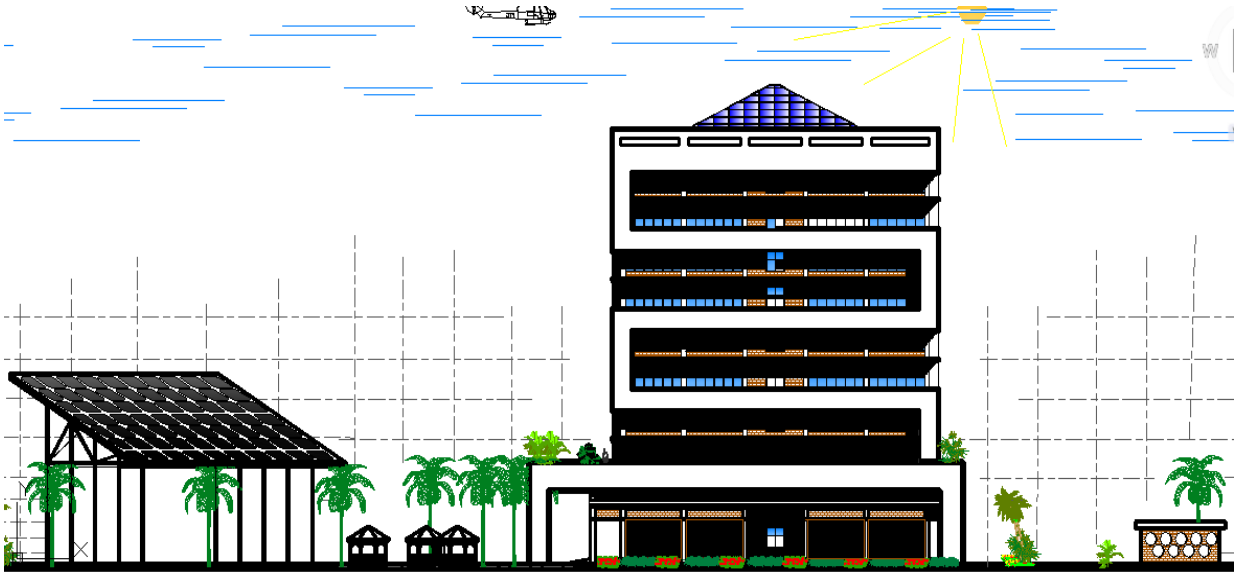
Appendix 2: Rooftop plan



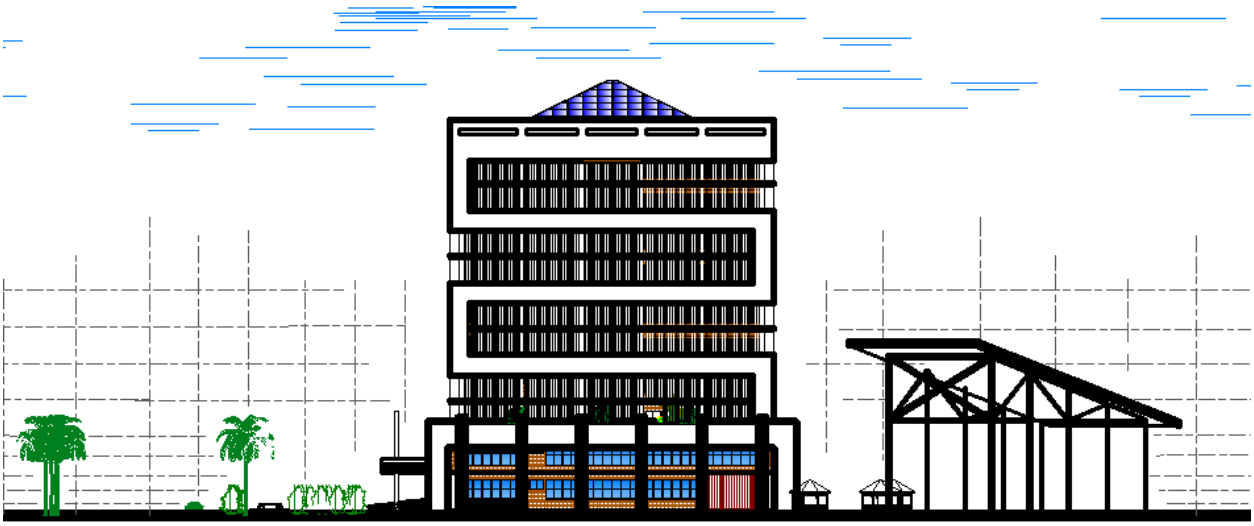
Appendix 3: Section x-x



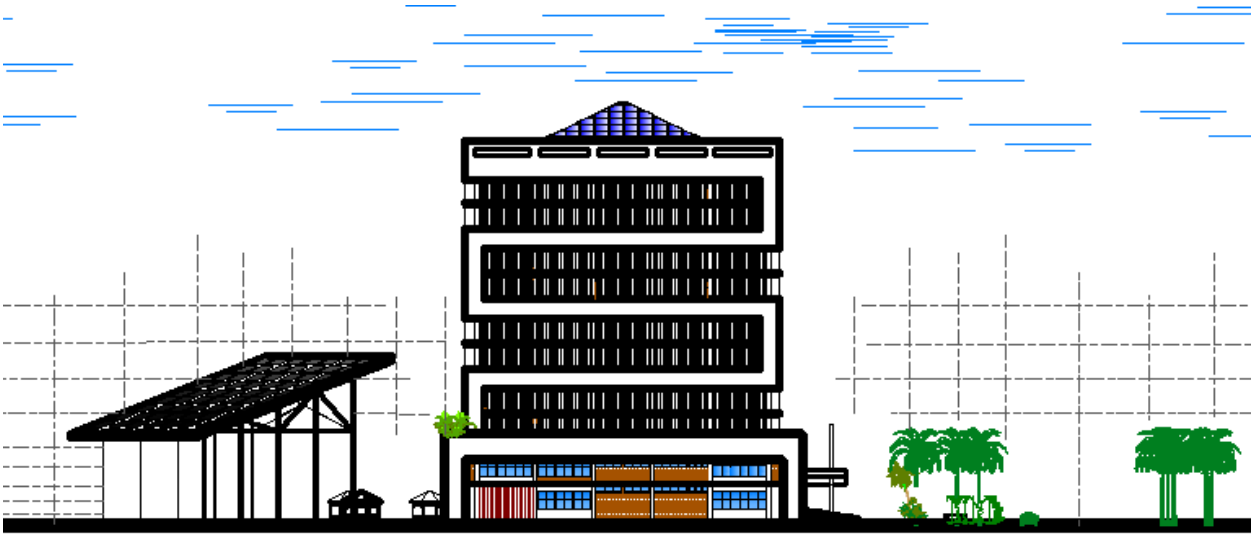
