APPLICATION OF BIO-CLIMATIC ARCHITECTURE IN THE DESIGN OF ENGINEERING COMPLEX, BAUCHI STATE UNIVERSITY, GADAU

BY

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M.SC/ENV-DES/314/2011-12

DEPARTMENT OF ARCHITECTURE,

FACULTY OF ENVIRONMENTAL DESIGN

AHMADU BELLO UNIVERSITY, ZARIA NIGERIA

OCTOBER, 2016

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A DISSERTATION SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES,

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DEPARTMENT OF ARCHITECTURE, FACULTY OF ENVIRONMENTAL

DESIGN AHMADU BELLO UNIVERSITY, ZARIA

NIGERIA

OCTOBER, 2016

DECLARATION

I hereby declare that the work in this dissertation entitled "*Application Of Bio-Climatic Architecture In The Design Of Engineering Complex, Bauchi State University Gadau* " was performed by me in the Department of Architecture under the supervision of Dr. Moukhtar M. Mai and Dr. Salisu A. S. 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 at any institution.

Hussaini IDRIS

Name of student	Signature	Date

CERTIFICATION

This dissertation titled "APPLICATION OF BIO-CLIMATIC ARCHITECTURE IN THE DESIGN OF ENGINEERING COMPLEX, BAUCHI STATE UNIVERSITY GADAU" by Hussaini IDRIS meets the regulations governing the award of the degree of Masters of Science (Architecture) of the Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

Dr. A.S. Salisu	_____	_____
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Member, supervisory committee	Signature	Date
Dr. A.S. Salisu	_____	_____
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Dean School of Post Graduate	Signature	Date

DEDICATION

This project is dedicated to my creator, Almighty Allah, for his continuous blessings and guidance, who made it possible for me to attain this level of education. And also to my lovely parents, Alhaji Idris Yusuf and Hajiya Hauwa Idris Yusuf for standing by me and see that I progress in life. And finally to my beloved brothers and sisters, who always wish me the best, in what I am doing.

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My grateful thanks are extended to all the lectures of Department of Architecture for their effort and patience in putting us through our studies especially my level coordinator and the test of timely academic and professional advisers throughout my years in the Department of Architecture ABU Zaria.I would also like to express my appreciation to all my colleagues in class for their enormous criticisms and contribution in the game of design.

My final and special appreciation to my beloved brothers and sisters Hassan, Zainab, Hafsatu, A'isha, Amina, Rufa'I, Mujahid, and Fatima Idris. And also to my beloved once Amina Gazama, Idris Sani and Abubakar A. Hamisu. I will not conclude without extending my regards to my uncles and aunties like; Late Alhaji Amadu, Baba Daso, Umar Babayo, Ali Babayo, Amina, Ladi, Biyo, Hajara, Aisha, late Yakubu and othes. Who always wishes me the best in all what I am doing in life. Thank you, may Allah bless you and reward you all in a more profound and pleasant way. Amin

ABSTRACT

Bioclimatic architecture refers to the design of buildings and spaces both interior and exterior, based on local climate, aimed at providing thermal and visual comfort, making use of solar energy and other environmental sources. The aim of this research is to proffer solution to some of the problems of thermal discomfort in academic environment by adopting bioclimatic architecture approach from design to construction stage. The intention is to minimize or eliminate the need for mechanical means of cooling, due to power shortage and the need to conserve energy, it becomes necessary to apply bioclimatic principles especially since the study area; Gadau has harsh (hot temperate) climate weather. This research discussed the key techniques and principles of Bioclimatic architecture, relavant literature were reviewed. The research method adopted in conducting this study was descriptive research which is qualitative in nature. An architectural survey, observation, checklists were used as research instruments. Case studies of exsisting faculty of engineering tecnology were undertaken to evaluate and analyse the application of bioclimatic architecture principles.

However the research findings reveled that major bioclimatic architecture principles were widely apply and explored in the design of institutional buildings in Nigeria, only few variables are not fully applied. The study recommend that single banking design concept, approprite construction techniques and accurate implementation of design (during construction stage) should be adopted inoder to achieve application of major bioclimatic architecture principles in buildings. Lastly, all the findings drawned from this research and analysis were applied in the design proposal of Engineering complex, Bauchi state university, Gadau.

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DEFINATION OF TERMS

Passive solar radiation: The solar energy that falls naturally on a building, is the heating space that utilizes the design of the building so as trap solar heat when.

Natural ventilation: is the process of supplying and removing air through an indoor space by natural means, meaning without the use of a fan or other mechanical system.

Cross ventilation: this is where there are pressure differences between one side of a building and the other, windows or vents placed on opposite sides of the building.

Thermal mass: is the ability of a material to absorb and store heat energy. High density materials like concrete, bricks and tiles have high thermal mass, lightweight materials such as timber have low thermal mass.

Shading device: The part of building that protected from the sun to reduce radiation in summer and should be able to get maximum radiation in winter. These shading devices include blinds, rollers, curtains, fins and overhangs.

Evaporative cooling: It reffered to reduction in temperature resulting from the evaporation of a liquid, which removes latent heat from the surface from which evaporation takes place.

Physiological cooling: This means Evaporation of perspiration, and it requires air movement and moderate to low humidity in the room.

Air infiltration: is the unintentional or accidental introduction of outside air into a building. Infiltration is sometimes called air leakage, uncontrolled inward leakage of air through cracks and in any building element and around windows and doors.

Bioclimatic architecture: this is the Building designs that take into account climate and environmental conditions to help achieve optimal thermal comfort inside. It deals with design and architectural elements, avoiding complete dependence on mechanical systems.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

Bioclimatic architecture refers to the design of buildings and spaces both interior and exterior, based on local climate, aimed at providing thermal and visual comfort, making use of solar energy and other environmental sources. Basic elements of bioclimatic design are passive solar systems which are incorporated onto buildings and utilize environmental sources such as; sun, air, wind, vegetation e.t.c for heating, cooling and lighting the buildings.

Accoding to Nahla (2007) the term “Bio-climatic architecture”, refers to the designed as that they readily respond to the effects of the local environment in order to provide comfort conditions for their occupants. Being environmental friendly leads to the construction of comfortable buildings with minimum depletion of natural resources and minimum waste.

Bioclimatic consists of two words, ‘bio’ meaning the natural form of living things and ‘climate’ the regular pattern of weather conditions of a particular place (Hornby, 2000). Bioclimatic architecture according to Proharam (2008) optimizes interactions between building and its environment, thus reduces heating and cooling needs, improving by the same way inhabitant comfort. It is defined by Martinez (2012) as the architecture of a place, taking into consideration the specific climatic conditions of the place, using free resources to reduce environmental impacts and energy consumption. Buildings are therefore, expected to be in tune with the local climate of the region where they are built, and incorporating the environment into it. Its focus is to integrate buildings into

their natural environment considering the climatic factors of the location for a particular design.

Bioclimatic buildings are designed and built on the basis of local climate and resources (energy and materials). Bioclimatic buildings make efficient use of solar radiation (energy from the sun) and make less use of concrete and aluminum materials that involve lots of energy production, favoring stone, earth and wood materials.

This thesis is all about designing School of Engineering Technology where bioclimatic design principles are applied to achieve a thermally conducive environment that will adequately cater for its users comfort.

1.2 Problem Statement

The building sector is responsible for almost 40% of the total final energy consumption on a national level. This consumption, either in the form of heat (using primarily oil) or electricity, besides being a significant economic burden due to the high cost of energy, results in large scale atmospheric pollution, mainly carbon dioxide (CO2) which is responsible for the greenhouse effect (Bioclimatic Design and Passive Solar Systems, 2015).

Adedayo (2013) stated that In every locality around the world, buildings are erected on daily basis as there is always a need for one form of structure or the other. Buildings consume a lot of natural resources due to various utilities and fittings used in the building system. The used up energy determines the amount of waste generated (Edem, 2010). It is imperative therefore, to be able to synergize our building designs comfortably with the local environment and the micro climate where they are to be built thereby adopting the bioclimatic design approach. The essence of any bioclimatic design is to be able to attain a degree of thermal comfort within structure.

The reduction of energy consumption in buildings can be achieved by simple methods and techniques, using an appropriate building design (bioclimatic architecture) and energy efficient systems and technologies, such as passive solar systems.

Thermal comfort is the cognitive state which determines contentment with the thermal environment and is evaluated by individual assessment (Edwards, 1999). It is further defined by British standard as "*That condition ofmind which expresses satisfaction with the thermal environment.*" Thermal comfort is therefore an important aspect of any designs enclosure as this determines the effectiveness of the buildings occupants. The term 'thermal comfort' is determined by the state of mind of an individual whether he or she is hot, cold or simply comfortable in their environment (Adedayo, 2013).

In trying to provide thermal comfort, high energy cost has become the most of draw backs institutional buildings there is high need for knowledge and desire to provide comfortable interior with minimal use of active (artificial) means.

Whilst designing for year-round comfort, it is important to pay particular attention to the design for the more dominant season. Gadau is located in what might be called a "summer driven climate", i.e. warmer weather occupies the major part of the year.

The problem with active means of thermal comfort is that they have by products that produce harmful emission that increase the global warming threat. Effort are being put in place to reduce active means of energy use while newly erected structure tends to have same problem, (Edwards, 1999).

This research is intended to check the extent to which bio-climatic principles can be applied in the design of a college/faculty to ensure design with nature as a remedy to the environment.

1.3 Research Question

The main research questions to this thesis design are:

i What are the core principles of bioclimatic design in hot humid climate?

ii To what extent, exploration of bioclimatic principle has enhanced natural environment in our institutional facilities?

iii How can this principle influence thermal comfort in an academic environment?

1.4 Aim and Objectives

The aim of this research is to proffer solution to some of the problems of thermal discomfort in academic environment by adopting bioclimatic architecture approach from design to construction.

In order to do this, they can be achieve though the following objectives:

i To determine the core principles of bioclimatic design in hot humid climate.

ii To determine the extent of thermal discomfort of academic environment.

iii To identify the possible causes of thermal discomfort in academic environment.

iv To apply appropriately bioclimatic principles in an engineering complex scheme.

1.5 Scope and Limitation of Research

The research aims at minimizing dependence on active energy e.g. air condition through the creation of a thermally conducive academic environment. This research is limited to the application of bioclimatic principles in the design of faculty of engineering complex. The researchis based on the research findings which will be used to provide a conducive environment that will adequately cater for users comfort. The layout will include the four departments of the Faculty of Engineering technology namely: Department of Mechanical Engineering,Department of Electrical Engineering, Department of Civil Engineering, and Department of Chemical Engineering.

1.5 Methodology of Research

Accoding to Rabiu (2014) A project is likely not to be successful as an exercise if a good research approach is not adopted. The aim of this research methodology is not only to unveil the unknown but also to state and clarify the known. The research for this project will be based on descriptive research method. The research methodology is grouped into two:

1. *Quantitative Element*: these include materials like climatic data which shall be analyzed based on their actual values collected. The mode of representation shall be charts, diagrams and tables.
2. *Qualitative Element*: these are elements which shall be allocated variables which shall be weighted based on its attributes, with respect to its positive or negative influence. The weight scale shall be from the number 0 (zero) to the number five (5), 0 being the lowest threshold and 5 being the highest threshold.

The Source of data collection instrument is group into three:

i *Literature review:* This include materials like book, papers, journals, write ups and magazines on related topics. Some of the literatures were gotten from existing project related to parts of this research.

Existing documents on climatic data and environmental data in relation to the site location shall be studies to fine out the design implications and studies.

ii *Case study:* Study of similar buildings with similar disciplines as that of the study of architecture shall be analyzed. Basically, qualitative research method will be used in the case study. Which include the following methods;

iii *Field survey:* Visit of buildings and careful observation of its bioclimatic principles features, in faculty of engineering technology building.

1.7 Significance of Study

Buildings are intensive energy consumers, thus contribute significantly to the greenhouse effect and climatic change, and have a severe overall environmental impact. As inhabitants of buildings, we can make our lives more comfortable, preserve the environment, our health and well being. The energy we consume in buildings is costly. It is worthwhile asking ourselves who pays for this consumption and why (Bioclimatic Design and Passive Solar Systems, 2015).

Outwater, Kroutikoa, Cornejo, Kolb & Shiau (2009) stated that all of us affect the energy performance of the buildings we live in. If we are aware of proper design, materials and use of technologies, we can apply them as far as possible in each case. Every action, even the simplest, can have energy benefits for our building.

The sun heats buildings. We can make use of this knowledge for passive heating by ustilising bioclimatic design strategies. Buildings should be protected from cold and heat using suitable insulation. Just as we protect ourselves from the sun in the summer, so should we protect the buildings we live in.

Natural cooling, compared to air conditioning, not only provides energy saving, economic and environmental benefits, but also constitutes a different approach, having as its goal, human comfort and well-being.We can utilise natural resources, and also reduce the internal loads of buildings accordingly.

Buildings must function rationally in order to ensure the efficiency of passive systems and energy saving techniques. We should not forget that energy consumption causes environmental degradation. In contrast, bioclimatic, energy efficient buildings improve the quality of life for their users.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Bioclimatic Design Principles

Adedayo (2013) state that, the term bioclimatic architecture is a term coined in the early 60s by the Olgyay brothers, they brought into existence the bioclimatic chart, which uses the psychrometry chart as a basis to relate climate as strategies to be used to determine thermal comfort of a particular location. According to Kane (2012), using the micro climate of a region to provide both thermal and visual comfort for occupants with renewable energy (solar) as a means of generating electricity and geothermal system for heating and cooling is an efficient system of eco friendly design. The bioclimatic design principle approaches both interior and exterior aspects of construction. This is achieved by using the essential feature of bioclimatic design to ensure landscape, construction materials and micro climate of a place are integrated actively with the existing environment (Martinez, 2012). Bioclimatic buildings can be achieved by considering the whole building life from design process through to construction. Materials used for construction and the methods used are important aspects of building sustainability, the building orientation, sun shading devices and size of openings must equally be considered in the design process (Adedayo, 2013).

Buildings affect the surrounding during their active periods, this is due to their necessity to heat, and cool and also provide lighting needs. During the life span of a building, only about 10% of its impact on the surrounding is corporal to building materials (Earth

Architecture, 2012). Energy efficient designs can reduce energy costs by 75%. The materials used in a building should have less CO2 discharges on the life cycle of the building (Earth Architecture, 2012). Bioclimatic design measures are centered primarily on the climate of a specific area.

Bioclimatic design takes into account the local climate and includes the following principles:

1. **Building form and orientation**: The building needs to be protected from heat gain into the structure especially during the hot periods. This can be reduced by the orientation of the building and materials used for construction (Martinez, 2012).

   Use of solar energy for heating buildings in the winter season and for day lighting all year round. This is achieved by the appropriate orientation of the buildings and especially their openings (preferably towards the south), by the layout of interior spaces according to their heating requirements, and by passive solar systems which collect solar radiation and act as "natural" heating as well as lighting systems.

2. **Use of sustainable power source**: Solar energy should be used as an alternative source of energy and also for lightning up the buildings all through the year. Building orientation towards the south and placement of openings is also to be considered (Kane, 2012).

   Heat protection of the buildings in winter as well as in summer, using appropriate techniques which are applied to the external envelope of the building, especially by adequate insulation and air tightness of the building and its openings.

3. **Sun shading devices**: Heat gain into the building during periods of high temperature can also be reduced by using sun shading devices and materials and paints that would permit less penetration of the solar rays (Adedayo, 2013). Protection of the buildings from the summer sun, primarily by shading but also by the appropriate treatment of the building envelope (i.e. use of reflective colours and surfaces).

4. **Used of Court-yard**: The courtyard is a regulator of air movement within building. Fathy (1998) illustrated the air movement by convection heat transfer where the density of thewarm air is less than the moderate cold air, hence, it rises high were an air switchingsituation happened between the light density (warm air), and the heavy density (moderate cold air), where it makes an air circulation.

5. **Natural ventilation and air quality**: Through the use of green/living walls, indoor air quality can also be improved as this will capture airborne particles while providing oxygen to liven up spaces. Air locks can also be installed in doors as it reduces the effect of heat on the building envelope (Moon, 2007).

   Improvement and adjustment of environmental conditions in the interiors of buildings so that their inhabitants find them comfortable and pleasant by increasing the air movement whithen the building.

6. **Heating and cooling techniques**: Ensure that materials used for glazing allow minimum solar radiation (glare) and adequate light in the interior spaces. Ensuring insolation combined with solar control for daylighting of buildings, in order to provide sufficient and evenly distributed light in interior spaces.

7. **Landscape**: Planting trees and incorporating artificial water bodies can also improve the micro climate of the environment. Improvement of the microclimate

around buildings, through the bioclimatic design of exterior spaces and in general, of the built environment.

2.2 Passive Solar Radiation

Accoding to Stauskis (2014) Passive solar refers to methods of collecting heat energy from the sun without using any moving parts. In its simplest form, called a direct gain system, passive solar is just a matter of orienting the building so that its longest side faces south, putting most of the windows on the south side, putting an overhang over them so the sun does not come in during the summer. In the simplest cases, called sun tempered, the amount of glass is not large, but gets more heat from passive solar, some mass is required (Nick & Koen, 2013). Figure 2.1 describe paths of energy exchange at the building microclimate.

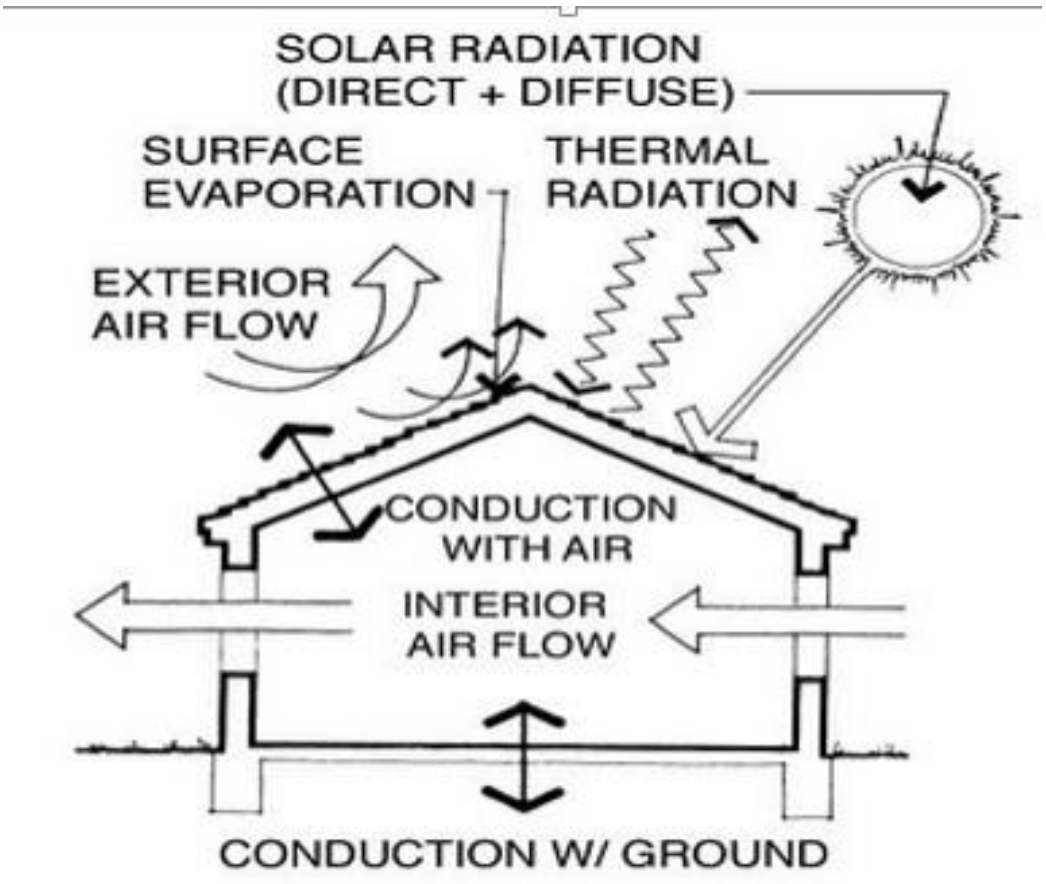

Figure 2.1: paths of energy exchange at the building microclimate.

Source: **(**http://new-architecture-archi.blogspot.com.ng/2012/01/principles-of-bioclimatic-design.html**)**

2.3 Natural ventilation

Accoding to Stauskis (2014) Natural ventilation is the process of supplying and removing air through an indoor space without using mechanical systems. It refers to the flow of external air to an indoor space as a result of pressure or temperature differences. There are two types of natural ventilation occurring in buildings: *wind driven ventilation* and *buoyancy-driven ventilation*. While wind is the main mechanism of wind driven ventilation, buoyancy-driven ventilation occurs as a result of the directional buoyancy force that results from temperature differences between the interior and exterior. There are two mechanisms by which natural ventilation is driven, ventilation because of wind and the other being the stack effect.

According to Reardon & Clarke (2008) Air movement is the most important element of bioclimatic. It increases cooling by increasing evaporation rates. In higher humidity, greater airspeeds are required to achieve the same cooling benefits. Air movement provides useful cooling in all climates but may be less effective in tropical climates during periods of high humidity, figure 2.2 illustrate air movement to achive vantilation.

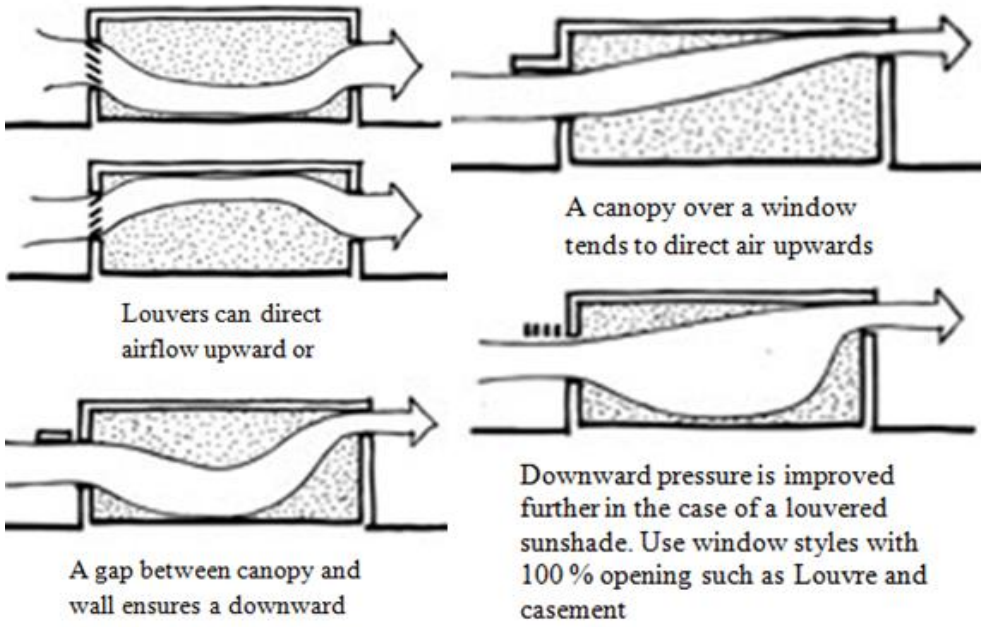

Figure 2.2: Ventilation (Air movement).

Source: (Reardon & Clarke 2008).

Since natural breezes can't be scheduled, architects often choose to enhance natural ventilation using higher headroom within buildings called stacks. It depends solely on air movement to cool occupants. Figure 2.3 illustrate how shading trees, wide overhanging roof, raised floor, free flow of air through the building to achieve .

Window openings on opposite sides of the building enhance cross ventilation driven by breezes. Ventilation requires the building to be open during the day to allow air flow. With openings near the top of the stack, warm air can escape, while cooler air enters the building from openings near the ground.

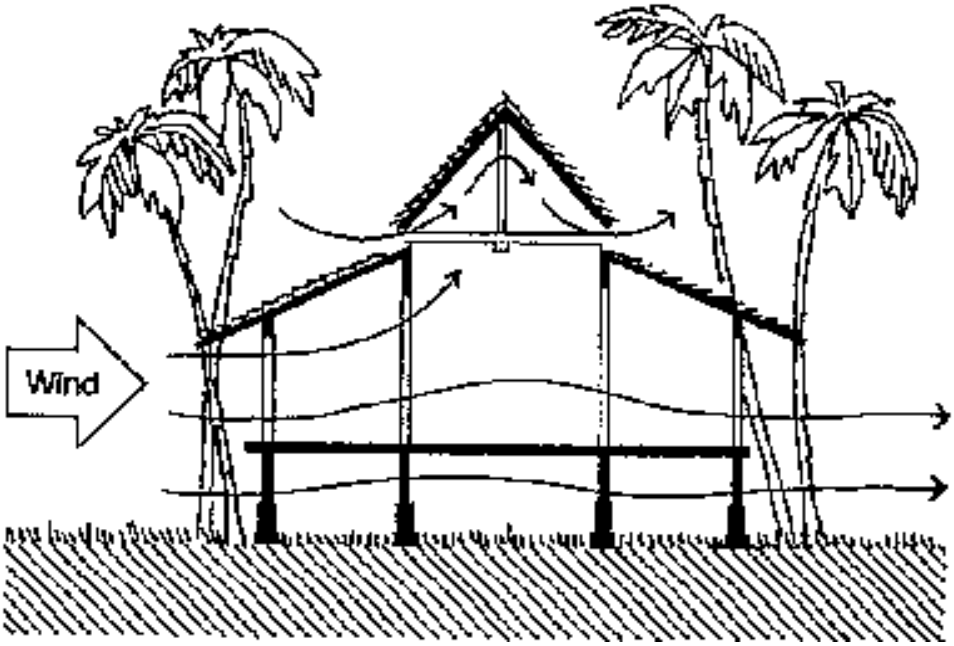

Figure 2.3: The main elements: Shading trees, wide overhanging roof, raised floor, free flow of air through the building to achieved stack effect.

Source: (http://www.nzdl.org/gsdl/collect/envl/archives/HASH7fb3.dir/p170b.gif)

Natural ventilation is due to wind forces, temperature differences, or both. Careful positioning of the openings in naturally ventilated buildings is a crucial parameter that determines the effectiveness of the process, figure 2.4 shows thermal buoyancy induced natural ventilation. Higher air speeds inside the building may enhance thermal comfort when they do not exceed certain values. Convective cooling by ventilation is a very effective method to improve indoor comfort, indoor air quality and reduce temperature. The technique is usually limited to night time ventilation however daytime ventilation may be used when ambient temperature is lower than indoor temperature (Allen & Henn, 2007).

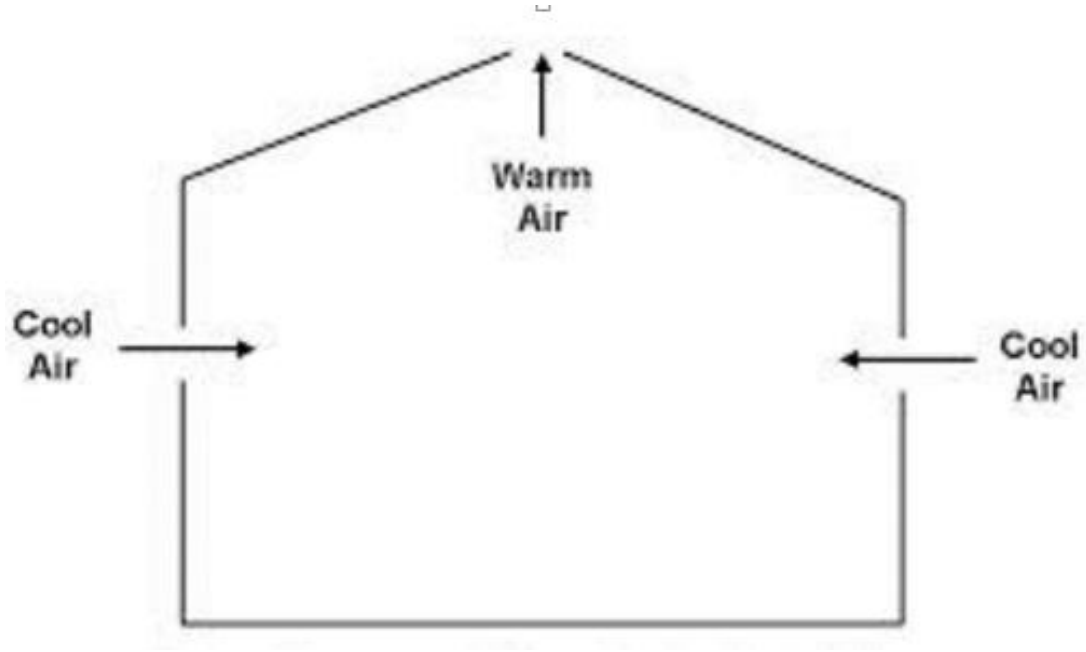

Figure 2.4: Thermal buoyancy induced natural ventilation.

