INTEGRATING PASSIVE ARCHITECTURE PRINCIPLES IN THE DESIGN OF FACULTY OF AGRICULTURE, FEDERAL UNIVERSITY GUSAU

BY

ABDULLAHI ABDULLAHI

DEPARTMENT OF ARCHITECTURE,

AHMADU BELLO UNIVERSITY, ZARIA

NIGERIA.

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BY

Abdullahi ABDULLAHI, BSc. Arch (ABU) 2012
MSC/ENV-DESIGN/44051/2012-2013

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FACULTY OF ENVIRONMENTAL DESIGN,
AHMADU BELLO UNIVERSITY, ZARIA, NIGERIA

FEBRUARY, 2017

Declaration

I declare that this thesis entitled "INTEGRATING PASSIVE ARCHITECTURE PRINCIPLES IN THE DESIGN OF FACULTY OF AGRICULTURE, FEDERAL UNIVERSITY GUSAU" is the outcome of my research work and has been written by me under the supervision of Prof. Mas'ud Abdulkarim and Arc. H.O. Saliu. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this project thesis was previously presented for another degree or diploma at this or any other university.

Abdullahi Abdullahi _____ _____

Certification

This thesis entitled “INTEGRATING PASSIVE ARCHITECTURE PRINCIPLES IN THE DESIGN OF FACULTY OF AGRICULTURE, FEDERAL UNIVERSITY GUSAU” by ABDULLAHI ABDULLAHI meets the regulations governing the award of the Master of Science degree of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

_____ _____

Prof. M. Abdulkarim Date

Chairman, Supervisory Committee

_____ _____

Arc. H.O. Saliu Date

Member, Supervisory Committee

_____ _____

Dr. A.S. Salisu Date

Head of Department

_____ _____

Prof. K. Bala Date

Dean, School of Postgraduate Studies

Dedication

Dedicated to my lovely parents Late Mal. Abdullahi Muhammad and Hajiya Hannatu Abdullahi whose guidance is invaluable.

Acknowledgement

I thank the Almighty Allah for giving me the fortitude and ability to attain up to this level of academic pursuit. My special thanks go to my supervisors, Prof. Mas'ud Abdulkarim and Arc. H.O. Saliu for their active support, encouragement and valuable criticisms leading to the success of this thesis and to all the lecturers in the department.

I would like to thank my parents and family for all the support they have given me. My parents taught me that education is the first and foremost aspect of my life.

Finally, I would like to thank all my friends and colleagues throughout the years who have influenced and shaped me in one way or another into the person I am today.

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Abstract

The hot-dry climate poses environmental challenges of high temperature and this extreme temperature has to be catered for at the design stage to avoid absolute dependence on active energy systems for indoor comfort. In Nigeria, where power supply is epileptic and erratic, most educational buildings depend on energy excessively to attain indoor comfort. Furthermore recent statistics show that buildings consume over 40% of non-renewable energy worldwide, which does not demonstrate well for sustainable development. Therefore the aim of this research is to investigate the potentials of integrating passive architecture principles and renewable energy sources in the design of educational buildings in hot dry climate in order to achieve self-sustaining educational buildings which will facilitate learning and overcome the state of discomfort with minimum energy utilization. A case study approach using a checklist is employed for the research within which three cases were purposely selected. The case study findings were then assessed based on the research variables and discussed by comparison with the secondary sources, so that conclusions were finally drawn. The result of the research shows that adopting certain passive design strategies through appropriate selection of building materials, proper building orientation, adequate natural ventilation, evaporative cooling, building form and application of some renewable energy sources can provide natural cooling and reduce the energy used for cooling in educational buildings. The research concludes that this will limit the energy demand for cooling and will also result in an adapted architecture to the climatic environment.

1.0 INTRODUCTION

1.1 Background to the Study

Within the last decade sustainable development and building practices have acquired great importance due to the negative impact of various development projects on the environment. In line with a sustainable development approach, it is critical for practitioners to create a healthy, sustainable built environment. The primary function of all buildings is to adapt to the prevailing climate and provide an internal and external environment that is comfortable and conducive to the occupants. However, in this era of climate change and global warming, providing comfort for the occupants of a building is quite challenging and very fundamental (Akande, 2010). Educational buildings are one of such buildings types when the potential links between building performance, thermal comfort, and energy consumption are considered. Students spend long periods of time in classrooms, and a good indoor environment can help to optimize conditions for students' performance. Moreover, Educational buildings are major energy consumers, due to significant demands for heating and cooling to provide thermal comfort conditions (Khaled et al., 2012).

Tropical climate is characterized by high ambient temperatures and solar radiation, a combination of these and other factors cause thermal discomfort in educational buildings. The common approach to maintaining comfortable thermal environment in buildings in tropical climates is using air-conditioning systems. In buildings where mechanical cooling is not affordable, buildings are occupied in harsh conditions which affect performance especially in schools and other work environments (Ojebode and Gidado, 2010). Furthermore, Adegbie (2016) stated that the current energy crises witnessed in Nigeria has led to massive use of alternative back-up power sources in buildings for the purpose of

space cooling and lighting. This condition leads to increase in the burning of fossil-fuel by buildings which account for about 40% of the global energy consumption and contribute over 30% of the CO2 emissions (Saliu and Achimugu, 2016).

Several efforts have been put in place to mitigate the negative impacts of thermal discomfort in educational buildings as a result of high ambient temperature and solar radiation. One of such efforts is the use of passive architecture (Ochedi et al., 2016). Naresh (2014) defined passive architecture as a climate responsive building that provides comfortable indoor conditions, without relying on energy from electrical and mechanical devices, otherwise known as artificial or non-renewable energy. In hot and dry tropics, the aim of passive architecture is to avoid solar radiation, promote ventilation from the prevailing wind and ensure daylight into the building. Furthermore Naresh (2014) stated that Passive design principles are methods to earn better energy performance in buildings for the delivery of a comfortable indoor environment and without negative impact on the outdoor environment. Moreover, major efforts towards achieving energy-conscious design in hot climate regions of the world have centred on the recommendation of passive techniques as the primary means of achieving comfort (Ochoa and Capeluto, 2008).

1.2 Problem Statement

Extreme heat presents special problems in educational buildings located in hot dry climatic region because of the retention of heat by the buildings. In this climatic region many of the educational buildings are not suitable for the occupants because a large proportion of the buildings are poorly designed for the climate (Akande, 2010). In addition, because their economies cannot provide mechanical air conditioning for the majority of the period; the

comfort and wellbeing of the occupants therefore depend entirely on the design and construction of the buildings. It is against this problem that this study seeks to investigate how passive design strategies for educational facilities may help to improved thermal comfort conditions, while also saving energy.

1.3 Justification

In Nigeria, most buildings hardly take passive architecture and energy efficiency into consideration due to ignorance, lack of awareness and/or improper policy on building regulations by Government. Use of mechanical devices to achieve thermal comfort in buildings is not only capital intensive but also generate greenhouse gases, air and noise pollution amongst others (Nwofe 2014). The concept of enhancing thermal comfort conditions in educational buildings through passive design principles has become very vital in an area like Gusau which has a climate that is hot throughout the year i.e. an average daily temperature range between 31.4°c and 33.2°c for a greater part of the year. Furthermore, the inconsistent nature of power supply and in addition to the greenhouse gas emissions from mechanical devices have prompted the need on how to achieve a thermally comfortable built environment in a hot dry climate of Gusau.

1.4 Aim and Objectives

The aim of this research is to investigate the potentials of integrating passive architecture principles and in the design of educational buildings in Gusau (Hot Dry Climate) with a view to enhancing self sustained buildings that will facilitate learning and overcome the state of discomfort with minimum energy utilization.

The objectives of the study are

i. To establish the concepts and principles of passive architecture as it relates to educational buildings.
ii. To investigate the application of passive architecture design principles in some existing educational building in hot dry climate.
iii. To demonstrate established passive architecture design concepts, which improve comfort and energy conservation in the design of proposed Faculty of Agriculture, Federal University Gusau.

1.5 Research Questions

The research questions are:

i. To what extent have passive architecture principles been applied in educational buildings in the climatic zone (Hot Dry Climate)?
ii. Why is the need for energy conservation in educational buildings in Nigeria?
iii. How can the application of principles of passive architecture enhance thermal comfort and reduce energy consumption in educational buildings?

2.0 LITERATURE REVIEW

2.1 Introduction

This chapter presents a theoretical background of the research topic, by giving an insight into previous works and reviewing relevant theories, concepts, current issues and debates by other researchers.

2.2 Definition of Passive Architecture

Passive Architecture (PA) is a term coined to describe buildings designed that are responsive to the local climatic conditions such that comfortable indoor condition is created naturally, for as long as possible (Adegbie, 2016). The terminology is expressed as 'passive' to portray a defensive or protective approach of building design in shielding occupants from the local climate elements; and 'architecture' place this responsibility to the Architect being the professional obligated to create good building design (Zaki *et al*., 2012). Fundamentally, in hot and humid tropics such as Nigeria, PA design strategies aim to avoid heat from the sun, promote natural cross ventilation from the prevailing wind and ensure daylight into the building. Interest in PA has grown, particularly in the last decade or so, as part of a movement towards more comfortable and resource-efficient buildings (Naresh, 2014).

Torwong (2007) says that PA can be referred to as a way of designing buildings that take advantage of the prevailing climate and natural energy resources, such as daylight and wind, to achieve a comfortable environment while minimizing artificial energy use and reliance on mechanical systems.

The building industry must reduce its energy consumption due to growing concerns about global warming and climate change. A sustainable way of reducing this energy consumption is by employing passive design solutions instead of mechanical ones: for example, a well-designed naturally cooled and ventilated building can consume only a third of the energy consumed by an air-conditioned building, while arguably providing a comparable level of comfort. This is because passive design allows buildings to adapt more appropriately to their local climates and take better advantage of natural energy resources, such as the wind and solar energy, to help condition their interior environments. Moreover, environments containing passive, naturally ventilated buildings appear to be much more pleasant and healthier than those containing mechanically ventilated buildings. Indeed, sick building syndrome is almost exclusively observed in the latter (Torwong, 2007).

2.3 Passive Design Principles of Buildings

The flow of energy in passive design is by natural means: radiation, conduction, or convection without using any electrical device. Taleb (2014) noted that maintaining a comfortable environment within a building in a hot climate relies on reducing the rate of heat gains into the building and encouraging the removal of excess heat from the building. To prevent heat from entering into the building or to remove once it has entered is the underlying principle for accomplishing cooling in passive design of buildings. This depends on two conditions: the availability of a heat sink which is at a lower temperature than indoor air, and the promotion of heat transfer towards the sink. Environmental heat sinks as identify by Taleb (2014) are:

i. Outdoor air (heat transfer mainly by convection through openings)

ii. Water (heat transfer by evaporation inside and / or outside the building envelope)

iii. The (night) sky (heat transfer by long wave radiation through the roof and/or other surface adjacent to a building

iv. Ground (heat transfer by conduction through the building envelope)

The PA design principles are discussed in details below

2.3.1 Solar Shading

Well-designed sun control and shading devices, either as parts of a building or separately placed from a building facade, can dramatically reduce building peak heat gain and cooling requirements and improve the natural lighting quality of building interiors.

Kumar (2005) evaluated the performance of solar shading. In their study they found that a decrease in the indoor temperature by about 2.5°C to 4.5°C is noticed from solar shading. The analysis suggested that solar shading is quite useful to development of passive architecture to maintain indoor room air temperature lower than the conventional building without shade. The following are different techniques for solar shading as noted by Kamal (2012);

i. Shading by overhangs, louvers and awnings
ii. Shading by roof
iii. Shading by trees and vegetation

2.3.1.1 Shading by Overhangs, Louvers and Awnings

Kamal (2012), stated that sun shading devices should be provided corresponds to the sun path. The design of effective shading devices will depend on the solar orientation of a particular building facade. For tropical countries, the best type and position for sun shading

devices is projected canopy at the top of windows on the east and west; and protruding fins at the sides of windows on the north and south. However, the same horizontal device is ineffective at blocking low afternoon sun from entering west-facing windows during peak heat gain periods in the summer. Figure 2.1 shows the different types of shading devices.

