INTEGRATION OF CLIMATE RESPONSIVE BUILDING ELEMENTS IN THE DESIGN OF FACULTY OF ENVIRONMENTAL STUDIES, FEDERAL UNIVERSITY BIRNIN KEBBI

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A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL, FEDERAL UNIVERSITY OF TECHNOLOGY MINNA, NIGERIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF TECHNOLOGY (MTech) IN ARCHITECTURE

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ABSTRACT

Traditionally, buildings were designed based on the pre conditions given by the surrounding environment, along with available natural resources to create comfortable and safe places. But nowadays, with the advent of mechanical method of heating and cooling, buildings have become less connected to their specific environment and more dependent on technical systems to comfort spaces, thereby consuming large amount of energy and harming the ecosystems of the environment through the use of fossill fuels. Application of climate responsive building elements adapts a building to its environment by moderating the outdoor climatic conditions to improve performance. This thesis aims at integrating climate responsive building elements in the design of faculty of environmental studies. The study area selected is Federal University Birnin Kebbi in Nigeria, based on the extreme climatic conditions of intense solar radiation and temperature, hence the study area provides the opportunity to investigate the effects of harsh weather on faculty buildings in the region. Three faculty buildings were randomly selected in the study area, modelled and analysed with the existing climatic data, using Ecotect simulation software. The simulation of the buildings was based on peak period of solar radiation (February, March, April, May and June) and extreme recorded temperature of a single day (45^{o}C of 10th April 2011). The results of the simulation show a slightly better performance along the East and West functions of the faculty buildings housing major functions (at 45^{o}C having an average differential temperature of 1 to 3 when compared with the outdoor environment in all the three selected faculty buildings) and a considerable better performance along the North and South functions of the faculty buildings housing lesser functions (at 45^{o}C having an average differential temperature of 3 to 6). A proposed climate conscious design faculty having an integration of courtyard veranders and shading devices was then simulated to compare with the selected case studies. Results of the simulation showed a better performance than all the selected existing case studies (having a temperature moderation level of 3.5-6 along major functions). From the findings of the research, it has been concluded that the designers of the faculty buildings did not take into consideration the extreme climatic conditions of the micro climate as illustrated with lack of good design orientation leading to the overall exposure of building elements to the climate. Climate conscious design approach not only can improve performance moderation of buildings but can as well reduce the emission of carbon dioxide to the atmosphere by reducing excess use of energy. The study recommends the enforcement of policies on planning regulations that will require all designers to have a synergic design approach showing relationship between building elements and micro climate.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Since the beginning of time, climate has affected all aspects of man activities and have shaped man intellectual responses in his quest for a better life (Kabiru, 2011). Climate according to Abiodun (2015) is a measure of the average pattern of variation in elements such as Precipitation, humidity, temperature, solar radiation and wind over a long period of time. These climatic elements have posed a lot of problem on man activities which brought about the need for dwellings that will respond to them (Hasselaar, 2006).

Machaira *et.al*. (2012) defined climate responsive architecture as a system that allows a building to moderate the climate for human comfort and wellbeing. In climate responsive architecture, building uses climate as a form determinant. Traditional buildings are a best example of climate responsive architecture (Remco *et al.*,2007; Abdul-manan 2016; Anh-Tuan *et al.,* 2011). Because local builders have shown great techniques in providing the most comfortable and healthy environment. Local builders use natural available materials and passive techniques (natural lighting, natural ventilation) to build and comfort their shelters. Remco (2007) further stressed that, the application of traditional technique is the most fundamental aspect of architecture which is providing shelter from the dynamic conditions of the environment. As humanity progressed from the traditional approach to the modern approach providing shelter transformed into providing comfort. During the traditional method of construction issues like energy conservation, environmental impact and resource depletion where no issues at all. It was the urge to provide comfort during the 20th century (modernism) that led to the increased in application of energy consuming mechanical systems for controlling the indoor environment. With result that buildings became significant energy consumers (Remco *et al.*, 2007).

Buildings now need to addressed these issues, mostly the new conventional public educational buildings (site) that are having activities ranging from one institute to the other depending on the nature of the school. However, there is a tremendous change noticed in how school work, this change has been driven by rapid development, with students overcrowding the tertiary institutions (Francisco, 2007). The current trend of higher-level education is accommodating large number of students per classes thereby generating lots of heat resulting in thermal discomfort in the interior spaces. This has posted a challenge of energy efficiency for public educational buildings making it difficult for the users to achieve comfort without huge amount of air conditioning systems (Jhaveri *et al.*, 2010). Another factor that is attributed with this problem is the nature of the building in respect of the climate.

Agboola (2011) pointed out that, climate and weather are the major environmental factors directly affecting building form and creating discomfort. Asli (2006) argued that, the driving force that act upon buildings to create comfortable space and shelter is climate. Buildings are supposed to be modifiers of microclimate, a space isolated from the climatic temperature and humidity fluctuations and sheltered from other environmental elements (Abiodun, 2015). This means building should take into account the climatic conditions of the location for its optimal comfort in order to achieve sustainability. The basic principle of climate responsive architecture is to achieve the least possible energy consumption concurrently with the provision of thermal comfort for the inhabitants.

1.2 Statement of the Research Problem

The climatic conditions of Federal University Birnin Kebbi (site) is characterised by a long dry season associated with cold and dry harmattan wind, intense sunlight and high temperature range. The heat temperature in this region can rise as high as 45^{o} C and the cold temperature mostly can go as low as 9.8^{o} C with dusty winds in most of the periods. But the worrisome about this weather is the discomfort and diseases it brings, with buildings using large amount of energy to comfort environment. And thus, contributing to the effect of global warming via the release of pollutants (carbon dioxide). Perhaps as mentioned by (Akande 2010) buildings in this region are not designed to respond to the extreme climate. Right from the design inception, climate is not considered as an attribute to respond to. Which resulted with the outdoor environment completely disconnected from the buildings and indoor environment generating large amount of energy to cool down the micro climate.

1.3 Aims and Objectives

1.3.1 Aim of study

The aim of this research is to integrate climate responsive building elements in the design of faculty of environmental studies, Federal University Birnin Kebbi.

1.3.2 Objectives of study

The objectives of the study are to:

1. Assess the climate responsive building elements employed on the faculty buildings
2. Examine the effectiveness of the applied techniques when compared with the micro climate of the region.

3. Propose an eco-friendly design of faculty of environmental studies that will reflect the climate of the region.

1.4 Research Questions

The research question is guided by the following questions:

1. What are those elements that are responsive to Hot Dry climate?
2. What is the relationship between the climate responsive building elements and the resultant indoor thermal condition of buildings in the study area?
3. What design concepts would be appropriate for a public educational building in the study area?

1.5 Scope of Study

The scope of the study will cover all the parameters that will reflect the climate of the region necessary for achieving thermal comfort in an educational building.

These parameters are:

i. Orientation
ii. Building form
iii. Thermal mass
iv. Dynamic insulation
v. Natural ventilation
vi. Natural lighting

The choice of Federal University Birnin Kebbi (study area) serve as a good ground to investigate the effectiveness of climate responsive building elements due to the disturbing harsh weather of the region. And with the expectation in the long run to help in shaping the master plan of the university for efficient thermal performance.

1.6 Justification of the Study

The proposed project (faculty of environmental studies) hopes to provide one of the immediate needs the Federal University Birnin Kebbi has been craving for. Thermal discomfort was presented as the daunting phenomenon for building users in the area and therefore a research study is needed to investigate the performance of the buildings (study area) in relation to the harsh climate of the region. Result of the findings as the end product of this study will be the design concepts for the proposed project but will also be recommended for use on any other upcoming developmental plans in the region.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 The Concept of Climate Responsive Architecture

Climate responsive design has been in existence since the beginning of man. The first structure was made by man using elements of a building that served as a shield against the effect of the environment. So, climate responsive strategy is said to be the foundation of any building design. The traditional buildings that have been existing for a considerable length of time are likewise a valuable example of climate responsive design. Where climatic variables determine the orientation, form and materials of the building (Remco, 1997). The local builders have used great techniques to construct their buildings appropriately to suit their environment, they utilized basic constructional methods and available materials to comfort their surroundings. Where there are woods, wooden structures will dominate the surrounding, while in some different territories' stones and mud.

Traditionally, climate determines the building materials to be use in the buildings in order to withstand the effects of the climate. As expressed by Hanna (2014) the information about the encompassing climate has dependably impacted the plan of buildings. Lamberts (2006) further iterated that climate responsive design is the study of the climatic conditions of the environment in relation to building site, so as to moderate the conditions of comfort of the occupants through the use of appropriate design strategies. The relationship between climate, comfort and architecture has been a steady concern and buildings have responded to local explicit conditions to a more prominent or lesser degree. The climatic responsive approach as pointed by Kwok *et al* (2007) suggests a use of consistent investigation, with befitting design procedures and the conscious environmental control in response to external impact. Davies, (1999) included that, climate responsive plan approach puts the inhabitant at the focal point of its design process, it sets up the connection among man and environment with the building as the shield. It unites controls of human comfort, climatology, building material science and the relationship between these components is portrayed by Vitruvius Tri-partite show (Hawkes 1996).

Hanna (2014) goes further in clarifying climate responsive design as an approach that limits effect of environmental resources on buildings; it looks to create an architecture which is progressively receptive to location, climate and human needs and which offers articulation to soundly based design parameters. Energy savings and low environmental impact are the consequences of the integration of climate responsive design approach on dwellings to achieve better comfort conditions (Zachman, 2001). Buildings in climate responsive architecture considers the climate as a matter of first importance, then landform, soil nature and vegetation so as to reduce their impacts to the shell of the buildings for good thermal ease and healthy living. (Machaira *et al.,* 2012).

Furthermore, according to Fathy (1986) climate responsive approach has more noteworthy impact and potential to reduce environmental effects, improving living conditions and performance of building.

2.2 The Need for Climate Responsive Architecture in Nigeria

Comfort is a necessity for every human being and over the years the search for it has been influenced by the impact of the climate. As elements of climate (solar radiation, precipitation, temperature, humidity) have posed a challenge to the design and construction of buildings that could comfort the occupants. Buildings now has to moderate the outdoor climate and provide comfort conditions for its occupants without excess use of energy.

One of the major challenges now facing designers is the problem of climate change fuelled by greenhouse gas emissions (Olotuah, 2015). The burning of fossil fuels has caused the concentrations of heat trapping greenhouse gases to increase significantly in the atmosphere. The gases prevent heat from escaping to space and thus have precipitated global warming. This is a serious environmental effect, and it is as a result of the adoption of uniform style of architecture irrespective of the climatic conditions thus consuming high energy in buildings. Subramanian *et al.* (2016) in their journal "Comparative investigation of traditional, modern and designed solar passive building" described how adoption of international styles of architecture in 20th century has eradicated traditional concepts to the local climate making it difficult to achieve comfort without use of mechanical systems. This practice is causing serious environmental impact (Kabiru, 2011). Architects using these concepts of design are endangering the eco-system contributing to the effect of climate change (Arup & Design Genre, 2016). Buildings must adapt to the climate of the region and its microclimate (Geetha and Velraj, 2012). The architects should take into consideration the climatic conditions of the location in order to design efficient buildings. As according Asli (2006) understanding and control of the climatic effects at the location of the building are crucial even before design decisions are made. Furthermore, there is a growing trend towards achieving low energy building designs with the aid of simulation (Aleksandrowicz *et al*, 2015).