Source: (Allen & Henn, 2007).

2.3.1 Spatial Configurations of Rooms

Stauskis (2014) stated that the overall special configuration of the building, rooms plays an important role. The set configuration determines the flow of air in the area. It is important to avoid harsh draughts, figure 2.5 shows Scheme of air paths.

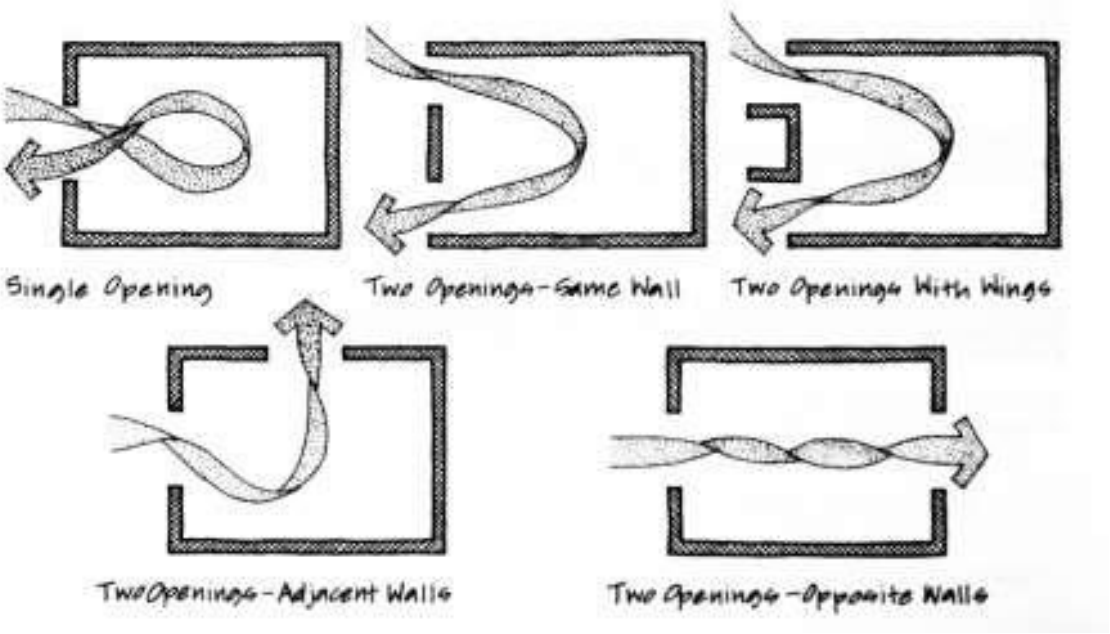

Figure 2.5: Scheme of air paths

Source:(https://sustainabilityworkshop.autodesk.com/sites/default/files/styles/large/public/core-page-inserted-images/window_horiz_placement_-_swl.jpg)

2.3.2 Cross Ventilation

This is valid not only for the design of the elevations, but also for the floor plan. Climate responsive building (1993) recommends that high humidity and warm temperatures require maximum ventilation, which leads to very open buildings. Free passage of air for cross-ventilation through the interior is important. An even more efficient solution is that of single-banked rooms with access from open verandahs or galleries. This can be achieved by large openings, not only in the outer walls but also in the internal partitions. Buildings are best built on stilts or at least on raised platforms. The floor is preferably elevated above the ground to allow for better ventilation, figure 2.6 shows different types of buildings that achieve cross ventilation.

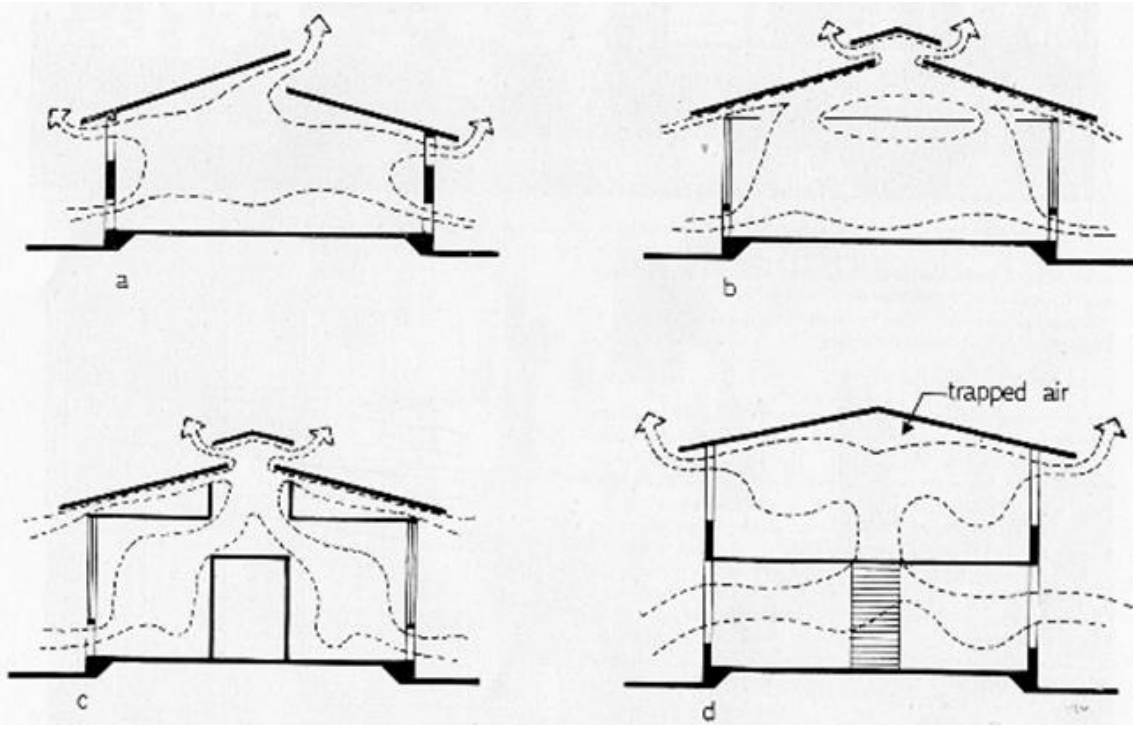

Figure 2.6: Different types of buildings that achieve cross ventilation.
Source: (http://www.oocities.org/kevgibson/images/solar-passive.jpg)

2.4 Building orientation

Generally, in all climates having the long axis in the east-west direction is the best, whether the idea is to collect solar or avoid it. This is because the south facing sun is high enough in the sky in summer that an overhang will keep it out, and low enough in the winter that the same overhang will have no effect, and in hot dry climate a reasonable size overhang can be built to keep the sun out all year long. In general, west facing solar gain is to be avoided in all climates because in order to get any in the winter, you get too much in the summer. East facing solar gain is acceptable in cool summer climates, but can also lead to summer overheating (Stauskis, 2014).

Reardon & Clarke (2008) stated that with good orientation the need for cooling is reduced, resulting in lower energy bills and reduced greenhouse emissions. In hot humid climates orientation should aim to exclude sun year round and maximize exposure to cooling breezes. Where ideal orientation is not possible, as is often the case in higher density urban areas, bio-climatic can still be achieved with careful attention to design. It is important to try to avoid windows on the east or west sides, because these sides of a building receive more of the sun's heat. Figure 2.7 illustrate how good orientation increases the energy efficiency of a building.

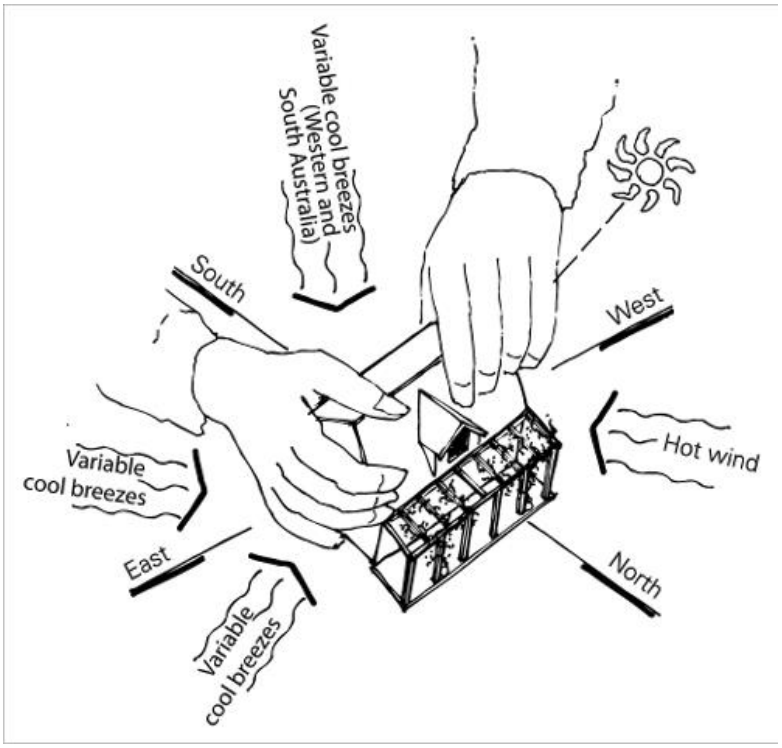

Figure 2.7: Good orientation increases the energy efficiency of a building.

Source: (http://www.yourhome.gov.au/sites/prod.yourhome.gov.au/files/images/PD-Orientation-GeneralPrinciplesOrientation-03_fmt.png)

If possible, buildings should be elongated along the east-west axis to maximize the south-facing elevation and the number of south-facing windows that can be incorporated. Reardon & Clarke (2008) emphasises on minimising east- and west-facing windows and sizing shading devices properly. Regardless of building type, most energy that is wasted can be attributed to poor design decisions regarding such factors as orientation, insulation, and glazing. Figure 2.8 demonstrate movement of the sun during the summer and the winter. Orientation issues should be addressed during site planning. To the maximum extent possible, east and west glazing should be reduced. Building's main orientation for tropical countries would have a directional emphasis on an axis 5° N of E. (Reardon & Clarke, 2008).

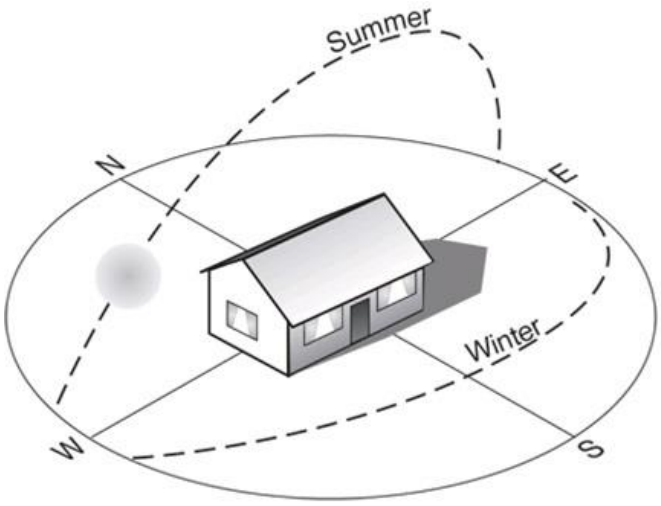

Figure 2.8: Movement of the sun during the summer and the winter.

Source: (https://buildcivil.wordpress.com/2013/11/04/passive-cooling-techniques/)

2.5 Building form

The intense diffuse solar radiation calls for buildings that have large overhanging roofs and wide shaded verandahs row house with hipped roof, elongated in E-W direction as shown in figure 2.9. These critical east and west walls are best protected if the house is covered with a hipped roof. Row houses elongated along the east-west axis provide the best shading of the critical east and west walls (Mohammed, 2010).

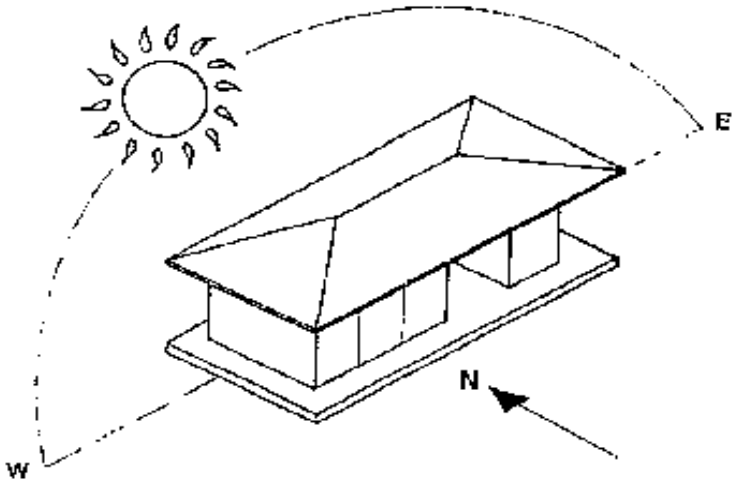

Figure 2.9: Row house with hipped roof, elongated in E-W direction.

Source: (http://www.nzdl.org/gsdl/collect/envl/archives/HASH7fb3.dir/p169a.gif)

The main goal is the reduction of direct heat gain by radiation through openings and of the internal surface temperature. This favors ventilation and heat emission at night time. The building should therefore be designed not only with protected openings, but also

with protected walls. Forms with large surface areas are preferred to compact buildings. In addition, the roof should extend far beyond the line of walls, with broad overhanging eaves as shown in figure 2.10, and other means of shading (Climate responsive Building, 1993).

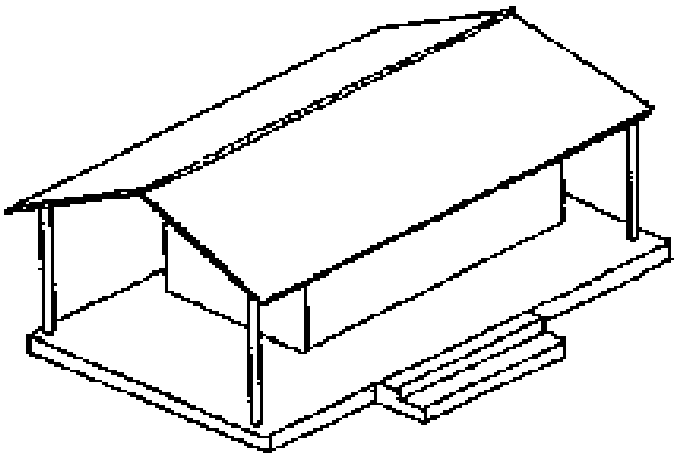

Figure 2.10: Low building with wide overhanging roof.

Source:(http://collections.infocollections.org/ukedu/collect/ukedu/index/assoc/sk02ce/p168b.gif)

2.5.1 Room arrangement

Accoding to Mohammed (2010) Rooms on the west side are cooler in the morning and heat up in the afternoon. Rooms facing north and south remain relatively cool if provided with adequate shading. The arrangement of rooms depends on their function. Since the thermal load is related to the orientation, rooms on the east side are warm in the morning and, if not built with much thermal mass, cool down in the afternoon. Thus, the rooms can be arranged according to their functions and according to the time of the day they are in use (Climate responsive Building, 1993).

It may not always be possible to arrange all the main rooms in an ideal manner. In this case, special care must be taken for the disadvantaged rooms. Special attention should be given to the arrangement of rooms with a high humidity (bathrooms). Here a proper cross-ventilation is especially important to avoid mould growth.

2.6 Thermal mass

Stauskis (2014) stated that thermal mass in a passive solar buildings, commonly concrete, brick, stone, and tile absorbs heat from sunlight during the heating season and absorbs heat from warm air in the building during the cooling season. Other thermal mass materials such as water and phase change products are more efficient at storing heat, but masonry has the advantage of doing double duty as a structural and finish material. In well-insulated buildings in moderate climates, the thermal mass inherent in buildings furnishings and drywall may be sufficient, eliminating the need for additional thermal storage materials.

Optimization of thermal mass levels depends on the properties of the building materials, building orientation, thermal insulation, ventilation, climatic conditions, use of auxiliary cooling systems, and occupancy patterns. For a wall material to store heat effectively, the rate of heat transfer through building materials and the effectiveness of thermal mass is determined by a number of parameters and conditions. It must have high thermal capacity and a high thermal conductivity value, so that heat may penetrate through the wall during the heat charging and discharging periods (Reardon & Clarke, 2008).

Thermal mass is the ability of a material to absorb heat energy. They are therefore said to have high thermal mass. Lightweight materials such as timber have low thermal mass. A lot of heat energy is required to change the temperature of high density materials like concrete, bricks and tiles. Appropriate use of thermal mass throughout a building can make a big difference to comfort and cooling (Reardon & Clarke, 2008). Constructed materials with high heat capacity, such as poured concrete, bricks and tiles, are typically contained in walls, ceilings, partitions and floors.

2.6.1 How thermal mass works

Thermal mass stores and re-radiates heat. Insulation stops heat flowing into or out of the building. Thermal mass is not a substitute for insulation. A high thermal mass material is not generally a good thermal insulator. During summer it absorbs heat, keeping the house comfortable. In cooler periods the same thermal mass can store the heat from the sun or heaters to release it at night, helping the building to stay warm, this is illustrate in Figure 2.11 below. A high mass building needs to gain or lose a large amount of energy to change its internal temperature, whereas a lightweight building requires only a small energy gain or loss (Reardon & Clarke, 2008).

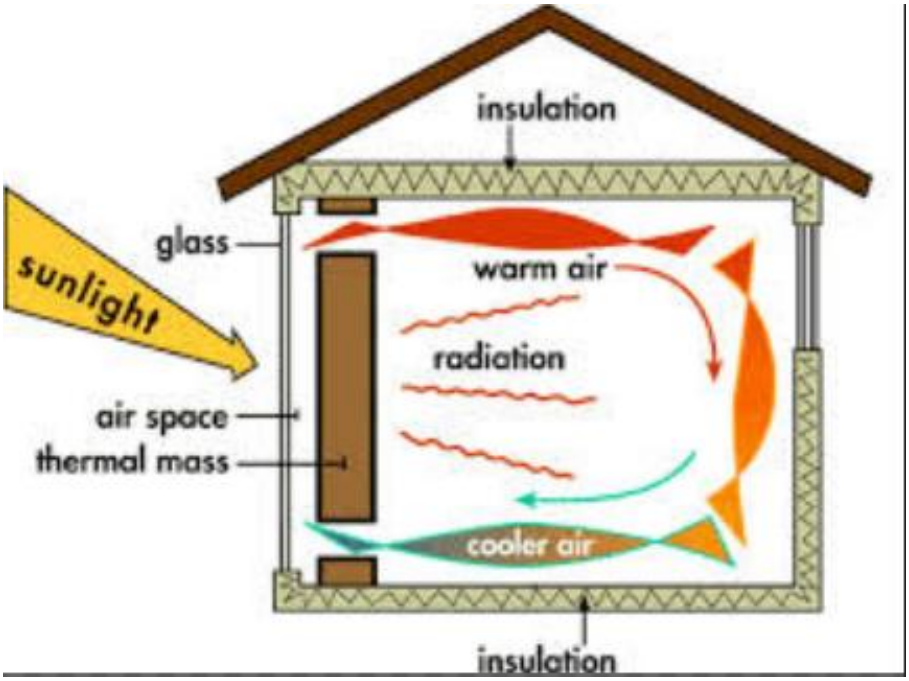

Figure 2.11: How thermal mass work.

Source: (https://www.permacultureglobal.org/post_projects/4842)

2.6.2 Thermal mass properties

i. *Low reflectivity***:** If there is considerable thermal mass in the walls, a more reflective floor will distribute heat to the walls. Matt or textured surfaces absorb and re-radiate more energy than light, smooth, reflective surfaces (Reardon & Clarke, 2008).

ii *Good thermal conductivity***:** For example, rubber is a poor conductor of heat; brick is good, reinforced concrete is better. The material must allow heat to flow through it. But if conductivity is too high energy is absorbed and given off too quickly to create the lag effect required for diurnal moderation (Reardon & Clarke, 2008).

iii *High density***:** For example, concrete has high thermal mass, Autoclaved Aerated Concrete (AAC) block has low thermal mass, and insulation has almost none. The more dense the material (i.e. the less trapped air) the higher its thermal mass (Reardon & Clarke, 2008).

The trombe wall is essentially a thermal storage wall. It takes advantage of time lag in the heat flow of a thick masonry wall, storing radiant heat from the sun during the day and releases the heat at night, figure 2.12 illustrate trombe wall.

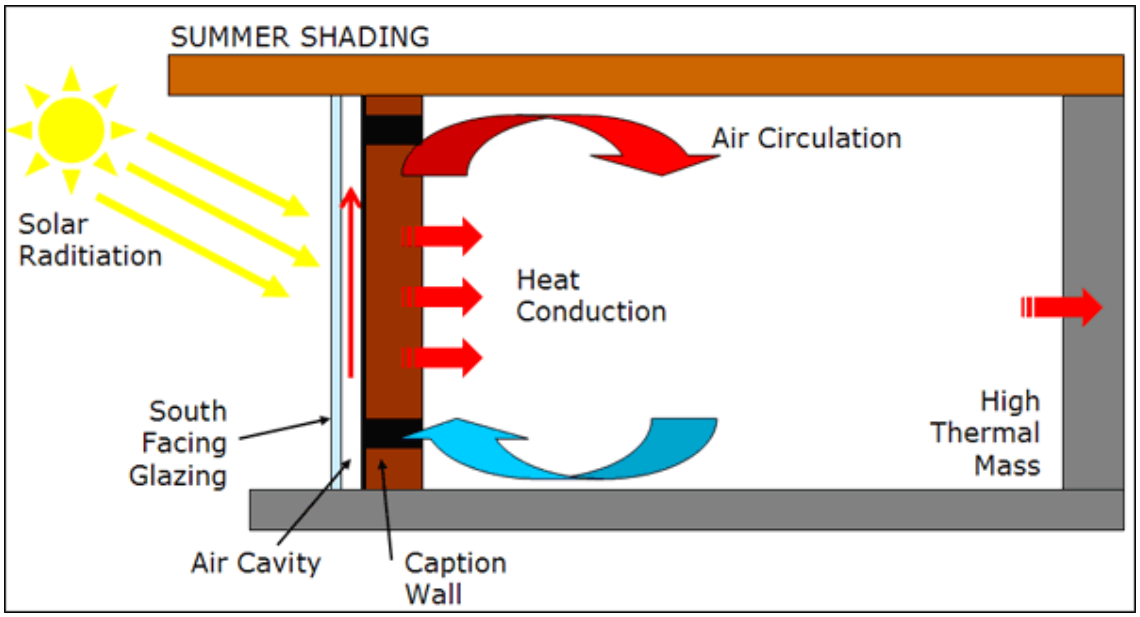

Figure 2.12: Diagram of Trombe Wall.

Source: (http://suryaurza.com/wp-content/uploads/2016/03/circ_xl.gif)

2.6.3 Impact of Thermal Mass and Insulation

Accoding to Stauskis (2014) when there are no many south facing windows, there is generally not enough solar gain to cause the building to overheat, but as the south

glazing goes above, mass is needed to absorb the additional heat as shown in figure 2.13. The mass serves not only to keep the afternoon temperature comfortable, but to release this extra heat during the night when the sun is not out.

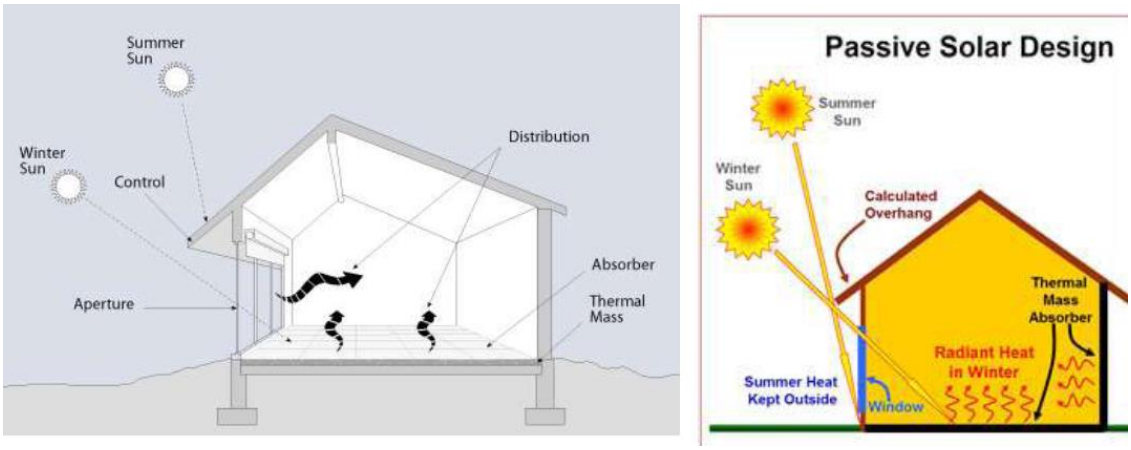

Figure 2.13: Thermal mass in the interior (floor) absorbs the sunlight.

Source: (https://greenpassivesolar.com/passive-solar/building-characteristics/thermal-mass/)

In order to be particularly effective in storing solar gain, the sun should shine directly on the mass, and the mass should be a dark colour so it absorbs it all (since the suns energy is all radiant). Figure 2.14 describe Thermal mass in the interior absorbs the sunlight and radiates the heat at night. If the mass is not directly in the sunshine, the air temperature will climb and the mass will absorb heat by conduction from the air, but this process is very slow, especially if the mass is on the floor, because solar gain can easily create highly stratified air (Stauskis, 2014).

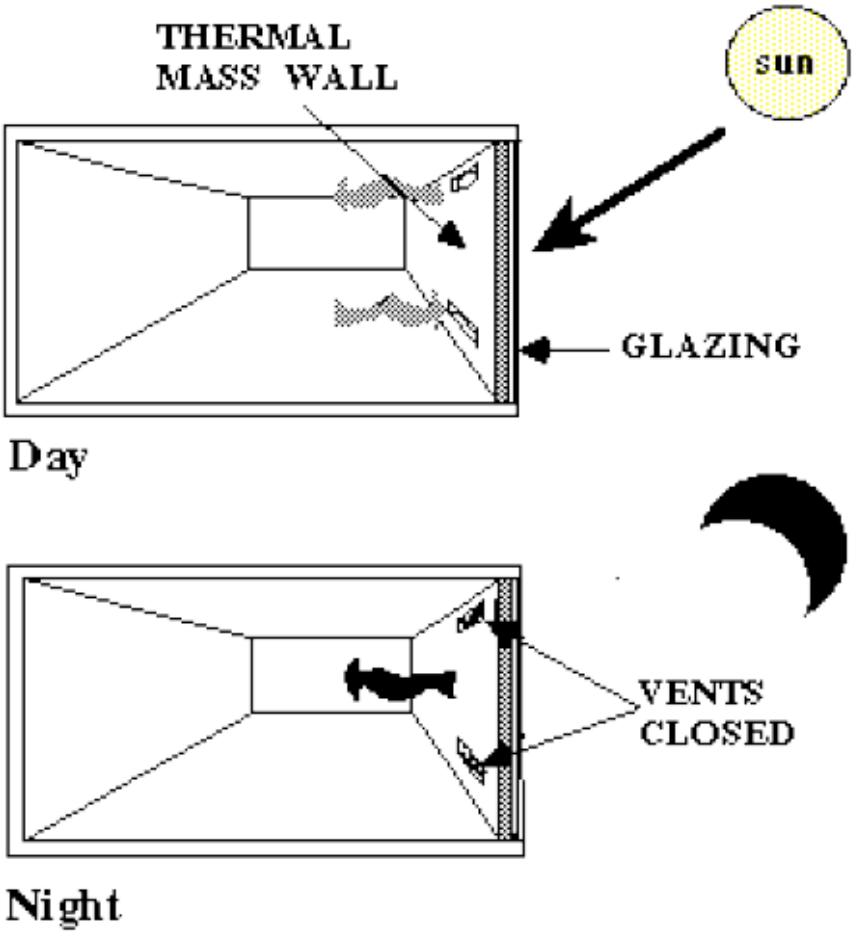

Figure 2.14: Thermal mass in interior absorbs sunlight and radiates heat at night.