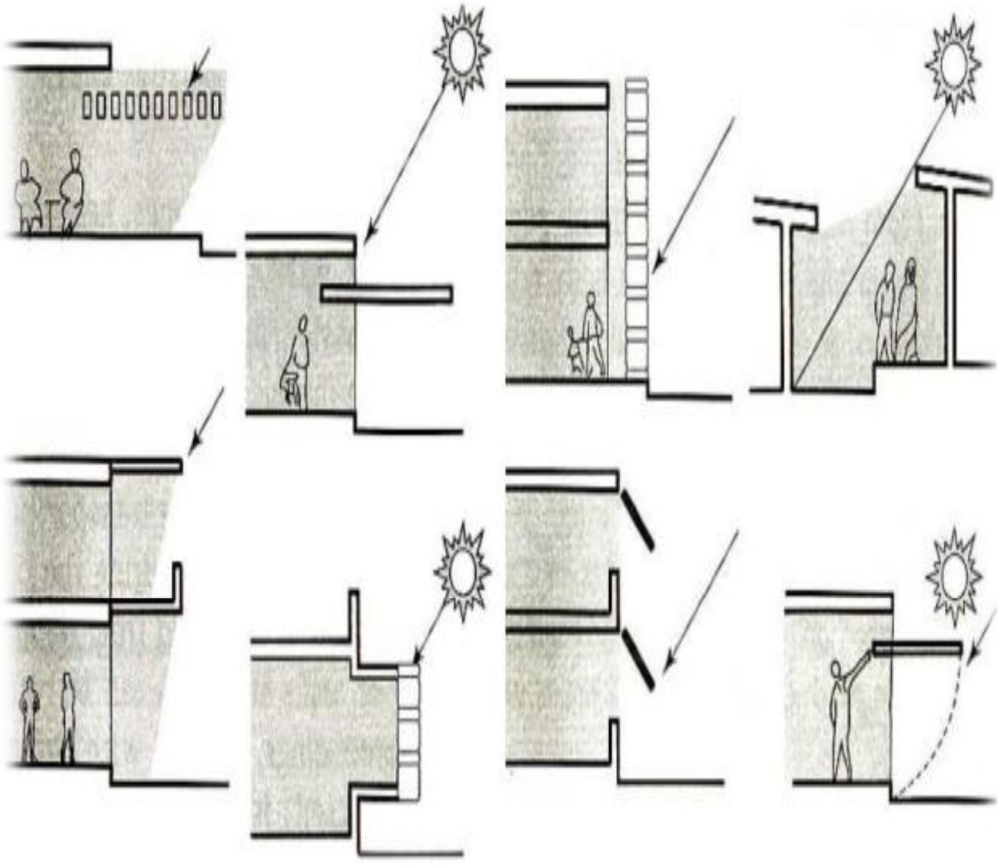


Figure 2.1 Different types of shading devices.

Source: Kamal (2012)

2.3.1.2 Shading of Roof

Shading the roof is a very important method of reducing heat gain. Roofs can be shaded by providing roof cover of concrete or plants or canvas or earthen pots etc. Shading provided by external means should not interfere with night-time cooling (Kamal, 2012). A cover over the roof, made of concrete or galvanized iron sheets, provides protection from direct radiation. Disadvantage of this system is that it does not permit escaping of heat to the sky at night-time (Figure 2.2)

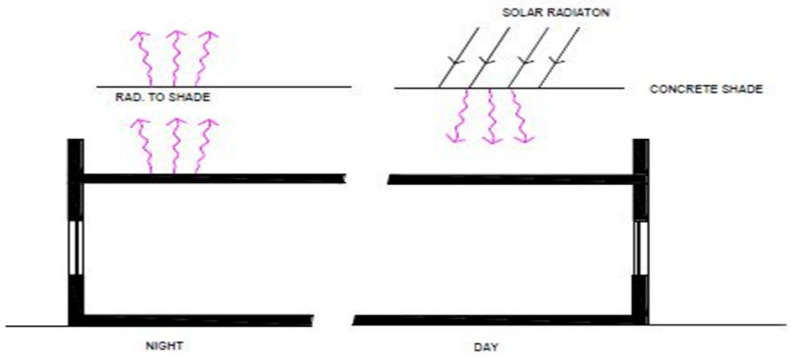


Figure 2.2: Roof shading by solid cover.

Source: Kamal (2012)

Naresh (2014) opined that a cover of deciduous plants and creepers is a better alternative. Evaporation from the leaf surfaces brings down the temperature of the roof to a level than that of the daytime air temperature. At night, it is even lower than the sky temperature (Figure 2.3).

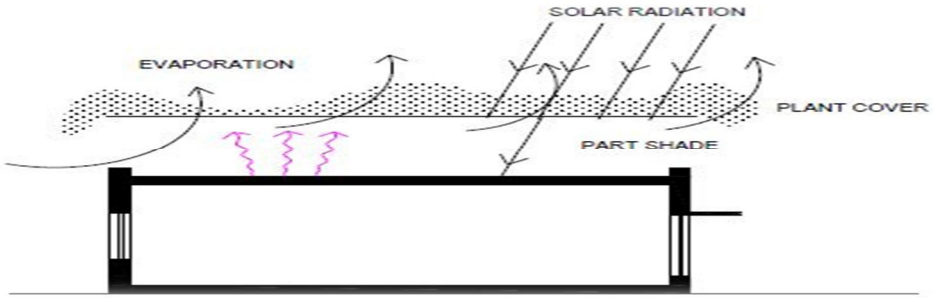


Figure 2.3: Roof shading by plant cover

Source: Kamal (2012)

Covering of the entire surface area with the closely packed inverted earthen pots, as was being done in traditional buildings, increases the surface area for radiative emission. Insulating cover over the roof impedes heat flow into the building. However, it renders the roof unusable and maintenance difficult (Figure 2.4). Broken china mosaic or ceramic tiles can also be used as top most layer in roof for reflection of incident radiation.

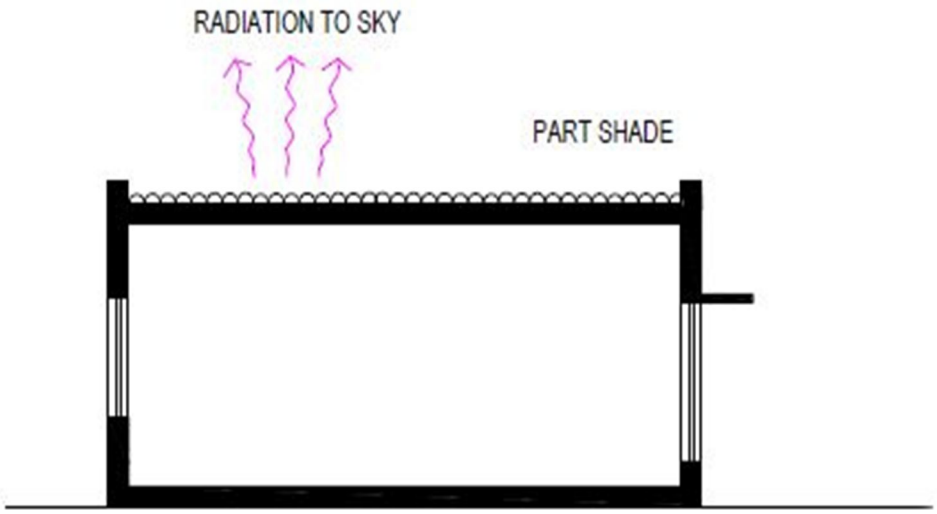


Figure 2.4: Roof shading by earthen pots.

Source: Kamal (2012)

Another inexpensive and effective device is a removable canvas cover mounted close to the roof. During daytime it prevents entry of heat and its removal at night, radiative cooling. Figure 2.5 shows the working principle of removable roof shades. Painting of the canvas white minimizes the radiative and conductive heat gain (Kamal 2012).

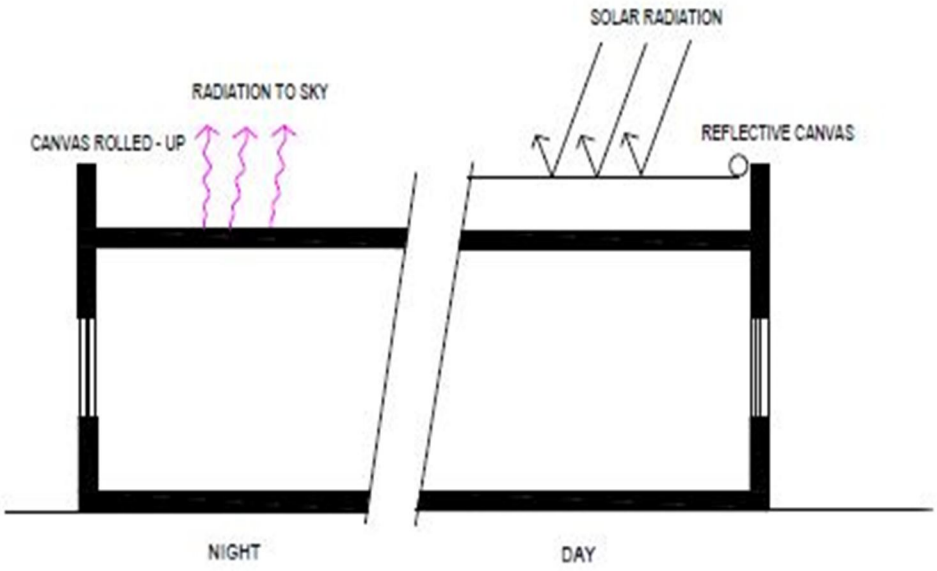


Figure 2.5: Removable roof shades.

Source: Kamal (2012)

2.3.1.3 Shading by Trees and Vegetation

Proper Landscaping can be one of the important factors for energy conservation in buildings. Vegetation and trees in particular, very effectively shade and reduce heat gain. Trees can be used with advantage to shade roof, walls and windows. Shading and evapotranspiration (the process by which a plant actively release water vapor) from trees can reduce surrounding air temperatures as much as 5°C. Different types of plants (trees, shrubs, vines) can be selected on the basis of their growth habit (tall, low, dense, light permeable) to provide the desired degree of shading for various window orientations and

situations. The following points enumerated by Kamal (2012) should be considered for summer shading;

1. Deciduous trees and shrubs provide summer shade yet allow winter access. The best locations for deciduous trees are on the south and southwest side of the building. When these trees drop their leaves in the winter, sunlight can reach inside to heat the interiors.

2. Trees with heavy foliage are very effective in obstructing the sun's rays and casting a dense shadow. Dense shade is cooler than filtered sunlight. High branching canopy trees can be used to shade the roof, walls and windows.

3. Evergreen trees on the south and west sides afford the best protection from the setting summer sun and cold winter winds.

4. Vertical shading is best for east and west walls and windows in summer, to protect from intense sun at low angles, e.g. screening by dense shrubs, trees, deciduous vines supported on a frame, shrubs used in combination with trees.

5. Shading and insulation for walls can be provided by plants that adhere to the wall, such as English ivy, or by plants supported by the wall, such as jasmine.

6. Horizontal shading is best for south-facing windows, e.g. deciduous vines (which lose foliage in the winter) such as ornamental grape or wisteria can be grown over a pergola for summer shading.

2.3.2 Materials and Construction Technology

The selection of the appropriate building material for the building envelope also plays a very important role in achieving thermal comfort within the building. The amount of heat

gain or loss and wind that flows into the building depends on components of the building envelope. The important components of the building envelope that affect the performance of the building are: Walls, Roof, Window, and Surface finishes. A building characterized by high thermal mass will absorb and store heat as well as facilitate slow rise of internal temperature on hot days. The essence of massive construction is to lower the maximum day time temperature and to raise the minimum night time temperature. In warm climates it is advantageous to use massive building construction. The discomfort at night due to flow of heat from the thermal mass could be addressed by creating additional ventilation into the building. High thermal mass construction is especially important in climatic regions with high diurnal ranges. They serve no useful purpose in climates with low diurnal ranges.

In hot climates, insulation is placed on the outer face (facing exterior) of the wall or roof so that thermal mass of the wall is weakly coupled with the external source and strongly coupled with the interior. Use of 40 mm thick expanded polystyrene insulation on walls and vermiculite concrete insulation on the roof has brought down space-conditioning loads of the retreat building in Gurgaon by about 15% (Majumdar, 2001). Air cavities within walls or an attic space in the roof ceiling combination reduce the solar heat gain factor, thereby reducing space-conditioning loads. The performance improves if the void is ventilated. Heat is transmitted through the air cavity by convection and radiation (Figure 2.6).