2.3 Design Approach

As indicated by Kabiru (2011) design with climate is basically determined by arranging an appropriate projection, a practical design approach is to do a phase by-phase staged way to deal with design plans. Haruna (2006) portrays architecture as being effective in the event that it demonstrates well and does the thing it is required to do. On the off chance that this achievement is to be accomplished, a staged approach (alluded to as Stages 1 and 2) is recommended and it includes examination/assessment and synthetic application of climatic design responses.

2.3.1 Stage 1

Examination and evaluation clearly: whatever investigation done in this stage would give explicit outcomes relying upon the components controlled by local conditions. The conclusions from the data in Stage one should direct the architect subsequently.

2.3.1.1 Analysis and issues to consider

i. Sun and temperature conditions in the area: these can help the Architect to know which form and orientation to be used in order to minimise exposure (Kabiru, 2011).

ii. The site's location in relation to the sun from morning to night: understanding the sun’s position in relation to the building can help the Architect to nowhere to position the openings of the building in order to mitigate solar access radiation (Kabiru, 2011).

iii. The wind direction and strength in combination with precipitation: taking note of this can help the Architect to identify places of exposure for good site planning (Kabiru, 2011).

iv. The ability of site terrain and vegetation to break winds and air currents: site terrain and nearby trees can be use shade building away from direct sunlight and high-pressured wind (Kabiru, 2011).

v. The determined level of comfort of an area based on the bio-climatic chart: comfort level of areas differs from one region to another, as comfort of occupants differ from their satisfaction of mind, body and soul (Kabiru, 2011).

vii. Occupancy: number of occupants that will reside in a building is also part of a major task to identify by the Architect for good space allocation and planning (Kabiru, 2011).

viii. Internal heat gain: internal heat gain can make a room space stuffy if cross ventilation is not achieved. Building generates heat internally depending on the material use and items to be use in room space (Kabiru, 2011).

2.3.1.2. Planning

i. Siting of buildings: An architect has to understand how best to site his building as this can help reduce exposure to climate (Kabiru, 2011).

ii. Position of buildings in relation to one another: buildings position to site has to be taken into consideration in order to achieve effective lighting and natural ventilation through building (Kabiru, 2011).

iii. Topography and vegetation: these have to be note during the inventory stage of the site design in order to understand the trees that are to be felled and those to maintain (Kabiru, 2011).

iv. Design and arrangement of building: climate of a region determines the best design that will suit the location. Achieving net-zero energy can only be done through understanding of climate (Kabiru, 2011).

v. Organisation of activities in and around buildings: how best an Architect organise his activities is critical during the design stage. A technical knowledge of site is needed to achieve this (Kabiru, 2011).

vi. Arrangement of building parts and structures: proper positioning of shading devices and openings can be done through identification of micro climate. This can be identified through simulation of building (Kabiru, 2011).

vii. volumes: height of floor to ceiling level has dictated during the design stage as this can help improve circulation of air (Kabiru, 2011).

2.3.1.3. Specifications: use of eco-friendly materials

i. Materials with low emissions: materials with low emissions has less impact on the environment as they can reduce the risk of climate change (Kabiru, 2011).

ii. Materials that are recyclable: materials that are recyclable are more advisable to be use on buildings in order to achieve sustainability. An Architect has to make use of materials that are available on site and also recyclable (Kabiru, 2011).

iii. Non-toxic/Low Toxic Materials: non-toxic or low toxic materials have less effect on the environment and on the occupants. As it is paramount for every Architect to choose less harmful materials for construction as they can affect the wellbeing of the occupants (Kabiru, 2011).

2.3.2 Stage two: synthetic application

This includes the use of different measures to manage the issues distinguished by the investigation and assessment process. Fundamentally, this implies taking measures to address Passive Cooling, Orientation, Shading, Insulation, Thermal Mass, Passive Sun oriented Heating and Renewable Energy (Kabiru, 2011).

2.4 Responsive Building Elements in Hot Dry Region

According to Remco (2007) building elements are components of a structure to be considered in designing a responsive building in order to moderate climatic conditions without excess use of energy.

These elements are as follow:

I. Landform
II. Open spaces and vegetation
III. Building Orientation
IV. Building form
V. Walls
VI. Roof
VII. Windows
VIII. Material composition

2.4.1 Landform

If there should be an occurrence of an undulating site, building on the leeward side of the incline is preferred. This shields the structure from direct effect of hot breezes which can be very uncomfortable (Remco, 2007).

2.4.2 Open spaces and vegetation

Open spaces, for example, patios and atria advance ventilation. They can be provided with lakes and wellsprings for evaporative cooling. Patios go about as warmth sinks during the day and transmit the warmth back around evening time. Vegetation is a controller of solar and wind penetration in buildings. It tends to reduce direct sunlight from striking and heating up buildings surfaces and alters the air temperature which in turn affects the heat transfer from the outdoor environment. Vegetation can also be used an internal shading elements and dust filters without compromising the external views (Remco, 2007).

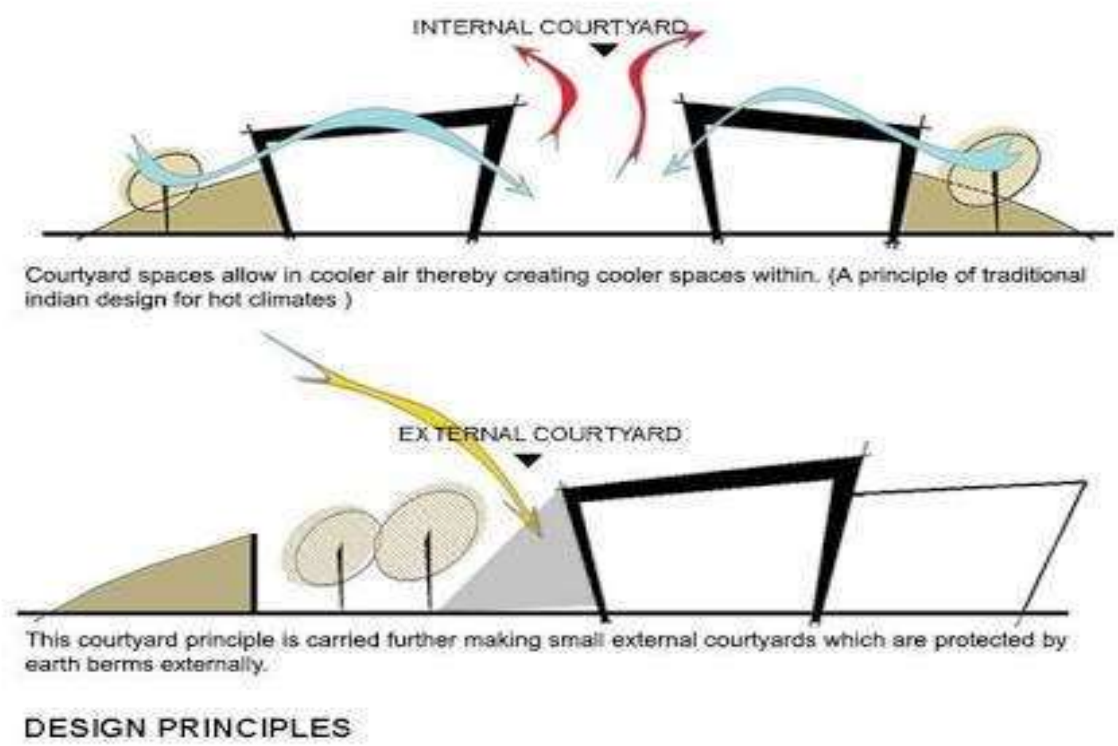

Figure 2.1: Design principles of a courtyard
(Source: Remco, 2007)

2.4.3 Building form and orientation

Generally, the form and orientation of building determines the amount of radiation it receives. The orientation of the building in relation to the sun reduces/improves the overall exposure of the building the sun, the form of the building then further regulates or maximises the extent of the exposure of the building to the sun. Careful measures are needed in the design of form and orientation of the building for optimal performance of building elements (Remco, 2007).

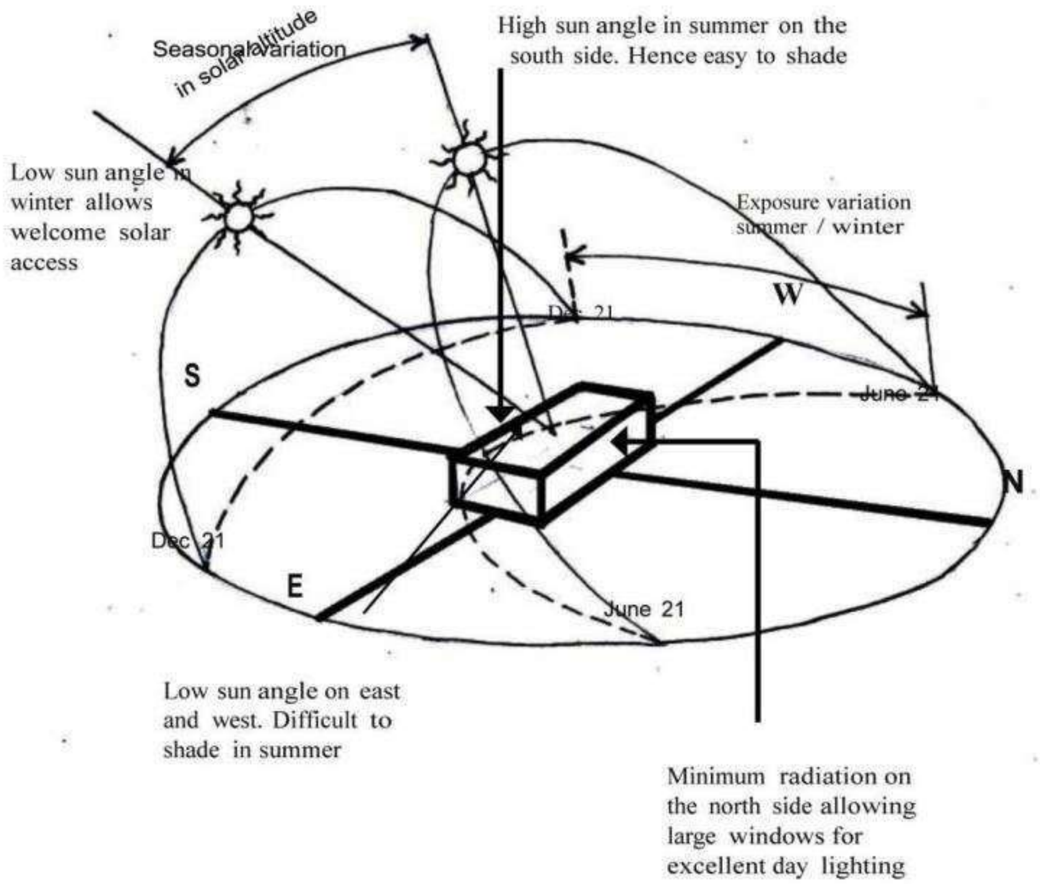

Figure 2.2: Best orientation of building
(Source: Remco, 2007)