Source: (http://passivesolar.sustainablesources.com/)

2.6.3.1 Insulation

Thermal mass is most useful in locations that have large swings of temperature from day to night, such as desert climates. Even if the thermal mass does not prevent heat energy from flowing into or out of occupied spaces, like insulation would, it can slow the heat flow so much that it helps people's comfort rather than causing discomfort as shown in figure 2.15 below. Using greater insulation means that less heat is needed on cold days, and less cooling on hot ones, making the amount of solar gain and night time cooling closer the actual demand (Stauskis, 2014).

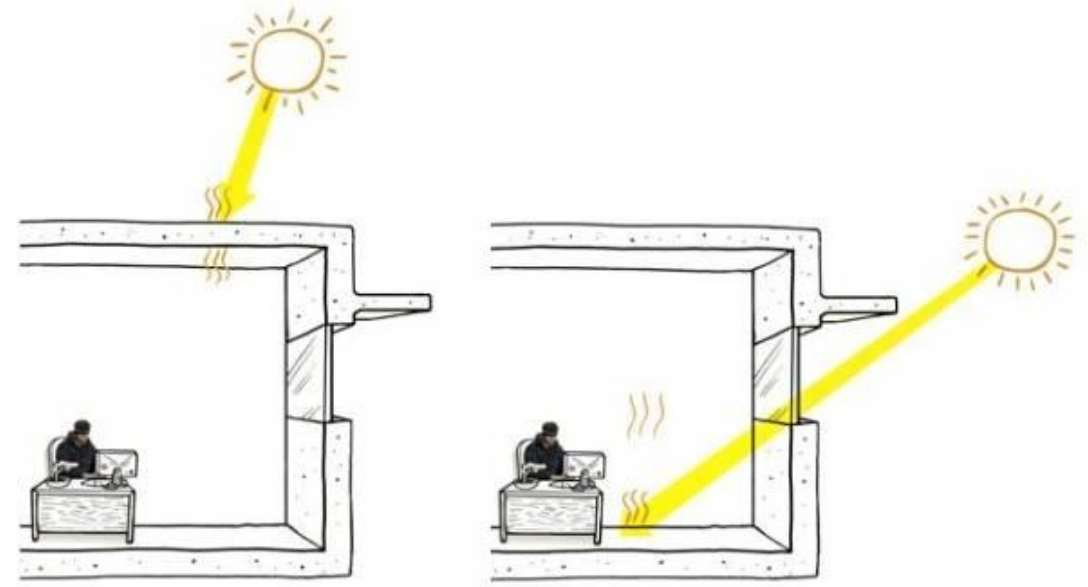

Figure 2.15: Insulation prevents thermal gain from leaking into the ground and Insulate coverings can interfere with thermal mass.

Source: (https://sustainabilityworkshop.autodesk.com/buildings/direct-solar-gain)

Accoding to Stauskis (2014) Thermal mass and Insulation has the following benefits:

i It is recommended to the exterior of the mass wall (toward sun) be dark colour.

ii A minimum space of 10 cm between the thermal mass wall and the glass.

iii Vents used in a thermal mass wall must be closed at night.

iv Thermal wall thickness should be approximately 25-35 cm for brick, 20-45 cm for concrete, 20-30 cm for adobe or other earth material.

v Direct-gain windows should be oriented due south, although the orientation may be varied by 30 degrees east or west of south without losing much efficiency.

vi Thermal mass floors that receive solar radiation should not be carpeted.

vii In direct gain storage thin mass is more effective than thick mass.

viii Locating thermal mass in interior partitions is more effective than exterior partitions. The most effective internal storage wall masses are those located between two direct gain spaces

2.7 Shading

Radiated heat has a different wavelength and cannot pass back out through the glass as easily. Olgyay (1951) emphasises that Shading of wall and roof surfaces is important to reduce heat gain, particularly if they are dark colored and heavyweight. Radiant heat from the sun passes through glass and is absorbed by building elements and furnishings, which then re-radiate it, Figure 2.16 shown the Penetration of radiant heat from sun. Shading requirements vary according to climate and building orientation. Shading of the building and outdoor spaces reduces temperatures, improves comfort and saves energy. Unprotected glass is often the greatest source of unwanted heat gain in a building. Shading can block up to 90 percent of this heat (Olgyay, 1951).

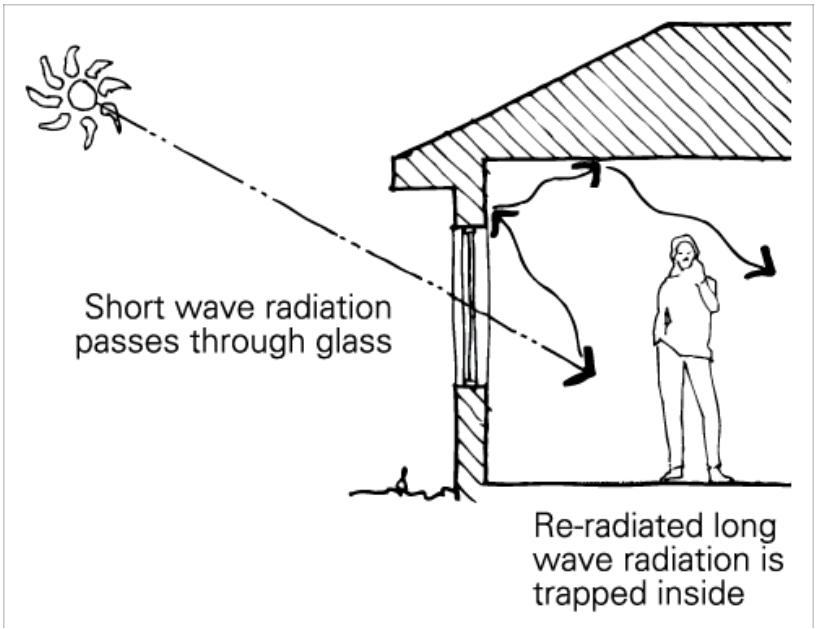

Figure 2.16: Penetration of radiant heat from sun.

Source: (http://www.yourhome.gov.au/passive-design/shading)

2.7.1 General guidelines for shading

Olgyay (1951) gave these general guidelines for shading. Internal shading will not prevent heat gain unless it is reflective. External shading devices over openings should be used. Lighter-colored shading devices reflect more heat.

2.7.1.1 Using plants

To shade the buildings, particularly windows reduces unwanted glare and heat gain. For all other climates use deciduous vines or trees to the north, and deciduous or evergreen trees to the east and west, as shown in Figure 2.17. Evergreen plants are recommended for hot humid and some hot dry climates.

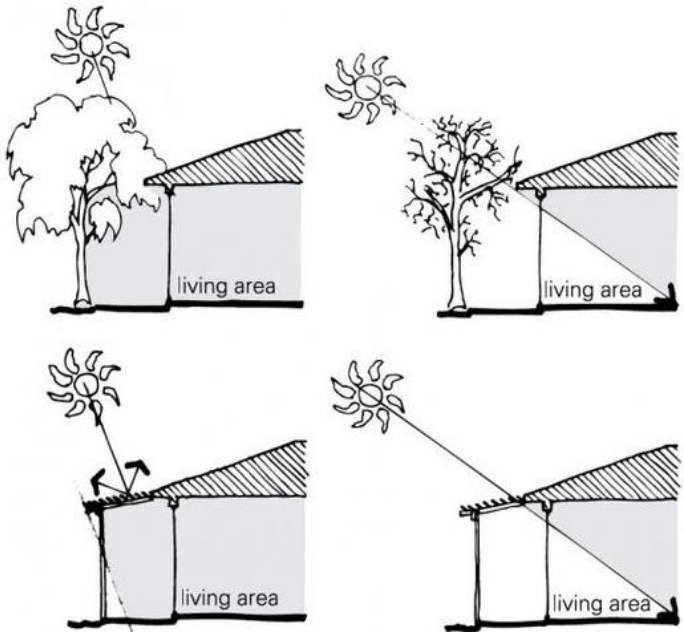

Figure 2.17: Effective shading solutions with ideal orientation, sun can be excluded using simple horizontal devices, including eaves.

Source: (https://www.pinterest.com/pin/379850549796471522/)

2.7.1.2 Shadow Angles and Shading Masks:

A shading mask can be created and overlaid onto the appropriate sun path chart to determine whether there is adequate shading during specific times of the day and year. Figure 2.18 shows Horizontal shadow angle and Vertical shadow angle with vertical and horizontal shading devices respectively, to achived good shading, it would be an angle from the windowsill to the outer edge of the overhang. More angles come into play with shading device design. When designing shading devices, the geometry of the device itself and its relationship of the face of a building produce a number of angles relative to the desired shadow being cast (Mohammed, 2010).

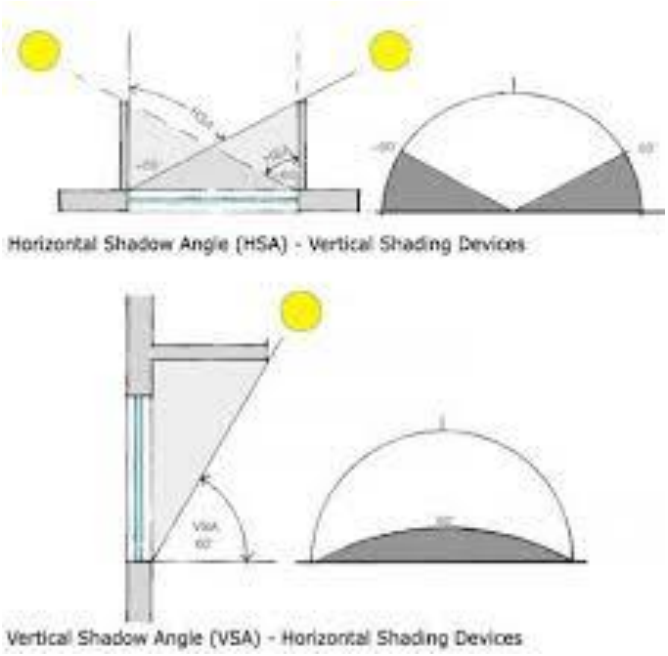

Figure 2.18: Horizontal shadow angle and Vertical shadow angle with vertical and horizontal shading devices respectively.

Source: (https://www.educate-sustainability.eu/kb/print/2188)

Altitude and azimuth angles are very useful in understanding solar position and sun path diagrams, but are much less useful in defining the shadow angles cast by a projection on a wall exposed to the sun, Figure 2.19 shows Altitude and azimuth angles, very useful in understanding solar position and sun path diagrams. North facing windows receive direct solar radiation in the summer, when the altitude of the sun is very low.

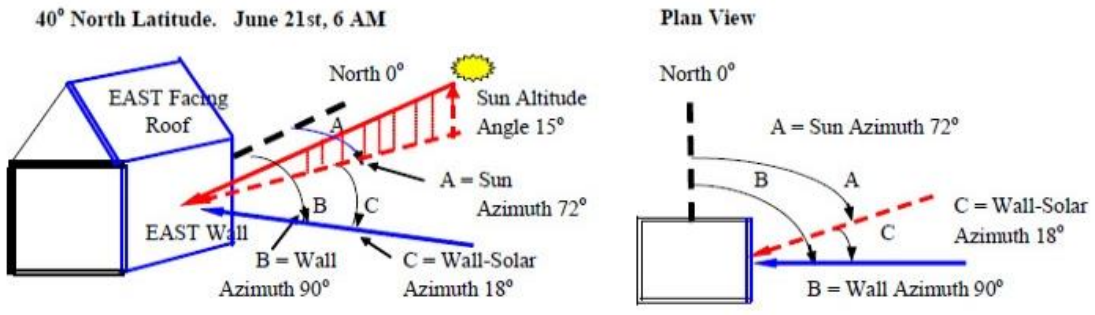

Figure 2.19: Altitude and azimuth angles are very useful in understanding solar position and sun path diagrams.

Source: (http://energy-models.com/earth-and-sun)

2.7.1.3 Shading for Orientation:

Fixed horizontal shading are often adequate above north facing glazing. Examples include eaves, awnings, and pergolas with louvers set to the correct angle. North facing openings and South facing ones above the tropic of capricon receive higher angle sun and therefore require narrower overhead shading devices than east or west facing openings. It is best to orient spaces to face north or south to avoid the east and west sun's low angle. Vertical fins are an effective strategy for east and west orientations. For shading on the north side, vertical fins are most effective, figure 2.20 shows horizontal overhang and vertical fins. Egg crate shading devices (a combination of overhangs and fins) provide optimal shading (Olgyay, 1951).

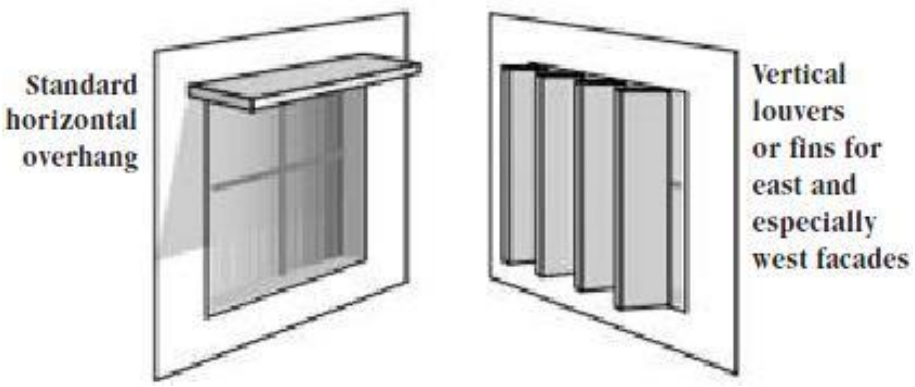

Figure 2.20: Horizontal overhang and vertical fins.

Source: (http://mingaonline.uach.cl/scielo.php?pid=S0718-72622012000100004&script=sci_arttext)

2.7.1.4 Operable Shading Devices:

Accoding to Mohammed (2010) the operation of a movable shading device can be as simple as twice a year adjustment for example, manually extending roller shades, awnings, rotating fins, or louvers according to the suns angle, Figure 2.21 illustrate how operable exterior window shading and movable devices work. Operable exterior shading devices are useful because they respond to daily and seasonal variations in solar

and weather patterns in ways that fixed shading devices simply cannot do. Although many facility managers are of the opinion that movable exterior shading devices require high maintenance and are prone to malfunctioning, the designer can apply appropriate technology to provide a low-maintenance solution. These devices are very effective at blocking low sun angles from the east or west. More complex movable devices are typically on automated daily and seasonal programs.

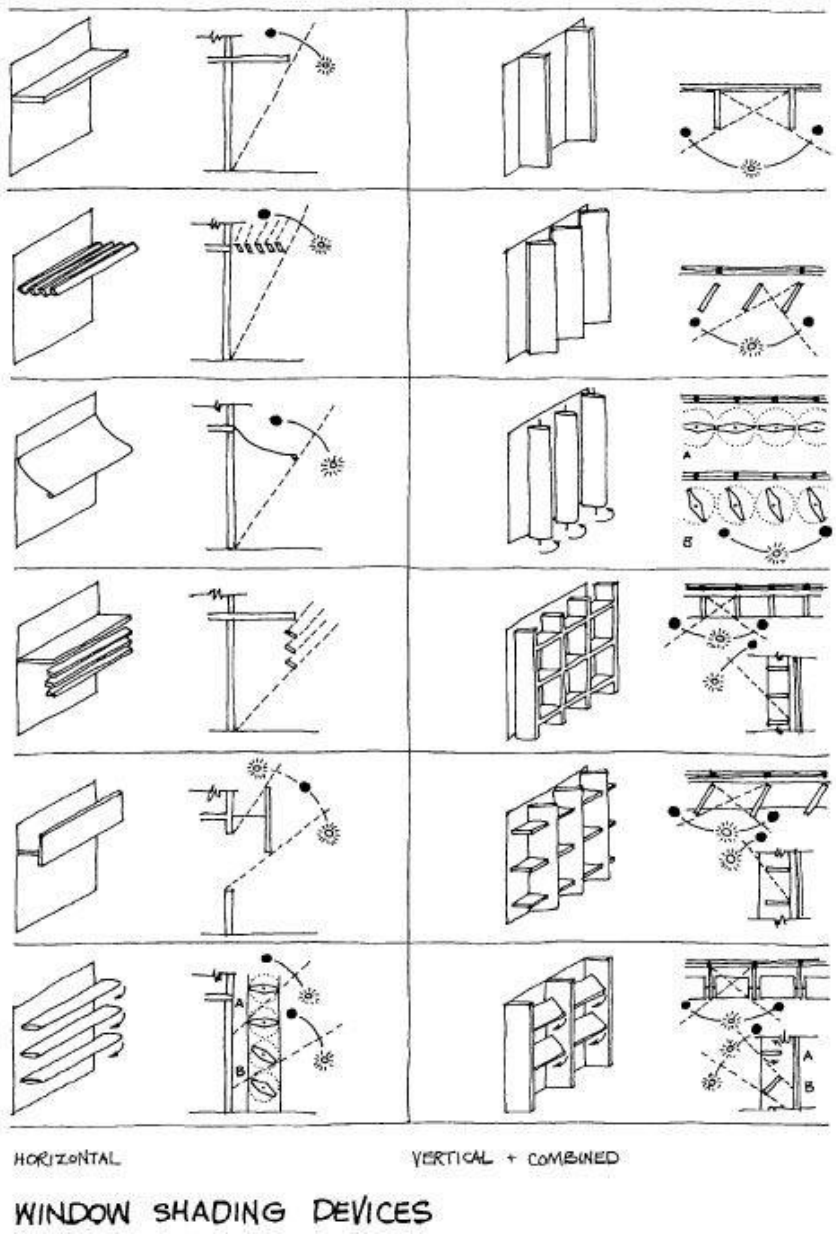

Figure 2.21: How operable exterior window shading and movable devices work.

Source: (https://s-media-cache-ak0.pinimg.com/736x/2b/4d/a8/2b4da86b5e4f1442af598edd79843fad.jpg)

2.7.1.5 Eaves and Overhangs:

The whole building should be shaded at all times. Correctly designed eaves are generally the simplest and least expensive shading method for northern elevations, and are all that is required on most single story buildings. The solar collection windows are protected from the summer sun. Properly sized roof overhangs can provide shade to vertical south windows during summer months, this is illustrated in figure 2.22 below. On east- and west-facing windows, a horizontal overhang is somewhat effective when the sun is at high positions in the sky but is not effective at low-altitude angles, Because of the high altitude of the sun, the most effective shading device for south-facing windows is a horizontal overhang (Mohammed, 2010).

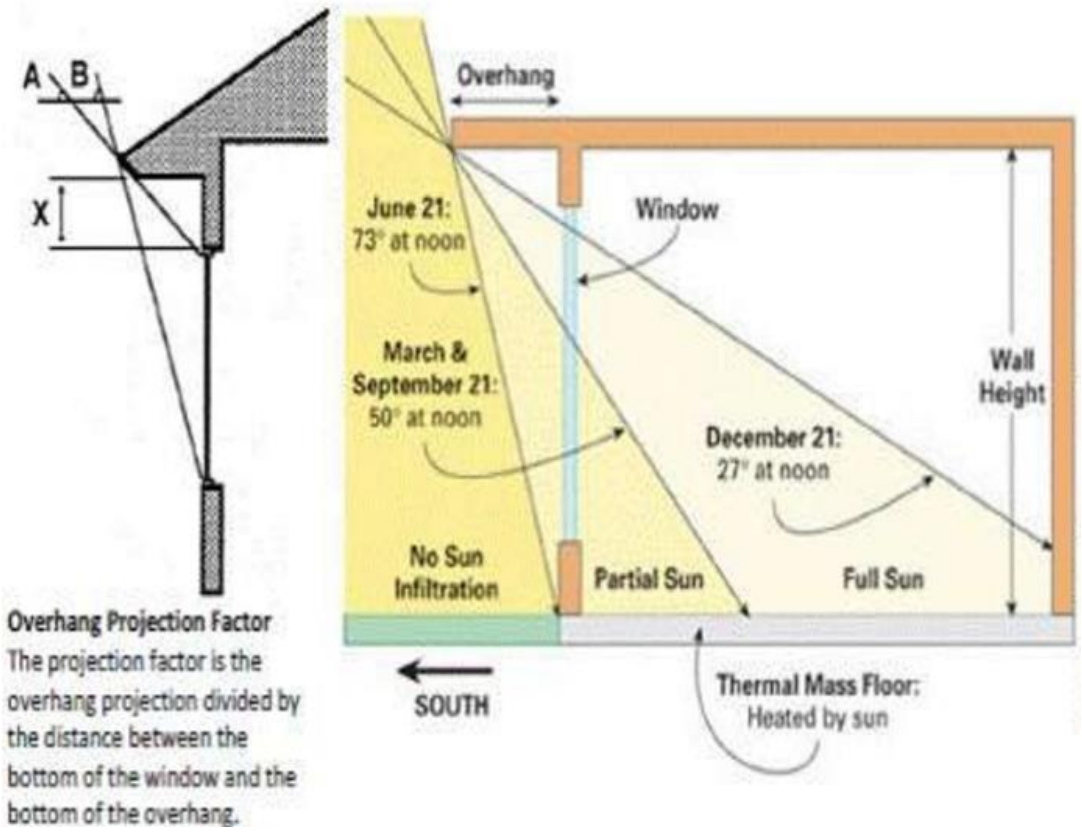

Figure 2.22: How Properly sized roof overhangs can provide shade to vertical south windows during summer months.

Source: (https://www.wbdg.org/resources/sun-control-and-shading-devices)

2.7.2 Windows

Typically, windows or other devices that collect solar energy should face within 30 degrees of true south and should not be shaded during the heating season by other buildings or trees from 9 a.m. to 3 p.m. each day. During the spring, fall, and cooling season, the windows should be shaded to avoid overheating (Stauskis, 2014).

2.7.2.1 Windows Orientation and Shading

In sunny southern locations, protecting your windows from the sun is an important component of good window management. The first step is to know how the sun moves through the sky and to orient the building and place the windows in it so as to minimize direct solar admission through your windows. Figure 2.23 and 2.24 1illustrate the Sun path on summer solstice at southern latitude and Sun path on winter solstice at southern latitude respectively. In the northern hemisphere summer the sun rises north of due east and sets north of due west, climbing rather high in the sky at solar noon on the summer solstice. In the winter the sun rises south of due east and sets south of due west, climbing not very high in the sky at solar noon on the winter solstice (Stauskis, 2014).

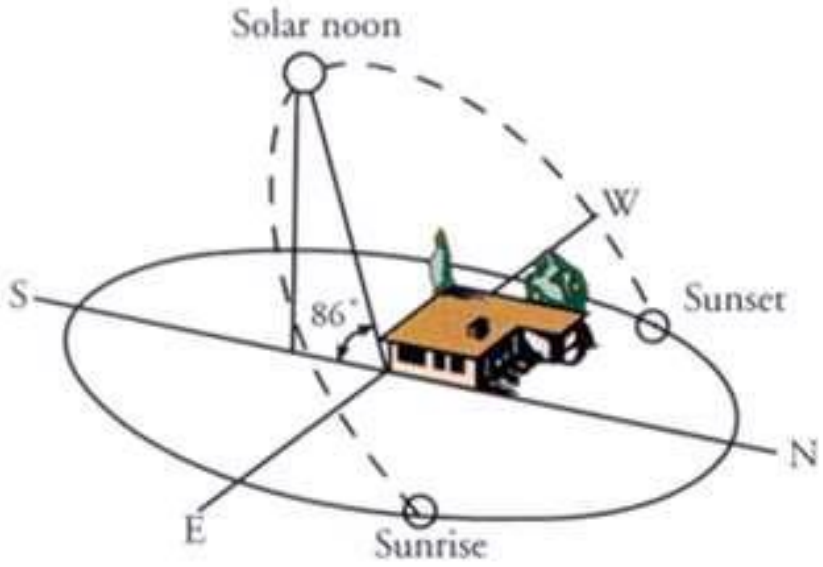

Figure 2.23: Sun path on summer solstice at southern latitude.

Source: (https://media.treehugger.com/assets/images/2011/10/solar-control.jpg)

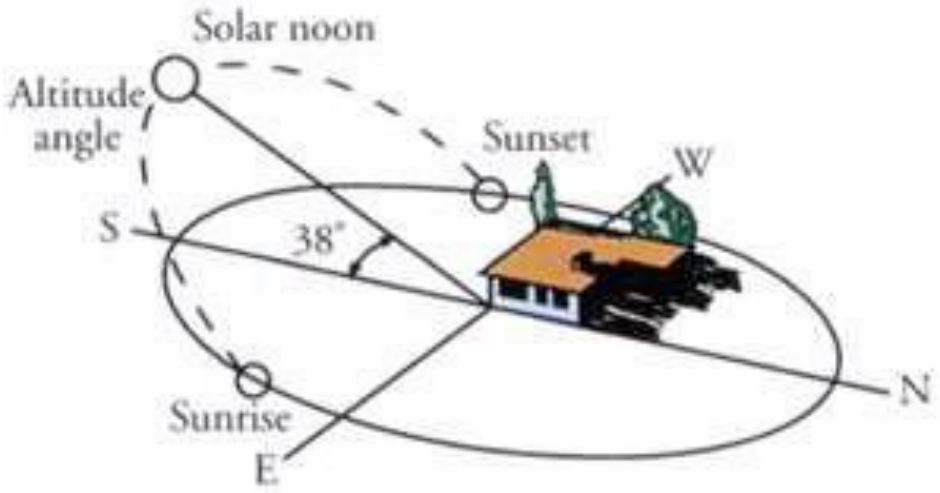

Figure 2.24: Sun path on winter solstice at southern latitude.

Source: (https://media.treehugger.com/assets/images/2011/10/solar-control.jpg)

Some of the important key points to remember when designing for orientation and shading (Keith & Andreas, 2010):

i The best position for the building is to be elongated on an east-west axis.

ii It is recommended for the building's south face to receive sunlight between the hours of 9:00 A.M. and 3:00 P.M. (sun time) during the heating season.

iii Interior spaces requiring the most light and heating and cooling should be along the south face of the building. It is better to locate less used spaces on the north.

iv An open floor plan optimizes passive system operation.

v Use shading to prevent summer sun entering the interior.

vi Landscape features such as trees or hedge rows can also serve as shading.

2.8 Landscaping

Accoding to Mohammed (2010) When correctly applied, the need for internal and external shading devices can be greatly reduced. Strategic planting of trees, shrubs and vines about a building and on structures such as pergolas and beam overhangs can,

along with urban form, help to modify the microclimate. Selective planting can shade not only windows and other apertures but also whole facades and roofs, reducing conductive as well as radioactive heat gains. Figure 2.25 shows how tall spreading trees provide shade and filtered light and solar radiation. These factors define the leaf type and the density of the vegetation. The shading effect of vegetation depends heavily on the plant type (trees, shrubs or vines), species, and age.