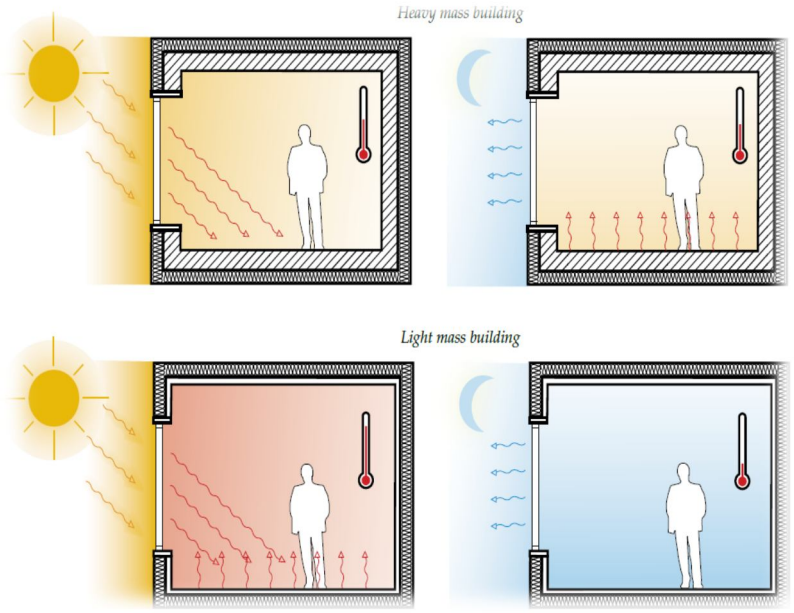


Figure 2.6: Effects of thermal mass

Source: Mikler et al. (2008)

2.3.2.1Buffer Spaces

Buffer spaces such as double facades and sunspaces are located along the building perimeter and can be occupied or unoccupied, as well as semi-conditioned or unconditioned. They improve building energy performance by widening the range of outdoor temperatures in which thermal comfort can be maintained in the building with low mechanical energy consumption. Especially helpful during winter, buffer spaces create another insulation layer in front of the envelope, slowing the rate of heat loss between the outdoors and the indoor conditioned space. Ideally, they should be convertible to fully exterior space during summer to aid in ventilation and cooling of the adjoining occupied space. See Figures 2.7 and 2.8.

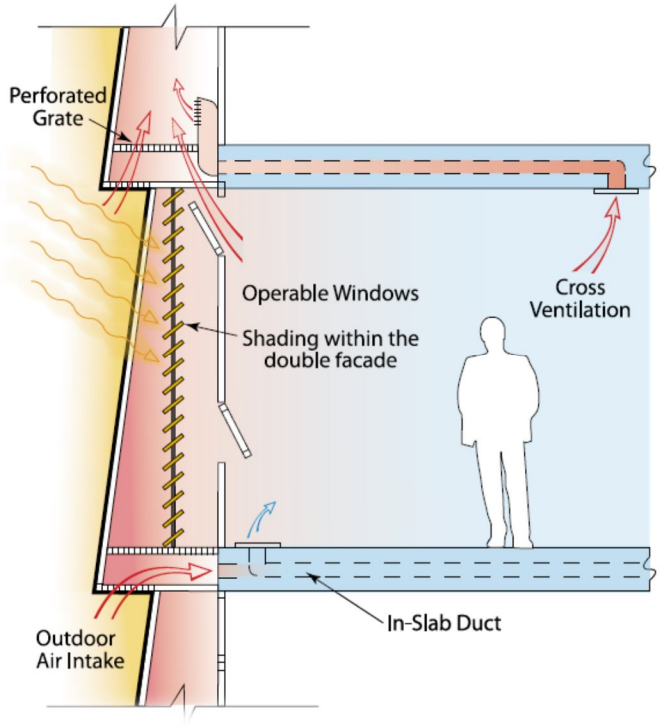


Figure 2.7: Double facade as buffer space (summer performance)

Source: Mikler el al. (2008)

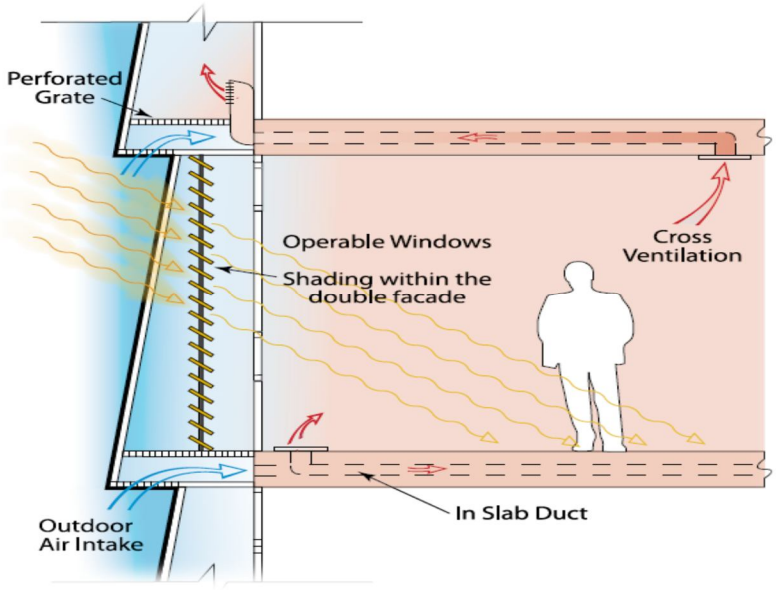


Figure 2.8: Double facade as buffer space (winter performance)

Source: Mikler el al. (2008)

2.3.3 Induced Ventilation Techniques

A primary strategy for cooling buildings without mechanical assistance (passive cooling) in hot climates is to employ natural ventilation. Ventilation is the process of replacing air in any space to provide high indoor air quality (i.e. to control temperature, replenish oxygen, or remove moisture, odors, dust and carbon dioxide). The following techniques are used to achieve induced ventilation in a building:

i. Solar Chimney
ii. Air vents
iii. Wind Towers

2.3.3.1 Solar Chimney

A solar chimney is a modern device that induces natural ventilation by the thermal-buoyancy effect. The structure of the chimney absorbs solar energy during the day, thereby heating the enclosed air within and causing it to rise. Thus air is drawn from the building into an open near the bottom of the chimney. The air exhausted from the house, through the chimney, is replaced by ambient air (Figure 2.9). However, if the latter is warmer than the air inside the house, as it usually is during the day in hot climates, the continued use of the solar chimney will then begin to heat the structure of the building previously cooled overnight (Barbera et al., 1984). The solar chimney is used to exhaust hot air from the building at a quick rate, thus improving the cooling potential of incoming air from other openings. Thus solar chimneys having a relatively low construction cost, can move air without the need for the expenditure of conventional forms of energy, and can help achieve comfort by cooling the building structure at night (Figure 2.10). They can also improve the

comfort of the inhabitants during the day if they are combined with an evaporative-cooling device (Taleb, 2014).

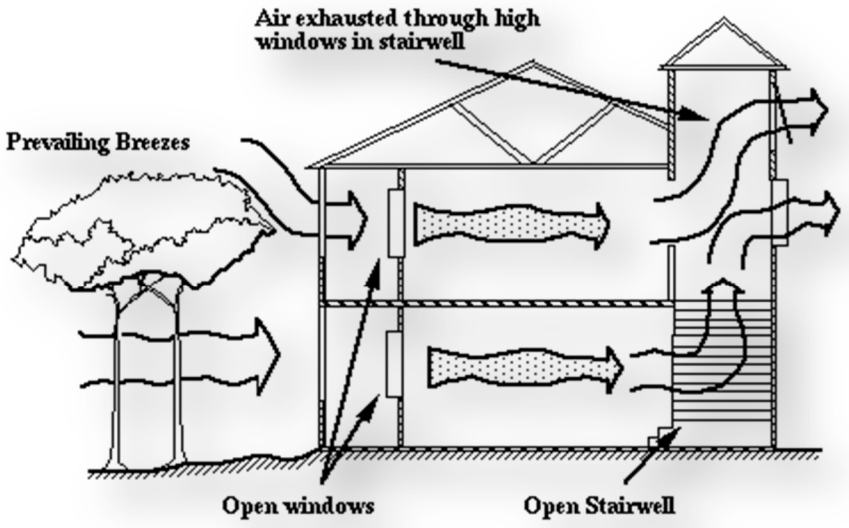


Figure 2.9: Thermal chimney effect built into a building

Source: Taleb (2014)

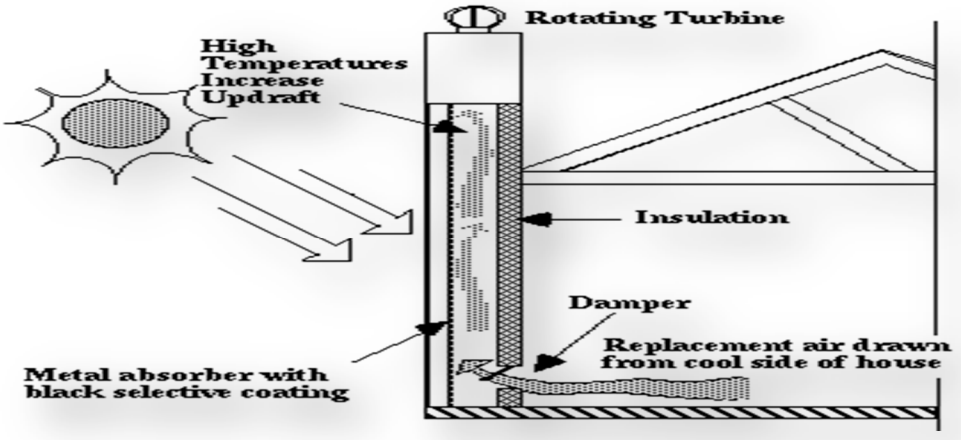


Figure 2.10: Solar Chimney

Source: Taleb (2014)

2.3.3.2 Air vents

Curved roofs and air vents are used in combination for passive cooling of air in hot and dry climates, where dusty winds make wind towers impracticable. Suited for single units, they work well in hot and dry and warm and humid climates. A hole in the apex of the domed or cylindrical roof with the protective cap over the vent directs the wind across it (Figure 2.11). The opening at the top provides ventilation and provides an escape path for hot air collected at top. Arrangements may be made to draw air from the coolest part of the structure as replacement, to set up a continuous circulation and cool the living spaces. The system works on the principle of cooling by induced ventilation, caused by pressure differences.

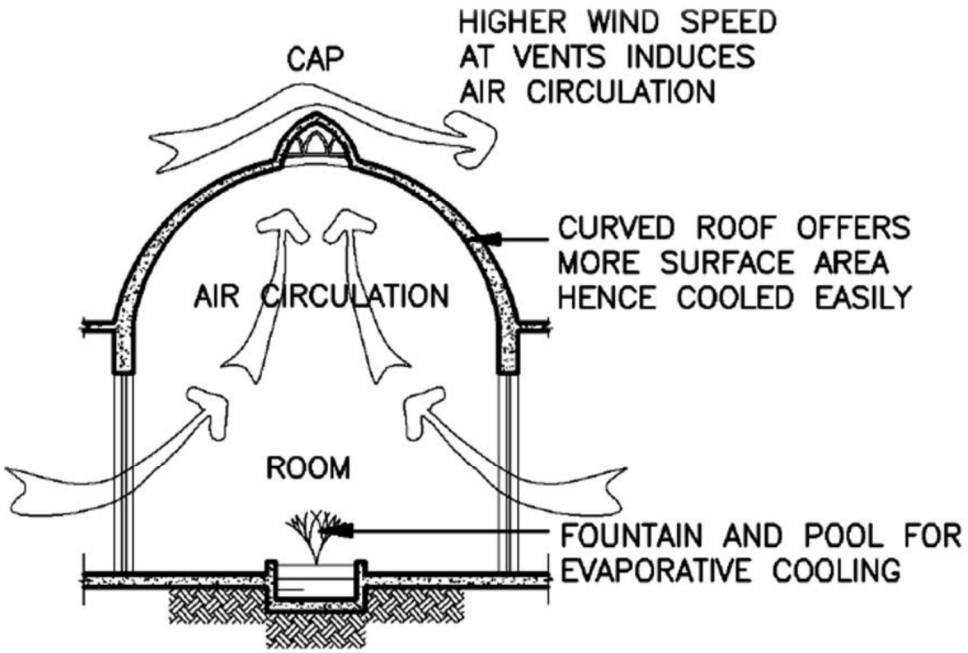


Figure 2.11: Induced ventilation through curved roof and air vents

Source: Taleb (2014)

2.3.3.3Wind Tower

In a wind tower, the hot ambient air enters the tower through the openings in the tower, gets cooled, and thus becomes heavier and sinks down. The inlet and outlet of rooms induce cool air movement. When an inlet is provided to the rooms with an outlet on the other side, there is a draft of cool air. It resembles a chimney, with one end in the basement or lower floor and the other on the roof. The top part is divided into several vertical air spaces ending in the openings in the sides of the tower (Figure.2.12). In the presence of wind, air is cooled more effectively and flows faster down the tower and into the living area. The system works effectively in hot and dry climates where diurnal variations are high.