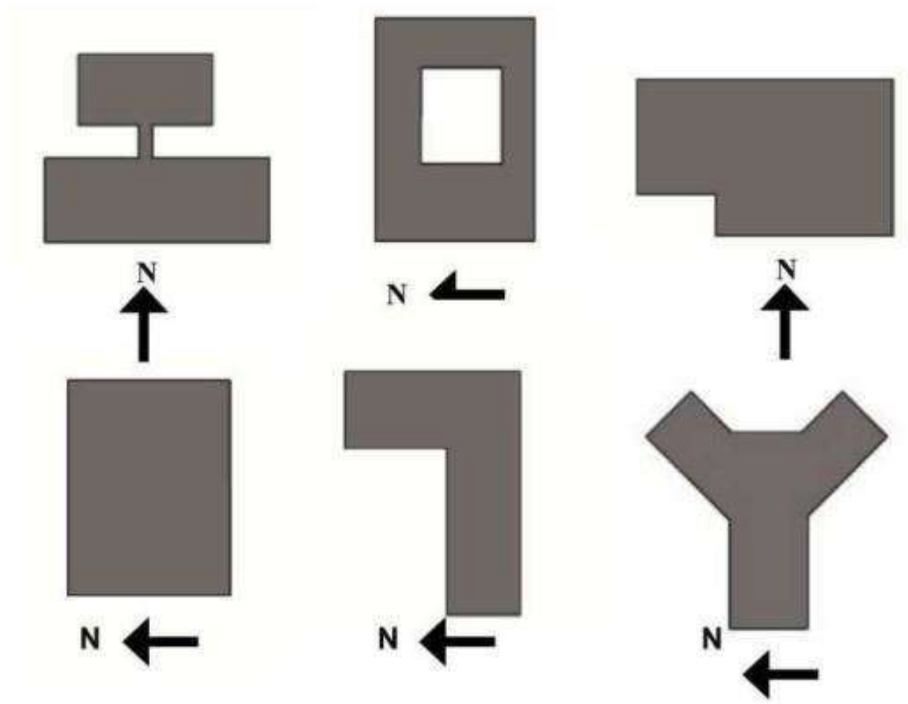

Figure 2.3: Best forms of building
(Source: Remco, 2007)

2.4.4 Walls

According to Remco (2007) walls in hot climates should be made of heat storing materials as they serve as shield of the building. The materials and thickness can be varied to control the heat gain.

The heat through the walls can be resisted through the following ways:

i) By increasing the thickness of the wall
ii) Adopting cavity walls
iii) By cladding heat insulating materials
iv) By using heat radiant barriers
v) By applying light coloured white wash on the expose surface of the wall

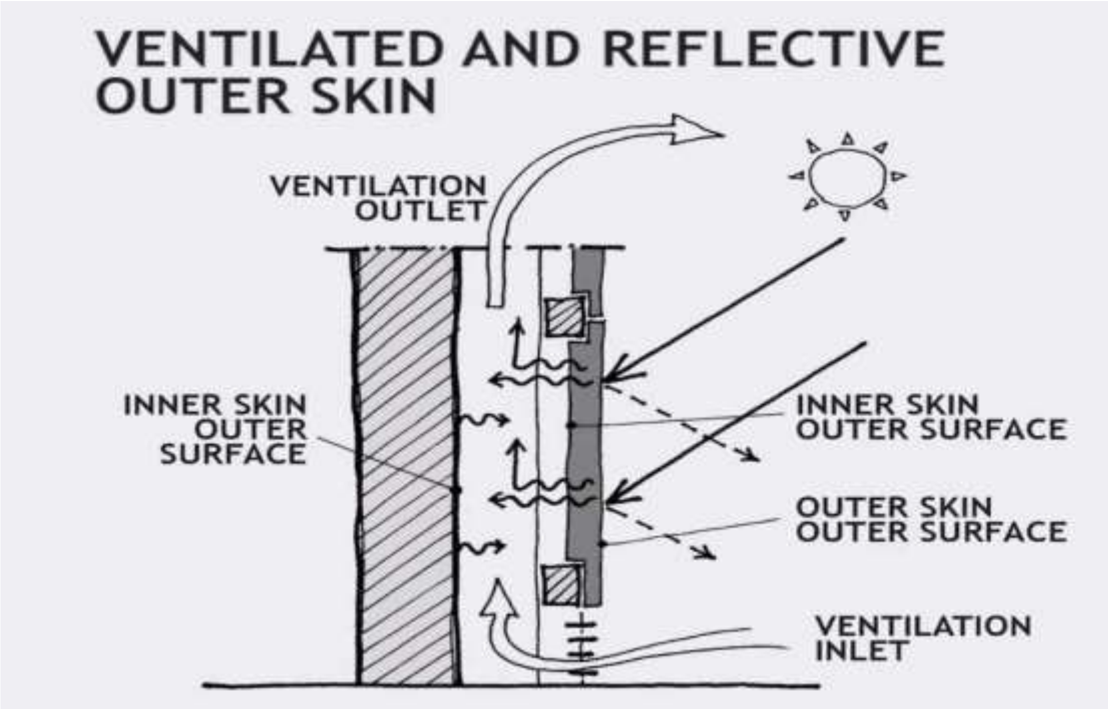

Figure 2.4: Cavity insulated wall
(Source: Remco, 2007)

2.4.5 Roof

The decision about roof shape, colour and composition are very crucial in hot climate because they determine the building overall performance. The roof receives the greatest solar radiation emission; therefore, its performance depends on its shape and composition of materials used (Remco, 2007).

Double skin ventilated roof is mostly advisable for this kind of climate as the heat between the two skins is removed by the airflow crossing the roof space from the prevailing wind, the heat load is reduce by the ventilation in the day time and rapid cooling is allowed at night (Remco, 2007).

A reflected surface is highly recommended on roofing sheet as it reduces the radiant heat transfer by the long wave radiation emitted by the upper layer. Radiant barriers should also be applied underneath the roof so as to prevent heat from reaching the internal fabric of the building (Remco, 2007).

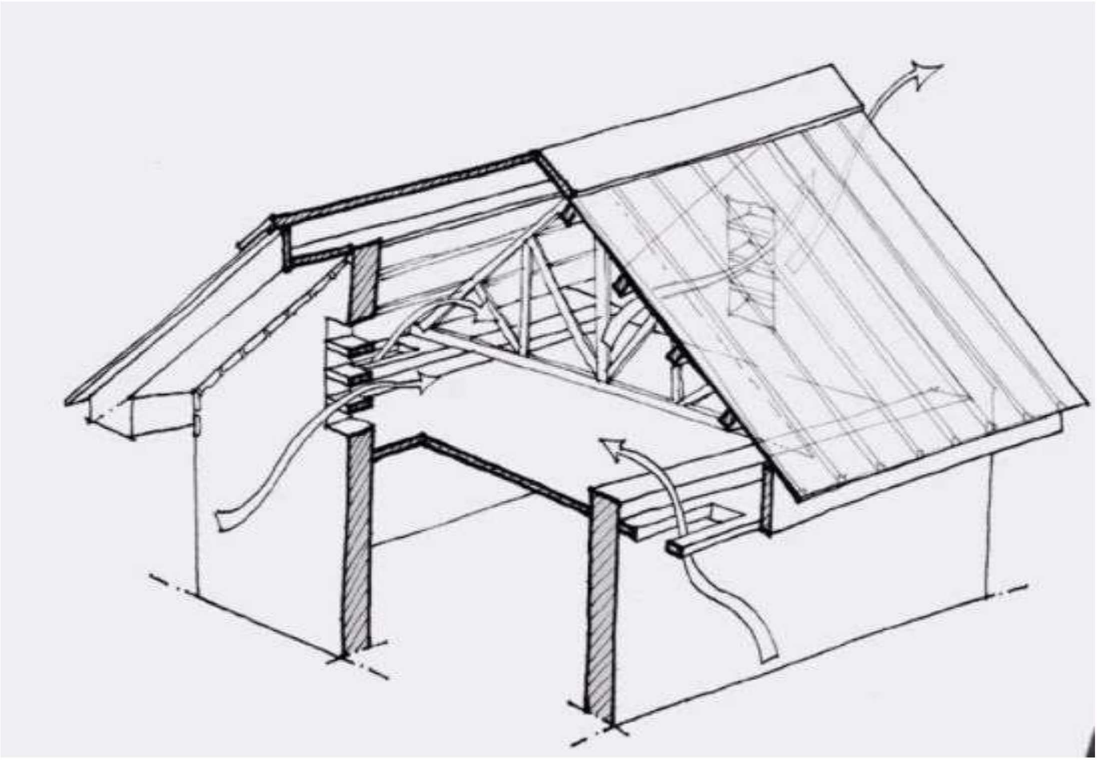

Figure 2.5: Double skin ventilated roof
(Source: Remco, 2007)

2.4.6 Windows

In hot and dry climates, lessening the window areas prompts lower indoor temperatures. More windows ought to be given in the North facade of the structure when compared with the East, West and South as it gets lesser radiation consistently (Remco, 2007).

All openings ought to be shielded from the sun by utilizing outer external shading devices, for example, fins. Moveable shading devices, such as window ornaments and venetian blinds can likewise be utilized. Ventilators are favoured at higher levels as they help in driving out hot air (Remco, 2007).

Since daytime temperatures are high during summer, the windows ought to be kept shut to keep the hot air out and opened during evening to concede cooler air (Remco, 2007).

2.4.7 Building material composition

The rate of heat transfer through a building material mostly depends on the effective ness of the thermal properties of the material. The higher the density and mass the more the storage of heat through the material, ability of the material to store heat during the day and effectively dissipate it at night is therefore determine by its thermal performance. The colour of the material can also help in re-radiating heat that its coming in through the building. Light coloured materials have a tendency of re-radiating the heat from the sun than dark colours. The re-radiation of the heat can further help in reducing the amount of heat storage in a building material (Moniem, 2017).

2.5 Sun, Temperature and Building Elements

Radiation from the sun determines the amount of heat gain or loss on the earth surface, the relationship between the sun and the site has to be taken into consideration in order to design efficient buildings (Ateeque *et al* 2017). Generally, the amount of solar access radiation on a building mostly depends on the position of the sun in relation to the building. The sun is dynamic and mostly moves in the direction of east to west (sunrise and sunset), the lower the angle of the sun in relation to the building the less the heat radiation and consequently, the higher the angle of the sun the more the heat radiation. Therefore, proper orientation of the building to the sun can control the overall heat gain or loss on the building elements (walls, roof and openings). Consequently, the decision on the choice of material type, shape and composition are determine by the effect of climate on the building site. The rate of heat transfer through a material depends on the effectiveness of the thermal properties of the material. The higher the insulation and mass of the material the more the storage of heat through the material and the less the heat transfer. So, ability of the material to store heat during the day and effectively dissipate it at night is determine by its thermal performance. Designers have to minimise the heat gain through the building elements by proper choice of colour, type and composition of the material (Olgae, 1963).

2.6 Climate in Study Area

Federal university Birnin Kebbi is located in Birnin Kebbi, capital of Kebbi State. The school was established on 23th February 2013 with the aim to increase access to education for the people of this region. The region falls under the hot and dry climatic conditions of the north-western Nigeria. In this type of climate, the mean summer temperatures are around 30°C but can reach a maximum of 45°C. Relative humidity is low and precipitation is very low. This lack of moisture, together with strong seasonal winds, can make wind-borne sand storms a major problem. According to Nigerian Meteorological Agency (2013), the climate of Kebbi State is hot and dry for most periods, of the year. The mean daytime temperature for most stations in the state is about 37°C. In summer, the highest temperature (about 45°C) is normally experienced in April, while minimum temperatures (about 30°C) are usually recorded in December. The State exhibits a remarkably high annual range of mean monthly temperatures.