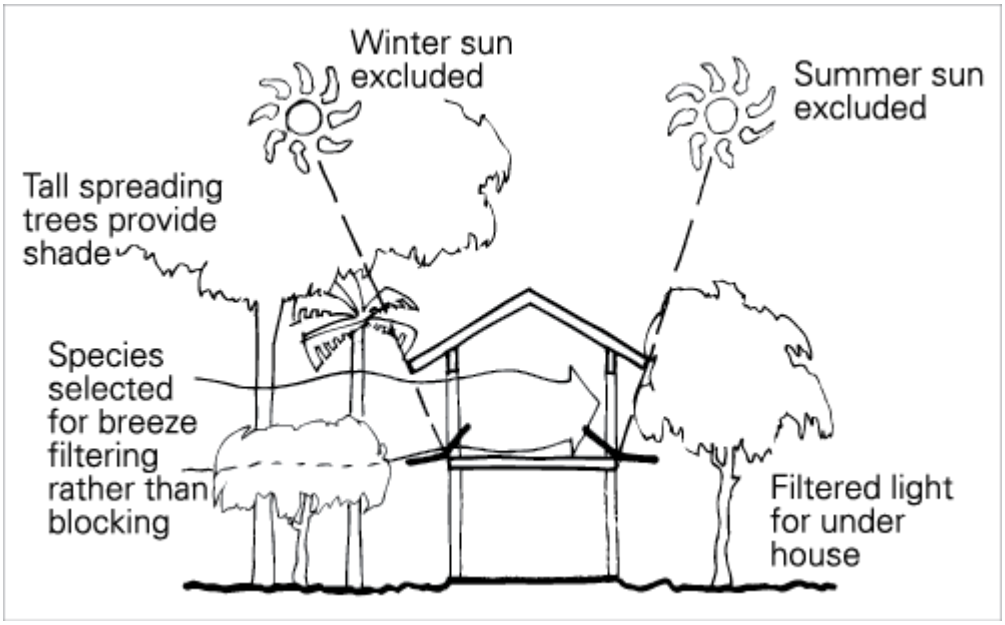

Figure 2.25: Tall spreading trees provide shade and filtered light and solar radiation.

Source: (https://www.happho.com/building-orientation-based-climatology-india/)

Givoni (2001) stated that a well-placed plant can deliver effective, cool shade, as well as add to the aesthetic value of a building. As well as shade, plants are also effective for cooling because they absorb the heat. Landscaping can be used to enhance a bio climatic system. Since leaves are generally dark and coarse they reflect very little light, they make ideal solar radiation controllers. The use of vegetation to shade a house is a cooling technique that can be very effective.

Givoni records that vegetation affects the internal temperature and cooling load of Buildings in various ways as follows:

i Vegetation on the eastern and western sides of a building can provide effective protection from solar.

ii The air temperature adjacent to the building's external façade is decreased, thus reducing conductive and infiltration heat gains;

iii Vines on walls and high shrubs close to walls will provide shade but also reduce the wind speed next to the walls;

iv Tall trees and pergolas situated a short distance from walls and windows will provide shade without significantly reducing ventilation;

v Vegetative ground cover around a building reduces reflected solar radiation and long wave radiation emitted toward the walls from the surrounding area, thus lowering the solar and long wave heat gain.

2.8.1 Using vegetation for buildings

Most people do not realise that simply planting a tree in a right place can result in energy savings. The right tree in the right place provides wind protection, shade, and cool air, while adding beauty, privacy, and wildlife habitat to the landscape (Stauskis, 2014).

Stauskis (2014) further stated that Deciduous trees (that lose all of their leaves each fall) save energy in summer by shading houses, paved areas, and air conditioners. Small deciduous trees and shrubs, and especially those with low, dense branches, also can serve as effective wind barriers. Large and small evergreen trees and shrubs save energy by slowing cold winds in the winter. They also provide shade, but since they often have branches near the ground, their shade is most effective when the sun is not directly overhead. Both deciduous and evergreen trees save energy in summer by directly cooling the air. This cooling happens as water evaporates from the leaf surfaces, much as our skin is cooled when we perspire (Stauskis 2014).

2.9 Evaporative Cooling

Even so, they use substantially less energy to maintain comfort compared to refrigeration systems. It is also possible to use these strategies in completely passive. Ventilation and evaporative cooling are often supplemented with mechanical means, such as fans. Systems that require no additional machinery or energy to operate. Courtyard pools cool your home through evaporation as shown in figure 2.26.

In dry climates, this is commonly done directly in the space. But indirect methods, such as roof ponds, allow evaporative cooling to be used in more temperate climates too. According to Harkness & Mehta (1978), evaporative cooling lowers the indoor air temperature by evaporating water.

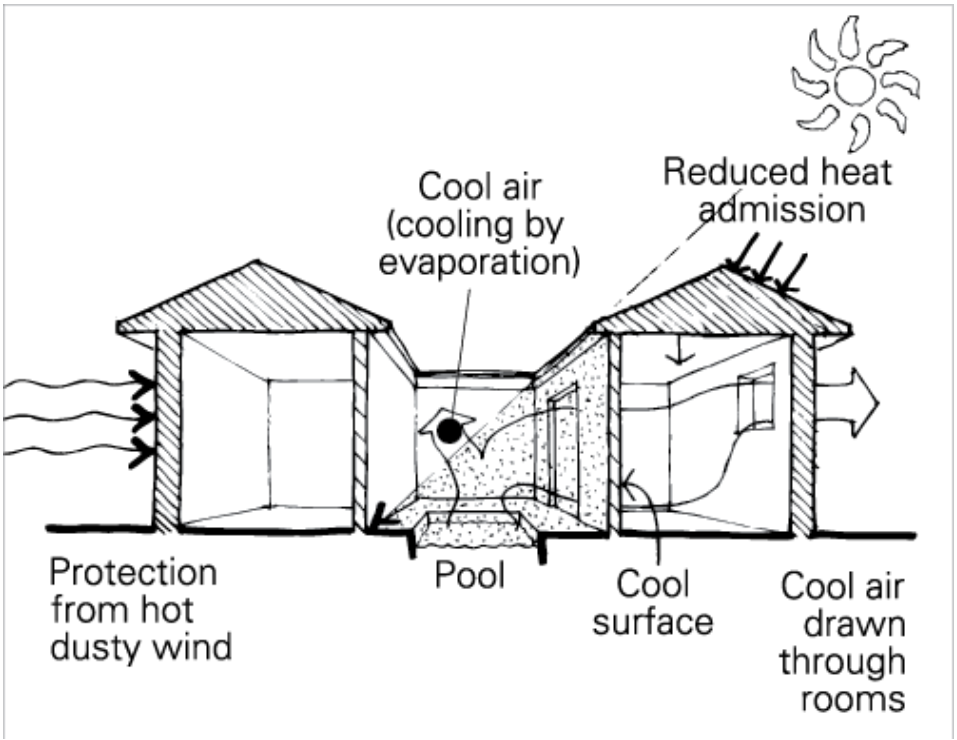

Figure 2.26: Courtyard pools cool your home through evaporation.

Source: (http://yourenergysavings.gov.au/guides/energy-saving-guide-northern-australia?items_per_page=All)

This cool tower action, as well as that of the earth cooling tubes, can be enhanced and distribution extended, by the placement of thermal chimney "drivers" which can pull the cooled air through the building with an increase in both air quantity and velocity. Cool towers utilize wet cooling pads, and the force of gravity. In either case, the cooler air now has a higher relative humidity, but this is not usually a problem and can even be a benefit in arid climates. (Harkness & Mehta, 1978). Heavier, cooled air "falls", via gravity, into the building and its momentum floods the habitable area.

The familiar evaporative cooler, precursor to the air conditioner, is a mechanical system which uses these principles with a motor to force air movement and distribution. One way of doing this according to Harkness & Mehta (1978) is to bring the outdoor air into the house through a moist filter or pad. Figure 2.27 shows how Swamp cooler drier outside air is drawn through a moist pad as moisture is picked up by the air heat is absorbed by the water, the result is cooler air. Evaporative methods can be used to enhance the cooling rates in convective cooling systems.

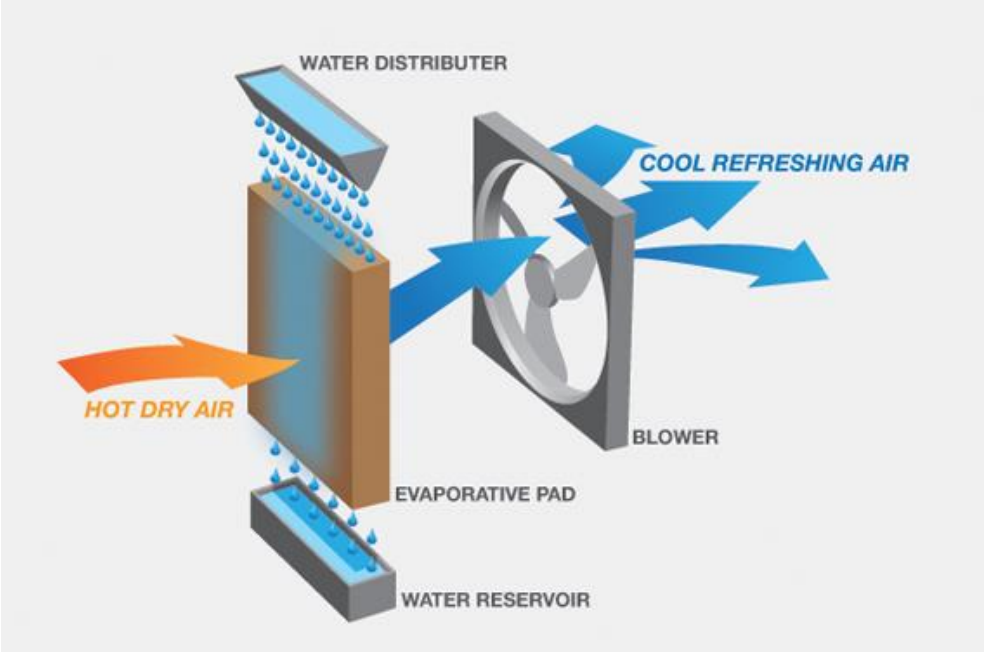

Figure 2.27: Swamp cooler drier outside air is drawn through a moist pad, as moisture is picked up by the air heat is absorbed by the water result is cooler air.

Source: (http://www.temperatureplus.com.au/ducted-evaporative-cooling/)

Simple introduction of a thin water layer over the water containment surface can increase the overall cooling rate of the roof by 50-100 percent due to the resulting evaporation. Harkness & Mehta (1978). Warm night air (27 degrees) may impede natural convection heat dissipation from a roof pond cooling system. Evaporative cooling strategies are well suited to those areas with the most severe cooling requirements.

2.9.1 Physiological Cooling (Evaporation of Perspiration)

Stauskis (2014) suggest that In total, there were 6 types of conditions inside the room; each had a different cooling situation:

i Passive cooling through mixing ventilations

ii Active cooling by convection through mixing

iii Active cooling through displacement ventilation.

iv Active cooling by radiation through the ceiling and mixing ventilation

v Active cooling by radiation through the floor and mixing ventilation

vi Active cooling through the floor and displacement

2.10 Air infiltration (Heat and cold control)

Accoding to Stauskis (2014) Air infiltration and humidity entry are things to consider when designing a building. Avoiding air infiltration can reduce energy costs drammatically, while reducing immoderate humidity access helps one avoid various diseases and get hurt by damaged building constructions.

It is important to understand how air exchange works, as well as humidity entry, in order to avoid these problems. Air infiltration happens through not so neat construction work between gaps of exterior and itnerior. Humidity levels in a room can be raised even by breathing or cooking food. As well as through heat bridges through windows or just simply bad roof build (Stauskis, 2014).

Considering floor-to-window, wall-to-window ratios, position of heating appliances in a room, even planting a right tree to the right place can reduce heating costs of a building. There are also some German-man made materials that help maintaining appropriate humidity levels (Stauskis, 2014).

Stauskis (2014) stated that Mostly air leaks through floors, walls and ceiling, as some gaps might have been missed during the construction; some electric outlets leak air through. Fireplaces are also a common place for the air to leak through since it has a direct access to outside air. Gaps between windows, as well as between doors might provide air infiltration as shown in figure 2.28 below.

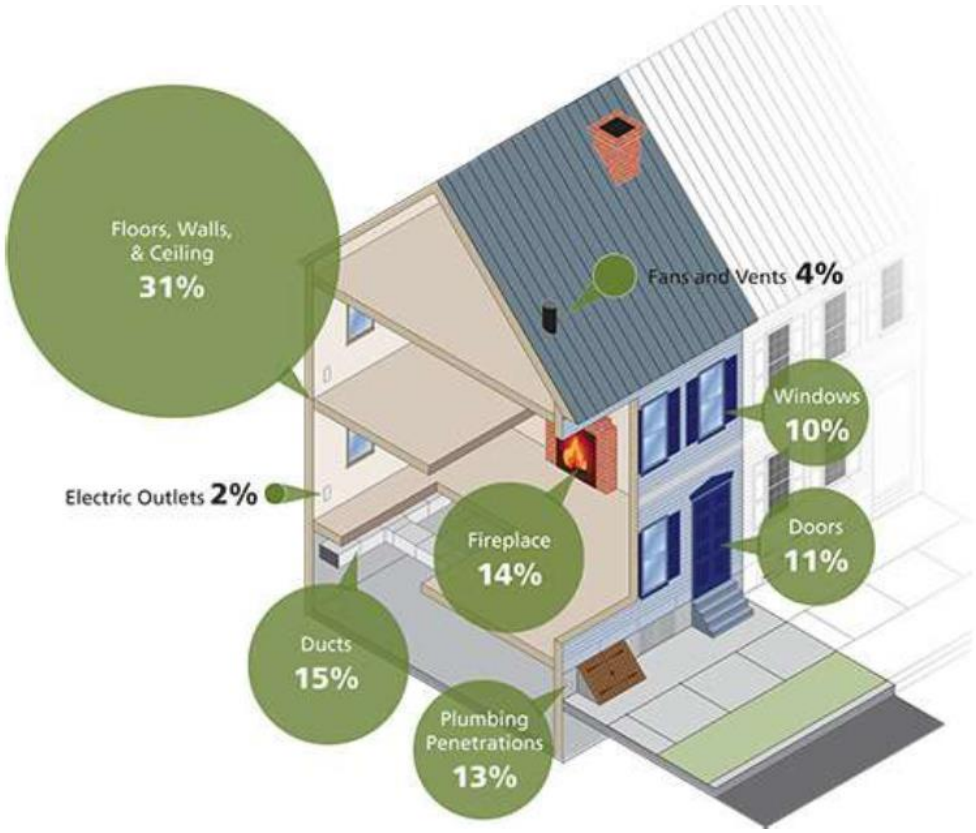

Figure 2.28: The percentage of air that some constructions leak.

Sources: (Stauskis, 2014)

Air infiltration is the exchange of air through cracks and gaps in the outside shell of a building. Infiltration increases heating and cooling costs and reduces the comfort for the people living. Loose fitting windows and doors, cracks between the house and the

foundation, and gaps around plumbing and electrical penetrations are typical sources of leaks (Stauskis, 2014).

Typical places to check for air infiltration are:

i Electrical outlets, switches, ceiling fixtures

ii Operable features of windows and doors – check for a loose fit

iii Badly fitting windows and doors

iv Baseboards

v Fireplace dampers

vi Chimney flashing and flues

vii Wall or window-mounted air conditioners

viii Plumbing, electrical, cable, and telephone penetrations

ix Ducts in unconditioned spaces

2.11 Bioclimatic zones in the tropics

Accoding to Nahla (2007) The hot-arid regions are marked by an absolute humidity (vapour pressure) of under 2.5 kPa and high daily temperatures in the summer months, to more than 50ºC, coupled with intense solar radiation. Summer and winter differ greatly and temperatures in winter can drop to 15ºC. Temperature differences between day and night can be as much as 20ºC in winter. Countries within this zone have strong direct radiation and high reflection of solar radiation by the earth's surface; slight precipitation and humidity; and the possibility of dust and sand storms and high temperature differences between day and night (Lippsmeier, 1980); Figure 2.29 shows the climatic zones in the tropics and moderate areas.

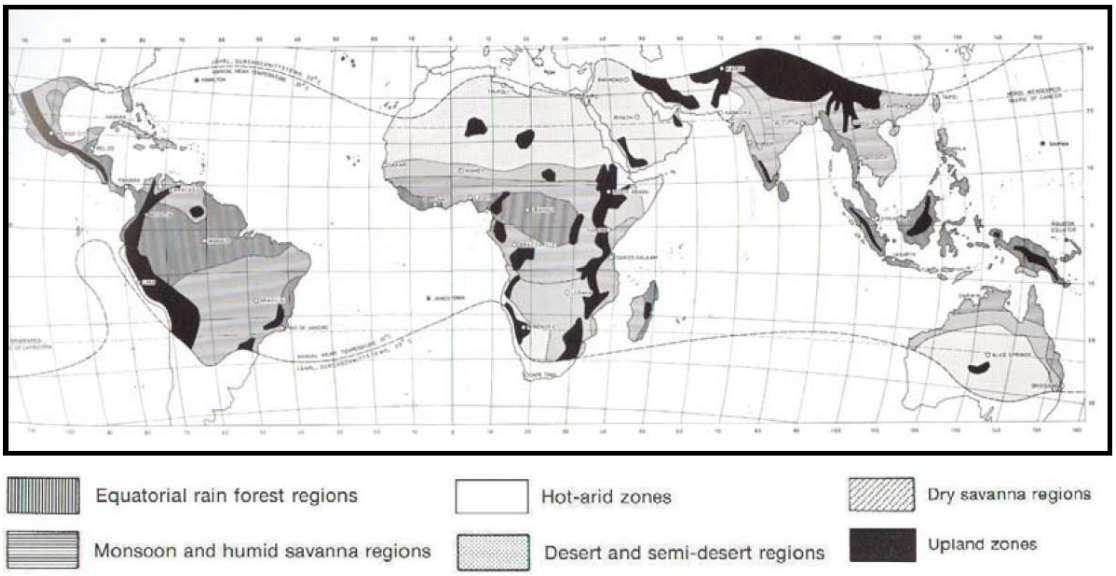

Figure 2.29: Climatic zones.

Source: Lippsmeier (1980)

2.11.1 Comfort Zone

The main climatic factors affecting human comfort are temperature, humidity and air movements. According to Lippsmeier (1980) the following factors affect the comfort zone:

2.11.1.1 Temperature:

During the course of the day, maximum temperature is reached about 2 hours after mid day, when the effects of direct solar radiation and high air temperature already prevailing are combined. The greatest heat gain is thus found on southwest or northwest (depending on season and latitude) and west façades. As a rule of thumb, it can be assumed that the highest temperature occurs 1-2 hours after the sun passes the meridian and the lowest, about 1-2 hours before sunrise (Nahla, 2007).

2.11.1.2 Humidity:

Nahla (2007) stated that, The moisture content of the air can, in contrast to the other constituents, fluctuate greatly and depends primarily on changes in air temperature. The higher the temperature the more moisture the air can absorb. To judge the compatibility

of climate, it is of utmost importance to have information about the moisture content of the air. Climate becomes less tolerable with increased moisture content. This is worsened by a combination of high temperature with humidity, by a high wet-bulb temperature. People feel uncomfortable under conditions witha vapour pressure of over about 2kPa. The cooling effect of evaporation from theskin is impeded above this level and the air itself cannot absorb enough moisture. Figure 2.29 above shows a bio-climatic chart illustrates the comfort zone in the hot areas.

2.11.1.3 Air Movement:

Lippsmeier (1980) further argues that the aim of all planning should be to create the greatest possible comfort for occupants. Also, that unfortunately, it is not possible to measure comfort objectively; only after experiments with many people under different environmental conditions can conclusions be drawn and guiding principles be laid down. Hence, it remains for the designer to plan and design as pleasant and comfortable an environment as possible. Some experimental results of studies on the comfort zone, expressed in effective temperatures, are illustrated in figure 2.30.

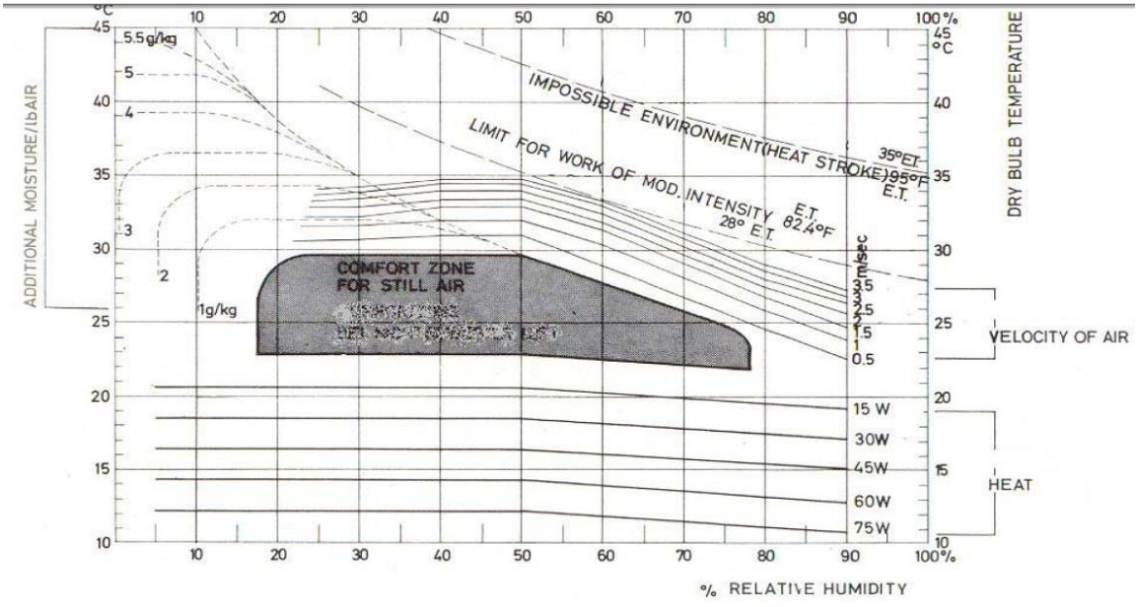

Figure 2.30: Bio-climatic chart.

Source: Lippsmeier (1980)

A large percentage of a building's energy load is derived from its mechanical systems engaging in climatic control to provide comfort for its inhabitants. Thermal comfort of the body is achieved through heat transfer by means of conduction, convection, radiation, and evaporation as shown in figure 2.31 below.

Analyzing building-bioclimatic charts can provide architects with energy efficient design strategies with respect to the local climate and environment. This chart does not start at zero degrees Fahrenheit, at least proportionally relative to adjacent temperature segments set at 10 degree intervals. It may be minor, but it could obfusciate data at the more extreme cold temperature ranges.

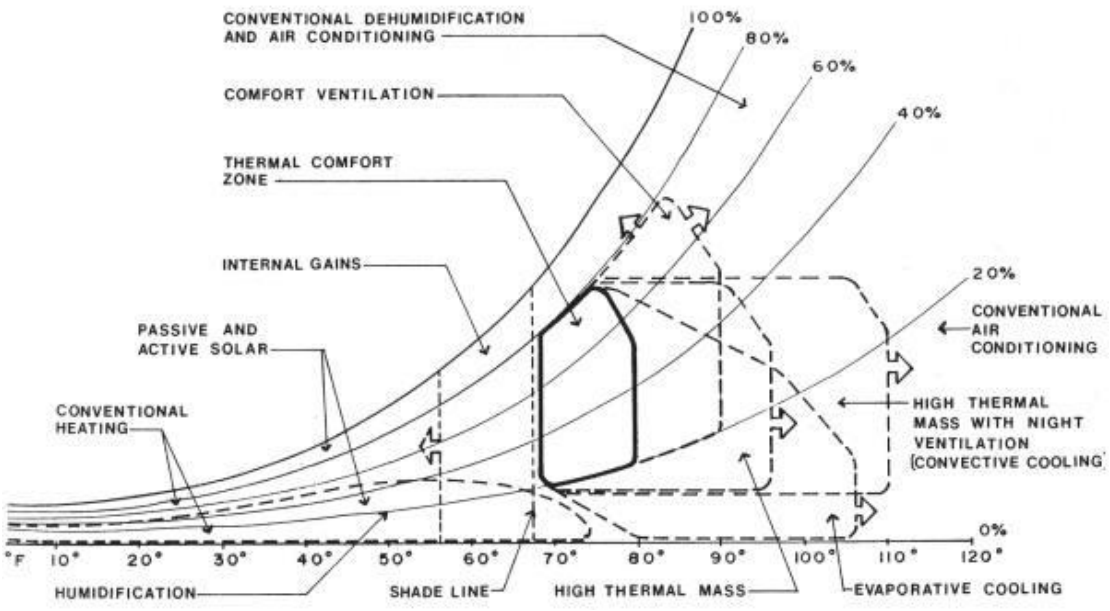

Figure 2.31: Building bioclimatic chart.

Source:(http://www.arch.ttu.edu/courses/2013/fall/5334/Students/Zuefeldt/03/bioclimatic_psych.jpg)

2.12 Thermal Comfort

Adedayo (2013) stated that, However, a number of buildings use (Heating Ventilation Air Conditioning) systems to keep check of their thermal environment. In recent times however, more energy efficient and environmentally friendly methods are used to heat

and cool buildings. Natural ventilation reduces or eliminates the amount of mechanical systems required to cool the building if adequately designed. Temperature could either rise to be too hot or too cold depending on season of the year. Therefore, the factors below should be considered when designing to achieve good thermal comfort (Omer, 2008).

i Building orientation

ii Cross ventilation

iii Construction materials

iv Roof, walls and floor insulation

v Window sizes and location

vi Additional cooling required during heat periods

2.12.1 Design factors affecting the level of thermal comfort

The improvement of housing quality is an issue of high priority in several countries. It has been found that many factors affect the level of this comfort; major effects, such as urban design, architectural design of the house and materials used in its construction, coupled with minor ones, such as economy, quality, e.t.c.

2.12.1.1 Urban Design

Alezzawi (1996) stated that the urban design of a settlement is one of the major factors which have an important effect on the thermal performance of the buildings within it. In general, most buildings in hot climates have evolved as a cluster moreor less connected to each other in order to prevent the penetration of solar radiation and to provide shade. Moreover, the building designs and shapes are also appropriate to the local climate.

2.12.1.2 Architectural Design

The architectural design of the building is one of the factors that affect the thermal comfort within. The architectural elements play a great part in influencing the thermal

comfort, one of these elements is the courtyard. Many studieshave been carried out on courtyards in building, which emphasize the importance ofthis enclosed space as being multi-functional, able to provide a convenient natural environment to the interior, which makes it an appropriate architecture solution for semi arid hot areas (Nahla, 2007).

This theory explains the function of the courtyard. Wazeeri (2002) refers to some studies, which have determined that the high efficiency and performance of the courtyard design is affected by certain specifications and factors; such as the orientation of the court, the court's dimensions, the latitude and the season.

Many studies were done on the courtyard, as Wazeeri (2002) commented, to improve its thermal performance to be more efficient and implemented in practice; the studies recommended of:

a. Using upper shading methods.

b. A presence of external parapet walls as a divider between the building to prevent the hot air on the neighbor roof to move to the building.

c. Providing slope to the roof in the direction of the courtyard. This helps coldnight air to flow into the court, as illustrated in Figure 2.32 below.

d. The large windows overlooking the courtyard should be closed during day to keep out the sun, and opened at night, to allow the cold air to enter the rooms.

e. Usage of wooden perforated pergola/ screens, vegetation on the pergola and the courtyard's walls and water elements such as fountains, provide moreshade to the court.