Appendix 4: Section y-y



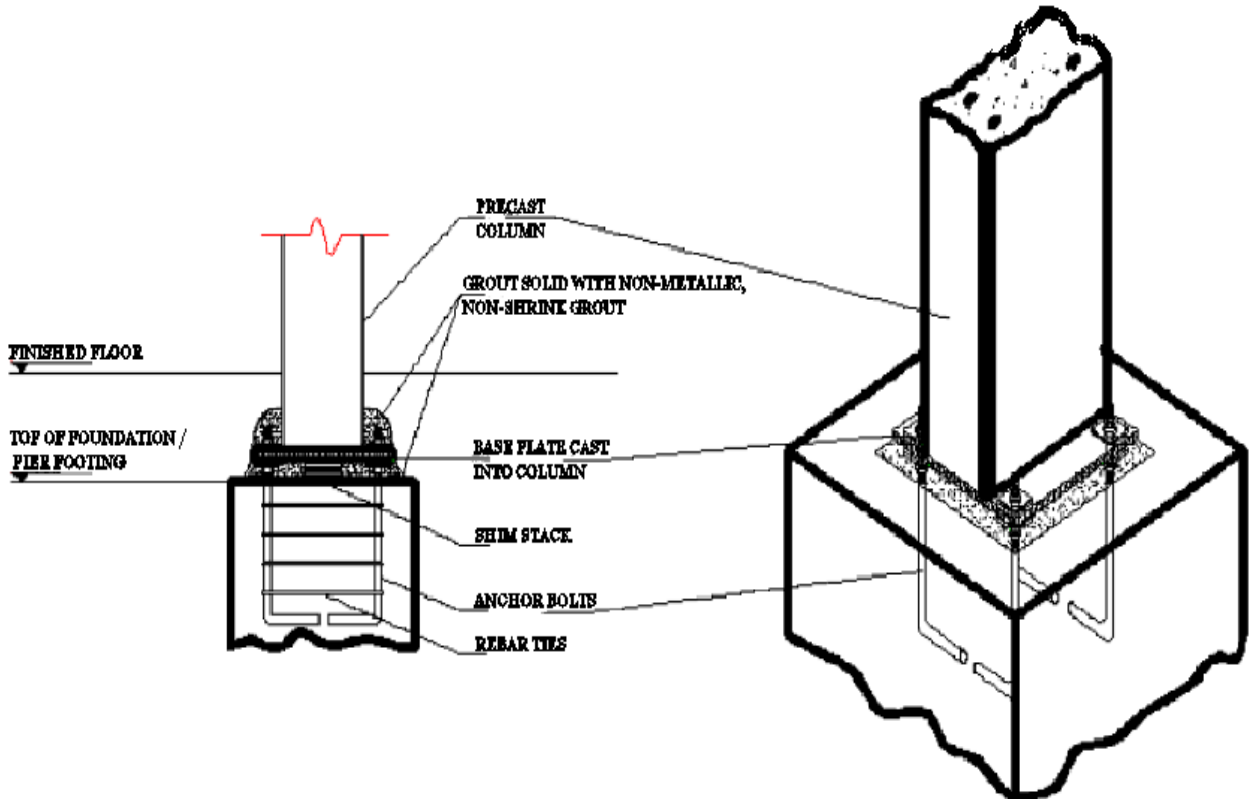
Appendix5: Rare elevation



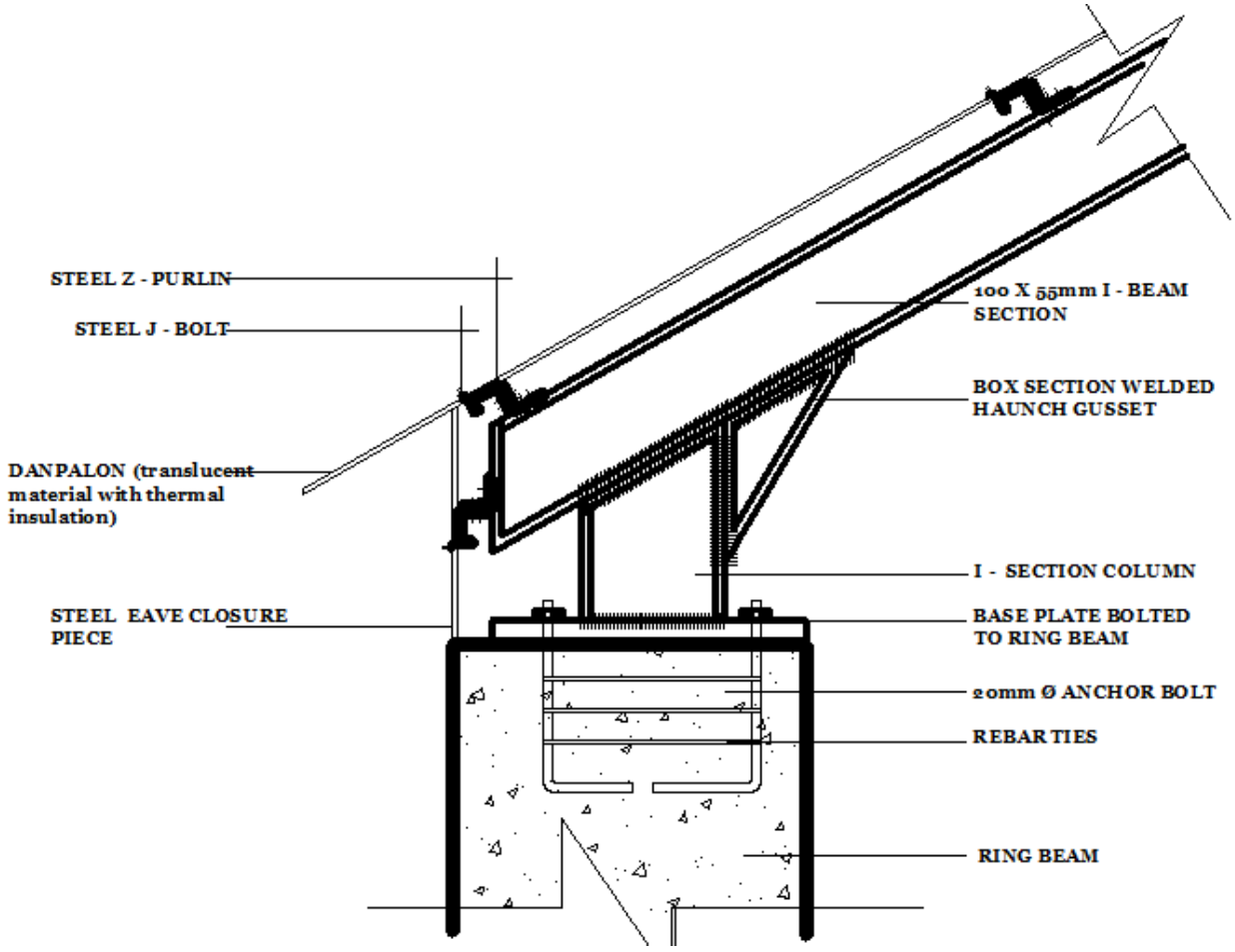
Appendix 6: Right side elevation