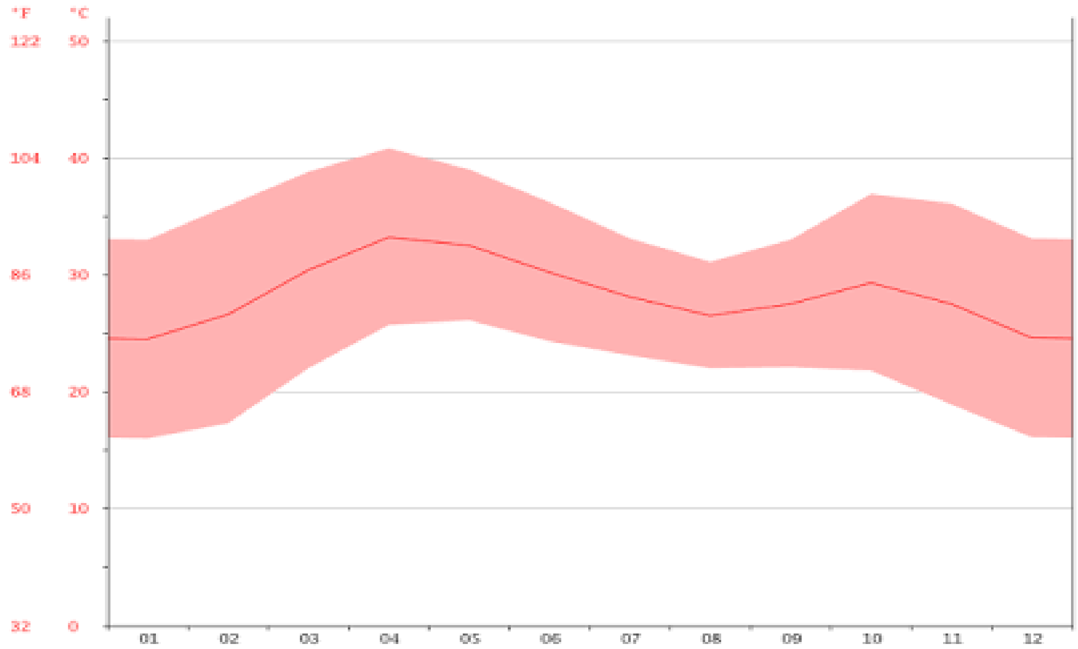

Figure 2.6 : Kebbi state Annual temperature chart
(Source: Nigerian metrological agency, 2012)

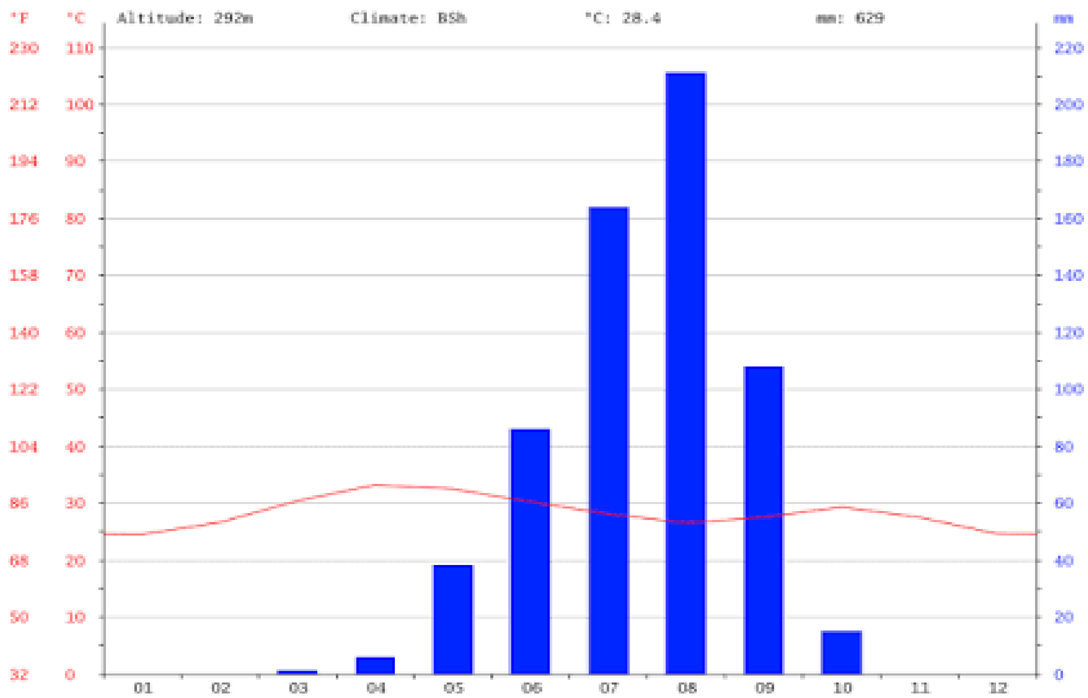

Figure 2.7: Kebbi state Annual rainfall chart
(Source: Nigerian metrological agency, 2012)

2.7 Research gaps

1. Building assessments were aimed at low energy design, thermal and visual comfort through the use of climate responsive design approach.

2. Buildings in the study area are not designed to take advantage of the climate of the region.

3. The instrument of assessing passive cooling strategies, using visual survey checklist generates building response to thermal comfort relationship.

4. The technique of using building simulation generate additional data which was not previously presented in the reviews

2.8 Architectural Design Consideration for Faculty Buildings

Design considerations are generated to bring to the attention of structure designers in applying the all-inclusive design requirements and principles to the type of structures and facilities. It is accordingly prescribed that the content of building projects and public facilities, particularly those planned for general use, ought to be taken into account by designers from the inception phase of the design structure.

2.8.1 Faculty of environment sciences

Faculty of Environmental Sciences is a multi-program unit of a University Education giving preparing in various controls identifying with the natural examinations.

Another significant component of a Faculty of Environmental Sciences is the presentation of continuous expert degree programs. The program comprises of five years pre-professional education pursued by two years of specific expert training ending in the award of degree programs and post-graduate degrees separately. Faculty of environmental sciences is planned with in any event more than two of the following academic departments: Architecture department, Building department, Estate survey, Quantity survey, Land surveys and Urban and Regional Planning department. Environmental faculty buildings are designed and planned within 3-5 stories floors so as to maintain a strategic distance from the utilization of lifts in a structure.

2.8.2 Space allocation

Neufert and Architect's handbook provided the scope and limitation of the faculty building complex as determined by the following space needs: Research/Workshop spaces, Administrative space, Practical/Design studio spaces, Teaching spaces, Circulation spaces, Offices, for both Graduate and Postgraduate Units:

1. Teaching spaces: - this incorporate standard classroom, supplementary classrooms, extra-huge classrooms, or extraordinary study halls, additionally spaces for showing materials and other auxiliary rooms. Space allocation for conventional teaching 2.00m²/student; for open hall spaces 3.00m²/student, for open arrangement educating 4.50m²/place including subordinate territories required for each subject. The standard room shape: rectangular or square (12 x 20, 12 x 16, 12 x 12, 12 x 10) m with a most extreme room profundity of 7.20m. It is conceivable to have windows on one side as it were. Floor regions are: customary study hall, 1.80 – 2.00m²/understudy; open arrangement 3.00 – 5.00m²/student. The reasonable tallness ought to be 2.70 – 3.40m.

2. Managerial space: - the space accommodated the administration staff whose undertaking is to deal with the undertakings of the workforce is another type of office space. At staff furthermore, departmental levels, staff are suited in their separate workplaces inside the authoritative square. Office zones will have separate workplaces for one to three individuals with workstations for learners, bunch workplaces for up to 20 individuals.

3. Functional/Design studio spaces: - each drawing studios requires (3.5 – 4.5) m^2, contingent upon size of drawing table (1.9 – 2.3) m^2. Drawing table of measurement for Ao size (920 x 1270) mm as fixed or flexible board. Drawings bureau for putting away drawings level, of same stature as drawing table, surface can likewise be utilized to put things on. There must be table tops for putting things on, drawing cupboards for hanging drawings or putting away level, appropriate for A0 at any rate. Every working environment ought to have a storage.

4. Workshop spaces: - University libraries are composed in it is possible that one or two layers. The one-layer framework is directed midway (book preparing and administrations) and typically has not many separate branches or subject's libraries. The two-layer framework incorporates a focal library and generally enormous number of personnel, subject furthermore, foundation libraries. Workshops ought to have enough space for adequate work zone similarly as workstation in office structure. Initially, brief stores for halfway completed stocks and general stores must be structured. Besides, organization and the board need work office, specialized workplaces, the board secretarial workplaces, meeting room.

5. Flow spaces: - Circulation are the spaces given inside the planned spaces to suit traffic activities which are essential for managing capacities. Like the walkways and verandas.

6. Workplaces, the manner by which office work is sorted out and organise are characterized (office structure, understudies/guests the executives, office innovation) influences the design for office space. The space dispensed to an individual to execute an assignment is referred to as a workstation. Office area requirements are classified in two sections. Firstly, individuals' space is calculated as (standard individual space x number of individuals) + further allowance for subordinate needs + a factor (generally 15%) for essential circulation. Furthermore, non-individuals' space (for example machine rooms, libraries and such for which fittings and gear sizes could easily compare to staff numbers in setting the region necessities) ought to be determined by informed evaluations dependent on existing good practice or equivalent examples + an extra factor for essential circulation.

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Introduction

Case study analysis strategy for research was adopted for this research as it enables a researcher to closely examine his data inside a particular substance. According to Zaidah (2007) case study research method can be used in areas that requires a holistic manner of approach to deal with research complex issues. It is perceived as a tool for data collection in many science studies (Zaidah 2007) as its role has turned out to be progressively noticeable as of late when dealing with community-based issues and how they are produced. One of the many reasons behind the recognition of case study method of research as an exploration strategy is that researchers were becoming more worried about the restrictions of quantitative methods in giving a top to bottom clarification of the social and behavioural issues being referred to. Through case study method of research, a researcher can go past the quantitative statistical results and comprehend the conduct conditions through the designer's perspective (Zaidah 2007). By including both quantitative and subjective information, case study clarifies both the process of phenomenon through complete observation and examination of the cases under study.

For the most part, case study will in general have an in-depth longitudinal assessment of case or event used. The longitudinal assessment gives a fundamental method for monitoring the events, by gathering information, breaking down data, and reporting the results over a period of time, particularly in situations where building performance condition are to be conducted. Studies on how a building resonate can as well be conducted through longitudinal case study method. Information gathered through observations are recorded to discover the level of the condition of a building. It is a unique way of observing any unusual phenomenon that exists in a set of data (Zaidah, 2007)

According to Yin (1984) case studies can be categorised into three types namely:

1. Exploratory case study: it sets to explore phenomenon in a data and serves as an interest to the researcher. In this case study also, field work is conducted in a research before any research questions and hypothesis are proposed.
2. Descriptive case study: it sets to describe the phenomenon which occur in the data in question. The goal set by the researcher is to describe the data as they occur.
3. Explanatory case study: it sets to examine the data closely both in depth and out-depth level in order to explain the phenomenon in a data.

Often times case studies have been dismissed for its lack of rigour and biasness in subjecting conclusions. Despite this criticism many researchers tend to accept case studies when conducting real life studies governing social issues and problems (Zaidah, 2007; Yin, 1994; Yin, 1984).