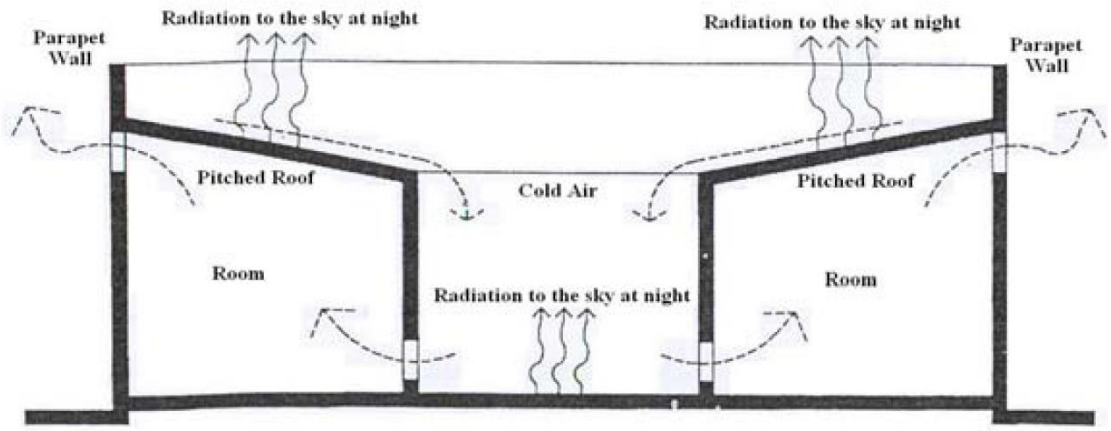

Figure 2.32: Making sloped roofs directed to the courtyard.

Source: (Wazeeri, 2002.)

2.13 The Need for Bioclimatic Design

Applying the principles of bioclimatic design in a building is a proven and efficient way to reach these two objectives. It is emerging that educational buildings are leading the way in the exploration of innovative design and construction for low energy and thermally effective climatic responsive architecture leading the way is Charles Strut University (Jones, 1998). That is why the role of bioclimatic facades in the development of sustainable buildings is essential today. The façade, being the interface where most of the thermal exchanges take place is key in this process.

2.13.1 The costs and benefits of bioclimatic architecture

There are many benefits of bioclimatic and energy conscious building design in general, such as: energy conservation, thermal/visual comfort, economic benefits (reduced fuel consumption, and cost of electromechanical equipment for heating, cooling, ventilation and lighting), environmental benefits (less pollution, reducing the greenhouse effect), social (improvement in the quality of life).

Accoding to Bioclimatic Design and Passive Solar Systems (2015) The largest amount of energy saving in buildings results from the proper and rational design, which

includes appropriate orientation and layout of the building, the size, orientation and location of its openings, protection of the building envelope (insulation, protection from the wind and sun), and also from the rational operation of its systems. Effective solar control (shading) and natural ventilation in the summer are of key importance in reducing the energy demands of buildings.

The amount of energy conservation through bioclimatic design varies depending on the type of building, the local climate and the particular technologies used. Buildings in Greece, energy savings of around 15 to 40% have been recorded for heating and cooling requirements of the buildings in comparison to well-constructed conventional buildings of the same age. In comparison to older buildings, the energy savings are even greater.

The application of bioclimatic design to new buildings does not increase the cost of construction, providing that simple systems and technologies are applied. If special technologies are used (i.e. solar walls or sunspaces), an increase of 10 – 15% in the cost of construction is considered reasonable. For retrofits of existing buildings, the cost is always higher. However, part of these costs can be incorporated into the overall building retrofitting cost (Bioclimatic Design and Passive Solar Systems, 2015)

CHAPTER THREE

3 RESEARCH METHODOLOGY

3.1 Introduction

This chapter includes details about the research methodology used in this thesis. The study was based on four items: the field survey of the three faculty of engineering technology in three geopolitical zones, observation of the exsisting structures and occupants, and data evaluation procedures.

According to Issa (2004) “The purpose of research methodology is to provide a detailed explanation on the procedures to be used in carrying out the research; that is, the master plan, to be followed in the conduct of the study.” The purpose of this research is to explore application of bioclimatic architecture, and apply the research findings in the design faculty of engineering technology, Bauchi state university, Gadau. This chapter therefore discusses the research method selected and used in conducting the study and is discused under the following headings: Introduction; Research method; Population of the study; Sampling; Research instrument; Procedure for Data collection and Procedure of data analysis.

3.2 Research Methods

The major factors that contribute to the selection of a particular research method in research projects are research purposes and circumstances. For this thesis, which is qualitative research, an evaluative research method would be employed to evaluate the faculty of engineering technology by conducting Case studies. According to Issa (2004), the critical issue aboutcase studies is that all variables connected with the unit (internal and external), have tobe thoroughly identified and evaluated. The ultimate goal here is to gather comprehensive information about that unit being studied.

This study ‘Application of bioclimatic architecture in the design of Engineering complex, Bauchi state university Gadau’ is based on evaluative analysis between the selected faculty of engineering technology based no bioclimatic architecture principles through physical observation.

3.3 Population

The population for this syudy are the existing schools of engineering technology in Nigeria. For the purpose of this research three schools are selected from the three (3) geopolitical zones of Northern and southern Nigeria.

3.4 Sample and Sampling Techniques

A non-probability sampling technique will be adopted, in order to obtain the adequate sample. A purposive sampling technique will be employed to select the exsiting schools of engineering technology. This sampling technique was chosen because faculty ofengineering technology shares similar characteristics interms of; geographical regeons, climate and cultural. From the sample drawn, three schools were selected for the thesis to represent the population in the three geo-political zones of the country. They are as follows:

i Faculty of Engineering Technology, Ahmadu Bello University, Zaria

ii Faculty of Engineering Technology, FUT Minna.

iii Faculty of Engineering Technology, University of Nigeria, Nsukka.

3.5 Research Instruments

Three research instruments would be used in conducting this study. These are the observation, checklists and documentary sources. The checklist was designed to conform to the standards of Bioclimatic architecture principles. The checklist was

designed with principles, technique and guidelines that respond to answered some of the research question.

3.5.1 Procedure for data collection

The information of this research proposal was obtained from the following procedure for data collection.

3.5.1.1 Case studies

This involved the visitation to notable faculty of Engineering Technology within Nigeria universities for personal observation of facilities, services rendered, problems, functional flow of activities within the institutions at large.

3.5.1.2 Visual survey

This was done by looking and identifying what has been achieved by existing faculty building where Bioclimatic Architecture principles has been applied.

3.5.1.3 Field Survey

Architectural drawings of the faculty of engineering technology were obtained from the physical planning office. However where there was no documentation available, it was surveyed and the drawings were prepared by the author. All observations and photographs were taken, details of these are given in Chapter 4.

3.6 Data Analysis and Presentation

The data collected for the research were evaluated according to analysis of the field survey,and represented in different forms which include:

i *Tables:* Data collected on this research were documented and presented on the case study assessment tables.

Ii *Photographs:* Pictures of the existing faculty of engineering technology were taken and documented showing the facilities and how bioclimatic principles were applied.

iii *Descriptive Analysis:* This can be viewed under the case study summary and conclusion sheets. This is use to show how elements and techniques of Bioclimatic architecture principles have been applied to achieved a thermal comport.

Iv *Figures:* Data collected on the case studies were documented in form of drawings.

CHAPTER FOUR

4.0 FINDINGS AND DISCUSSIONS

4.1 Introduction

The findings from the case studies carried out have been discussed under the following sub-headings: Background, general description, available facilities, appraisal and case study selection criteria assessment of the exploration of bio climatic principles in the Architectural design of Faculty of Engineering technology.

The case studies were selected based on the site location and the geo political zone that has some similarities and slight differences in the climatic condition.

i Federal university of technology, Minna

ii Ahmadu Bello University, Zaria

iii University of Nigeria, Nsukka.

4.2 Case Study One: (Faculty of Engineering, Ahmadu Bello University, Zaria)

4.2.1 Introduction

The university runs two separate campuses: the Kongo campus which hosts the faculties of Law and Administration. The Samaru campus which houses the administrative offices and the faculties of engineering, environmental design, sciences, and languages, veterinary medicine, education, medicine, pharmacy, social-sciences, arts and research facilities;

The Ahmadu Bello University was founded in 1962, as the University of Northern Nigeria. It is the largest university in Nigeria, and the second largest in Africa, second only to the Cairo University, Egypt. The faculty of engineering is located in the Samaru campus of the university, and is comprised of the following departments:

i Electrical Engineering

ii Metallurgical Engineering

iii Textile Science and Technology

iv Chemical Engineering

v Surveying

vi Civil Engineering

vii Mechanical Engineering

viii Water Resources and Environmental Engineering

4.2.2 General Description

The Layout of faculty of engineering, ABU, Zaria is located at the core academic zone in the campus as shown in Plate I.The “main complex” is comprised of three departmental buildings, which contains a pond as well as outdoor lounging areas in conjunction with the lecture theatre building, enclosing a rectangular court, Plate III shows the use of water pond and landscaping to enhance evaporative cooling of the faculty of engineering. The Use of horizontal and vertical fins on the facade of the main complex for shading as shown in Plate II. On the other hand, the “new complex” is comprised of a large, u-shaped building, water resources and environmental engineering and textile science and technology, housing the departments of metallurgical engineering, as well as various workshops.

The faculty is developed in two main parts: the “main complex”, comprising the departments of mechanical, of which there are two, the Wolfson and Kainji lecture theatres; electrical and civil engineering, along with the administrative offices and the lecture theatres and also the use of open air courtyard system as shown in Plate V.The “new complex”, water resources engineering and textile science and technology

comprising the departments of metallurgical. The department of chemical engineering, is located separately, in the faculty of sciences complex.

Plate I: Layout of the faculty of engineering, ABU, Zaria

Source: Google Earth (2014.)

Plate II: Use of horizontal and vertical fins on the facade of the faculty of engineering building.

Source: Authors field work (2014)

Plate III: The use of water pond and landscaping to enhance evaporative cooling of the faculty of engineering.

Source: Authors field work (2014)

Plate IV: The faculty of engineering (ABU)

Source: Authors field work (2014)

Plate V: The use of open air courtyard system for the faculty of engineering building
Source: Authors field work (2014)

4.2.3 Appraisal

The “main complex” appears to have been constructed quite a while ago, which is just a jumble of departmental buildings and workshops, but still shows better planning than the new complex.While the provided exterior stations may not exactly be called “study stations”, they do foster spontaneous student interactions, and are placed at a very important location, just outside of the lecture theatres. The parameters used in conducting these case study are tabulated in Table 4.1, as shown below.

Table 4.1: Findings from case study of Ahmadu Bello University, Zaria

VARIABLES OF STUDY		WEIGHT FACTOR	**REMARKS**
Building Form and orientation	The building shape is combination of four (4) rectanguler forming an enclosure. Two Buildings longer side facing North-South axis, while the other two buildings longer side facing East-West, to reduce solar radiation on building envelope. Orientation is 50% achived.	3	**Good**
Use of sustainable power source	The main power/energy source is by artificial means. Hence the aim is not achived.	2	**Fair**
Use ofSun shading devices	Vertical and horizontal Shading devices were incorporated in the design and both the Eastern and the Western sides of the main complex are shade against solar glare.	5	**Excellent**
Use of Court-Yard	Court-yard was considered in the design to enhance air movement, but not well landscaped, hence the aim was actualized but the intension was 50% achieved.	3	**Good**
Natural ventilation and air quality	Natural ventilation is used 50% achived, but cross ventilation is not achived becaused double banking is used in the design concept. Most windows in the workshop were dead lights and only the high level windows can be opened hence reducing air flow.	3	**Good**
Heating and cooling techniques	No other heat modulation and dissipation techniques was used.	1	**Poor**
Landscape	Landscaping element are used in the courtyard protecting ground from impact of solar radiation, use of water pond for evaporative cooling is also achived.	3	**Good**

Source: Authors field work (2014)

Weight Factor: Excellent = 5, Very Good = 4, Good = 3, Fair = 2, and Poor = 1.

4.2.5 Conclusion

It was observed that the design, faculty of Engineering Tecnology, Ahmadu Bello University Zaria, partially fulfill some bioclimatic architecture principles, hence making the building less thermally comport. Therefore, for the building to be thermal comport some mechanical technique need to be apply.

4.3 Case Study Two: (Federal University of Technology Minna, Niger State)

4.3.1 Introduction

It is a specialized university of technology. The federal university of technology, Minna was established on 1st February, 1983, the objective for its establishment is to give effect to the Nation's drive for much needed self-reliance in Sciences, Engineering and especially technology. At its inception, the university acquired on a permanent basis, the facilities of the former government teachers' college Bosso which now serves as the Bosso campus of the university. The university acquired 10,600 hectares of land along the Minna Kataeregi-Bida Road for the main campus of the university popularly known as "Gidan Kwano", to cater for the kind of necessary expansion envisaged it has undergone a tremendous face-lift and wears a beautiful outlook befitting a modern university. The school of engineering technology was established in 1984. It has grown to a full fledge faculty consisting of five (5) departments which offer bachelor of technology degree programs. The departments are as follows.

i. Mechanical
ii. Computer/ Electronics
iii. Civil
iv. Chemical
v. Electrical

4.3.2 General Description

The complex is made up of a three story “E” shaped block with an open courtyard bounded by a fence on one side. Each wing of the building is allocated a specific function. This divides the building into three (3) distinct functional units, one for department offices, the second for classrooms. Plate VII Structure exposed to too much sun with no trees to reduce solar radiation as shown below. All the departments occupy different floor levels though their facilities may not all be on the same floor level. Workshop, library/data room, laboratory, and the computer room and the third wing were partitioned to form offices for lecturers. The faculty interioruse of single banking offices with an atrium to enhance stack effect as shown in plate VIII.

Plate VI: The Courtyard is the only area with a good attempt at landscaping.

Source: Authors field work (2014)

Plate VII: Structure exposed to much too sun with no trees to reduce solar radiation.
Source: Authors field work (2014)

Plate VIII: Use of single banking offices with an atrium to enhance stack effect

Source: Authors field work (2014)

4.3.3 Available facilities

Offices are provided for all lecturers but are shared sometimes by up to four (4) individuals per offices. All departments have their individual library/data rooms; however they all share a single computer room. So also are the six relaxation spots, two to every floor. Photocopying, typing and printing rooms are two in number and occupy the two extreme end of the complex both on the ground floor. Sanitary facilities are provided at all floor levels.

i. Offices
ii. Conference room
iii. Computer room
iv. Library/Data room
v. Relaxation shops
vi. Sanitary facilities
vii. Workshop and Laboratory
viii. Photocopying /typing /printing room
ix. Classrooms

The entire complex will now be critically analyzed taking into consideration the planning, lighting and ventilation systems, construction, as well as landscaping and circulation with reference to bio climatic as shown in Plate VI, which shows the Courtyard the only area with a good attempt at landscaping.

4.3.4 Appraisal

There is a regular arrangement of fenestrations all carried on regularly arranged and spaced beams supported on columns at intersection points. The walls are of sand-screed blocks externally faced with red bricks. The beams also carry flat slabs of simple construction.

Due to poor orientation, the studios and classrooms receive a high proportion of direct sunlight and extra effort was made to curb this effect by use of curtains. There is an extensive use of air conditioners and ceiling fans because some of the windows are fixed light. Natural lighting and ventilation was strived for by extensive use of windows of both normal and high levels.

The plan form takes on a single banking system with corridor running the entire length of the "E" shaped form facing the enclosing courtyard as shown in figure 4.1. The structural plan is made up of simple regular grid of supporting columns spaced by about 7.6m to 7.2m.

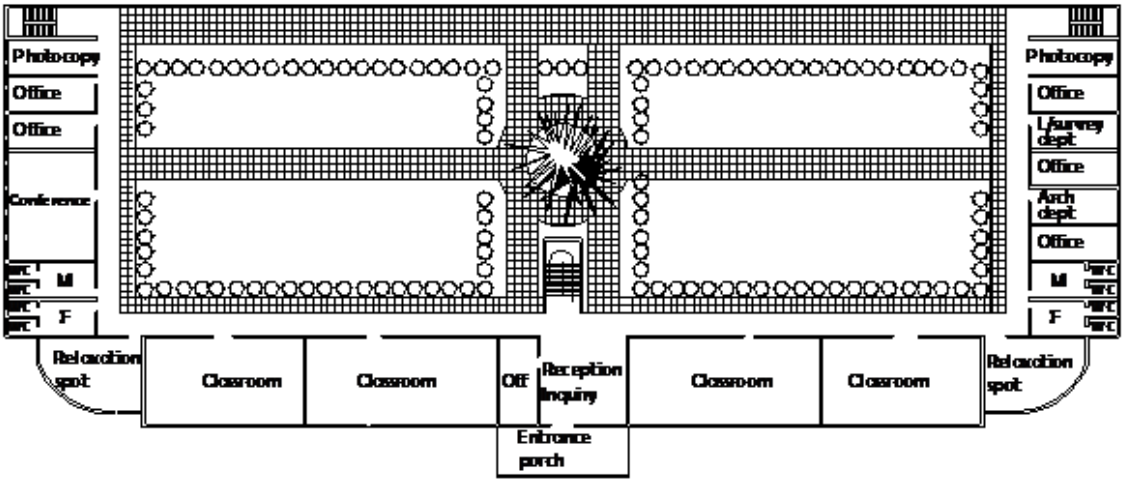

Figure 4.1: Ground Floor Plan School of Engineering technology, Federal University of Technology Minna.

Source: Authors field work (2014).

The parameters discussed above are represented in Table 4.2 as shown below, Findings from case study of Federal University of technology, Minna.

Table 4.2: Findings from case study of Federal University of technology, Minna

VARIABLES OF STUDY		WEIGHT FACTOR	**REMARKS**
Building Form and orientation	The building shape has an 'E' shape on plan. The Buildings longer side facing North-South axis, to reduce solar radiation on building envelope. Orientation is 75% achived.	4	**Very Good**
Use of sustainable power source	The main power/energy source is by artificial means. Hence the aim is not achived.	2	**Fair**
Use of Sun shading devices	Only Vertical Shading devices were incorporated in the approch. Lobbies/varandahwere also used for protecting functional spaces against Solar radiation.	3	**Good**
Use of Court-Yard	Court-yard was considered in the design and iswell landscaped with both soft and hard landscape element to enhance air movement, 50% achieved.	3	**Good**
Natural ventilation and air quality	Single banking of functional spaces arrengement to achieve cross ventilation. Natural ventilation is 70% achived, Workshop with clerestory windows for expelling lighter hot air.	4	**Very Good**
Heating and cooling techniques	Exterior wall faced with bricks which have low thermal mass, hence heat discharge at night will below. hence heat modulation and dissipation techniques was used.	4	**Very Good**
Landscape	Soft and hard landscape element were used in the courtyard, but the approch and the exterio are not landscape, hence 50% is achived.	3	**Good**

Source: Authors field work 2014.

Weight Factor: Excellent = 5, Very Good = 4, Good = 3, Fair = 2, and Poor = 1.

4.3.5 Conclusion

The design faculty of Engineering Technology, Federal University of Technology, Minna, has incorporated all the bioclimatic architecture principles but almost all the principles were incorporated satisfactory, only (Use of sustainable power source) is fairly achieved. Hence making the building partially compotable.

4.4 Case Study Three: University of Nigeria,Nsukka

4.4.1 Introduction

The University was formally opened on 7th October 1960, as the climax to the Nigerian independence celebrations in the Eastern Region. There are modern shopping facilities and a large market in Nsukka town. The main campus of the University is located on 871 hectares of a hilly site in the town of Nsukka, and enjoys a very pleasant and healthy climate, about eighty kilometers north of Enugu. Additionally 209 hectares of arable land are available for an experimental agricultural farm and 207 hectares for staff housing development.

The former Nigeria College of Arts, Science and Technology, Enugu, was incorporated into the University in 1961; the administrative capital of Enugu State of Nigeriaand its buildings now form the Enugu Campus (200 hectares) of the University located in the heart of Enugu. Enugu is a modern city, accessible by air, rail and road. Teaching hospital attached to the University is presently sited in old State General Hospital on a 14-hectare site (about 4 kilometers from the Enugu Campus of the University). The new teaching hospital is now completed at Ituku-Ozalla (25 kilometers south of Enugu) on a 500-hectare site. The College of Medicine and the Faculties of Business Administration, Law and Environmental Studies, are located at the Enugu Campus.

A third campus was opened in October 1973 in Calabar, Cross River State. The campus at Calabar became a full-fledged University of Calabar in October 1977.

4.4.2 General description

The Faculty of Engineering is located at the Enugu Campus. It comprises of four departments namely:

i chemical

ii Mechanical

iii Electrical

iv Civil

The ground and first floor plans are design with rows of offices and lecture rooms with verandah in front, with a central courtyard. Figure 4.2 shows Ground and first floor plans school of Engineering UNN. Plate IX is showing the picturial view of Landscaped courtyard protecting ground from impact of solar radiation. The faculty has good shading devices as shown in Plate X Recessed windows on the North & South facade with horizontal fins for shading. Plate XI shows Both ends of courtyard have covered resting area protecting students from the sun. The exterior environment is well landscape as shown in Plate XII, the Part of North facade shaded by trees. Buildings within the faculty are interconnected with shaded pedestrian walkways as shown in Plate XIII. Table 4.3 shows the findings from case study of University of Nigeria, Nsukka.

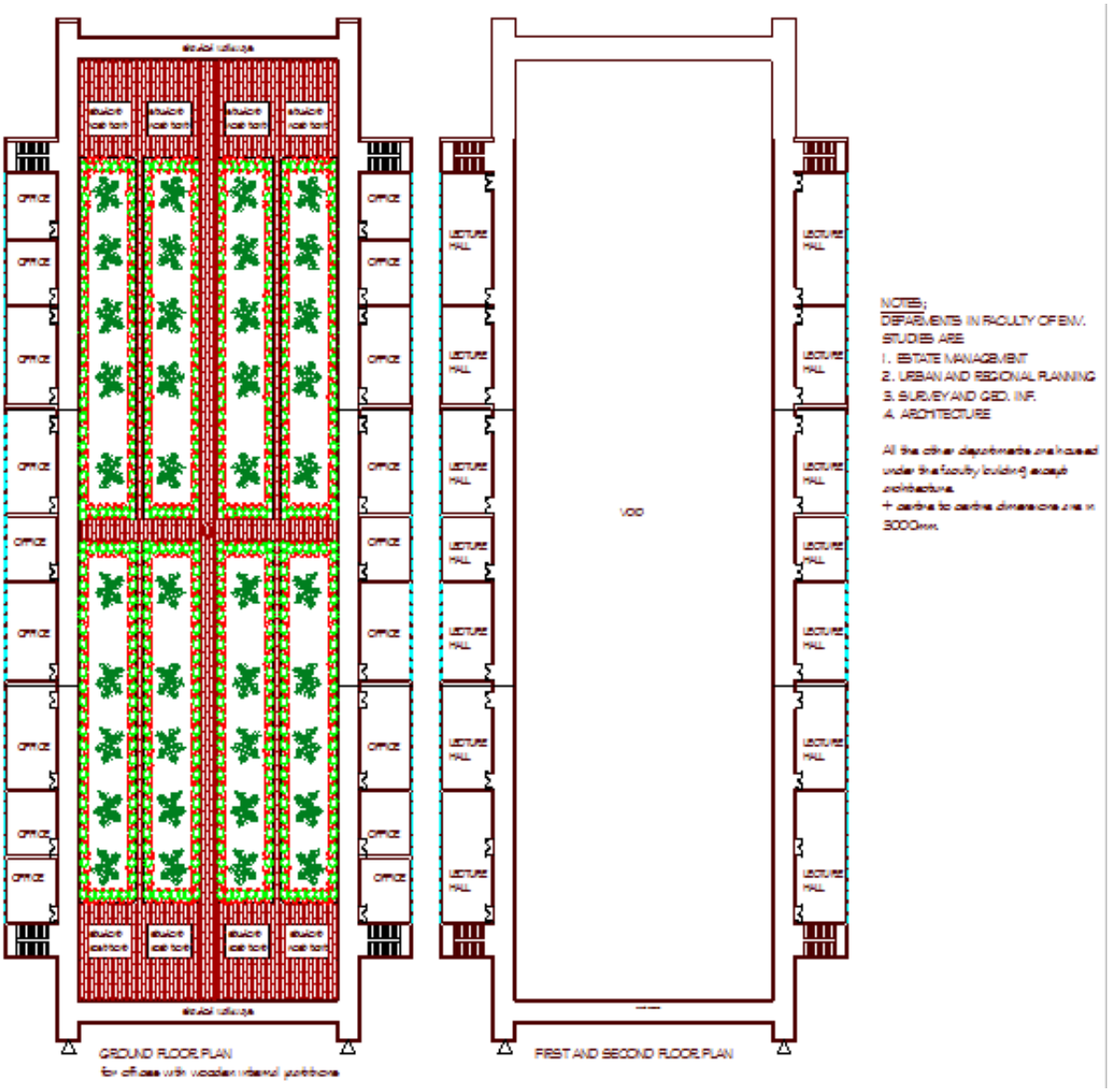

Figure 4.2: Ground and first floor plans school of Engineering UNN

Source: Authors field work (2014)

Plate IX: Landscaped courtyard protecting ground from impact of solar radiation
Source: Authors field work (2014)

Plate X: Recessed windows on North & South facade with horizontal fins for shading
Source: Authors field work (2014)

Plate XI: Both ends of courtyard have covered resting area protecting students from sun

Source: Authors field work (2014).

Plate XII: Part of North facade shaded by trees.

Source: Authors field work (2014)

Plate XIII: Shaded pedestrian walkway.

Source: Authors field work (2014)

4.4.4 Appraisal

The "main complex" appears to have been constructed quite a while ago, which is just a jumble of departmental buildings and workshops, but still shows better planning than the new complex. The faculty, especially in its main complex, does show some good planning, most especially with its articulation of exterior space. The integrated fishpond also serves to make this court more of a place of interest.While the provided exterior stations may not exactly be called "study stations", and are placed at a very important location, just outside of the lecture theatres, they do foster spontaneous student interactions. Table 4.3 shows the findings from case study of University of Nigeria, Nsukka.

Table 4.3: Findings from case study of University of Nigeria, Nsukka

VARIABLES OF STUDY		WEIGHT FACTOR	REMARKS
Building Form and orientation	A linear rectangular form was adapted for the building with the longer side facing the North-South axis, hence reducing openings on the East and West facades which is more susceptible to solar radiation.	4	**Very Good**
Use of sustainable power source	The main power/energy source is by artificial means. Hence the aim is not achived.	2	**Fair**
Use of Sun shading devices	Vertical and horizontal Shading devices were incorporated in the design with recessed windows on the facades. Lobbies/varandah were also used for protecting functional spaces against Solar radiation, 90% is achived.	5	**Excellent**
Use of Court-Yard	A lager Court-yard was considered in the design and iswell landscaped with both soft and hard landscape element to enhance air movement, 90% achieved.	5	**Excellent**
Natural ventilation and air quality	Single banking of functional spaces arrengement to achieve cross ventilation. Natural ventilation is 80% achived, Workshop with clerestory windows for expelling lighter hot air.	4	**Very Good**
Heating and cooling techniques	Naturally without mechanical refrigeration, its high thermal mass allows this structure to act as a heat sink. Slowing the rate of temp change within the building and enabling it to be cooled.	3	**Good**
Landscape	Soft and hard landscape element were used both in the courtyard and the exteriou environment. Hence the aim was 80% achived.	4	**Very Good**

Source: Authors field work 2014.

Weight Factor: Excellent = 5, Very Good = 4, Good = 3, Fair = 2, and Poor = 1.

4.4.5 Conclusion

The design of the faculty of Engineering technology University of Nigeria, Nsukka had incorporated the bioclimatic architecture principles to some extent and all the principles incorporated was actually achieved only (used of power source) in negetive,which makes the building to be better and thermally comport.

4.5 General Summary

A summary of the various applied techniques of bio-climatic principals, their performance rating, whether they perform well or not are shown in table 4.4 below from the case studies.

It was observed during the fieldwork from the case studies that the most important and frequently occurring bioclimatic principals are (Use of Sun shading devices and Building envelope and orientation) the bioclimatic principals that was not properly implemented are (Use of sustainable power source and Heating and cooling techniques).