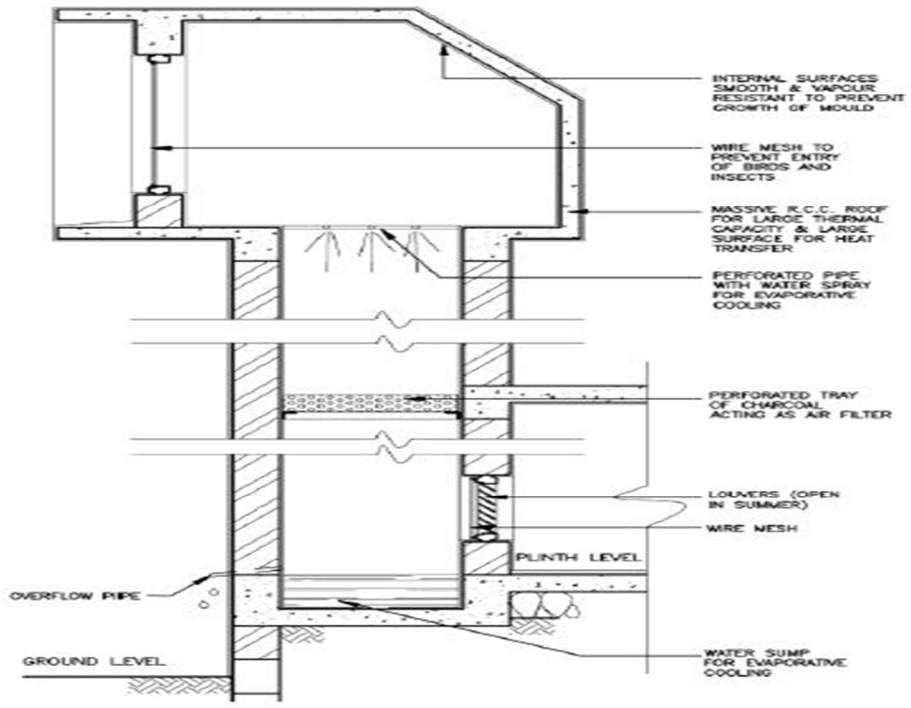


Figure 2.12: Section and detail of a wind tower.

Source: Taleb (2014)

2.3.4 Evaporative Cooling

Ford (2001) defined Evaporative cooling as a passive architecture principle in which outdoor air is cooled by evaporating water before it is introduced in the building. Its physical principle lies in the fact that the heat of air is used to evaporate water, thus cooling the air, which in turn cools the living space in the building. However passive evaporative cooling can also be indirect. The roof can be cooled with a pond, wetted pads or spray, and the ceiling transformed into a cooling element that cools the space below by convection and radiation without raising the indoor humidity.

2.3.4.1 Passive Downdraft Evaporative Cooling

Passive downdraft evaporative cooling systems consist of a downdraft tower with wetted cellulose pads at the top of the tower. Water is distributed on the top of the pads, collected at the bottom into a sump and re-circulated by a pump. Certain designs exclude the re-circulation pump and use the pressure in the supply water line to periodically surge water over the pads, eliminating the requirement for any electrical energy input. In some designs, water is sprayed using micronizes or nozzles in place of pads, in others, water is made to drip. Thus, the towers are equipped with evaporative cooling devices at the top to provide cool air by gravity flow. These towers are often described as reverse chimneys (Figure 2.13). While the column of warm air rises in a chimney, in this case the column of cool air falls. The air flow rate depends on the efficiency of the evaporative cooling device, tower height and cross section, as well as the resistance to air flow in the cooling device, tower and structure (if any) into which it discharges (Thompson et al, 2006). Passive downdraft evaporative cooling tower has been used successfully at the Torrent Research Centre in Ahmedabad. After post occupancy evaluation by Leena and George (2007), temperatures

of 29 –30 °C were recorded inside the building when the outside temperatures were 43 – 44 °C. Six to nine air changes per hour were achieved on different floors. See Plate I.



Plate I: Torrent Research Centre in Ahmedabad.

Source: Thompson et al. (2006)

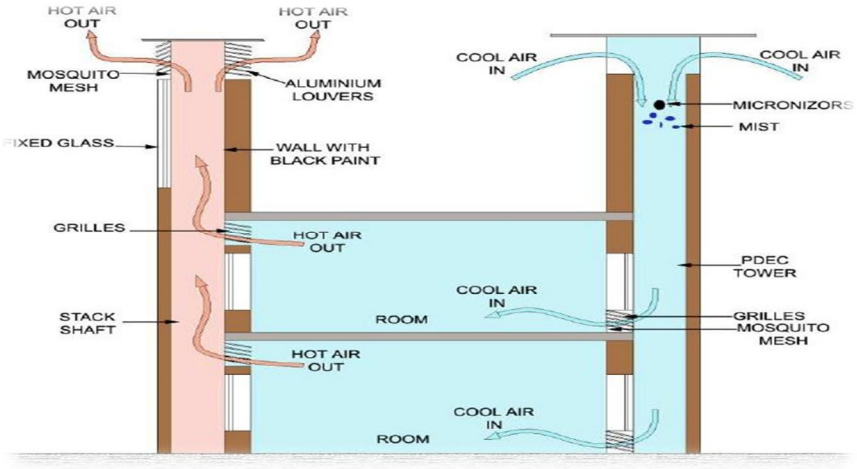


Figure 2.13: Passive downdraft evaporative cooling tower.

Source: Thompson et al. (2006)

2.3.4.2 Roof Surface Evaporative Cooling

In a tropical country, the solar radiation incident on roofs is very high in summer, leading to overheating of rooms below them. Roof surfaces can be effectively and inexpensively cooled by spraying water over suitable water-retentive materials (e.g., gunny bags) spread

over the roof surface. Wetted roof surface provides the evaporation from the roof due to unsaturated ambient air. As the water evaporates, it draws most of the required latent heat from the surface, thus lowering its temperature of the roof and hence reduces heat gain. However, the water requirement for such arrangement is very high and it is a main constrain in the arid region to adopt this technique (Kumar 2005).

2.3.5 Building Orientation

According to Bhatia (2008) the fact that sun is lower in the sky in winter than in summer allows us to plan and construct buildings that capture that free heat in winter and reject it in summer. The orientation of the whole building plays an important part; the ideal orientation for hot and dry climates should be to keep long axis of the building East-West as shown in Figure 2.14. This will reduce the heat gain. Conversely, buildings with their long axis running north/south will have higher peak cooling loads and will require larger cooling equipment and obviously high energy costs. Many site considerations can affect the passive design approach, including urban design opportunities and constraints, building orientation on the site, shade from other buildings, wind pattern, proximity to industry, noise, and urban character. These all need to be considered to optimize the integrity of passive design strategies and some may pose design conflict. The importance of orientation in a building must be considered at the outset, when the architect is planning the location of the building on the site, the aim being to ensure the maximum comfort for occupant in the interior spaces.

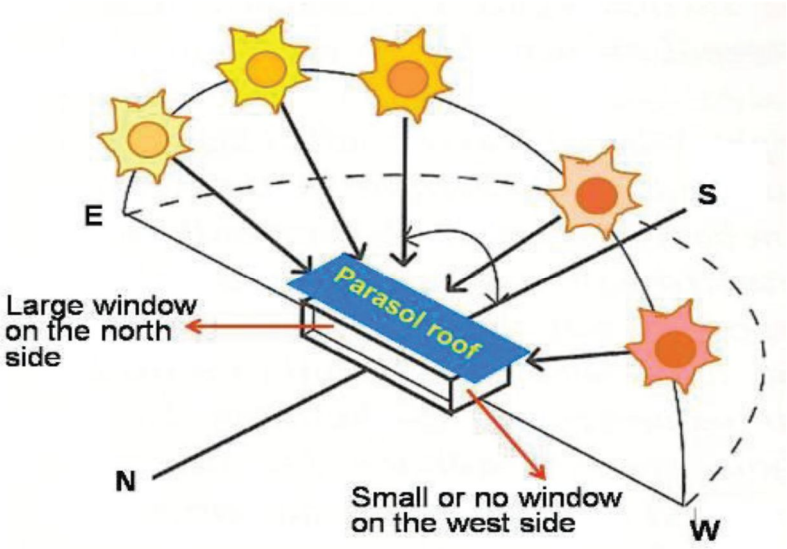


Figure 2.14: Perfect orientation of building

Source: Koch- Nelson (2002)

2.3.6 Building Form

Building form and have great potential to reduce building energy intensity, but they often fall under the influence of great array of factors (planning considerations, building type and use, feasibility and initial cost). Certain common building shapes greatly increase envelope area to volume ratio (e.g., thin high-rise towers), which can decrease building energy performance in heating dominant buildings. With a similar square footage, buildings with a smaller exterior envelop area will achieve better energy-efficient performance. A compact building shape significantly reduces the building's energy intensity and reduces the need for active mechanical systems (Mikler *et al.*, 2008).

Holtz (n.d.) observed that elongated shapes are beneficial for all kinds of passive solar buildings, but especially day lighted buildings. An elongated building can have as much as a 15-25% reduction in energy use over a compact building of the same size, due to its greater ability to use daylight. Rosenlund (2000) gathered that the form of the roof is also

very important in passive design. This is because cylindrical and dome roofs have a higher heat transfer coefficient and larger area than flat roofs of the same base. The area of the roof that absorbs solar energy is nearly the same, whereas the convection heat transfer area is higher for the curved types.

2.4 Passive Cooling Techniques

According to Geetha (2012) cooling is the transfer of energy from a space or from the air, to a space, in order to achieve a lower temperature than that of the natural surroundings. Passive cooling techniques are therefore associated with the thermal comfort of the occupants of a building. The passive cooling of buildings is broadly categorized under three sections namely;

i. Heat prevention/reduction, (Reduce heat gains)
ii. Thermal moderation (Modify heat gains) and
iii. Heat Dissipation (Remove internal heat).

2.4.1 Heat Prevention/Reduction, (Reduce Heat Gains)

It is very important to know that minimizing internal heat gain will improve the efficiency of passive cooling techniques. The site design is influenced by economic considerations, zoning regulations and adjacent developments, all of which can interfere with the design of a building, with regard to the incident solar radiation and the available wind. Vegetation does not only give pleasant outdoor spaces but also enhances the microclimate and hence reduces the energy required for cooling. Solar control is the primary design measure to be

employed for heat gain protection. Therefore, various shading devices should be used to prevent the penetration of incident solar radiation into the building.

2.4.2 Thermal Moderation Techniques

The heat gain in a building could be managed in two ways: that is through the use thermal mass and passive cooling techniques. Thermal mass is a material with high thermal capacity capable of absorbing and storing heat during the day. It is typically contained in walls, floors, and partitions. The heat stored in the thermal mass is released in the night to the surrounding when the air temperature is lower than that of the thermal mass. The passive cooling method involves the use of additional ventilation to cool the building at night. And this coolness is extended to the early morning hours of the following day, thereby saving cooling energy by up to 20%. Because the outdoor air temperature is cooler than that of the indoor air at night, the night ventilation techniques are based on the use of the cool ambient air to reduce the indoor air temperature, and also the temperature of the building's structure. Several factors affect the cooling efficiency of night ventilation including the relative difference between indoor and outdoor temperatures at night, the air flow rate, the thermal capacity of the building, and the efficient coupling of the air flow and thermal mass (Geetha, 2012).

2.4.3 Heat Dissipation Techniques

Geetha (2012) opined that in most cases, the avoidance and modulation of heat gains alone may not keep the indoor temperature to the barest minimum. A more advanced cooling strategy involves heat expulsion to heat sinks, such as the upper atmosphere and the ambient sky, by the natural processes of heat transfer. The design of a building plays a very important role in influencing the cooling potential of a natural cooling technique. Natural

cooling refers to the use of natural heat sinks for the dissipation of excess heat from interior spaces, including:

a) Natural/passive ventilation,

b) Ground cooling and

c) Radiative cooling

a) Passive Ventilation

Natural ventilation is the most vital instrument for passive cooling. Generally, adequate ventilation must be allowed to promote healthy indoor spaces by enhancing air quality and giving the required levels of oxygen. Traditionally, ventilation of buildings was achieved by natural means. In most traditional buildings, infiltration levels were meant to encourage indoor air flow. However, recent buildings have minimized air infiltrations in a bid to reduce cooling or heating energy. Designing an efficient naturally ventilated building requires a good knowledge of the air flow patterns around it and the effect of the surrounding buildings. The objective is to ventilate the largest possible parts of the interior space. Achieving this objective depends on the window location, interior design and wind characteristics. Geetha (2012) observed that natural ventilation can be achieved through the following:

I. **Wind-driven cross ventilation:** this type of ventilation occurs via ventilation openings that are located on the opposite sides of an enclosed space (Figure 2.15). The depth of the building's floor span in the direction of the ventilation flow must be limited to effectively remove the heat and pollutants from the space by typical driving forces. In order to ensure sufficient ventilation flow, the

pressure difference between the inlet and outlet openings should be high, while the internal resistance to air flow should be low.