This research will therefore involve descriptive type of case studies so as to compare the existing case with the pre-existing theories. The manifested design of the Architect will be investigated and then be compared with the climate of the environment so as to assess the actual performance of the buildings. The goal of the research is to investigate the climate responsive building elements in faculty buildings.

Most important things to investigate in the case study are:

a) **Orientation and micro-climate:** Assessing the manifested design and the micro-climate of that place will help understand the reason of the orientation of the building on how it minimise/maximise the overall building surfaces.

b) **Form and function:** Assessing the form of the buildings will help in uncovering the reason behind chosen form and the function of building. Form and Function go hand in hand. The form of the building should be able to convey the function of the building.

3.2 Population of the Study

The population of study included three faculty buildings in the study area (Federal University Birnin Kebbi, Kebbi state, Nigeria).

3.2.1 Sampling

Purposive sampling was used for this study on the bases of form and orientations of the buildings in the study area and their micro climate conditions.

3.3 Instruments for Data Collection

The instruments used for data collection in analysing the case studies are as follows:

3.3.1 Photographs

Photographs of all the three selected case studies were taken in order ascertain the climate responsive building elements used in the buildings.

3.3.2 Sketches

Sketches of all the selected case studies were made and modelled with the used of Revit Architecture in order to examine the manifested design intentions of the buildings.

3.3.3 Simulation

The three selected case studies were simulated with the aid of Ecotect Analysis 2011, based on the climatic conditions of the region. So as to investigate the actual performance of the buildings when subjected to extreme climatic conditions.

3.4 Procedures for Data Collection

The procedure for data collection involved visits to the three case studies and taking the analyses of their architectural features paying more attention to the form and orientation as it determines the overall exposure of the building to the micro-climate.

3.5 Case Study Selection Criteria

Case studies were selected purposely based on sharing same micro climatic conditions of the study area, and of having different forms and same orientations.

3.6 Variables of the Study

In the cause of identifying and examining the factors that are responsible for heat discomfort in faculty buildings some variables from past literature were considered in this research namely:

i. Building type
ii. Building orientation
iii. Building form
iv. Building materials

3.7 Simulation

Software simulation tools are an important support tools for designers to predict performance of building and reduce energy usage (Kimmo, 2008). The building simulation software can be used to identify variables that can support the designers in making decisions on the best measures to apply for any building to be built or already existing. According to Aleksandrowicz (2015) with the use of building simulation software designers can consider the choices of heating and cooling a building. As the software allows one to predict thermal behaviour of building prior to their construction and simulate the building performance in their current conditions.

Simulation software tools can be used to calculate the following variables:

i. Indoor temperature

ii. Consumption needs of HVAC systems

iii. Interior comfort of the inhabitants

iv. Needs for heating and cooling

v. Levels of ventilation

vi Natural lighting needs of the occupants.

Hence, Ecotect simulation software was to calculate the indoor temperature of the three selected case studies. Simulating these buildings can help determine the performance of building when subjected to existing climatic conditions of the environment. The higher the moderation of micro climate the more the performance of the building and vise versa. The selected case studies were simulated in their existing form, orientation and materials used using Ecotect Analysis to determine the manifested design intention of the designer, climatic module of the study area (Federal University Birnin Kebbi, Kebbi state), gotten from Nigerian Meteorological Agency (NIMET) was inserted in the Ecotect software. The simulation of the buildings were based on extreme recorded temperature of the day (10^{th} April, 45^{o}c) and intense solar radiation of peak periods (March, April, May and June). The basis of this simulation is to identify elements that are expose to the climate and their actual performance.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 School of Environmental Studies

Building description: This is a faculty building located in the temporary site of the Federal university Birnin Kebbi having coordinate ($12^0$19’53” N, $4^0$09’16”), housing three departments of the environmental studies namely Architecture, Building and Quantity Survey. The structure comprises of partitioned offices as separate wing departments with studio rooms separated from the offices forming a ring like structure. The offices are located along the north eastern direction and studio rooms at the south west direction as shown in Figure 4.1. The building also has the presence of courtyard as its central core with clustered vegetation all around the courtyard as shown in Plate III.

The Table 4.1 shows the features of the building elements that were applied in Revit architecture in modelling the structure.

Plate I: View of the exposed openings of the building
(Source: Author’s fieldwork, 2019)

Plate II: View of shading devices along south direction
(Source: Author's fieldwork, 2019)

Plate III: View of existing courtyard and vegetation
(Source: Author's fieldwork, 2019)

Envelope configuration: the building walls are composed of sandscrete blockwork with reinforced concrete columns supporting the entire structure, rendered with a plaster of 25mm thickness and finished with light coloured texcotte paint with no any insulation attached as shown in Plate I and Plate II. The roof covering has a light colour dark green with a thickness of 0.55mm with no air vent or radiant heat barriers attach to it. The transparency component of the building as shown in Plate I and Plate II, consists of operable projected windows of 3000mm x 2700mm along the major functions (classrooms) and 600mm x 2400mm along the lesser functions (offices) all of which are of single layer having a thickness of 3mm with no insulation embedded to them. The whole building is shaded internally with trees around the courtyard as shown in Plate III, but Plate I and Plate II shows little presence of vegetation around the external part and with extended parapet walls shading the openings of the building from the top.

Cooling and lighting facilities: the building has a considerable number of air-conditioning systems as shown in Plate I, connected to the major function of the spaces (classrooms) and with little or no amount in the lesser function spaces (offices and conveniences), making the building completely rely on technical systems and unshaded wide openings to comfort the spaces. The lighting system comprised of series of fluorescent lamp units of 40watts each in power and 1200mm in length.

Source of energy: the building depends on the electricity from power generating company as shown in Plate I and fuel/diesel generators to operate all systems in the building such as lighting, HVAC, computers and different appliances.

Table 4.1: Physical properties of simulated building materialse

Building elements	Type	Thickness	Colour	Texture
Wall	Hollow Sandscrete block	230mm(Density2002.21kg/ m^3)	Light	rough
window	Single glazed	8mm	Reflective blue	reflective
ceiling	P.V.C panels	5mm	Light	smooth
Roof	Long-span Aluminium	0.55mm	Light	smooth

(Source: Author's fieldwork, 2019)

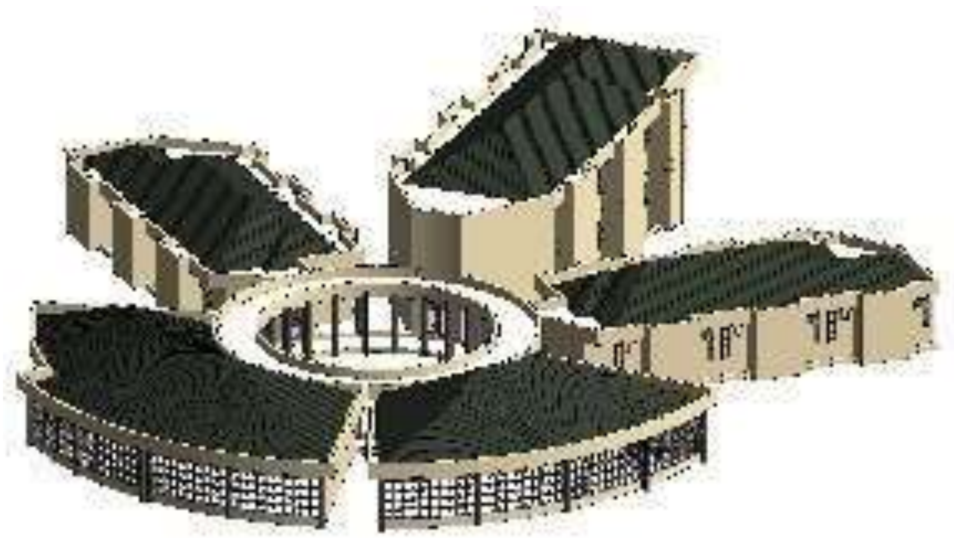

Figure 4. 1 Revit model of school of environmental
(Source: Author's fieldwork, 2019)

4.1.1 Simulation on effect of orientation

The Building was simulated based on the peak solar access radiation. The sun path direction was maintained East-west facing the structure as the orientation of the building could determine the elements of the building that are exposed to solar radiation. The colour bar located on the top right corner of Figure 4.2 shows the amount of heat gain from yellow to deep blue. The roof which is the component of the buildings most exposed to solar radiation has yellow colour, followed by the windows and walls facing the sun direction with different shades of brown colour while the shaded walls areas have the least effect of sun radiation from the colour brown to blue.

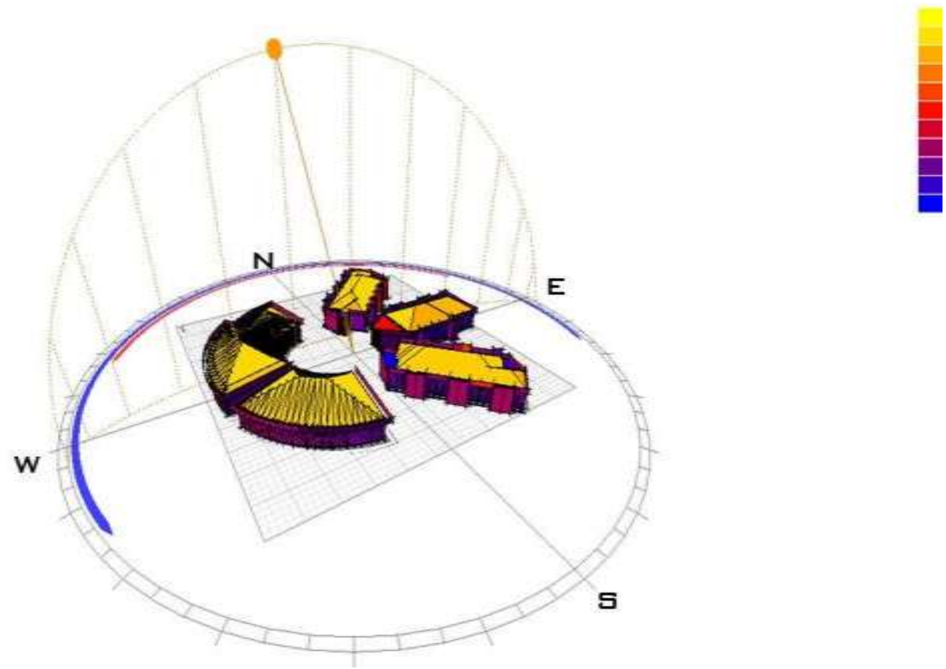

Figure 4. 2: Rendered image of the simulated model
(Source: Author's fieldwork, 2019)

4.1.2 Effect of temperature on building elements

The Table 4.2 shows the differential moderation temperature level of the building indoor spaces and the general outdoor temperature of 45°c. On the ground floor, the north Eastern rooms alongside the east room and east south rooms have the highest differential temperature as shown in the Figure 4.3 chart. However, the west south and west north rooms have the joint lowest moderation.