From the case studies the level of application of bioclimatic principles were; University of Nigeria, Nsukka, has properly applied with weight factor 5 (excellent), Federal University of technology, Minna has the weight factor of 4 (very good) and Ahmadu Bello University, Zaria has the low with weight factor of 3 (good), as shown in table 4.4 below.

If the above listed variables and principles are properly and practically applied in academic buildings, then such building will be thermally compote. In chapter seven of this thesis it will be clearly illustrated how these bioclimatic principals will be applied in the design proposal.

Table 4.4: Performance rating of various case studies carried out

	VARIABLE	SUB-VARIABLE	A.B.U Zaria	F.U.T. Minna	U.N.N Nsukka
1	**Building envelope and orientation**	Building shape Building form South-north orientation	Good 3	Very Good 4	Very Good 4
2	**Use of sustainable power source**	Use of solar system Use of wind	Fair 2	Fair 2	Fair 2
3	**Use of Sun shading devices**	Vartical shading devices Horirontal shading devices Use of fins, recessed, trees e.t.c	Excellent 5	Good 4	Excellent 5
4	**Use of Court-Yard**	Opend court-yard Close court-yard	Good 3	Good 3	Excellent 5
5	**Natural ventilation and air quality**	Cross ventilation Window type	Good 3	Very Good 4	Very Good 4
6	**Heating and cooling techniques**	heat modulation and dissipation techniques evaporative cooling insolations thermal mass	Poor 1	Very Good 4	Good 3
7	**Landscape**	Sorft and hard landscape elements Water bodies	Good 3	Good 3	Very Good 4
	SUMMARY		**Good**	**Very Good**	**Excellent**

Source: Field Work (2014)

Weight Factor: Excellent = 5, Very Good = 4, Good = 3, Fair = 2, and Poor = 1.

CHAPTER FIVE

5.0 SITE LOCATION AND ANALYSIS

5.1 Site Location

Bauchi state is located in the park savannah region of Nigeria between latitudes 11°51N" north of the equator and longitudes 6°10" east of the Greenwich meridian. The total area of covered is 34,467.5 square kilometers. It is bounded by Yobe state, Gombe state, Plateau state and Jigawa state respectively. The site for the proposed faculty of Engineering Technology is located in Bauchi state university, Gadau campus Gadau. Figure 5.1 is showing the location of Bauchi State in Nigeria Map.

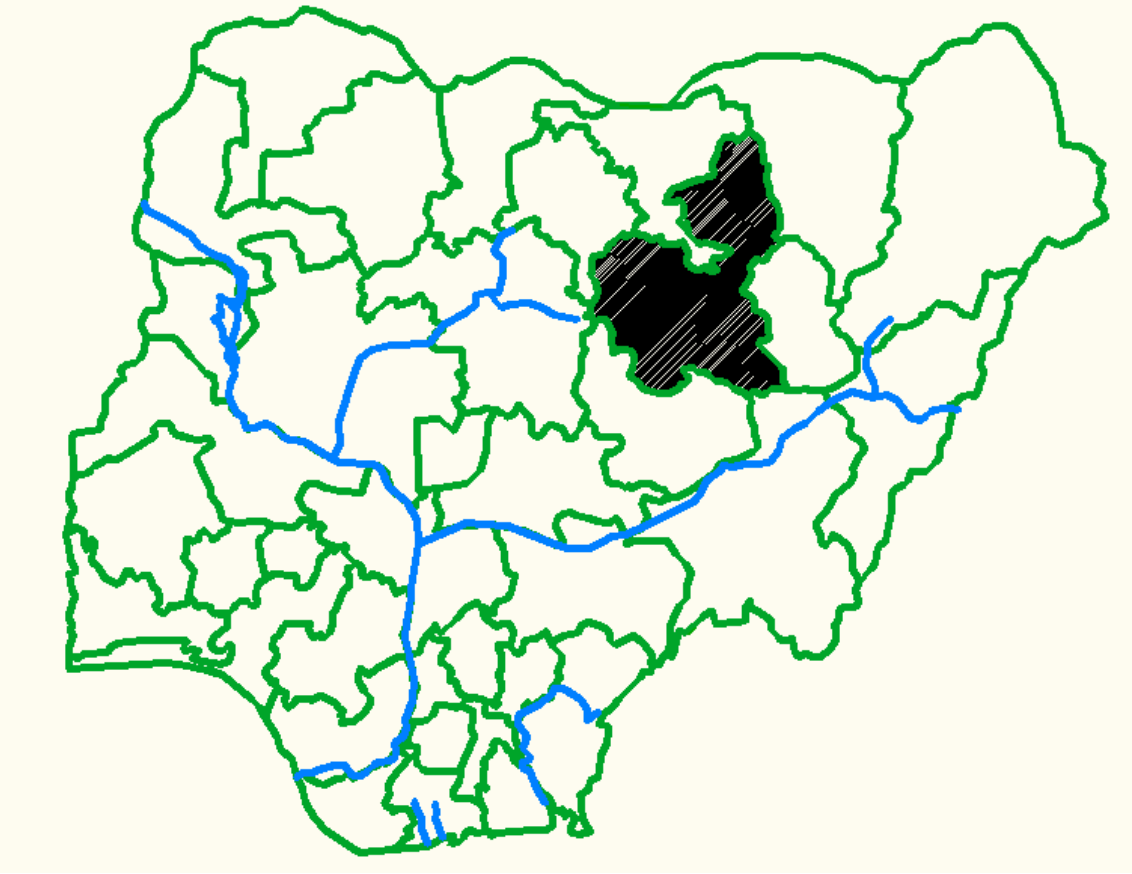

Figure. 5.1: Location of Bauchi State in Nigeria Map

Source: (google.com)

5.2 Site Characteristics

5.2.1 Topography

The state has a total land area of approximately 36,710 square kilometers. Its topography is characterized by undulating land, with sand dunes of various sizes spanning several kilometers in parts of the State. The southern part of Bauchi comprises the Basement Complex while the northeast is made up of sedimentary rocks. The soil is relatively stable as other erected structures around the site have shown no deformation due to instability of the soil. The site has relatively slope with natural drainage features around it. This provides a large buildable land area for construction.

5.2.2 Vegetation

Most parts of Bauchi lie within the Sudan Savannah with elements of Guinea Savannah in the southern part. The Sudan Savannah vegetation zone is also made up of vast grazing lands suitable for livestock production. The vegetation is characterized by bush land - shrub land mosaic dominated by acacia species and low trees. The tree stratum is less dense than that of the savannah woodland, but more substantial than that of the shrub savannah.

5.2.3 Soils

The soils underlying are derived from granite. Their suitability for development land uses varies with depth, occurrence or iron pan, texture, streets and underground utilities occur when soils are shallow, strong, and locally high in swelling clays or iron pan or poorly drained erodability, run-off potential and drainage. Severe constraints for foundations.

5.2.4 Physiography

The area is characterized by gentle terrain. A visual scale is created by the green vegetation around the site and the campus.

5.2.5 Climate

In the daytime temperatures generally reach highs to around 38°C - 33°C, at night the temperature drops to 30°C -27°C. Table 5.1 shown theMonthly temperature distribution in Bauchi and Figure 5.2 present the Average temperature of Bauchi, as shown below. The climate of Bauchi is the temperate and it is characterized as the dry season.

Table 5.1: Monthly temperature distribution in Bauchi

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Mean Max. Temp.	33.2	35.7	37.0	35.4	32.8	30.1	30.3	28.9	29.3	30.7	33.9	33.7
Mean Min. Temp.	18.2	22.9	25.4	27.1	24.2	23.4	23.5	23.1	22.3	22.2	20.3	19.6

Source: Climate charts.com (2014)

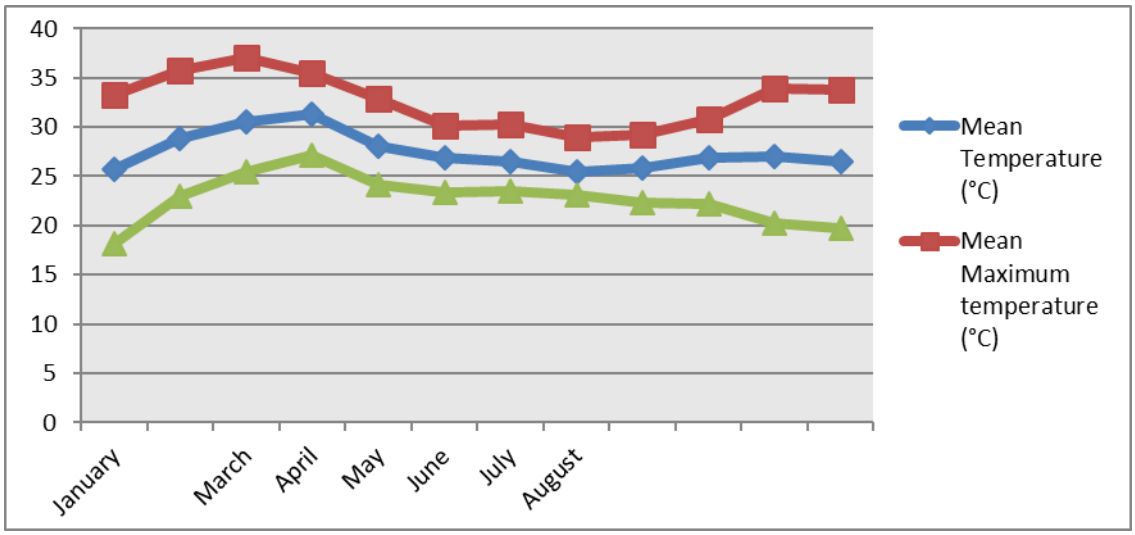

Figure 5.2: Average temperature of Bauchi

Source: Climate charts.com (2014)

5.2.5.1 Sun and Cloud cover

November sunshine hours vary from 8.9 to 9 hours per day. January sunshine hours are quite high, 8.7 to 9.5 hours. Minimum sunshine hours per day occur in August with as low as 5.1 hours per day. There is a general increase in the total hours of sunshine further north of the Atlantic coast.

5.2.5.2 Rainfall

Rainfall starts in April and increases from 161.5mm in June to 281.6mm in August to its maximum throughout the year. Annual total rainfall lies within a range of 960mm to 1150mm. The rainy season lasts for an average of 155 days.Table 5.2 shows the Monthly rainfall distribution in Bauchi and Figure 5.3 illustrate the Average precipitation in Bauchi respectively.

Table 5.2: Monthly rainfall distribution in Gadau

Month	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Mean	0.0	0.0	27.0	76.5	166.6	193.8	186.9	225.0	235.1	140.4	1.4	0.0

Source: Climate-charts.com (2014)

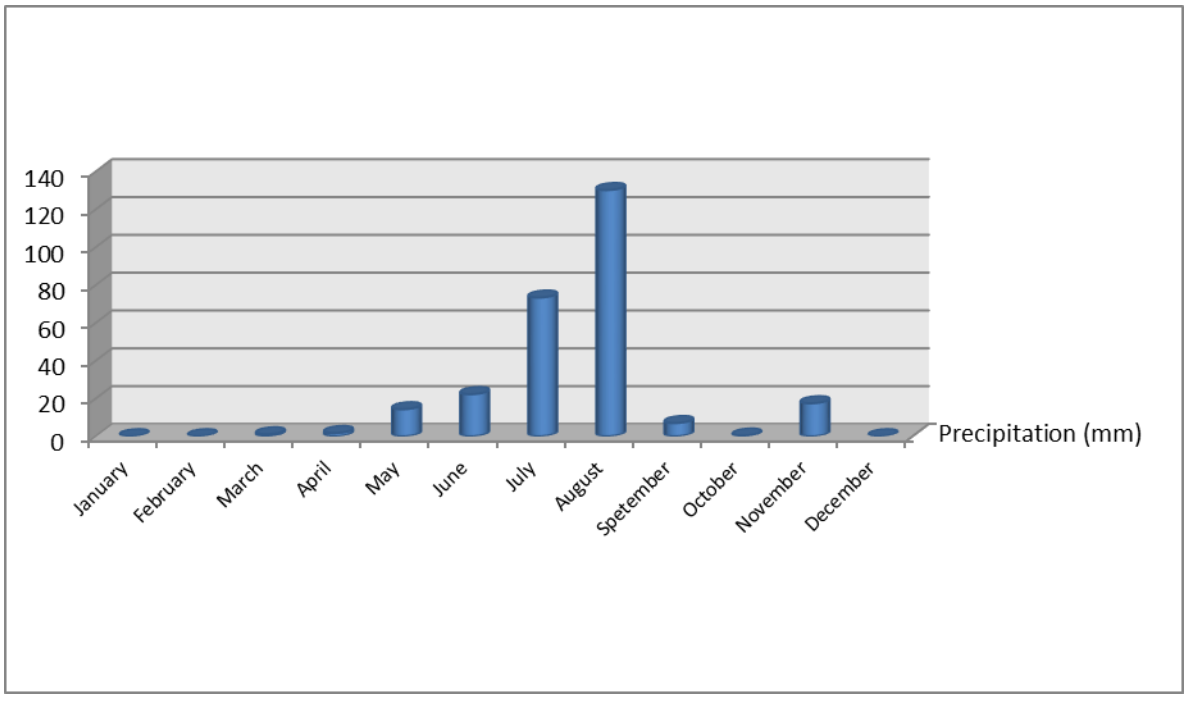

Figure 5.3: Average precipitation in Bauchi

Source: Climate-charts.com (2014)

5.2.5.3 Wind

The prevailing winds in Bauchi state are the southwestern and northeastern trade wind patterns. The northeastern trade wind originates from the Sahara desert and it brings dusty breeze and harmattan. The southwestern trade wind originates from the Atlantic Ocean and it brings moist cool breeze and rainfall. And also the building shall be oriented so as to achieve the south western wind and wind breakers shall be introduced to reduce the effect of the harmmattan wind. The wind speed ranges from 2.96 to 4.31 meters per second, varying from month to month.Table 5.3 show the monthly wind speed distribution in Bauchi and figure 5.4 represent the monthly wind speed chart of bauchi respectively.

Table 5.3 Monthly Wind Speed distribution in Bauchi

Month	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Mean (mm)	8.9	6.3	8.5	6.6	11.6	10.3	11.4	9.7	6.9	6.7	5.8	8.6

Source: Climate-charts.com (2014)

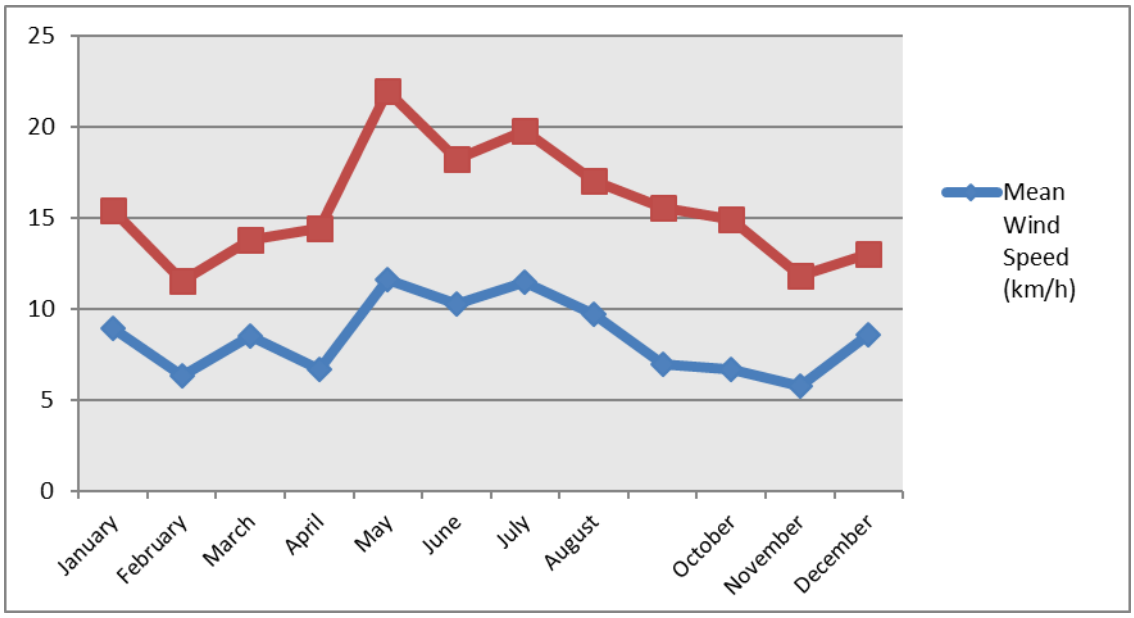

Figure 5.4: Monthly Wind Speed chart of Bauchi

Source: Climate-charts.com (2014)

5.2.5.4 Humidity

Humidity values generally drop during the dry season, from November – March. High humidity levels are attained during the rainy season. Table 5.4 showthe Monthly Relative humidity distribution in Bauchi and Figure 5.5 illustrate the Mean humidity chart of Bauchi respectively.

Table 5.4: Monthly Relative humidity distribution in Bauchi

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Mean (mm)	34.9	25.1	52.3	56.2	72.4	74.6	78.7	84.2	82.4	75.4	58.7	66.7

Source: Climate-charts.com (2014)

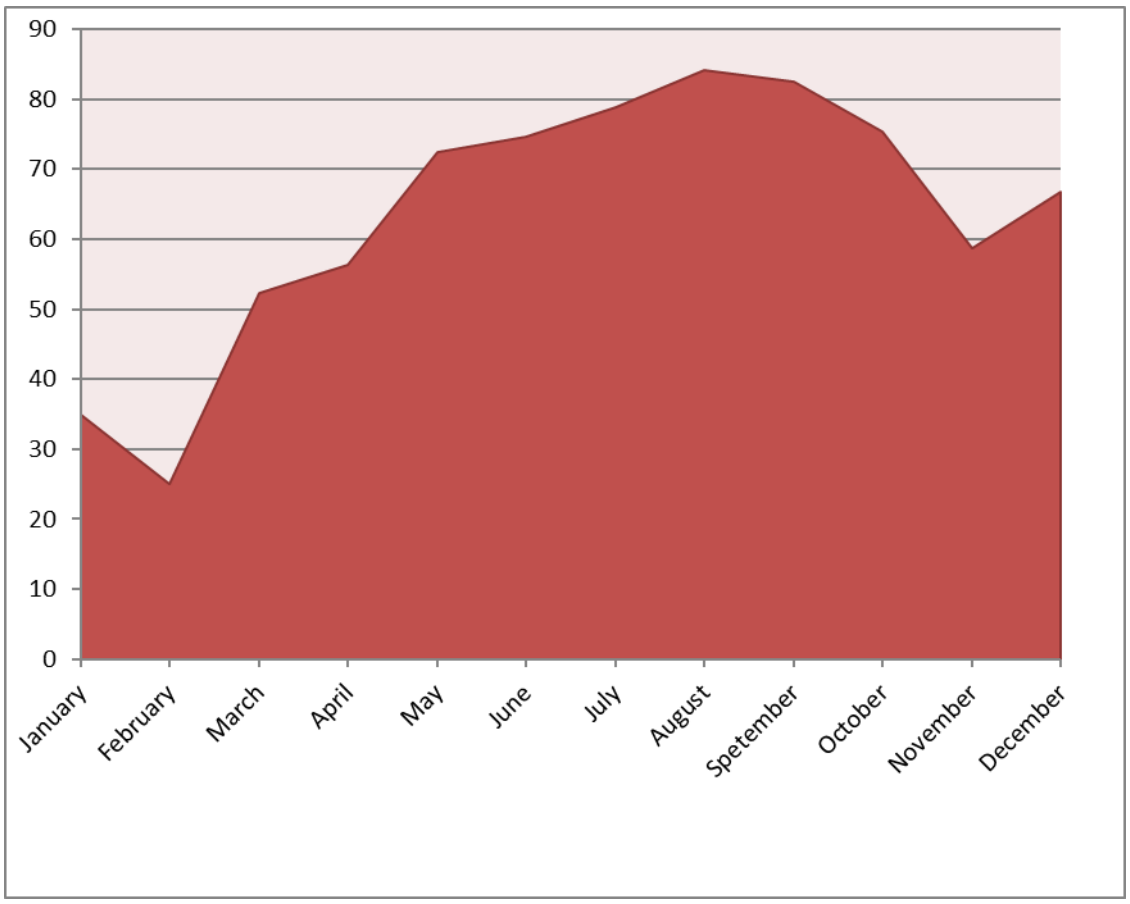

Figure 5.5: Mean humidity chart of Bauchi

Source: Climate-charts.com (2014)

5.3 Site Selection Criteria

In selecting a site for the faculty of Engineering Technology in the campus, one has to consider some factors that are very essential to the effective actualization of the project. Three sites have been selected. Site A is located outside the academic core. Site B is located within the academic core. Site C is also located within the academic core. This three site are shown in figure 5.6, as shown below.

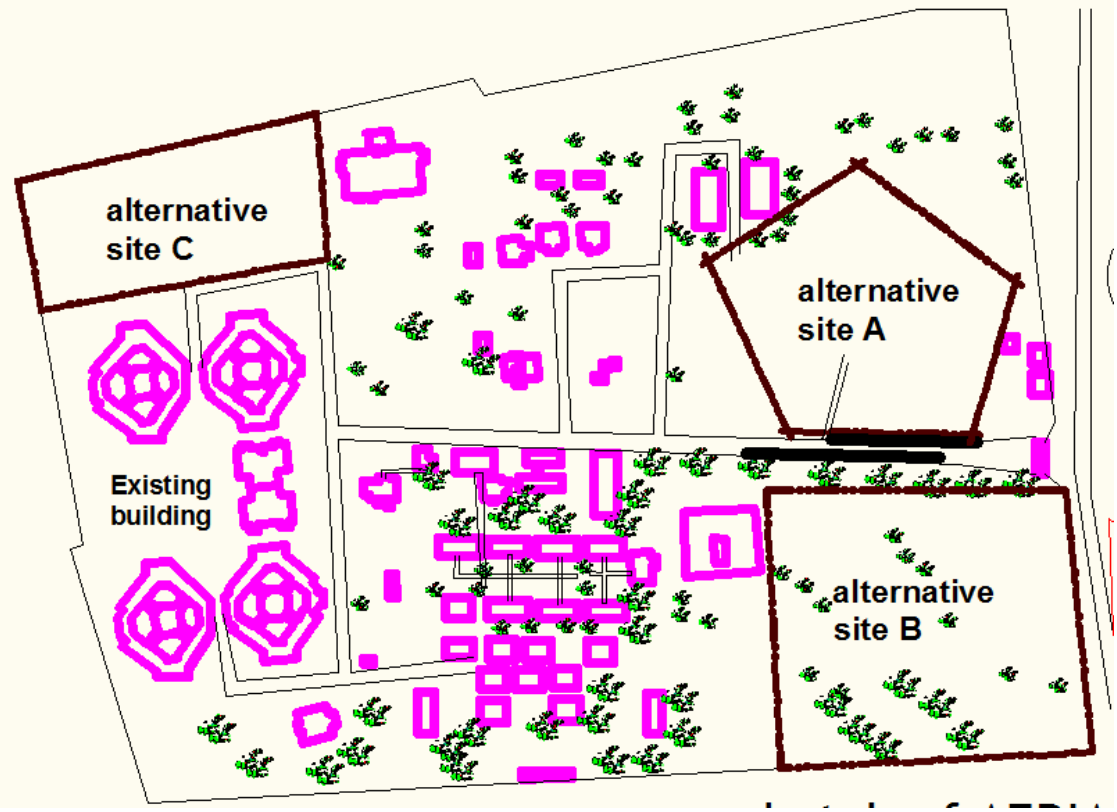

Figure 5.6: Academic core of the University of Gadau

Source: Authors field work (2014).

The following under listed criteria shall be used to weigh the suitability of each of the site and thus the most appropriate site shall be selected. Table 5.5 shows the comparisons of site selection criteria between chosen sites. They are:

i Site Location/Accessibility

ii Land use compliance

iii Presence of bio climatic features

iv Size of site, Possibility for expansion, suitability and availability

v Proximity to Student Hostels

vi Availability of services

Table 5.5: shows the comparisons of site selection criteria between chosen sites.

CRITERIA	SITE A	SITE B	SITE C	REMARKS
Site location/ Accessibility	4	4	2	Site BLocated along the campus main road
Land use compliance	3	4	3	Site B is more compliant
Presence of bio climatic features	3	5	2	Site Bwithin the academic core has more organic features
Size of site, Possibility for expansion, suitability and availability	3	5	2	Site 2 is more spacious
Proximity to Student Hostels	3	5	3	Site B within the academic core is more accessible to students and staff
Availability of services	4	5	2	Site B is more sited close to services
Total	**20**	**28**	**14**	

Source: Author, 2014

Weighing scale: Excellent- 5, Very good- 4, Strong-3, Weak- 2, Very Weak -1.

5.4 Site Analysis

The site has the following characteristic;

5.4.1 Access

The site is readily accessible since the campus major road pass in front of the site. At the moment, both vehicular and pedestrian access is possible on the site. This is illustrated in figure 5.3, as shown below.

5.4.2 Vegetation

The natural vegetation consists of the Sudan and the guinea savannah. Site to be well landscaped and trees retained to reduce solar radiation and avoid soil erosion. Densely distributed vegetation with existing trees spread on site with a grass cover. This is illustrated in figure 5.3, as shown below.

5.4.3 Utilities

Water supply is readily available from the campus water supply system. There is electricity supply on and around the site. However, a central sewage disposal system (soil and water) can be constructed to collects sewage from the site and channel to the central collection points. Both telephone service line and G.S.M can be easily connected to the site. This is illustrated in figure 5.3, as shown below.

5.4.4 Topography

The site has a relatively flat gently sloping to the north-western part. Low lying strip of land with 0.5% gradient sloping towards the north-west end of the site. Site drainage would take this direction in order to use the concept of natural gravity. This is illustrated in figure 5.3, as shown below. Earthwork to be carried out and table tops created for parking spaces. While the water supply should come from south-eastern direction in order to also use the principle of natural gravity.

5.4.5 Air Movement

a. South West Trade Winds: Blowing north east across the site with rain and humid air from the Atlantic Ocean. Wind pressure to be created through small external openings and large internal openings. This is illustrated in figure 5.7, as shown below.

b. North East Trade Winds: Bringing dry humid desert winds sweeping south west across the site Trees and shrubs to be used as shield and air filter.

c. Orientation of Buildings: Longer side of the building should face north-east direction to reduce discomfort.