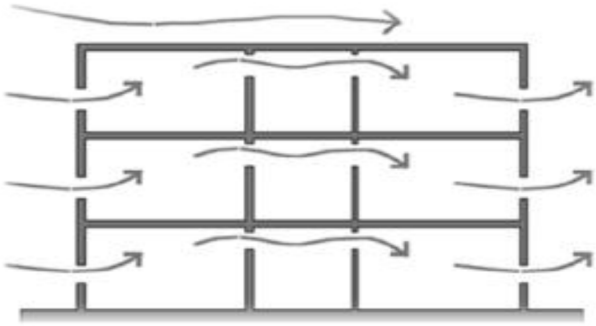


Fig 2.15: Concept of wind-driven cross ventilation

Source: Geetha (2012).

II. **Buoyancy-driven stack ventilation:** buoyancy-driven stack ventilation or displacement ventilation relies on density differences to draw cool outdoor air into the building at low ventilation openings and exhausts (Figure 2.16). A chimney or atrium is frequently used to generate sufficient buoyancy forces to achieve the desired flow. However, even the smallest wind will induce pressure distributions on the building envelope that will also act to drive the airflow

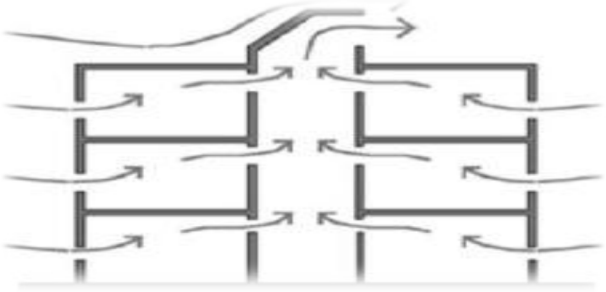


Fig 2.16: Concept of wind-driven cross ventilation

Source: Geetha (2012)

III. **Single-sided ventilation:** single-sided ventilation is generally meant to serve single rooms, and so, provides a local ventilation solution. The ventilation airflow in this case is driven by room-scale buoyancy effects and small differences in envelope wind pressures. As a result, the driving forces for single-sided ventilation tend to be relatively small and highly variable (Figure 2.17).

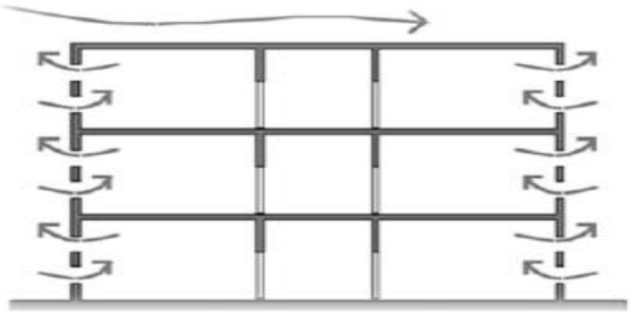


Fig 2.17: Concept of wind-driven cross ventilation

Source: Geetha (2012)

b) Ground Cooling

According to Geetha (2012), the concept of ground cooling is based on heat dissipation from a building to the ground, which during the cooling season has a temperature lower than the outdoor air. This heat dissipation can be accomplished in two ways: by direct contact of a larger section of the building envelope with the ground; by injecting air that has been previously circulated underground into the building by means of earth-to-air heat exchangers (Figure 2.18).

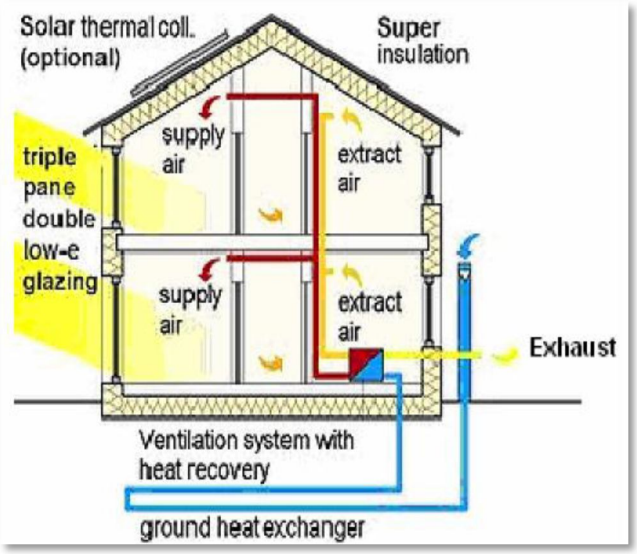


Fig 2.18: Concept of wind-driven cross ventilation

Source: Geetha (2012)

c) Radiative Cooling

Geetha (2012) stated that radiative cooling is based on heat loss by long wave radiation emission from one body towards another body of lower temperature, which plays the role of the heat sink. In the case of buildings, the emitting body is the building and the heat sink is the sky, since the sky temperature is lower than the temperatures of most of the objects on earth. The earth gives up its heat received from the sun by this mechanism, so as to maintain its thermal equilibrium. There are two methods of applying radiative cooling in buildings: direct, or passive radiative cooling, and hybrid radiative cooling. In the first, the building envelope radiates towards the sky and gets cooler, which enable heat loss from the interior of the building. In the second case, the radiator is not the building envelope, but usually a metal plate. The operation of such a radiator is the opposite of an air flat-plate

solar collector. Air is cooled by circulating it under the metal plate, before it is injected into the building.

2.5 Principles of Natural Ventilation

Busato (2003) stated that the main driving force that triggers natural ventilation in buildings is the pressure difference across the building envelope. This pressure difference can be created by wind pressure, thermal buoyancy (stack or chimney effect) or by combination of both. These effects operate in a building in varying proportions, depending on the strength of the prevailing wind and temperature conditions. In principle, airflow occurs between areas of positive and negative pressure as indicated in Figure 2.19. Cross ventilation occurs between these polarities of pressure. One empirical design rule is that openings should be widely distributed over individual surfaces and different facades of the building envelope. This ensures that the openings will be at different pressures, and that the subsequent airflows will be well distributed in the building.

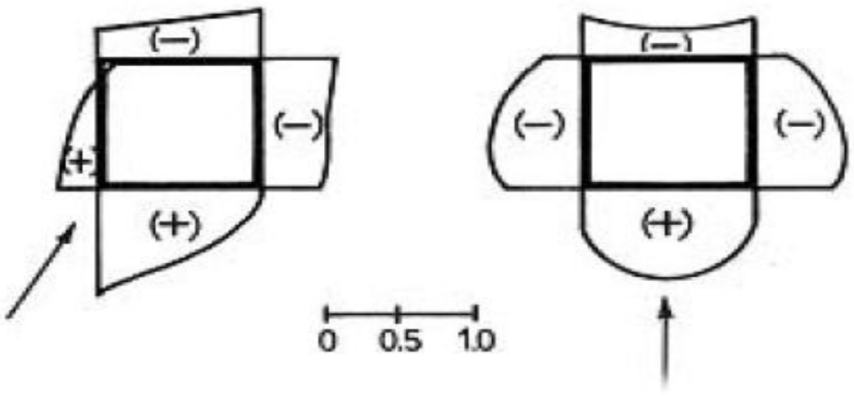


Fig 2.19: Schematic distribution of wind pressure around a building

Source: Busato (2003)

The resistance to the flow of air through the building affects the actual flow rate. Natural ventilation and infiltration are driven by pressure and suction across the building envelope as indicated in Figure 2.20 below.

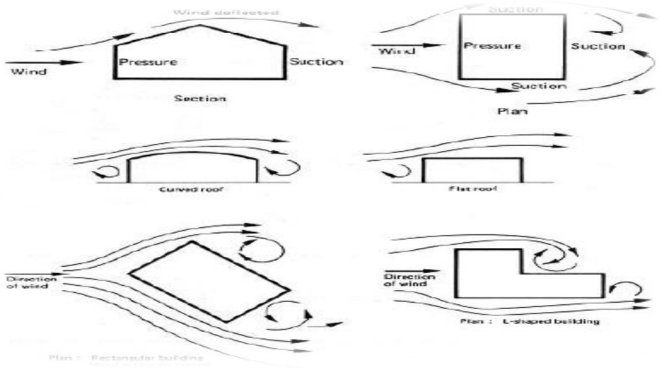


Fig 2.20: Wind pressure, suction and wind flow around buildings
Source: Busato (2003)

The shape and orientation of the building relative to the direction of the wind are both directly related to the way in which the airflow behaves around volumes. Other obvious factors affecting airflow patterns around the building are the topography, the physical relationship to surrounding volumes and obstacles: other buildings, fences, vegetation etc. The relationship between high and low rise buildings, for instance, can cause turbulence increasing the air velocity resulting in greater wind pressures. The positioning of buildings within the “leeward shadow” or suction zone of the structures can also have a considerable impact on the amount of air going through the air inlets of naturally ventilated buildings. In order to avoid this shadow effect, the distance between the buildings has to be at least six times the height of the first obstructing volume. Alternatively, a staggered volume can be used as shown in Figure 2.21 below.

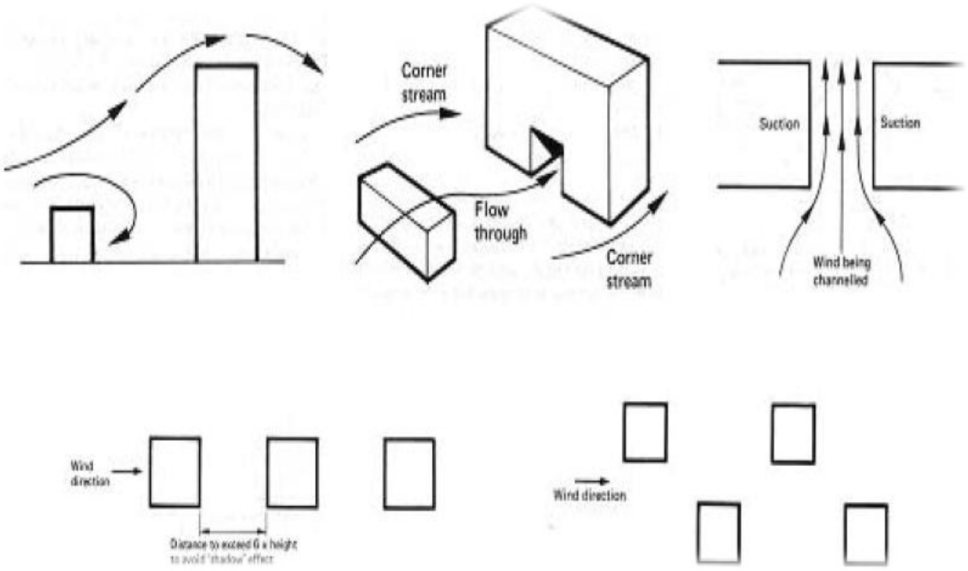


Fig 2.21: Windflow and shadow effect between buildings
Source: Busato (2003)

2.6 Energy and the Environment

Construction is one of the most important economic sectors worldwide. The total world's annual output of construction is close to $3 trillion and constitutes almost one-tenth of the global economy , about 30% of the business is in Europe, 22% in the United States, 21% in Japan, 23% in developing countries and 4% in the rest of the developed countries (Carrier industry council of Australia, 2013). Energy consumption of the building sector is high. Buildings use almost 40% of the world's energy; although figures differ from country to country, buildings are responsible for about 30-40% of the total energy demand. Application of intensive energy conservation measures has stabilized energy consumption for heating in developed countries. However, energy needs for cooling increases in a dramatic way (Adnot, 1999). Greenhouse gas emissions cause global warming which is detrimental to our environment. The earth is covered by a blanket of gases in the

atmosphere which allows light energy from the sun to reach the earth's surface. This light energy is converted to heat energy. These gases are called greenhouse gases. Most of the heat is re-radiated towards space but some is trapped by greenhouse gases in the atmosphere. This is a natural effect, which keeps the earth's temperature at levels necessary to support life. The problem we face is that human actions – particularly burning fossil fuels and land clearing – are generating more greenhouse gases. These additional gases trap more heat and raise the earth's surface temperature. This is known as the enhanced greenhouse effect – it causes global warming and is changing our environment. Reducing the use of energy reduces the power generation where the majority of greenhouse gases are generated.