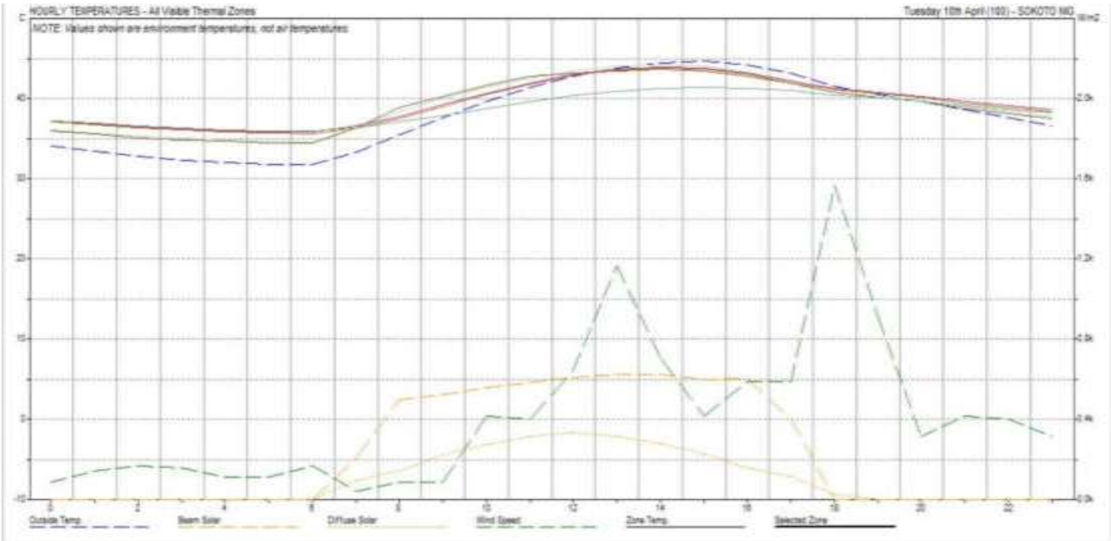

Figure 4. 3 Differential moderation temperature for a hottest day
(Source: Author's fieldwork, 2019)

Table 4.2: Differential moderation outdoor temperature at 45ºc

	North-East Rooms	East-Rooms	East-South Rooms	West-South Rooms	West-North Rooms
Ground Floor	3	3	3	1	1

(Source: Author's fieldwork, 2019)

4.2 Faculty of Art and Social Science

Building description

The Faculty of Art and Social Science building of Federal University Birnin Kebbi is located on coordinate (12º19'53" N,4º09'16" E), it houses staff offices for school of art and social science. The building has a cross like shaped with the head form which is the main entrance is oriented to face the east direction and the tail end facing the west direction as shown in Figure 4.4. The Table 4.3 shows features of the building that were applied in Revit architecture in modelling the structure.

Plate IV: View of the faculty veranda
(Source: Author's fieldwork, 2019)

Plate V: East view of faculty building
(Source: Author's fieldwork, 2019)

Plate VI: North view of faculty building
(Source: Author's fieldwork, 2019)

Plate VII: West view of faculty building
(Source: Author's fieldwork, 2019)

Plate VIII: View of corridor in the faculty building
(Source: Author's fieldwork, 2019)

Envelope Configuration: the building in Plate IV, Plate V, Plate VI, Plate VII and Plate VIII is from sandscrete block work and reinforced concrete construction, finished with light coloured beige texcotte from outside and light-coloured cream paint from inside. The glazing systems consists of two panels sliding windows with upper fixed lights having a dimension of 1200mm width and 1500mm height forming a window to wall ratio ranging between 25 to 30%. The window panels consist of an uninsulated glazing with a thickness of 3mm and a reflectivity of blue colour. The external envelope has no shading device except for the roof overhang projecting from the top of the first floor and existence of some scattered trees around the building as shown in Plate V and Plate VI. The roof has no vents or insulation except for the hardboard ceiling that is covering the head rooms.

Cooling and lighting: the building is ventilated and cooled by air-conditioning systems along with ceiling fans connected to all the offices, also sliding windows are use to control the flow of natural air to minimal level as shown in Plate V. As effective natural ventilation cannot be gotten from the sliding windows.

The lighting systems consists of a series of ceiling lamp units of a power of 25 watt, distributed according to a spacing of 3m interval and are all controlled manually by user's as shown in Plate IV and Plate VIII.

Energy source: the building depends on electricity from power generation company and fuel/diesel generators to power all systems in the building such as lighting, HVAC and different electrical appliances as shown in Plate VI and Plate VII.

Table 4.3: Physical properties of simulated building materials

Building elements	Type	Thickness	Colour	Texture
Wall	Hollow Sandscrete block	230mm (Density 2002.21kg/m^3)	light	rough
window	Single glazed	8mm	Reflective blue	reflective
ceiling	Hardboard ceiling	3mm	light	smooth
Roof	Long span Aluminium	0.55mm	light	smooth

(Source: Author's fieldwork, 2019)

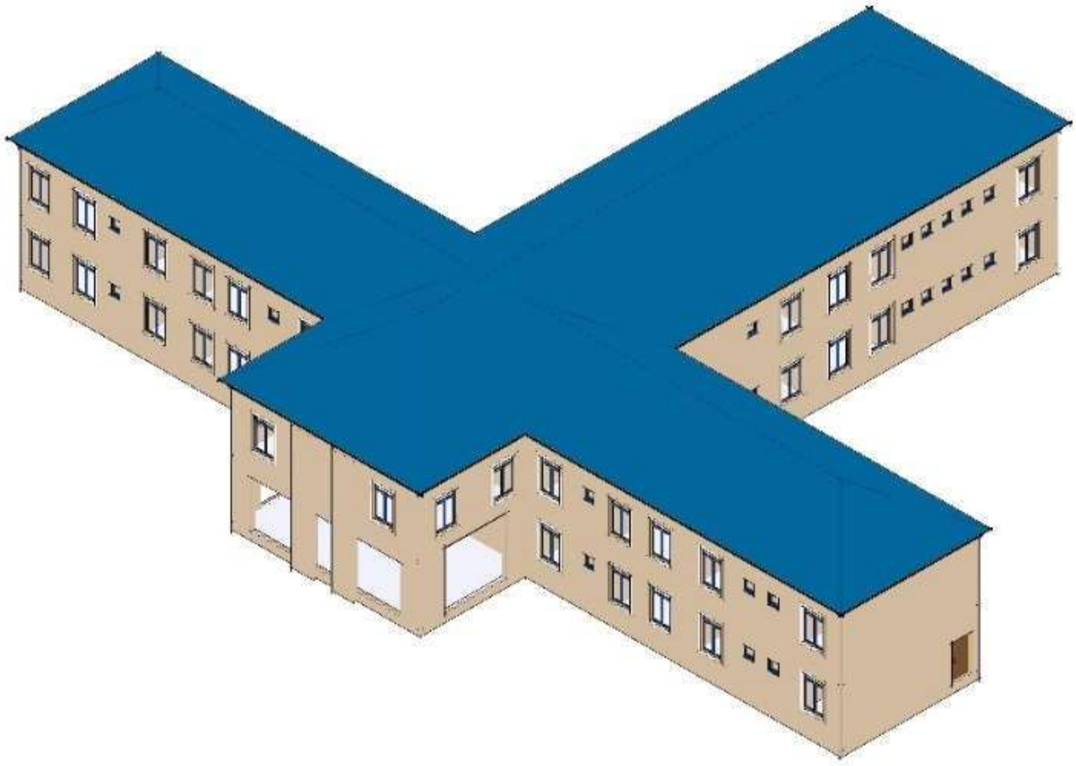

Figure 4. 4: Revit model of school art and social science
(Source: Author's fieldwork, 2019)

4.2.1 Effect of orientation on building elements

Building was model to mimic existing as-built orientation with regards to the sun and its component materials from the roof, wall and windows.

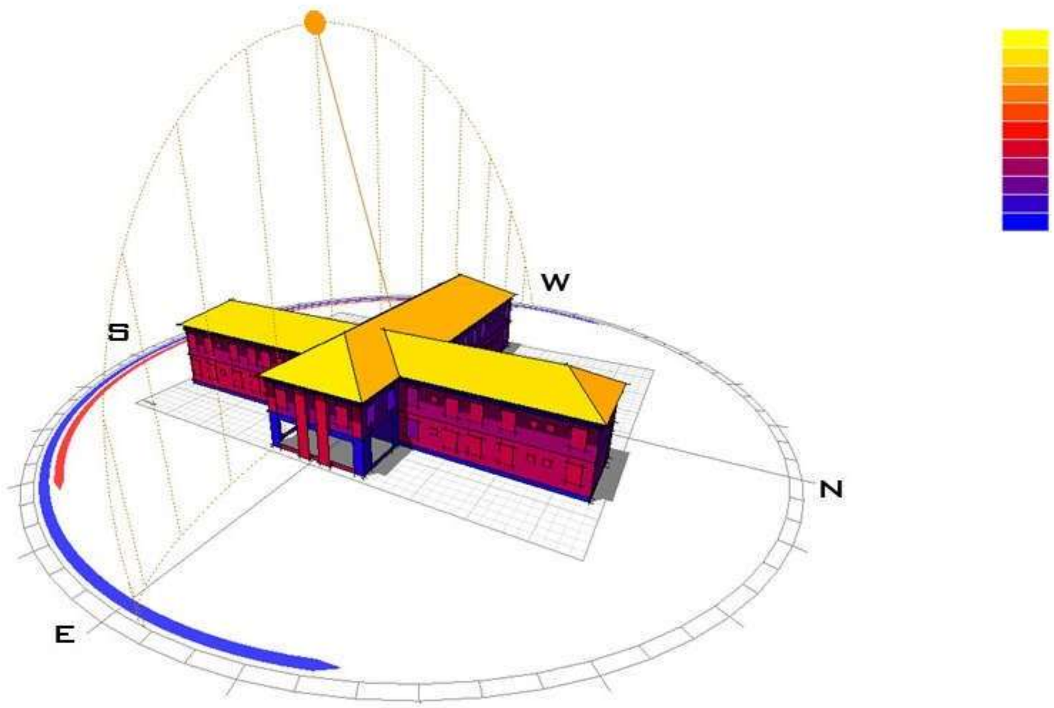

Figure 4. 5: Rendered image of the simulated model
(Source: Author's fieldwork, 2019)

Results from the simulations showed that the roof has the highest exposure to radiation from the sun as indicated on the high to low meter bar in Figure 4.5 above, this represents the radiation level of the roof in yellow. The windows and walls with the colour red are directly facing the sun direction while elements that are shaded away from the sun having colour meter brown to blue.

4.2.2 Effect of temperature on building elements

From the chart in Figure 4.6, there is an appreciable variation in temperature moderation along the north, east west and southern ends of the building at 45^{o}C outdoor temperature. On the ground floor, the south room has the highest moderation followed by the north and west rooms on the first floor. Subsequently the east rooms on the ground floor and first floor are with the least moderation.