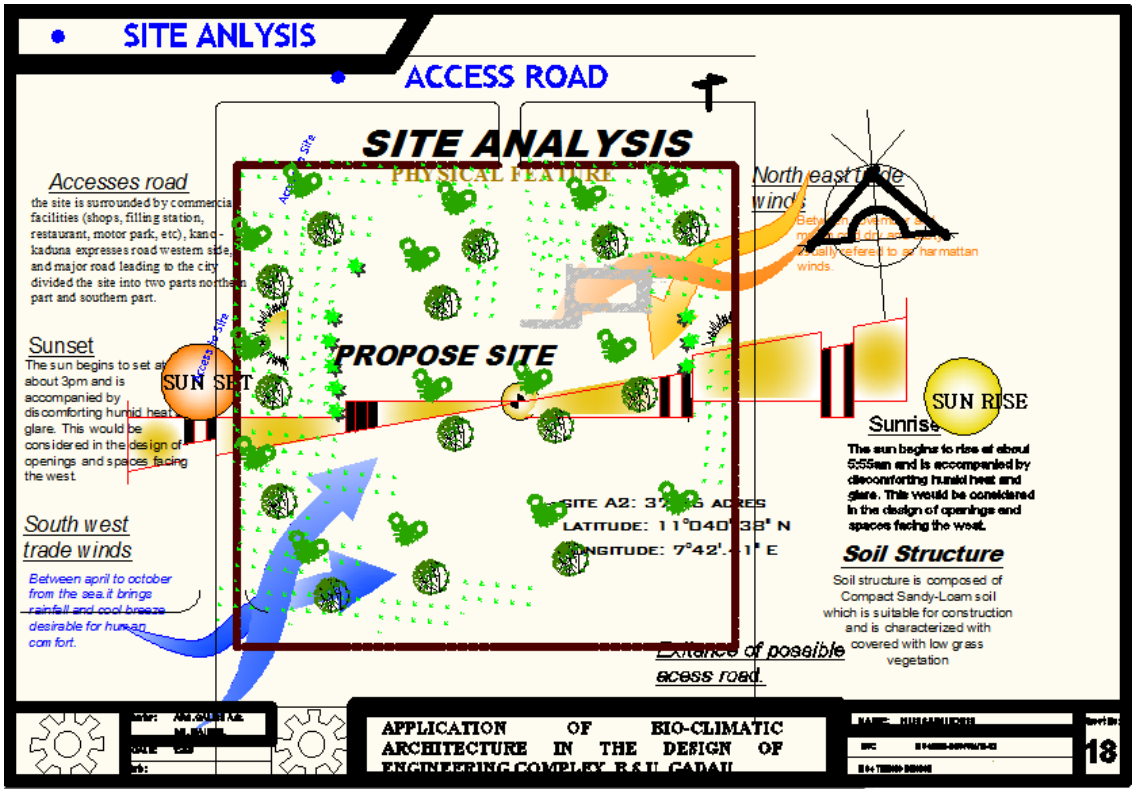

Figure 5.7: Site analysis (climatic data)

Source: Author, 2014

CHAPTER SIX

6.0 DESIGN BRIEF AND REPORT

6.1 Purpose of Design

The proposed Faculty of Engineering Technology shall be viewed as a thesis proposal for the design, that will incorporate in Bioclimatic design principles which will accommodate both staffs and student in a thermally comportable built environment.

The proposed faculty shall be a single unit of building that will integrated complex functions, which is hoped to be a manifestation of the various factors to enhance better environment for learning.

The objective of this proposed design is to apply the bioclimatic design principles suitable for hot humid climate. The faculty of engineering complex shall house departments for the four most basic engineering disciplines. These are:

i. Electrical engineering department
ii. Chemical engineering department
iii. Mechanical engineering department
iv. Civil engineering department

6.2 Brief Proposal

The school facility aims at housing four interrelated disciplines of engineering technology. The faculty will provide and cater for both academic and administrative functions, considering both staff and students along with supporting ancillary facilities. These academic spaces include Seminar rooms, lecture theatres, learning studios, workshops and laboratories. The administrative spaces for the school will be comprised basically of work stations, Deanery, offices and staff conference room. Ancillary accommodation such as departmental library, computer laboratory and parking spaces are also to be provided.

6.3 Population and Space Requirements

The population of the faculty shall be composed of staff and students, and their proportions shall be as stipulated by the Nigerian Universities Commission.

6.3.1 Student Population

The student population shall be composed of undergraduate and postgraduate students, with the postgraduate students including both masters (M.Sc.) and doctorate (Ph.D.) students. Table 6.1 is showing the projected population of students as shown below.

Table 6.1: Table showing the projected population of students

Department	**100 Level**	**200 Level**	**300 Level**	**400 Level**	**500 Level**	**M.Sc. 1**	**M.Sc. 2**	**Ph.D.**	**Total**
Mechanical Engineering	40-50	40-50	40-50	40-50	40-50	30-40	30-40	20	280-350
Electrical Engineering	40-50	40-50	40-50	40-50	40-50	30-40	30-40	20	280-350
Civil Engineering	40-50	40-50	40-50	40-50	40-50	30-40	30-40	20	280-350
Chemical engineering	40-50	40-50	40-50	40-50	40-50	30-40	30-40	20	280-350
TOTAL	**160-200**	**160-200**	**160-200**	**160-200**	**160-200**	**120-160**	**120-160**	**80**	**1120-1400**

Source: NUC Guidelines (2004)

Each department thus has a projected student population of 280-350 students, yielding a total projected population of 1120-1400 students.

6.3.2 Staff Population

The Nigerian Universities Commission stipulates an optimum staff to student ratio of 1:10. Table 6.2 is showing projected staff population as shown below.

Table 6.2: Table showing projected staff population

Department	Staff:Student Ratio	Student Population	Staff Population
Mechanical Engineering	1:10	280-350	28-35
Electrical Engineering	1:10	280-350	28-35
Civil Engineering	1:10	280-350	28-35
Chemical engineering	1:10	280-350	28-35
TOTAL		**1120-1400**	**112-140**

Source: NUC guidelines (2005)

Each department thus has a staff strength of 28-35, giving a total staff strength of 112-140 staff.

6.4 General Spatial Requirements

The facilities provided, shall be grouped into academic facilities, administrative facilities, and ancillary facilities.

6.4.1 Academic facilities

The academic spaces shall include:

i. Library
ii. Classrooms
iii. Learning studios
iv. Lecture theatres
v. Deanery
vi. Staff offices
vii. Seminar rooms
viii. Laboratories and workshops
ix. Breakout spaces

6.4.1.1 Library

It shall be large enough to cater for the needs of both staff and students. A library shall be provided to cater for each of the department.

6.4.1.2 Classrooms

The classrooms shall be designed to cater for the maximum number of students, as their use would require, such as 50 students for undergraduate classes, or 20 students for doctoral students. These spaces shall be provided, to cater for large group instruction, where it is required that the teacher address a large group of students, with little or no requirement for student participation. The classrooms shall also be provided with generous natural lighting and ventilation, through operable windows.

6.4.1.3 Learning Studios

They are to be used when a class is broken into small groups, each to deal with an assigned task. They shall be laid out, so as to foster the identities of each small group, and provide privacy, as well as awareness of the overall context of the larger group; it could also be used as examination venue. These spaces shall be provided to cater for the needs of small group learning, as well as project and group-based learning.

6.4.1.4 Lecture Theatres

These are provided to cater for instances where large group lectures are required, such as interdepartmental courses. Two lecture theatres are to be provided, each catering for 500 students. The lecture theatres shall also be centrally located, to foster their use as a shared resource, and immediately adjacent to the lecture theatres shall be large lobby spaces. Provisions shall also be made for the use of projectors.

6.4.1.5 Laboratories and Workshops

They shall be designed to hold a large number of users, both staff and students, since they usually host large group activities. Storage spaces as well as attendant offices shall be provided as well. They shall be located at easily accessible points and properly zoned and buffered to prevent noise disturbance to other parts of the site, as they are prone to generate noise. These are to be provided to cater for research as well as demonstrations.

6.4.1.5 Staff Offices

These will provide for both academic and administrated functions. These spaces shall provide the required space for the staff to carry out their functions, as well as provide the avenue for formal interactions between staff and students, or between staff.

6.4.1.6 Seminar Rooms

These spaces shall be provided to cater for presentation and seminar-style educational requirements. In addition, these spaces can also function to host meetings for small groups. They are to be used when a small group of staff or students, or even of both, require to be addressed, or receive a presentation from a speaker, who may also be a staff or a student.

6.4.2 Administrative Facilities

6.4.2.1 Faculty Offices

These accomodetion include the office of the dean, as well as general faculty meeting spaces.

6.4.2.2 Departmental Offices

These spaces are those reserved for the heads of departments, and the associated meeting spaces.

6.4.3 Ancillary Facilities

The ancillary spaces include supporting facilities such as the parking area, the exhibition areas, Business centres, cyber café, cafeteria, the terraces and sit outs.

6.5 Schedule of Accommodation

The schedule of accommodation has been obtained from NUC benchmark minimum academic standards (BMAS, 2005) for engineering technology. Table 6.3 represent Spaces required for the office of the dean, table 6.4 represent Academic spaces required for each department, and table 6.5 represent Administrative spaces required for each department, as shown below.

Table 6.3: Facilities required for the office of the dean.

Facilities	No. Required	No. of Users	Area per User (m^2)	Space Area (m^2)	Total Area (m^2)
Secretary	1	1	18	18	18
Office of the Dean	1	1	22	22	22
Deputy Dean	1	1	18	18	18
Conference Room	1	20	2.8	56	56
Faculty office	4	4	8	16	32

Source: NUC Benchmark Minimum Academic Standards for engineering technology (2005).

Table 6.4: Academic spaces required for each department.

Facilities	No. Required	No. of Users	Area per User (m^2)	Space Area (m^2)	Total Area (m^2)
Professor (20%)	4	1	25	25	100
Senior Lecturer (35%)	7	1	16	16	80
JuniorLecturer (45%)	9	1	16	16	112
Assistant Lecturer	6	1	16	16	96
Senior Technical Staff	3	1	16	16	48
Junior Technical Staff	5	1	16	16	80
Laboratory (Technical)	3	40	5	200	600
Laboratory (Computer)	1	30	5	150	300
Workshop	1	-	-	800	800
Classroom	3	50	1.2	60	150
Learning Studio	1	30	2	60	120
Seminar Room	1	20	2	40	120
Drawing Room	1	30	5	150	150
Lecture Theatre	1	150	1	150	300
Library	1	400	1.25	500	500
Toilet	3	15	6	2	12

Source: NUC Benchmark Minimum Academic Standards for Engineering technology (2005).

Table 6.5: Administrative facilities required for each department.

Facilities	No. Required	No. of Users	Area per User (m^2)	Space Area (m^2)	Total Area (m^2)
Head of Department	1	1	20	20	20
Office					
Secretary	1	1	20	20	20

Source: NUC Benchmark Minimum Academic Standards for Engineering technology (2005).

6.6 Design Report

Different case studies were carried out, major parameters that were used in their planning and designs were studied, and the major ones are incorporated in the proposed project. These served as the basis for my own design proposal. They are as follows:

6.6.1 Plan concept

The building form is thus developed from a geometric figure (i.e square shape), it is futher modified into four multiples number of rectangles, which are generated from an arrangement of progressive rectangles along a square. The concept is conceived by arrangement of rectanguler blocks with square central court-yard.

The plan concept evolved from the composition of the four department which constitute the faculty of engineering technology. This is to take maximum advantage of the central court-yard and the building orientation to create micro-climate and reduces solar radiation. Figure 6.1 describe concept development, as shown below.

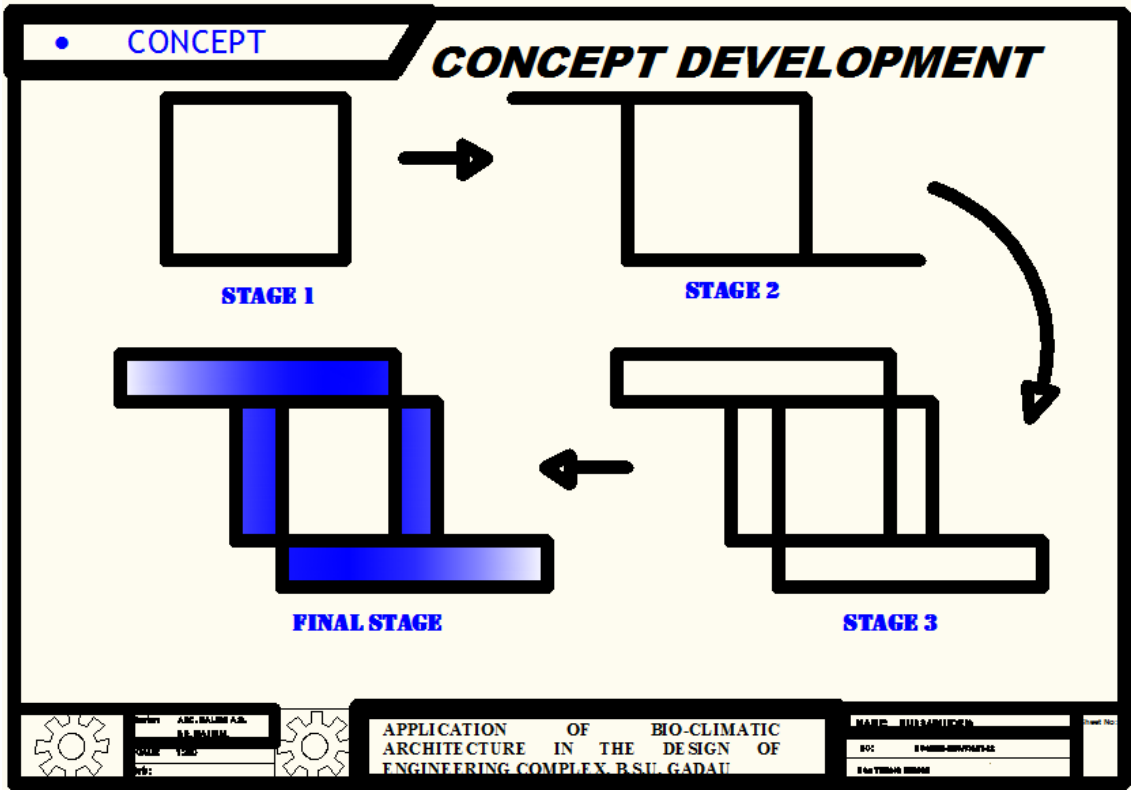

Figure 6.1: Plan concept

Source: Author, 2014

6.6.2 Site Planning

The emergency exits are created towards the front as well as the back of the building, with an exits in front very close to the parking area. The site is laid out with the parking spaces, immediately to the front of the site, and being the first point of contact with the development. Immediately beyond the parking spaces, the building's main entrance comes into view. There are four number of workshops, one to be allocated to each department in the faculty. To the back of the site, a secondary access is provided, to cater for deliveries to the workshops, which are located in this area. Figure 6.2 shows the site layout.

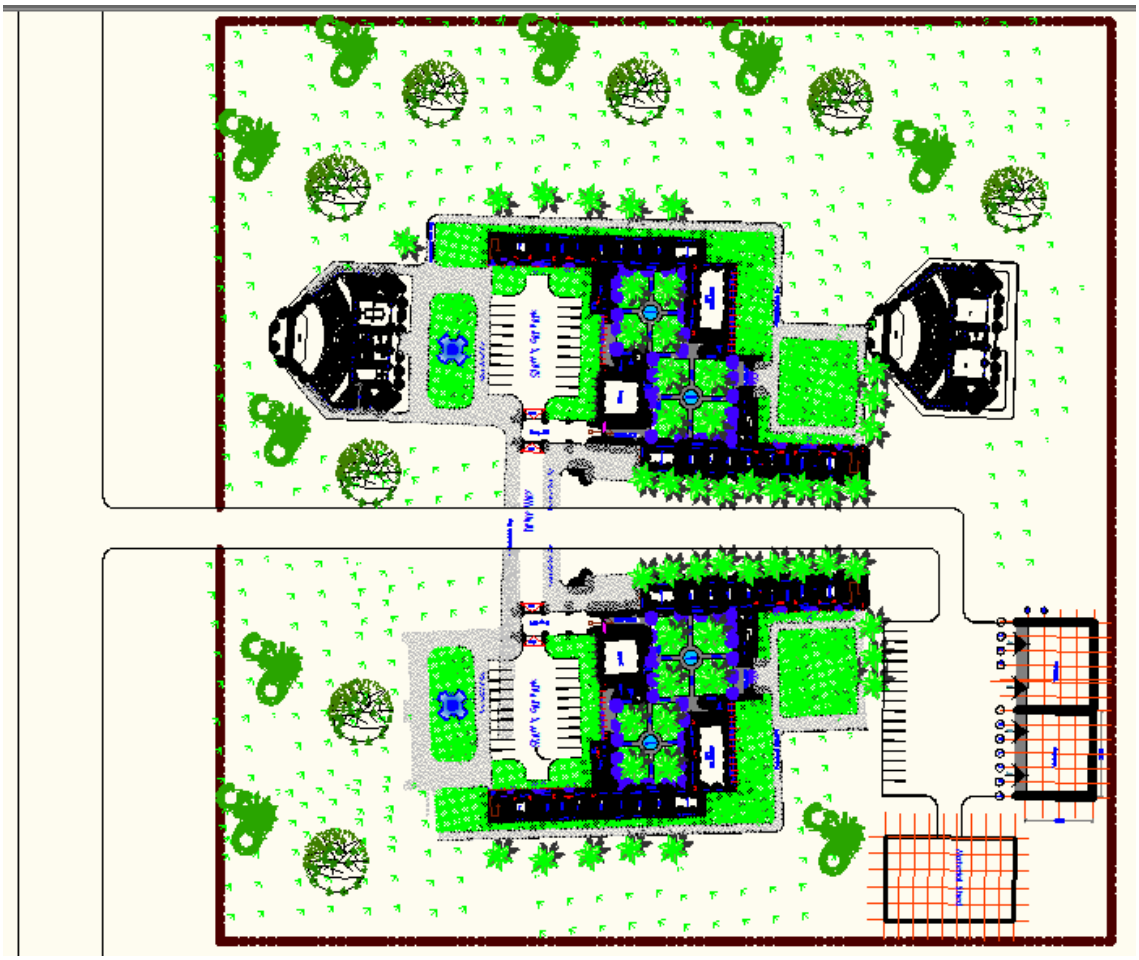

Figure 6.2 Site Plan

Source: Author, 2014

6.6.3 Design strategies

Internal heat gains draw air up into each floor. Fresh air then passes through low-level openings which bring the temperature up to the desired level. Air flows relatively freely beneath the exposed concrete soffits through open castellated beams. Single banking was adopted to achieve cross ventilation. The floor-to-ceiling dimension of 3.5m assists the natural buoyancy-driven displacement strategy by ensuring warm, stale air remains above head height.

Larger part of the office zone has controlled ventilation through stack effect. The Engineering complex has a central court-yard which serves as a source of light and ventilation which admit day light and fresh air into the building.

6.6.4 Design considerations

The following techniques were applied in the course of the design to minimize the overdependence on active cooling or mechanical systems, in other words, enhancing bioclimatic condition of the building.

6.6.4.1 Building orientation

The longer facades of the building is positioned in the north-south direction and the shorter facades mostly made of toilets, auxiliary and services are placed on the east-west direction. This is to reduce the cooling demand of the building.The orientation of the building took advantage of the natural forces of sun and wind.

6.6.4.2 Ventilation

Natural ventilation is produced by forces that results from air changes carried by difference in temperature stack effect, where warmer and lighter indoor air is displaced by cooler and denser outdoor air, and by air movement produced by pressure differences. These forces are rarely sufficient to create the appreciable air movement required to provide thermal comfort. When wind pressure is very high, some measure of control can be employed. Natural elements such as landscaping and the use of structural devise like fins overhang serve as wind breakers.

Some factors which may be prevalent on the site may affect natural ventilation: topography, orientation of building on site, grouping of buildings, and distance between buildings. Other factors like size of openings and their position, building interior plan, design of inlet and landscape may arise from design decisions.

6.6.4.3 Shading

However, the same horizontal device is ineffective at blocking the morning sun from the east and the low afternoon sun from entering west-facing windows during peak heat gain periods. The design of effective shading devices depends on the solar orientation of the building facades. For example, simple fixed overhangs were used at the north and the south facing windows, because of their effectiveness in the dry season when sun angles are high.

6.6.4.4 Lighting

In other words, it involves the admission of natural light source (sunlight) into the interior of the building. Natural lighting deals with the lighting up of an interior space without artificial aids. It is the ratio of indoor luminance to outdoor luminance.

To achieve and maintain proper and adequate admittance of light in a building, natural means are employed. Lighting of the engineering complex is a very important consideration. By this we refer to the amount of illumination and the quality of illumination withen interior of a building receives at a particular time or period of the day. Hences Natural lighting is achieved in the design by adopting single banking with central court-yard.

6.6.4.5 Landscape

The exterior outdoor area include soft and hard landscaping elements. The soft includes the planting of trees, flowers, etc. they act as wind breakers and sound barriers for the adjoining site. They are also used to provide shade for the parking areas and the pedestrian walkways. The hard landscape includes roads, pedestrian walks, water bodies, stones, rocks, etc. Water bodies like artificial ponds, fountains at the exterior envelope

help in beautification. Other effects can be created by the use of sculptures, and light fixtures.

Sitting areas sheltered by trees and canopies or thatch roofs with shops around them to create a relaxing environment. Pavements and concrete surfaces should be limited to the roads, parking areas, walkways and sitting areas, this is because these materials enhance glare and increase the level of discompote.

CHAPTER SEVEN

7.0 SUMMARY, CONCLUSION AND RECOMMENDATION

7.1 Summary of Findings

In summary this thesis has clealy explain the term bioclimatic architecture and stated it principles. The aim of this research is to proffer solution to some of the problems of thermal discomfort in academic environment by adopting bioclimatic architecture approach from design to construction.

Current relavant literature were reviewed, and the bioclimatic principles identified are; Building form and orientation, Use of sustainable power source, Use of Sun shading devices, Use of Court-Yard, Natural ventilation and air quality, Heating and cooling techniques and Landscape.

The research method adopted in conducting this study was descriptive research which is qualitative in nature. The research instrument used for data collection were field suvery and case study approch, and the procedue used were checklist and observation.

However based from the case study conducted, the findings shows that, major bioclimatic architecture principles are apply and widely explored in the design of institutional buildings in Nigeria. This can be seen from the case study summary sheet in chapter four (4), where it shows that only few variables are not fully applied.

The site location for the proposed desing of engineering complex is Gadau. The site characterictics and climatic variables were discussed based on; topography, vegetation, soil, physiograph, climate, temprature, humidity, sun, rainfall and wind. The comparison of site selection criteria and site analysis were carriedout.

Lastly, all the findings drawned from this research and analysis were applied in the design proposal of Engineering complex, Bauchi state university, Gadau.

7.2 Conclusion

The effect of buildings in Nigeria is that they tend to used expensive air conditioning systems inside the interio of building, in an attempt to maintain a thermally comfortable internal environment. The studies carried out in the course of this research shows generally that, institutional buildings in Nigeria are expensive to maintain; it require considerable cooling almost throughout the year. This situation makes it imperative to consider the use of environmentally sensitive technologies in the provision of thermally compotable conducive environment.

The intent of the thesis was to examine the bioclimatic architecture principles, its level of applicability, with particular reference to institutional development. In this research, several bioclimatic architecture principles were reviewed and discussed with reference to their design implications and architectural interventions. Generally, concern for natural environment is the majority of architectural design practices, even in the developed countries. Studies have shown that the application of bioclimatic architecture principles in buildings may reduce their energy consumption up to 40% - 50%. Bioclimatic building design should be the first aim of any building designer, because in most cases, it is a relatively low-cost exercise that will lead to savings in the capital and running costs of the building.

The conclusion drawn from these study are perhaps with an intuitive application of some of the mentioned bioclimatic architecture principles in institutional building design in Nigeria, it will become more economical and natural to enhance thermally compotable, well conducive academic environment.

7.3 Contribution to Knowledge

The architectural contributions of this study using the basis of previous findings are:

I The study has shown that proper used of bioclimatic architecture principles like building form and orientation in institutional building reduces solar radiation into the building envelop.

II The study demonstrated that, bioclimatic architecture principle can reduce to greater extent the use of energy/power and mechanical cooling devices (air conditioning, fans e.t.c.) up to 40%- 50% in institutional buildings.

III The study also highlighted the used of court-yard to create a micro-climate in institutional buildings.

IV Approprite use of building materials with higher thermal mass like (high density concrete and bricks), construction techniques for insulation, air lenkages and accurate application of the design (during construction stage) should be implemented.

V The study has shown that single banking design concept should be adopted inoder to achieve the application of major bioclimatic architecture principles in the design of engineering complex buildings.

7.4 Recommendation

This thesis can be used as starting point towards more detailed research in the development of bioclimaticarchitecture. Further investigation into sustainable design, passive cooling, comfort levels in building andenergy effeciency buildingcould be pursued.

Appropriate research should aim at better understanding of bioclimate architecture, and to understand thermal comfort requirements under transient conditions during the heat

period. It is therefore recommended that for effective design and good thermal comfort in buildings, thefollowing factors should be considered:

i The general public should be heightened an awareness on the cost benefits and economical aspect of bioclimatic architecture principles.

ii The government Regulatory Authorities should ensure and pass into law, before building approvalthat all architectural designs have meet the requirements of bioclimatic architecture principles.

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APPENDICES

APENDIX A: Findings from case study

VARIABLES OF STUDY	WEIGHT FACTOR	**REMARKS**
Building Form and orientation		
Use of sustainable power source		
Use of Sun shading devices		
Use of Court-Yard		
Natural ventilation and air quality		
Heating and cooling techniques		
Landscape		

Source: Authors field work 2014.

Weight Factor: Excellent = 5, Very Good = 4, Good = 3, Fair = 2, and Poor = 1.

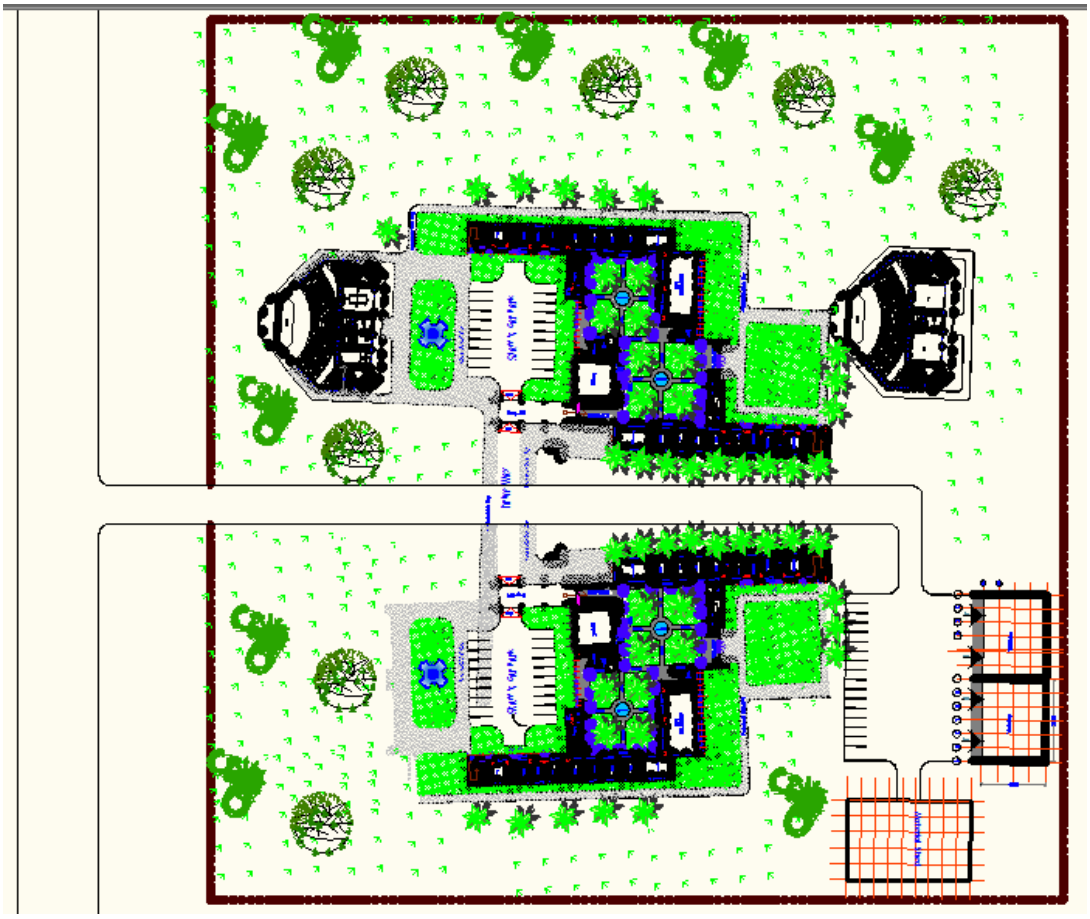
APENDIX B: Performance rating of various Case Studies carried out

	VARIABLE	SUB-VARIABLE	A.B.U Zaria	F.U.T. Minna	U.N.N Nsukka
1	Building envelope and orientation	Building shape Building form South-north orientation			
2	Use of sustainable power source	Use of solar system Use of wind			
3	Use of Sun shading devices	Vartical shading devices Horirontal shading devices Use of fins, recessed, trees e.t.c			
4	Use of Court-Yard	Opend court-yard Close court-yard			
5	Natural ventilation and air quality	Cross ventilation Window type			
6	Heating and cooling techniques	heat modulation and dissipation techniques evaporative cooling insolations thermal mass			
7	Landscape	Sorft and hard landscape elements Water bodies			
	SUMMARY				

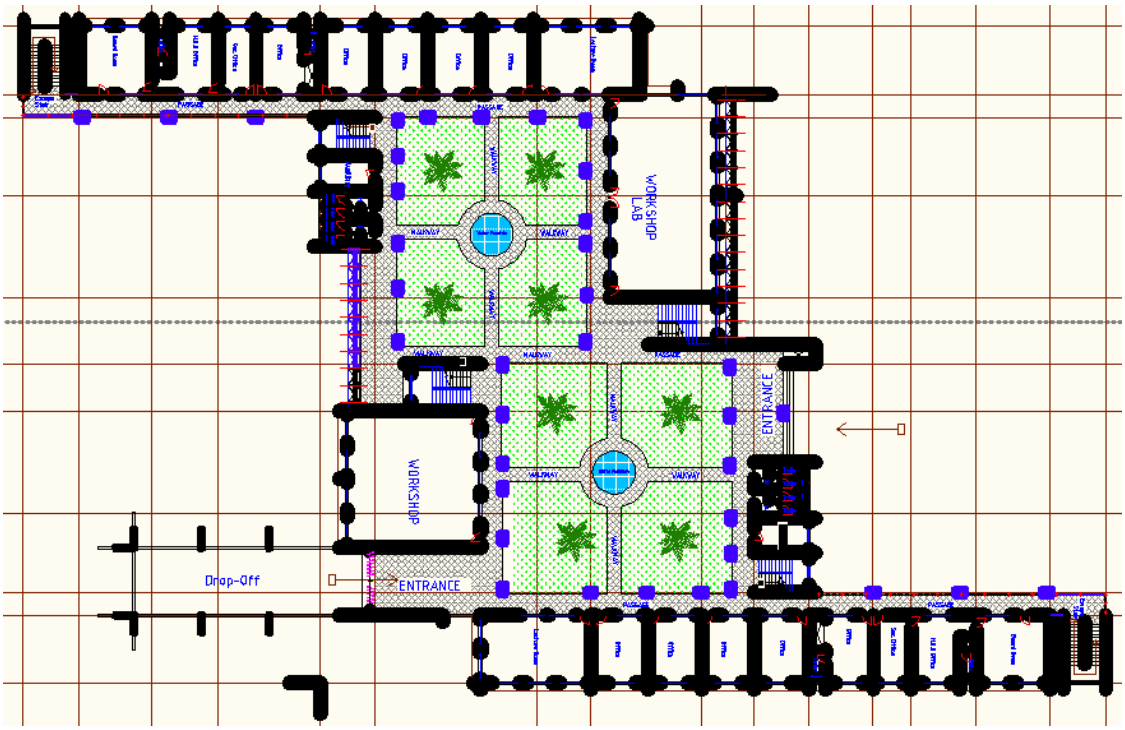
Source: Field Work, 2014.