2.6.1 Energy Use in Nigeria

Nigeria has a broad base and abundance of fuel sources: hydro, natural gas, coal, solar, wind and geothermal. However the use of these fuel sources has been largely skewed in favors of hydro power and crude oil, leaving the other sources either untouched or poorly harnessed. It has been established that fossil fuels accounts for 94% of exports from Nigeria in 2006 with only a small fraction of this available for domestic use and about 40% of households connected to the national electricity grid (Akpu, 2012). Thus, the greenhouse gases associated to fossil fuel consumption in such areas will be likely higher thereby increasing the risk of global warming and climate change. Greenhouse gases are also produced from other sources either natural (combustion, respiration) or artificial (deforestation and other human activities). A large percentage of Nigeria's populace relies on fuel wood for cooking (Nwofe, 2013) which then makes the environment largely polluted with greenhouse gases such as carbon (iv) oxide and carbon (ii) oxide. The United

Nations Environmental programme (UNEP), sustainable construction and Building Initiative (SCBI) noted that 30-40% of the global energy use comes from the building sector (U.S. Environmental Protection Agency, 2012). This implies that use of energy efficient buildings will offset the greenhouse gases (CO2, CO, CH4) by 30-40% which could have emanated from the building sector thereby saving our climate from the negative effect of these gases.

2.6.2 Energy Efficient Buildings

Energy efficient buildings are designed in a way that ensures that energy is used at a reduced cost, and in a sustainable and conserved manner. Energy efficient building is a cure to attaining a "sustainable city or eco-city". Eco-cities are designed to achieve maximum comfort by occupants with emphasis on reduced energy inputs, water and food, waste output of heat, and reduced air, noise and water pollution (Devuyst, 2011). Energy efficient building is relatively unknown in Nigeria due to certain factors which include: ignorance/illiteracy, poverty, lack of awareness and/or poor Government policies toward achieving such concepts in buildings.

2.7 Renewable Energy Systems Integration

The integration of renewable energy systems into the building at the very early stage of the design process is an important issue regarding sustainable building. By means that, it is very important to consider which technologies will be more suitable according to the site conditions and the building structure.

According to Abdeen (2012) integrating renewable system into the building, such as PVs and wind turbines, represents a good practice that has many advantageous aspects, such as:

i. It works as both building envelope material and energy generator
ii. It saves in materials and energy costs
iii. It drastically reduces CO2 emissions
iv. It actually adds architectural value to the building as well as providing a public expression of sustainable commitment.

2.7.1 Building Integrated Photovoltaic

Basically, an integrated renewable system into the building is used to replace conventional materials on the building envelope, such as the roof, façade or skylights. The integrated systems is increasingly becoming a good practice because the initial cost can be offset by reducing the amount of cost spent for producing and installing building materials. In fact, the systems, mostly PV and in some case Solar Panels are used to construct part of the building and they are available in several forms (Abdeen, 2012).

According to the envelope in which they will be integrated, they can be available in different types, such as:

i. a thin film solar cell integrated into a flexible polymer roofing membrane suitable for flat roofs (Plate II)
ii. modules roof tiles, solar shingles and panels normally used in pitched roofs
iii. solar modules mounted on the façade of the building
iv. (Semi) transparent modules used to replace architectural components made with glass, such as windows or skylights, which can work as well as shading (Plate III.



Plate II: Thin film solar cell integration for flat roofs

Source: Abdeen (2012)



Plate III: Integration of PhotoVoltaic as shading

Source: Abdeen (2012)

The International Energy Agency IEA has fixed some architectural parameters to better define an integrated energy system into the building. In particular to what concert the integration of PVs, it suggests that the system:

i. Must be naturally and architecturally integrated into the building context

ii. Must be adapted at the building modular system and being in harmony with it in order to create a well material composition.

A well designed integration means that the renewable energy system is turned into a part of the roof/façade, becoming a weatherproof skin of the building itself and working as insulation as well. Building Integration PV system (BIPV), for example, is becoming a common practice because it can drastically reduce the overall cost of the construction because the panels are perfectly integrated into the building and mounting racks are no longer required (Smith, 2003). The system as also the advantage to be turned into an aesthetically pleasing energy generator system that is does not require roof penetration and that can give a new image to the whole building.

2.7.2 Wind Turbines Integration

Smith (2003) opined that wind turbines integration is a good choice of renewable energy as it is cheaper in terms of installed cost per kilowatt than photovoltaic cells and therefore it is an attractive proposition as a building integrated power source. In addition, urban wind turbines are gaining acceptance over large scale wind farms because large scale projects are being constructed in isolated locations which require making the infrastructure for transmitting the generated power and distributing it among end users, which is costly and causes power losses during transmission and distribution. The idea of exploiting wind energy in the built environment is attractive because wind energy is considered one of the most reliable clean sources of energy on the planet and wind turbines are likely to be in operation for about 85% of the year, and have a service life of at least 20 years.

Islam *et al.* (2011) classified three methods of integrating wind turbines into the built environment; the first is the building integrated wind turbines, where a separate wind turbine is located on a free-standing tower away from the building itself; the second is the building mounted wind turbines, where the wind turbine is installed on to the building

structure and the third is the building augmented wind turbines where the building form is shaped to concentrate wind flow and is shaped towards the wind turbine.

2.8 Thermal Comfort in Educational Buildings

The American Society of Heating, Refrigerating and Air-Conditioning Engineers defines thermal comfort as that condition of mind which expresses satisfaction with the thermal environment. A definition most people can agree on, but also a definition that is not easily converted into physical parameters. Thermal comfort is a key component for quality of indoor environments. Environmental elements such as heat from electrical lighting, lack of adequate ventilation, high humidity levels, and poorly performing building envelopes can contribute to health problems at workplaces. Thermal discomfort in school buildings can create unsatisfactory conditions for both teachers and students (Fademi et al., 2014). This can be distracting for the occupants and is likely to reduce their productivity and performance. The challenge is to come out with self-sustaining buildings which will facilitate learning and overcome the state of discomfort with minimum energy utilization. It is worth noting that generally, most of the research conducted revealed that building occupants ascertained indoor thermal condition to be acceptable even though the thermal sensation votes (TSV) exceeded those specified by the highly recognized American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) standard . This standard specifies conditions in which majority of the occupants will find their environment thermally acceptable. The standard suggests that there might be other contributory factors (psychological, health state of occupants, adaptation, etc.) which are responsible for this occurrence. In addition, the negative effects of heat on student's learning capacity can be alarming.

There are six major factors that determine comfort (CIBSE, 2007). They are:

1. Ambient air temperature

2. Humidity

3. Radiation

4. Air movement

5. Clothing

6. Activity

Other factors such as age, sex, body shape, state of health, ethnic grouping and diet may have some effect on thermal comfort but research (Nicol *et al.*, 2012) shows they are not significant.

2.9 National Universities Commission: Benchmark Minimum Academic Standard for Agriculture Programmes in Nigerian Universities

According to Nigerian Universities Commission (NUC, 2007), the Benchmark Minimum Academic Standards (BMAS) are for the training of undergraduate students wishing to obtain first degrees in the different areas of Agriculture. The Benchmark Minimum Academic Standards for undergraduate training in the Agriculture Discipline is broad-based and designed to give a more practical and functional training in the various areas of the Agriculture discipline.

2.9.1 Programmes and Degrees in View

The departments that should constitute the initial phase of the proposed Faculty of Agriculture Complex, Federal University Gusau include Soil science, Animal Science, Crop Science, Agriculture economics and rural sociology, fisheries and Forestry and wood technology. They are chosen to be the take-off or pioneer departments in order to meet up with the professional requirements of the region, and also due to their strong relevance in the Agriculture discipline.

2.9.2 Philosophy and Objectives of Agriculture Discipline

Production of graduates that are adequately equipped with the comprehensive theoretical knowledge and practical skills required for engaging in productive and economic agricultural production. The objectives of the programmes are:

a. To produce graduates geared towards self-employment;

b. To produce graduates with sufficient technical, productive and entrepreneurship skills who will be involved in production, research and entrepreneurship in any aspect of agriculture and other related disciplines;

c. To produce graduates that are relevant to themselves, the industry and society and who can contribute effectively to national development goals in Agriculture.

2.10 Chapter summary

This chapter began with an extensive review of relevant literature on various passive architecture principles. These numerous principles were then wrapped up to six, comprising of solar shading, Materials and construction technology, induced ventilation techniques, evaporative cooling, building orientation and building form, enough to suit the

requirements of the climatic region under consideration. The next part of this chapter contains an elaborate discussion on natural cooling and ventilation as being the natural means of providing the building's operational energy. There was also a brief overview on the use of Building Integrated Photovoltaic and wind turbines as a way of complementing the electricity from the grid. The last part the chapter examines the provision of NUC regarding the benchmark minimum academic standard for Faculty of Agriculture.

3.0 RESEARCH METHODOLOGY

3.1 Introduction

This chapter describes the methodology and the procedures applied to achieve the objectives of this research. It consists of; research design, sampling technique, variables of the study, analysis method, data collection procedures and the instruments for data collection.

3.2 Research Design

This research adopts a descriptive research approach. Descriptive approach is used for exploratory studies with interest in finding out the relationships between identified variables. The study adopted the case study methodology, because this allows the researcher to explore and understand complex issues. In case study research**,** the researcher provides a detailed account of one or more cases. Case study research usually relies on qualitative data, and can be used to address exploratory, descriptive, and explanatory research questions (Yin, 2009). This case study is based on the evaluation of design principles that reflect passive architecture design approach in educational buildings.

3.3 Population of the Study and Sampling Technique

The population of study is with respect to the building and not its users', this is due to the nature of the variables and research method which is qualitative. Therefore the population for the study is educational building in Universities located in hot dry climate of Nigeria.

Jonson and Christensen (2008) noted that case study selection was comparable to sampling in a quantitative research and that cases were usually purposely selected. This meant that

cases were identified for study due to their inherent qualities which were in consonance with the phenomenon under investigation. The sampling method used was a purposive sampling in which the buildings chosen typified the particular character.

The sample selection criteria were based on;

i. Educational buildings in hot dry climate which provide spatial organizational context for designing Faculty of Agriculture.
ii. Federal Government owned Univerisity

The sample for the study included three Faculty of Agriculture selected from different universities in Nigeria. These are

i. Faculty of Agriculture, Ahmadu Bello University, Zaria
ii. Faculty of Agriculture, Beyero University, Kano
iii. School of Agriculture and Agricultural Technology, Federal University of Technology, Minna.

3.4 Variables of the Study

Case study research in Architecture goes beyond the documentation and description of the physical characteristics of the built environment. Therefore, to give a full assessment of the selected case studies in the research, they have to be judged based on the research question or proposed design problem. This can be in the form of variables that seek to point out certain features associated to the research. The variables in this research are classified into dependent and independent variables.

3.4.1Dependent Variables

The dependent variables are:

i. Energy conservation

ii. Thermal comfort

3.4.2 Independent Variables

The independent variables are:

i. Orientation
ii. Form of the building
iii. Solar shading
iv. Induced ventilation techniques
v. Building materials and construction
vi. Evaporative cooling techniques

3.5 Data Collection

The following methods are adopted for data collection:

i. Literature Review and Documentation: Review of existing literature was carried out on passive architecture principles. Architectural data books (useful for obtaining design guides, functional flows, space requirements), journals, unpublished thesis projects in the research area (to review contributions to research), were also evaluated.

ii. Case Studies: A case study offers an opportunity to study a particular subject in depth, and usually involves gathering and analyzing information that may be both qualitative and quantitative. Qualitative analysis of case studies were carried out based on the design principles that reflect passive architecture. The method used to carry out the case study was Visual Survey. A visual survey was done by looking

and identifying what has been achieved by the already existing buildings with reference to integrating passive architecture principles in educational buildings.

3.6 Instrument of Data Collection

The instruments of data collection used in this study are: Photographs, Sketches and Notes.

3.6.1 Photographs

Photographs were taken of relevant case studies to ascertain the features of passive architecture they possess as well as the extent, to which they were applied, that is to say, if their extent of application was excellent, very good, strong, weak, very weak or non-existent.

3.6.2 Sketches

Sketches were made of some parts of the selected case studies. These sketches showed the spatial organization of some of the case studies.

3.6.3 Notes

These notes where in form of field forms outlining the variables of passive architectural design as they relates to educational buildings.

3.7 Procedures of Data Collection

The procedure for data collection involved visits to three local case studies and taking a visual analysis of their architectural features paying more attention to passive architecture principles. These buildings were then evaluated on the created field forms or field paper.

3.8 Data Analysis and Presentation

Analysis of the collected data is based on the descriptive accounts as observed and noted through the instruments of data collection which shows how the elements and features of passive architecture design principles have been applied to archive a suitable learning environment.

This description covered primarily two aspects;

i. Passive architecture design principles
ii. Spatial organization and design

The data are represented in the following form:

i. Photographs: pictures of the existing Faculty building were taken and documented showing the facilities and how passive architecture elements were applied.
ii. Tables: Data collected were documented and presented in the case study assessment tables.