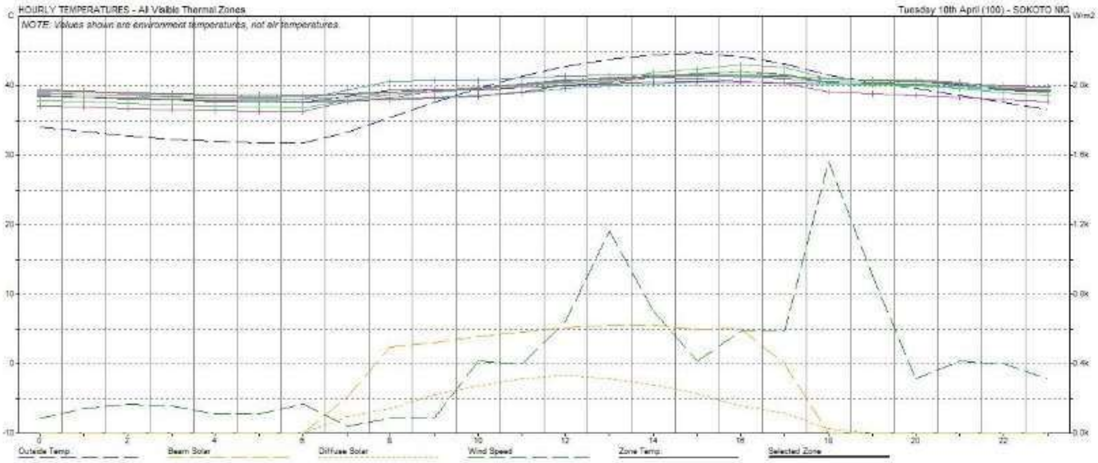

Figure 4. 6 Differential moderation temperature for a hottest day
(Source: Author's fieldwork, 2019)

Table4.4:Differentialmoderationoutdoortemperature at 45ºc

	North Rooms	South Rooms	East Rooms	West Rooms
Ground Floor	3	4.5	2	3
First Floor	3.5	4	2.5	3.5

(Source: Author's fieldwork, 2019)

4.3 Faculty Lecture Hall

Building description: The faculty lecture hall is located in the school of federal university birnin Kebbi (12º19'49" N, 4º09'02" E). the building houses classrooms, offices and conveniences for the faculty building of art and social sciences. The form of the building comprises of a combination of rectangular and square shape with open courtyard forming the central area as depicted in Figure 4.7. It is oriented with the shorter side facing east-west and longer side facing north-south.

The Table 4.5 shows features of the building that were applied in Revit architecture in modelling the structure.

Plate IX: North view of the faculty lecture hall
(Source: Author's fieldwork, 2019)

Plate X: Interior view of classroom in the faculty lecture hall
(Source: Author's fieldwork, 2019)

Plate XI: East view of the faculty lecture hall
(Source: Author's fieldwork, 2019)

Plate XII: West view of the faculty lecture hall
(Source: Author's fieldwork, 2019)

Envelope configuration: The external and internal walls of the building shown in Plate IX, Plate X, Plate XI and Plate XII were constructed with sandscrete block work and reinforced concrete columns and beams, plastered with 25mm cement mortar and finished with light washed texcotte paint. The glazing systems are top hung projected windows of 3mm glass panes and highly reflective blue shades, having varying sizes of 3000mm x 1200mm, 3000mm x 600mm, 1200mm x 600mm and 2000mm x 600mm as shown in Plate IX, Plate XI and Plate XII. The wall to window ratio is about 40-45% with no insulation or shading device attach on both external walls and windows, aside from courtyard that is integrated in the heart of the building as shown in Figure 4.7. The roof is long span aluminium of 0.55mm light coloured blue shade with no radiant heat barriers and air vent embedded to it.

Cooling and lighting: cooling is provided from both the unshaded windows on either sides of the building and mechanical ceiling fans that are equipped in the spaces. There is no presence of HVAC in all the spaces, which means the building rely on natural ventilation to cool the spaces as shown in Plate X.

The building lighting system consists of fluorescent lamp units with reflective sheets to maximise light distribution and wide unshaded external glazing to provide natural lighting.

Source of energy: Plate XII shows the existence of national electricity grid from power generation and fuel/diel generators to run systems such as lighting, computers and different electrical appliances.

Table4.5:Physicalpropertiesofsimulatedbuildingmaterials

Building elements	Type	Thickness	Colour	Texture
Wall	Hollow Sandscrete block	230mm (Density2002.21kg/m^3)	light	rough
window	Single glazed	8mm	Reflective blue	reflective
ceiling	Hardboard ceiling	3mm	light	smooth
Roof	Long-span Aluminium	0.55mm	light	smooth

(Source: Author's fieldwork, 2019)

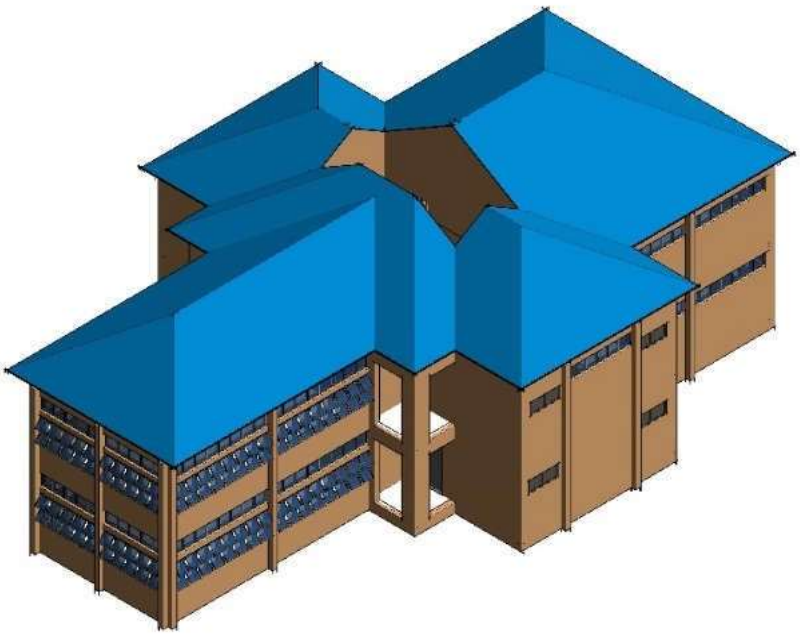

Figure 4. 7: Revit model of school of art and social science
(Source: Author's fieldwork, 2019)

4.3.1 Simulation result: effect of orientation on building elements

From Figure 4.8, the building was simulated based on peak period of solar radiation in which the sun path direction along the East-west axis facing the structure. As consistent with the other two buildings simulated the roof with colour yellow is the most exposed component, followed by the windows and walls in the sun direction with colour yellow to red while the shaded walls are least exposed with the colour ranging from brown to blue.

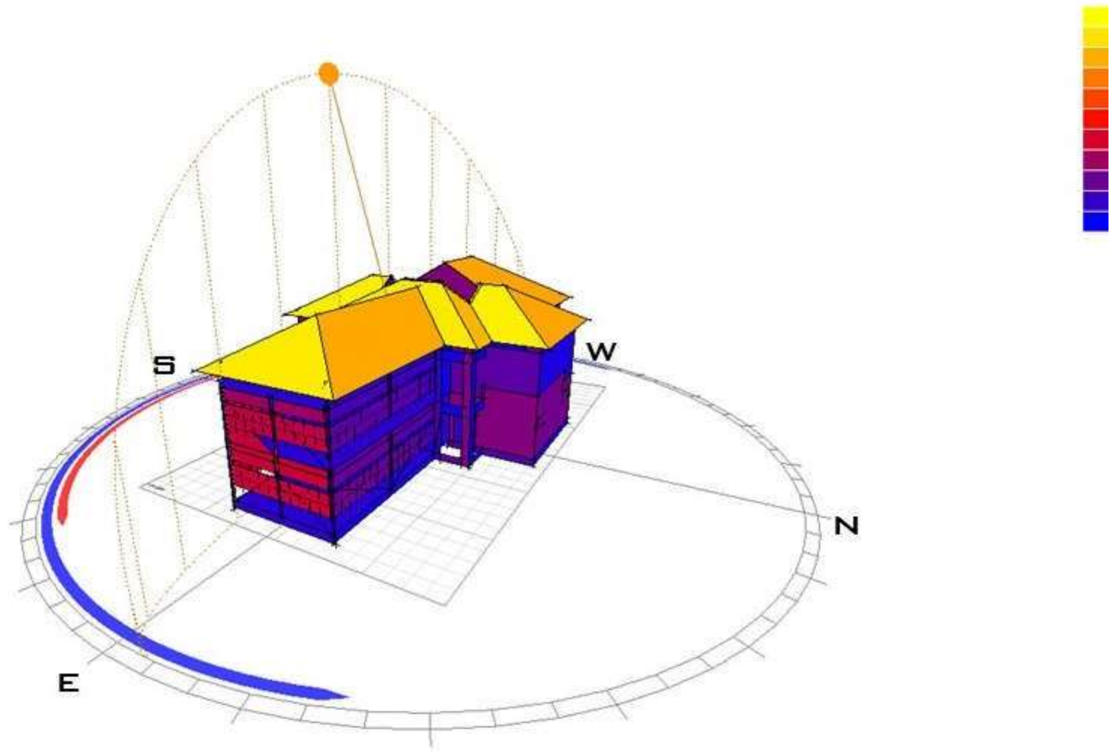

Figure 4. 8 Rendered image of the simulated model
(Source: Author's fieldwork, 2019)

4.3.2 Effect of temperature on building elements

The Figure 4.9 below shows the differential moderation temperature level of the building functions. At outdoor temperature 45°c, the north and south rooms on the ground and first floor have the highest temperature moderation in the building while the east and west rooms have a lower moderation compared to the others. There is also a slight difference in the result between the ground and first floor as shown in Table 4.6.

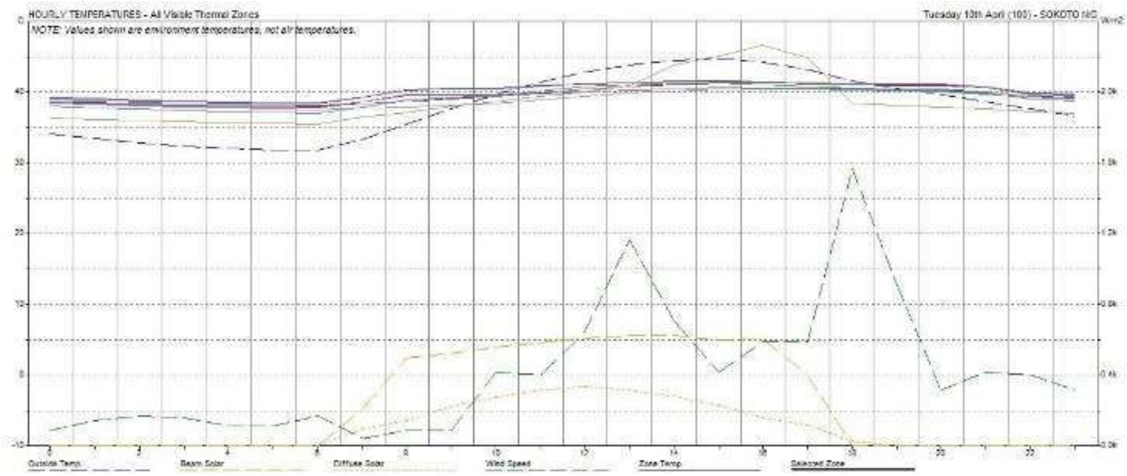

Figure 4. 9 Differential moderation temperature for a hottest day
(Source: Author's fieldwork, 2019)

Table4.6:Differentialmoderationoutdoortemperature at 45ºc

	North Rooms	South Rooms	East Rooms	West Rooms
Ground Floor	6	5	3	1
First Floor	6	5	4	1

(Source: Author's fieldwork, 2019)

4.4 Findings and Discussion

The findings from the research reveals that the designers of the building did not put orientation with regards to the direction of the sun into consideration during the design of the buildings as shown with building orientation in Figure 4.2, 4.5 and 4.8. From this perspective the buildings proved to be climatically ineffective as the major functions of the building are facing the east-west direction. Furthermore, a larger number of the windows in Figure 4.2, 4.5 and 4.8 are located along the east-west axis of the sunrise and sunset causing the slight moderation in temperature of these spaces as revealed in Table 4.2, 4.4 and 4.6. The exposure of the roof to solar radiation is responsible for difference in temperature between the ground floor and the first floor as shown in Table 4.4.