Weight Factor: Excellent = 5, Very Good = 4, Good = 3, Fair = 2, and Poor = 1.

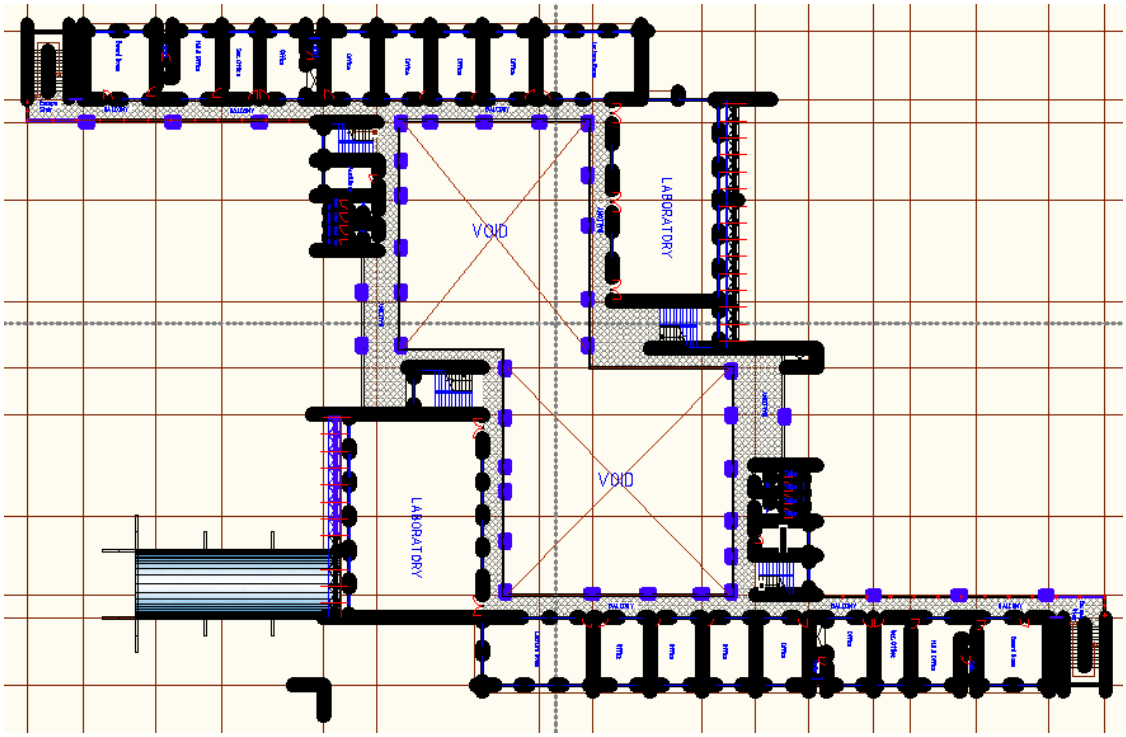
APENDIX C: SITE PLAN



APENDIX D: GROUND FLOOR PLAN



APENDIX E: FIRST FLOOR PLAN



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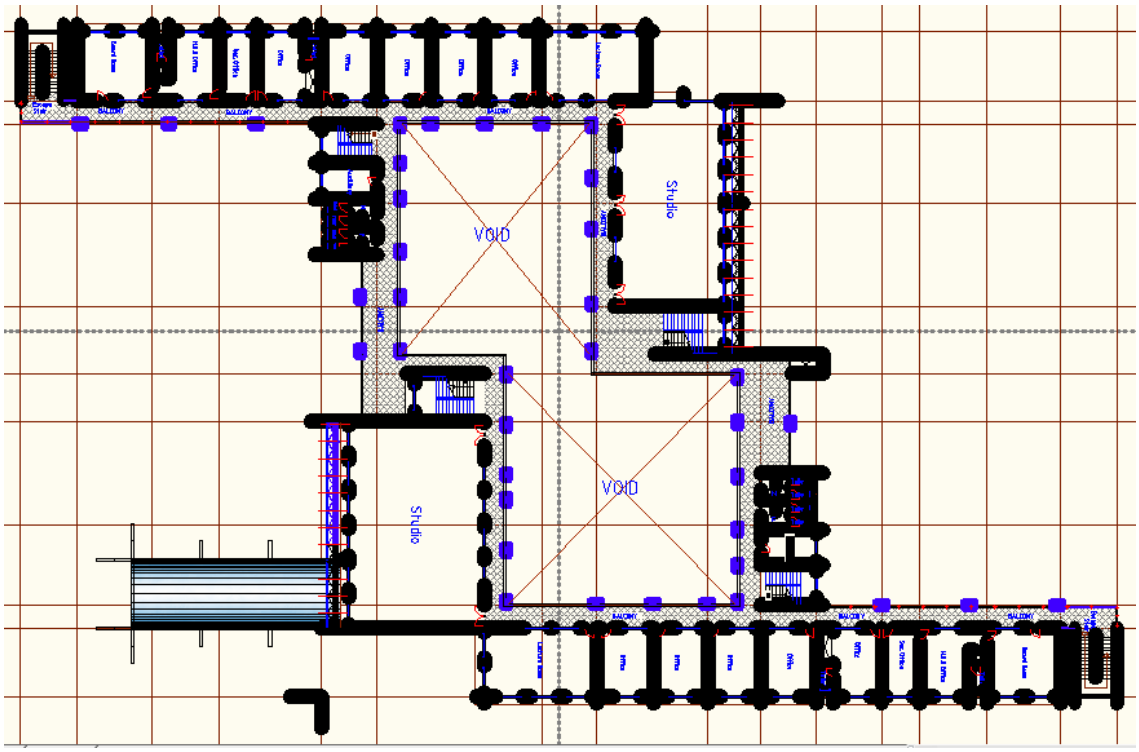

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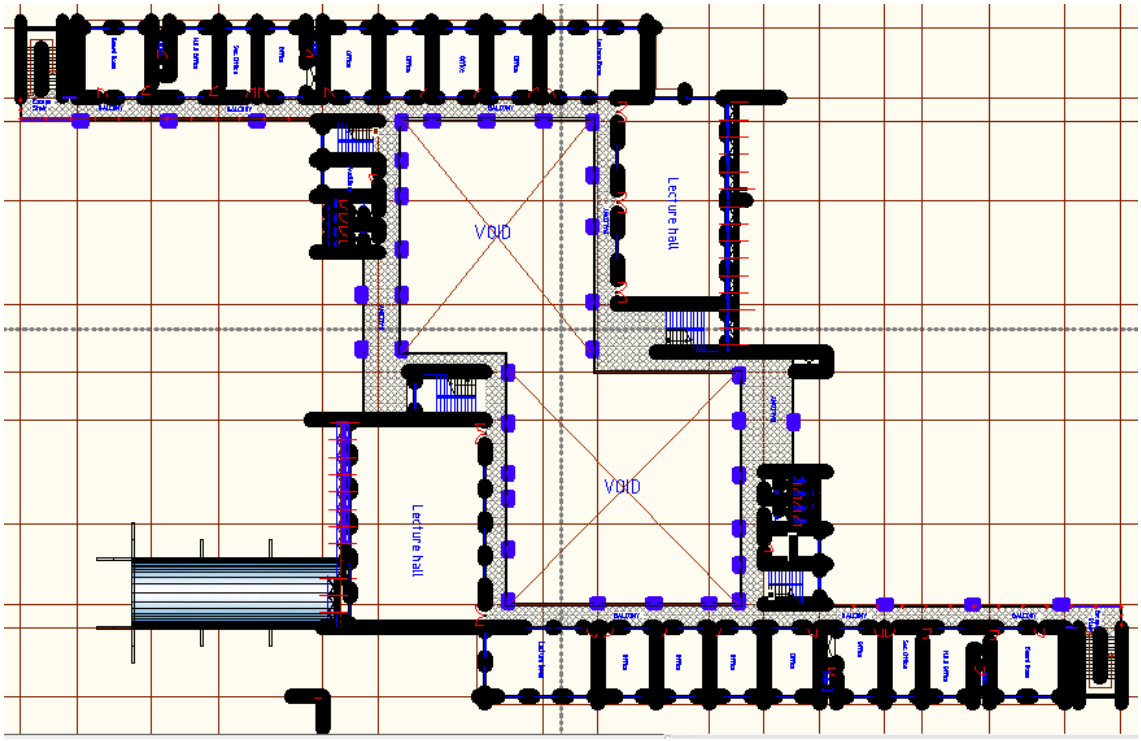
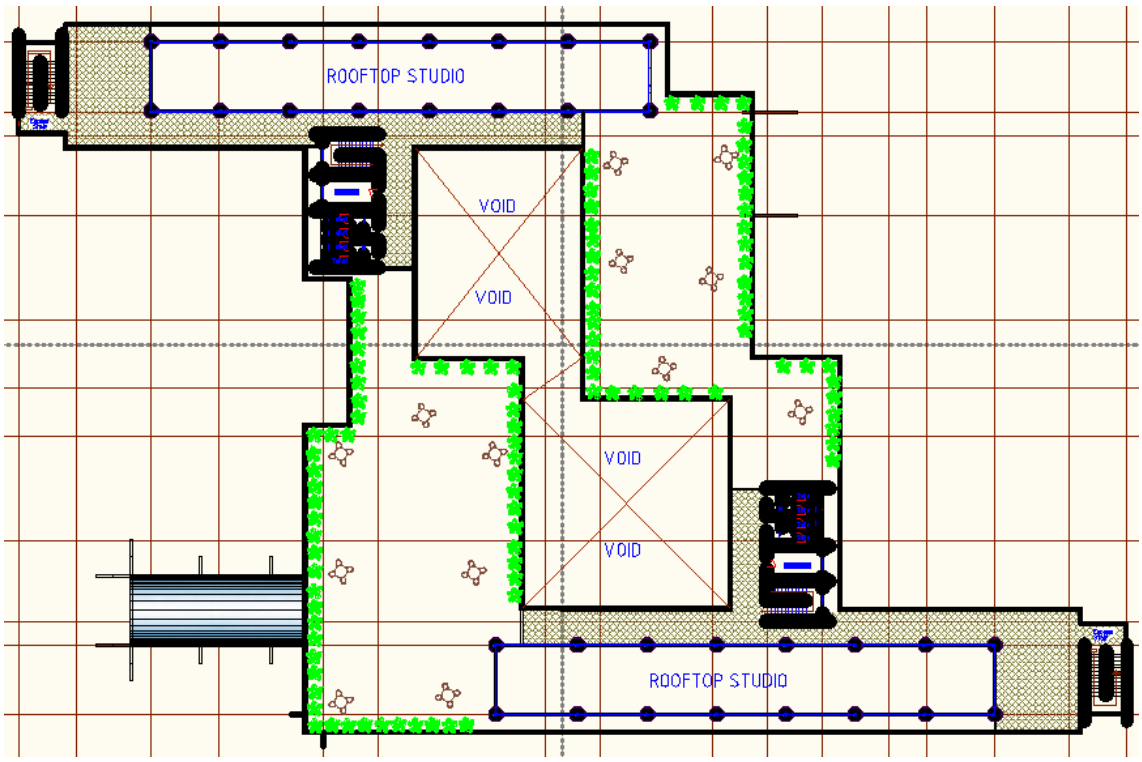
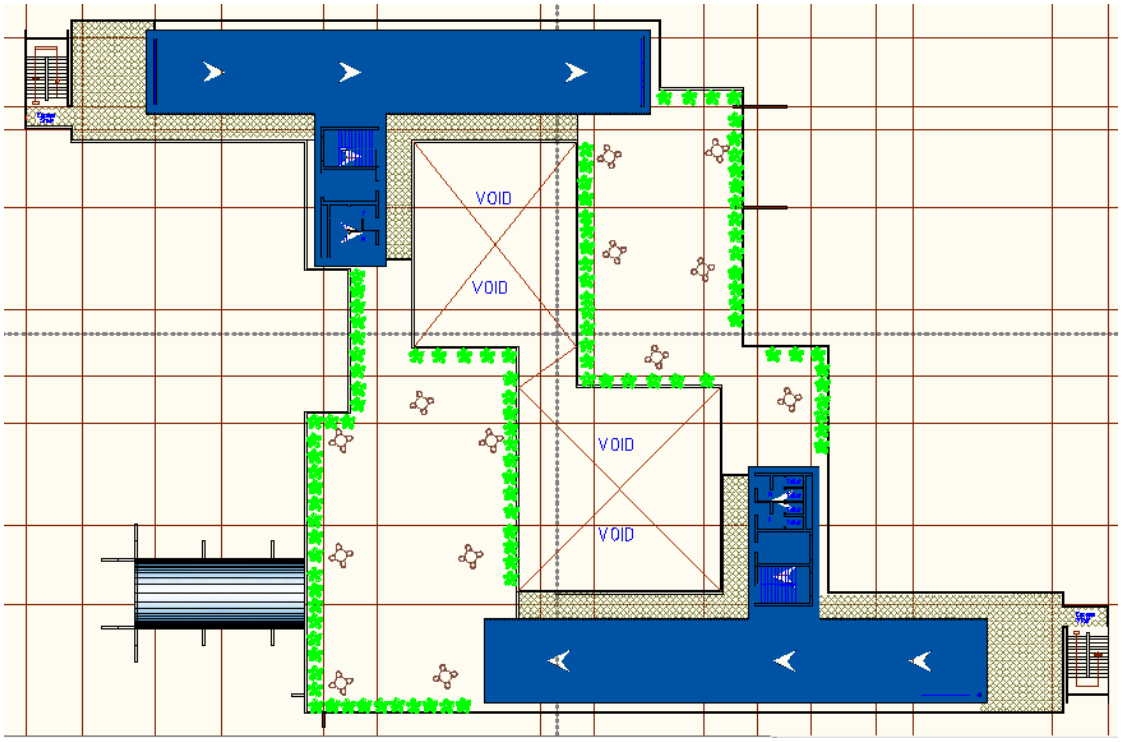


APENDIX H: FOURTH FLOOR PLAN



APENDIX I: ROOF PLAN



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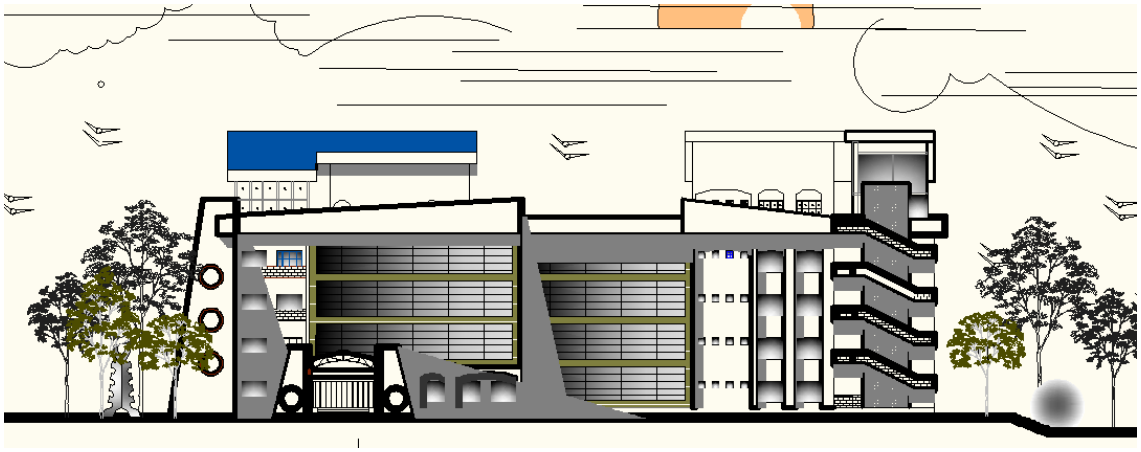
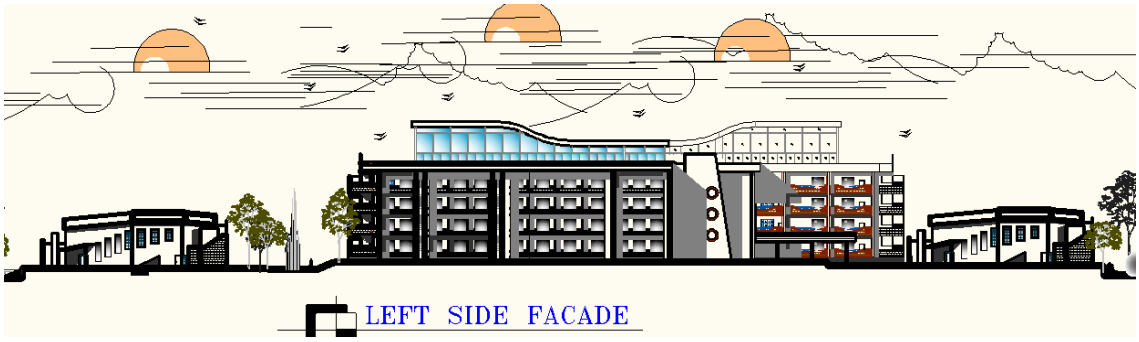
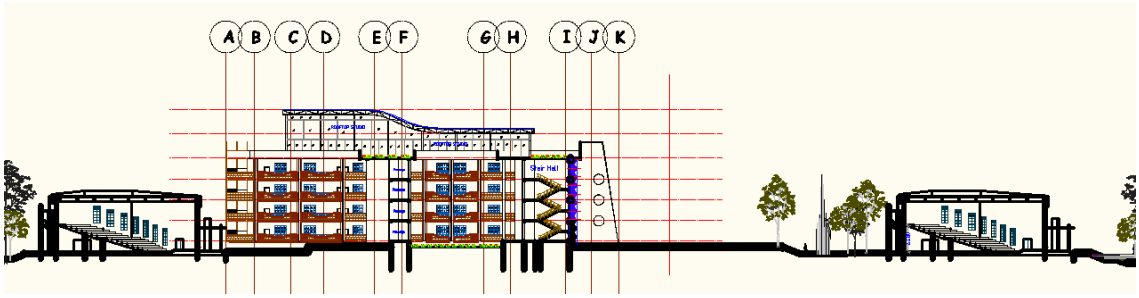


APENDIX K: REAR VIEW

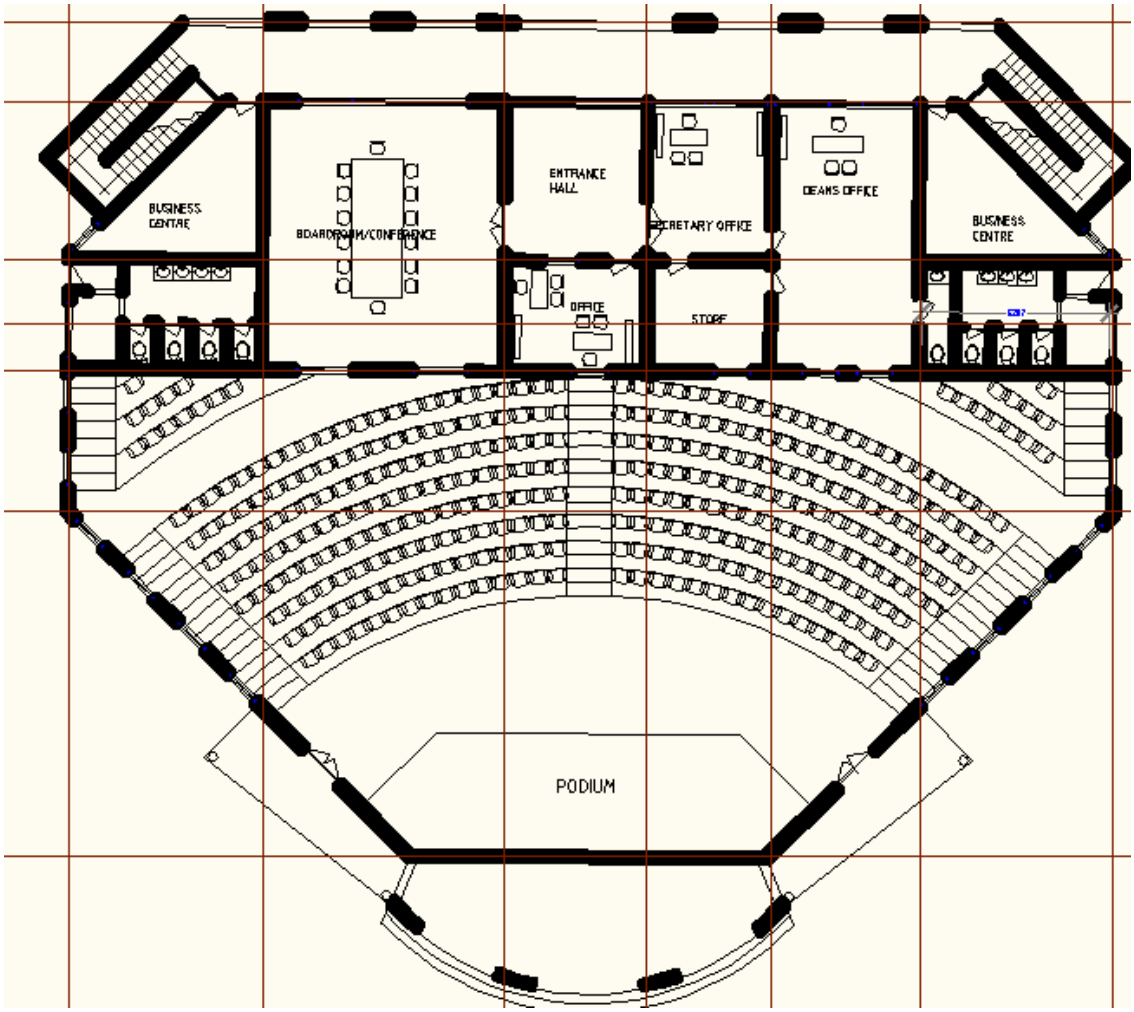
APENDIX L: SOUTH ELEVATION



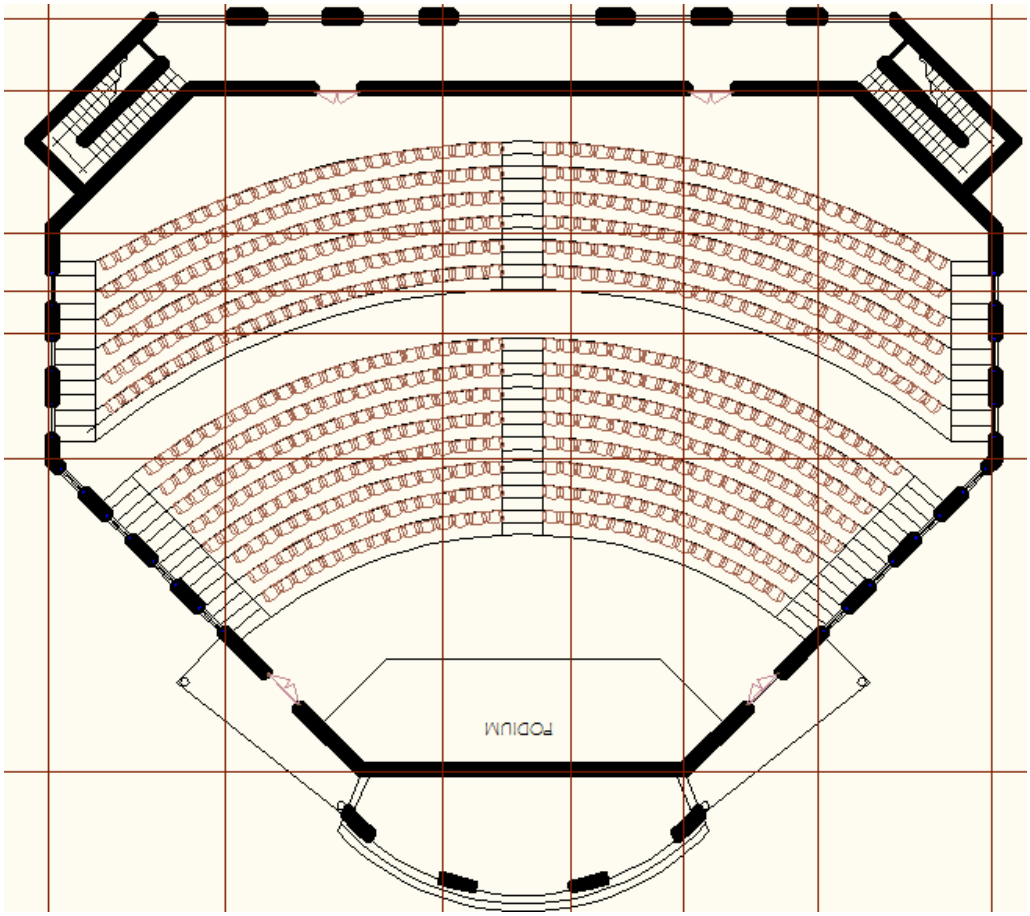
APENDIX M: SECTION X-X



APENDIX N: GROUND FLOOR PLAN OF LECTURE THEATER



APENDIX O: FIRST FLOOR PLAN OF LECTURE THEATER



APENDIX P: ROOF PLAN OF LECTURE THEATER