3.9 Check List

To assess case studies, dependant and independent variables are identified. This aids the researcher to produce an assessment check list(Table 3.1) based on literature reviewed (Akande, 2010; Arif, 2012; Zaki *et* al., 2008; Geetha , 2012) in chapter two that provides features connected to passive architecture principles adopted. A Likert scale was used in the checklist to show how effective these principles were applied. The respective scores from the Likert scale are; 5 (Excellent) means the application was very high, 4 (Very good)

means the application was high, 3 (Good) means the application was moderate, 2 (Weak) means the application was low and 1 (very weak) means the application was very low.

Table 3.1 Passive Architecture Principles Checklist

PASSIVE ARCHITECTURE PRINCIPLES **Scale Factor: Excellent = 5, Very good = 4, Good = 3, Weak = 2, Very weak = 1.**		
VARIABLES	SCALE FACTOR	REMARK
1. SOLAR SHADING		
(a) Shading by overhangs, louvers and awnings		
(b) Shading by roof		
(c) Shading by trees and vegetation		
(d) Shading by textured surfaces		
2. MATERIALS AND CONSTUCTION		
(a) High thermal mass building materials		
(b) Double glazing		
(c) Cavity walls		
3. INDUCED VENTILATION TECHNIQUES		
(a) Solar Chimney		
(b) Air Vent		
(c) Wind Tower		
(d) window openings		
4. EVAPORATIVE COOLING		
(a) Passive downdraft evaporative cooling		
(b) evaporative cooling by surrounding water body		
5. BUILDING FORM		
6. ORIENTATION		

Source: Researcher, (2015) based on (Akande, 2010; Arif, 2012; Zake etal., 2008 and Geetha, 2012)

4.0 DATA PRESENTATION AND DISCUSSION

4.1Introduction

This chapter presents data collected from three case studies. These are Faculty of Agriculture Ahmadu Bello University (A.B.U) Zaria, Faculty of Agriculture Beyero University (B.U.K) Kano and School of Agriculture and Agricultural Technology (F.U.T.M) Minna. The objective is to evaluate the level of Passive Architecture principles they exhibit.

4.2 Case Study One: Faculty of Agriculture Ahmadu Bello University (A.B.U) Zaria

4.2.1 Background

According to the A.B.U's website, the Faculty of Agriculture, Ahmadu Bello University, Zaria, is the oldest and one of the leading Agricultural Schools in Nigeria and in the West African Sub-region. The Faculty is made of eight (8) departments mixed with some facilities (abu.edu.ng).

The following sections discussed Passive architecture principles and renewable energy sources as shown in checklist under the headings; Solar Shading, Insulation, Induced ventilation techniques, Evaporative cooling, Building form, orientation and renewable energy sources.

4.2.2 Solar Shading

The faculty buildings have a well-designed sun control and shading devices placed in the building's facade. These reduce the building peak heat gain and cooling requirements (Plate IV).



Plate IV: Solar shading devices within the Faculty, A.B.U Zaria

Source: Researcher (2015)

There is also proper landscaping which provide shade and reduces heat gain, these trees also provide shade to the roofs, walls and windows (Plate V).



Plate V: Soft landscape within the Faculty, A.B.U Zaria

Source: Researcher (2015)

4.2.3 Materials and construction

The building materials used are sandcrete blocks of low thermal mass, meaning that they have low time lag, or not capable of storing heat for a long time. The windows are made of

single glazing which also provide low insulation and most of the heat gain or loss is through the windows.

4.2.4 Induced Ventilation Techniques

Open able windows are provided on the external walls; in case of double banking, high level windows were provided on the corridor walls. The window openings help to move hot air out, so a buoyancy effect can be created by the use of these openings. In the faculty building there is no solar chimney, air vent and wind towers which can enhance the ventilation of the buildings. See (Plate VI).



Plate VI: open able windows provided within the Faculty, A.B.U Zaria

Source: Researcher (2015)

4.2.5 Evaporative Cooling

There is no means for evaporative cooling such as a water body and passive downdraft evaporative cooling within the faculty. A water body can cool the air when it combines with water and evaporates leading to reduction in air temperature. It should also be noted that water does not simply cool the air, it also cleans it.

4.2.6 Building Form

Most of the buildings within the faculty are rectangular in shape. This affects exposure to wind as well as sunshine accessibility. The shape also limits its exposure on east and west sides, and consequently results for shallow floor plan that encourages natural cross ventilation. See Plates VII, VIII and IX.



Plate VII: Rectangular form buildings within the Faculty, A.B.U Zaria

Source: Researcher (2015)

4.2.7 Orientation

Most of the buildings within the faculty are oriented with longer sides facing the north and south axis, and most of the fenestrations are on this axis with fewer on the east and west (Plate VIII).



Plate VIII: Fenestrations on the north façade, A.B.U Zaria

Source: Researcher (2015)



Plate IX: Aerial view of the faculty showing building form and orientation, A.B.U Zaria

Source: Researcher (2015)

Table 4.1 Case Study one assessment sheet: Faculty of Agriculture ABU Zaria.

PASSIVE ARCHITECTURE PRINCIPLES
Scale Factor: Very High = 5, High = 4, Moderate = 3, Low = 2, Very Low = 1, Not Available = 0.

VARIABLES	SCALE FACTOR	REMARK
1. SOLAR SHADING		
(a) Shading by overhangs, louvers and awnings	5	
(b) Shading by roof	3	POSITIVE
(c) Shading by trees and vegetation	5	
(d) Shading by textured surfaces	4	
2. MATERIALS AND CONSTRUCTION		
(a) High thermal mass building materials	2	
(b) Double glazing	1	NEGATIVE
(c) Cavity walls	1	
3. INDUCED VENTILATION TECHNIQUES		
(a) Solar Chimney	0	
(b) Air Vent	1	NEGATIVE
(c) Wind Tower	0	
(d) window openings	5	
4. EVAPORATIVE COOLING		
(a) Passive downdraft evaporative cooling	0	NEGATIVE
(b) evaporative cooling by surrounding water body	0	
5. BUILDING FORM	5	POSITIVE
6. ORIENTATION	4	POSITIVE
TOTAL SCORE = 36 out of 85 points which is 42%		

Source: Researcher, (2015).

4.3 Case Study Two: Faculty of Agriculture Beyero University Kano

4.3.1 Background

Bayero University Kano (BUK) is a university situated in Kano, Kano state. It was founded in 1977. It is located approximately 12.8 kilometers from the city along the Kano- Gwarzo road. The Faculty of Agriculture (BUK) is made of five departments with the vision to provide a world class environment for high quality academic and training in all areas of Agriculture, trough teaching, research and extension to local and international communities.

4.3.2 Solar Shading

The buildings in the faculty do not have a well-designed sun control and shading devices placed in the building's facade. There seems to be no deciduous trees around the site to provide additional shading. The design does not exhibit any attempt to shade the roof, which is the major receptor of solar radiation (Plate X).



Plate X: Buildings within the faculty without shading devices and with little landscaping, B.U.K

Source: Researcher (2015)

4.3.3 Building Materials and Construction

The walls are of sandcrete blocks, which are of poor thermal capacity. The roof is gently sloped and covered with corrugated long span aluminum roofing sheet. The walls were built as single wall construction (Plate XI). The roof is also not doubled. Therefore, it can be concluded that the materials and construction techniques are not responsive to the climatic conditions of the region.



Plate XI: Low thermal materials and construction which provide inadequate insulation, B.U.K

Source: Researcher (2015)

4.3.4 Induced Ventilation Techniques

The faculty complex is generally single banked which enables windows to be easily placed on the sides of positive and negative pressure for cross ventilation.In the faculty building there is no solar chimney, air vent and wind towers which can enhance the ventilation of the buildings (Plate XII).



Plate XII: Single banked building with operable windows, B.U.K

Source: Researcher (2015)

4.3.5 Evaporative Cooling

There is no provision for evaporative cooling such as a water body and passive downdraft evaporative cooling within the faculty. A water body can cool the air when it combines with water and evaporates leading to reduction in air temperature.

4.3.6 Building Form

The faculty building is semi hexagonal in shape. It is also not a compact form as all the offices are spread in single banking, thereby exposing most of the perimeter walls to sunshine.

4.3.7 Orientation

Due to the irregular and oblique shape of the faculty, some of the windows with no shading devices are directly exposed to sun rays. The longer sides of the building should always be

facing North and South, especially in the tropical climate. This is to avoid hot sun from the west which brings about discomfort (Plate XIII).

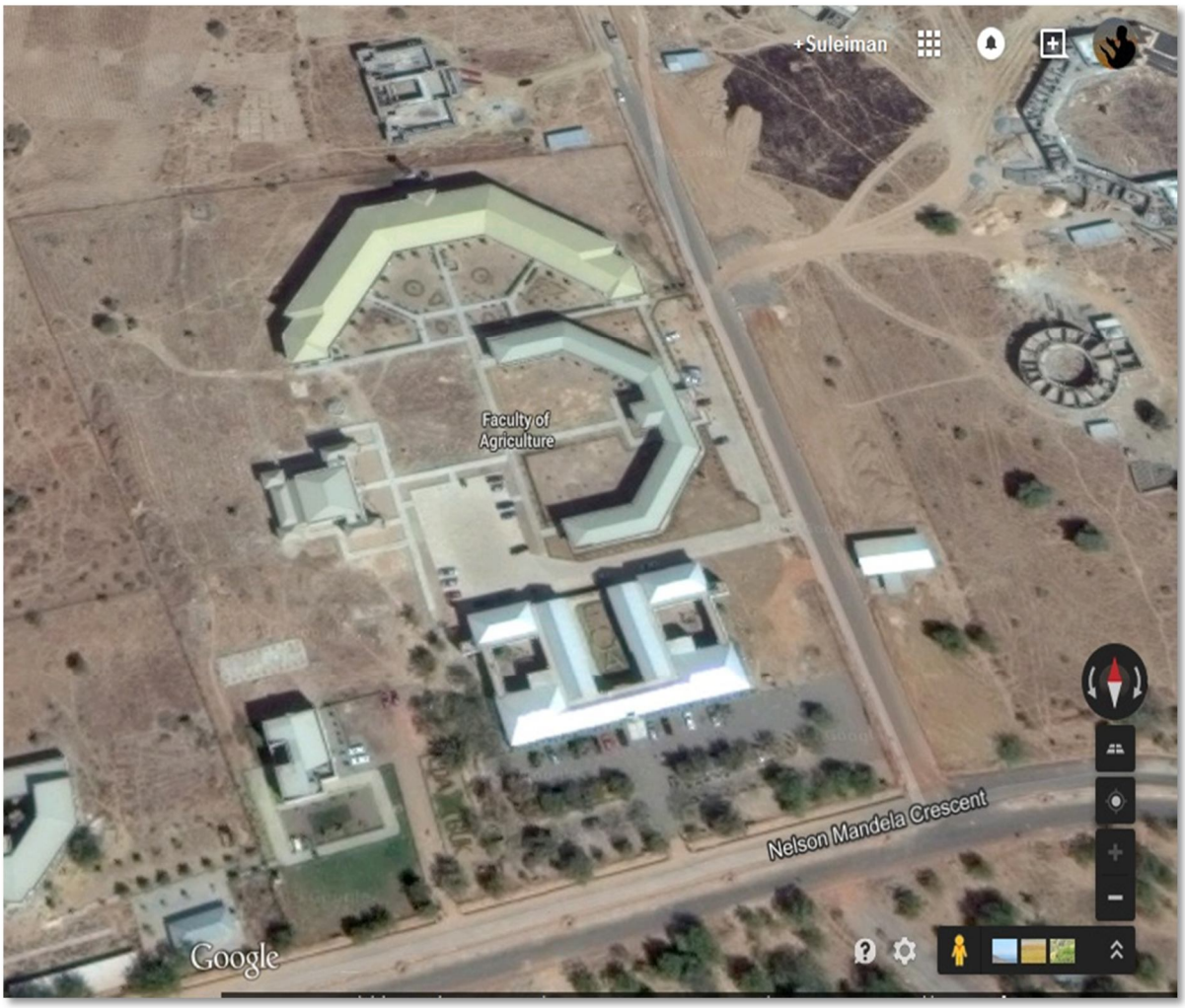


Plate XIII: Aerial view of the faculty showing building form and orientation, B.U.K

Source: Researcher (2015).

Table 4.2 Case Study two assessment sheet: Faculty of Agriculture BUK.

PASSIVE ARCHITECTURE PRINCIPLES
Scale Factor: Very High = 5, High = 4, Moderate = 3, Low = 2, Very Low = 1, Not Available = 0.