Besides orientation, the application of sun shading devices in Figure 4.2 was among the reason behind the appreciable moderation temperature of the building's wing; north east, east and east south wing axis as shown in Table 4.2. The functions of the building on those axes are entirely masked from sun penetration when compared to west south and west north rooms. Furthermore,

Courtyard and verandas application have significant impact on the north and south rooms of the building in Figure 4.8, as remarkable temperature moderation is achieved in Table 4.6.

4.5 Proposed Faculty Building

The proposed project is design to accommodate six departments, having six number of floors with first and second to house classrooms and third and fourth accommodate offices. The building form consisted of three rectangular wings each having a courtyard and verandas separating its sections. The three wings were arranged through a spiral ring (Atrium) that serves as its converging point for occupants coming in and going out of the building.

Two major climatic concerns were given close attention during the design process, that is extreme temperature and intense solar radiation as they posed a challenge in designing a comfortable building in this region. In tackling the challenges, the orientation of the building was done in sort away that the shorter sides of the building wings will be facing the East and West direction and longer sides facing North and

South to reduce overall exposure of building elements to the climate. The functions of the building were carefully designed to maximise the number of classrooms and offices towards the preferable directions of North and South and orientating spaces of lesser to East and West.

Close attention was given to natural ventilation in designing this project, as the location of the building was almost ideal for natural ventilation with little obstruction from adjacent buildings. Also, the arrangement of spaces around courtyards was not only intended to mitigate the effects of solar exposure but also to enable cross ventilation of classrooms and offices.

4.5.1 Sun protection

Although space allocation and building massing were intended to overcome the negative effects of solar exposure, nevertheless, vertical and horizontal shading devices were applied around the building openings to prevent sun penetration into internal fabric of the building. In addition to shading devices, aluminium sun protection screens were designed on this building on both the east and wet direction to break in sun rays from showering into the service areas.

4.5.2 Envelope configuration

Special attention was given to the design of roof as it has the highest exposure to the sun throughout the day. So double ventilated roof with radiant heat barriers was adopted for this design. As it helps to flush accumulated heat within the roof space and can as well slow down the passage of heat into the functions of the building. Polyurethane insulated boards were also design to be cladded on exterior walls in order to improve storage of heat through the walls.

Low emission windows were as well chosen for this kind of climate as they emit low heat and glare into the building spaces. The windows were position completely away from sun direction that is the East and West direction, because most of the heat gain in the functions of the building comes through windows that are facing the sun direction. Further shading by trees can then be use to enhance cooling.

4.5.3 Simulation

Simulation with Ecotect analysis was then tested on the building with consideration of the single day extreme climatic conditions of the environment (temperature 45^{o}c). Figure 4.10 shows solar access radiation on building elements and moderation level of building functions at extreme temperature.

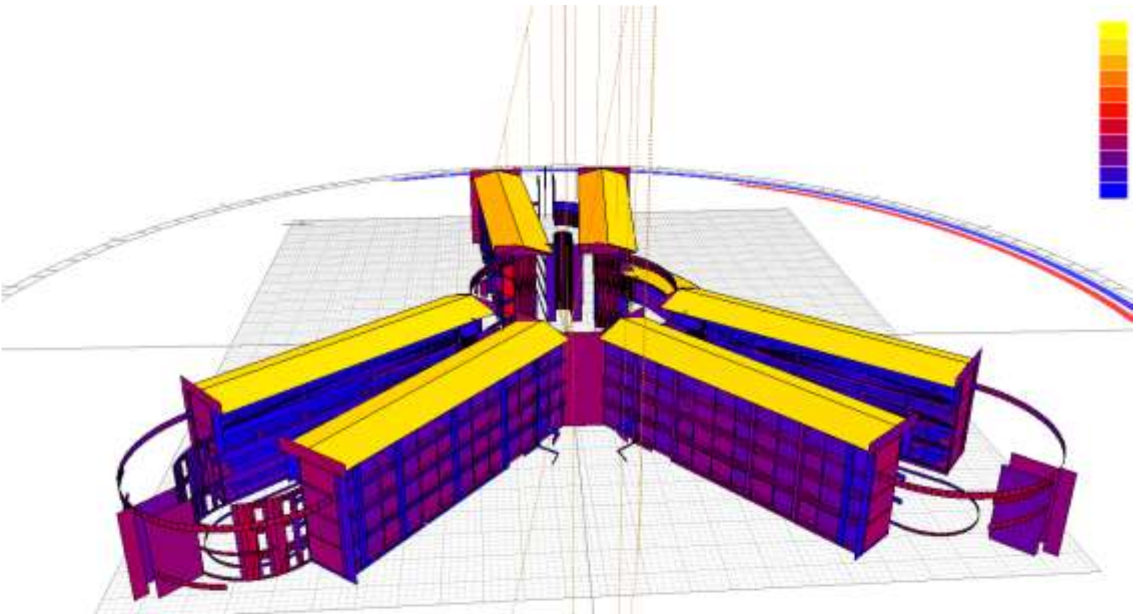

Figure 4. 10 Solar access radiation on building elements
(Source: Author's fieldwork, 2019)

As shown from the Figure 4.10 elements of the building facing the East and West have more exposure than those facing North and South, the roof with colour yellow with the highest exposure followed by the walls facing the East and West direction proper use of vegetation can reduce the exposure of building walls to the sun along East and West direction. Also, the use of shading devices have made it possible for the building openings to be shielded from direct solar radiation.

Courtyard and verandas have as well shown to have the least exposure to solar radiation with shaded colour blue, therefore integrating courtyards can not only improve ventilation but can as well mitigate solar radiation.

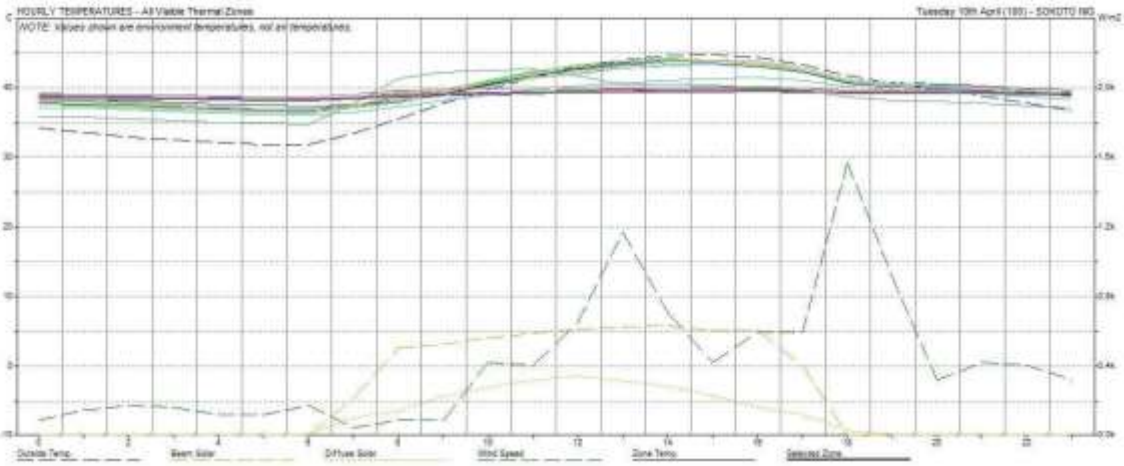

Figure 4. 11 Simulated moderation temperature level for a hottest day (Source: Author's fieldwork, 2019)

Table4.7: Differential moderation outdoor temperature at 45oc

	North East Rooms 1	North-East Rooms II	South-East Rooms I	South-East Rooms II	West Rooms I	West-Rooms II	Conveniences
Ground floor	5	5.5	5	5.5	6	6	3
First Floor	5	5.5	5	5.5	6	6	2.5
Second Floor	3.5	4	3.5	4	4.5	4.5	2
Third Floor	3.5	3.5	3.5	4	4.5	4.5	2

(Source: Author's fieldwork, 2019)

Simulation results in Figure 4.11 shows the temperature moderation level of the building functions at 45^{o}c, building functions along extreme corners of the building wings have lesser differential temperature moderation levels (2-3) than only the other functions due to the direct orientation of the room functions to sun, lesser functions like conveniences, store and shops would be placed along these directions. Also functions of the building on second floor and third floor have slight differential temperature moderations (3.5-4.5) than functions on ground floor and first floor (5-6), administrative offices are best suited to be on the second and third floor while classrooms on both ground and first floor due to the population of occupants staying in classrooms are far more than those in the offices. More also priority should be given to the faculty students in order to comfort their stay during their study program.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

From the findings, it can be concluded that the selected case study buildings were not designed to suit the climate as shown with the lack of good orientation. It is apparent that the designers did not put into consideration the extreme micro climate of the site during the design process as the major important functions are facing the east-west direction and spaces with lesser importance facing the north south direction. More also the lack of sun shading devices in two of the three case studies simulated proved to be a major factor in the heat gain within these buildings. Meanwhile, the proposed climate conscious design project has proved to have a better moderation level than all the selected case studies. As extreme climatic condition of the region was first taken into consideration before the establishment of form, orientation and building materials that will respond to it. Therefore, consideration of climate right from the design process along with simulation can help predict performance of building and on the long run reduce the emission of carbon dioxide to the atmosphere.

5.2 Recommendations

Climate responsive design strategy has already been adopted in many parts of the countries. The government needs to encourage this type of practice in order to achieve sustainable development goal by protecting the environment from global warming.

Architects now needs to be aware of the effects of climate on building projects due to the adoption of uniform style of design without due consideration of the micro climate of the region. This practice has affected many buildings that could comfort occupants without the need for mechanical cooling. Most decision that affects building energy use and performance occurs right from the schematic design stage. Timing for the climate consideration has to be taken right from the design process to ensure good comfort conditions for the occupants. Therefore, there is the need to establish policies on planning regulations that will require all designers to have a synergic design approach showing relationship between building elements and micro climate. This approach not only can improve the wellbeing of the occupants but can as well reduce the risk of climate change by minimising the overall carbon footprint of the buildings.

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APPENDICES

APPENDIX A (OBSERVATION SCHEDULE)

1. Name of Building____
2. Building type (if storey, the number of storeys would be required)____________`________
3. Number of classes/offices in the Building____________________________________
4. What materials were used for the construction of the following

   i. Floors________________________
   ii. Walls_________________________
   iii. Windows_____________________
   iv. Ceiling_______________________
   v. Roofs________________________

5. Percentage of vegetational space on the site of the Building

   a. 1%-25%
   b. 26-50%
   c. 51%-75%
   d. 76%-100%

6. Building orientation

   a. North
   b. East
   c. West
   d. South
   e. North-east
   f. North-west
   g. South-east
   h. South-west

7. Distance between buildings

   a. 1-3m
   b. 4-6m
   c. 7-9m
   d. ≤10m

8. Percentage of window to wall area

   a. 1% - 25%
   b. 26% - 50%
   c. 51% - 75%
   d. 76% - 100%

9. Position of openings
   a. Towards north direction
   b. Towards east direction
   c. Towards west direction
   d. Towards North direction

10. Type of shading devices used
    a. Vertical shading
    b. Egg-Crete shading device
    c. Horizontal shading
    d. Shading by trees or vegetation