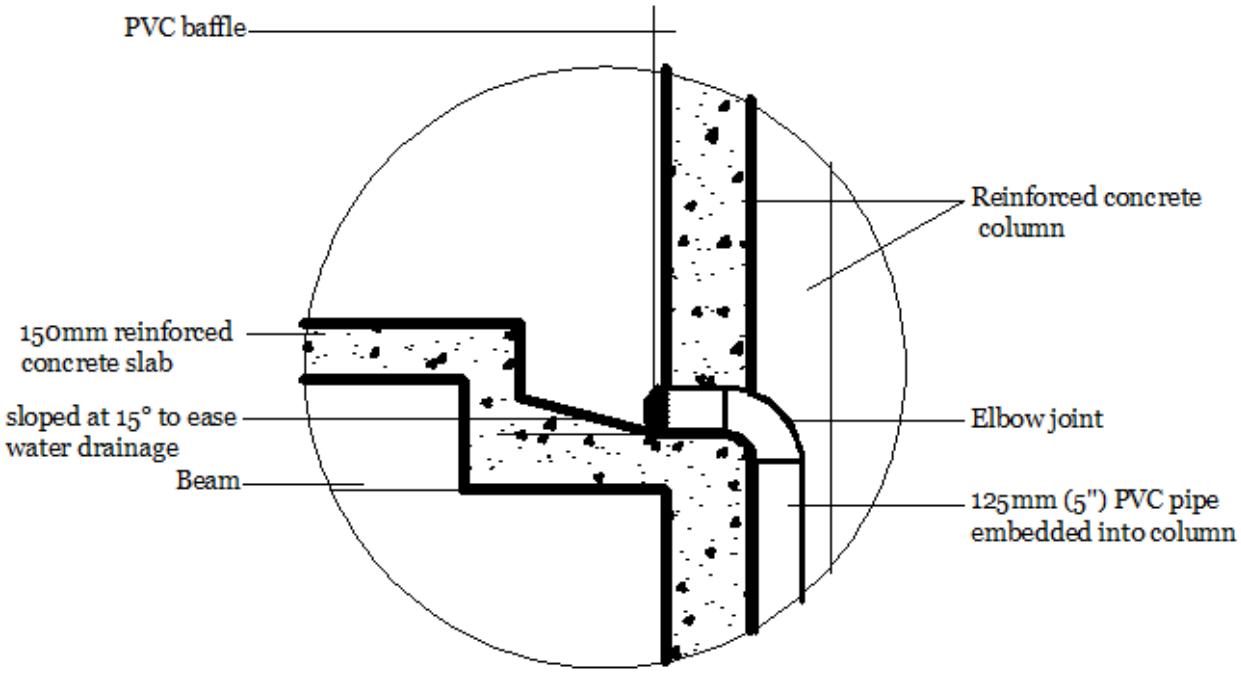
Appendix7: Left side elevation



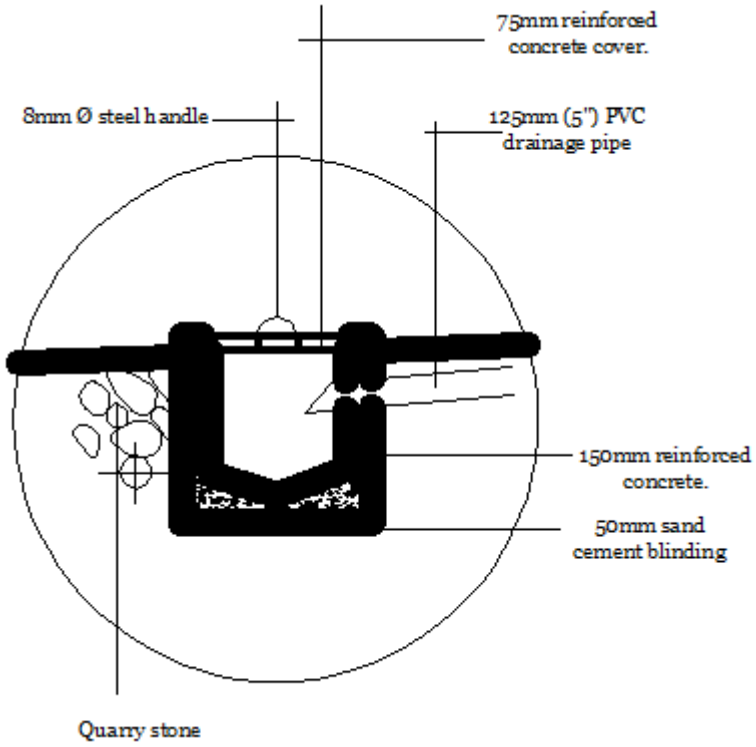
Appendix 8: Detail at foundation footing



Appendix 9: Detail at skylight to wall connection



Appendix 10: Detail at roof drainage.



Appendix 11: Detail at down pipe drainage.

Appendix 12: 3D view 1.

Appendix 13: 3D view 2.