VARIABLES	SCALE FACTOR	REMARK
1. SOLAR SHADING		
(a) Shading by overhangs, louvers and awnings	1	
(b) Shading by roof	1	NEGATIVE
(c) Shading by trees and vegetation	2	
(d) Shading by textured surfaces	3	
2. MATERIALS AND CONSTRUCTION		
(a) High thermal mass building materials	2	
(b) Double glazing	1	NEGATIVE
(c) Cavity walls	1	
3. INDUCED VENTILATION TECHNIQUES		
(a) Solar Chimney	0	
(b) Air Vent	1	NEGATIVE
(c) Wind Tower	0	
(d) window openings	5	
4. EVAPORATIVE COOLING		
(a) Passive downdraft evaporative cooling	0	NEGATIVE
(b) evaporative cooling by surrounding water body	0	
5. BUILDING FORM	4	POSITIVE
6. ORIENTATION	4	POSITIVE
TOTAL SCORE = 25 out of 85 points which is 29%		

Source: Researcher, (2015).

4.4 Case Study Three: School of Agriculture and Agricultural Technology, Federal University of Technology Minna

4.4.1 Background

Federal University of Technology Minna was founded in 1983. In 2014 the university has 8 schools (Faculties). The school of agriculture and agricultural technology was established in the year 1986. Presently it is made up of five departments with mission to produce graduate that are adequately equipped with comprehensive theoretical knowledge and practical skills required for engaging in efficient agricultural production for self-employment and conducting of cutting edge problem solving research in aspects of agriculture. The following sections discuss Passive architecture principles and renewable energy sources as shown in checklist.

4.4.2 Solar Shading

Use of fin shading devices on north and south facing walls; these reduce the building peak heat gain and cooling requirements presence of deciduous and non-deciduous trees within and outside the faculty (Plate XIV).



Plate XIV: Solar shading in the north and south facing walls, F.U.T.M

Source: Researcher (2015)

The landscaping is only provided around the parking area which is not adequate, because it does not give shade to the walls and roof of the building. These trees provide conducive micro climate to the environment (Plate XV).



Plate XV: Landscaping in the parking areas, F.U.T.M

Source: Researcher (2015)

4.4.3 Materials and construction

The building materials used do not suit well the climatic region as far as passive architecture is concerned. For instance, the walls are of sandcrete blocks which have the tendency of making the interior temperature unbearable due to their uncertain thermal capacities. The roof is gently sloped and covered with corrugated long span aluminum roofing sheet (Plate XVI).



Plate XVI: Low thermal materials and construction which provide inadequate insulation, F.U.T.M

Source: Researcher (2015)

4.4.4 Induced Ventilation Techniques

Use of projectable windows on external walls; high level windows on internal walls.In the faculty building there is no solar chimney, air vent and wind towers which can enhance the ventilation of the buildings (Plate XVII).



Plate XVII: Windows for cross ventilation, F.U.T.M

Source: Researcher (2015)

4.4.5 Evaporative Cooling

There is no provision for evaporative cooling such as a water body and passive downdraft evaporative cooling within the faculty. A water body can cool the air when it combines with water and evaporates leading to reduction in air temperature. It should also be noted that water does not simply cool the air, it also cleans it.

4.4.6 Building Form

The building form is mostly rectangular which limit its exposure on east and west sides to the sun.

4.4.7 Orientation

Most of the faculty component buildings are well oriented with respect to sun and wind directions with longer side facing north and south direction (Plate XVIII).

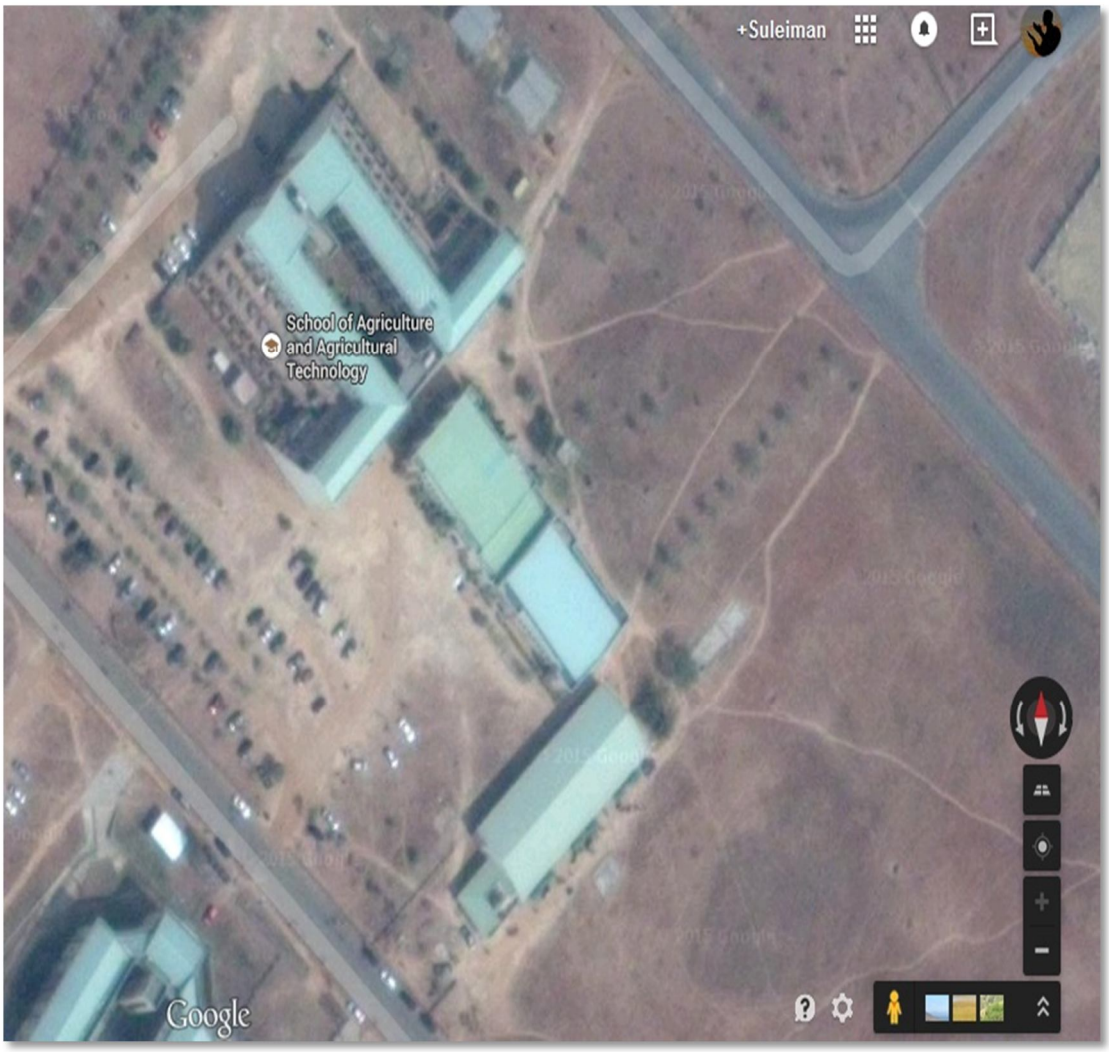


Plate XVIII: Aerial view of the faculty showing building form and orientation, F.U.T.M

Source: Researcher (2015)

Table 4.3 Case Study three assessment sheet: School of Agriculture and Agricultural technology FUTM

PASSIVE ARCHITECTURE PRINCIPLES
Scale Factor: Very High = 5, High = 4, Moderate = 3, Low = 2, Very Low = 1, Not Available = 0.

VARIABLES	SCALE FACTOR	REMARK
1. SOLAR SHADING		
(a) Shading by overhangs, louvers and awnings	3	
(b) Shading by roof	3	POSITIVE
(c) Shading by trees and vegetation	2	
(d) Shading by textured surfaces	3	
2. MATERIALS AND CONSTRUCTION		
(a) High thermal mass building materials	2	
(b) Double glazing	1	NEGATIVE
(c) Cavity walls	1	
3. INDUCED VENTILATION TECHNIQUES		
(a) Solar Chimney	0	
(b) Air Vent	1	NEGATIVE
(c) Wind Tower	0	
(d) window openings	5	
4. EVAPORATIVE COOLING		
(a) Passive downdraft evaporative cooling	0	NEGATIVE
(b) evaporative cooling by surrounding water body	0	
5. BUILDING FORM	5	POSITIVE
6. ORIENTATION	4	POSITIVE

TOTAL SCORE = 30 out of 85 points which is 35%

Source: Researcher, (2015).

4.5 Summary of Findings and Discussion

Figure 4.1 and Table 4.4 illustrate comparison between the principles applied by each case study. 'Solar Shading' has been most applied by Faculty of Agriculture ABU because; it has shading devices on the windows and a well landscaped environment that aids solar shading. The least in score in terms of solar shading is faculty of Agriculture Beyero University Kano (B.U.K) which has little or no shading devices on the windows, and there are no deciduous trees around the sites to provide additional shading.

'Induced ventilation techniques' has also been poorly applied in all the cases. All the cases do not have wind towers, air vents and solar chimneys, which aid in providing induced ventilation. The only means of natural ventilation applied by the cases is the windows, because some of the windows are placed at one end of positive pressure, and other windows at the other end of negative pressure which aid in providing wind driven cross ventilation.

'Evaporative Cooling' has not been applied by all three cases. There is no provision for evaporative cooling such as a water body and passive downdraft evaporative cooling within the buildings

'Building form and Orientation' these two principles are inter-related and so all three cases score similar marks. The building form is mostly rectangular which limit its exposure on east and west sides to the sun. Most of the buildings are well oriented with respect to sun and wind directions with longer side facing north and south direction.

Table 4.4 Comparison of passive architecture principles in the case studies

Passive Architecture Principles	A.B.U % Score	B.U.K % Score	F.U.T.M % Score
Solar Shading	85	35	55
Materials and construction	27	27	27
Induced Ventilation Techniques	30	30	30
Evaporative Cooling	0	0	0
Building Form	100	80	100
Orientation	80	80	80

Source: Researcher, (2015)

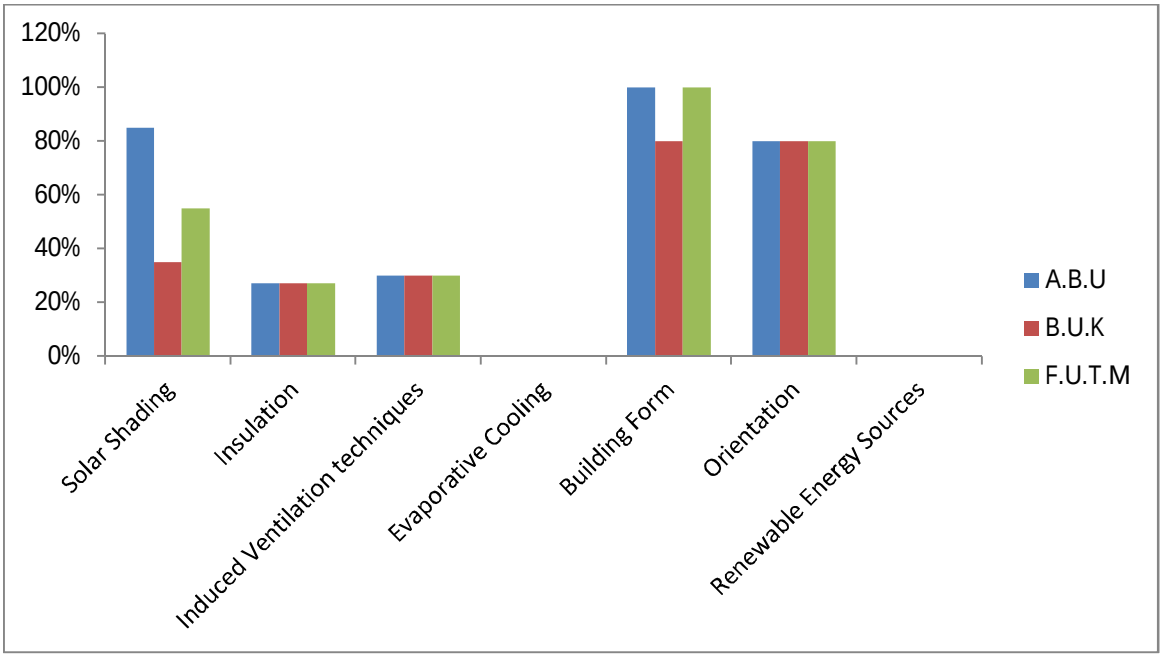


Fig. 4.1: Comparison of passive architecture principles in the case studies

Source: Researcher (2015)

Faculty of Agriculture Ahmadu Bello University Zaria scored the highest, making it the best case study that features almost all the passive architecture elements under consideration, followed by then School of Agriculture and Agricultural technology Minna. Bayero University Kano scores the lowest as illustrated in Figure 4.2.

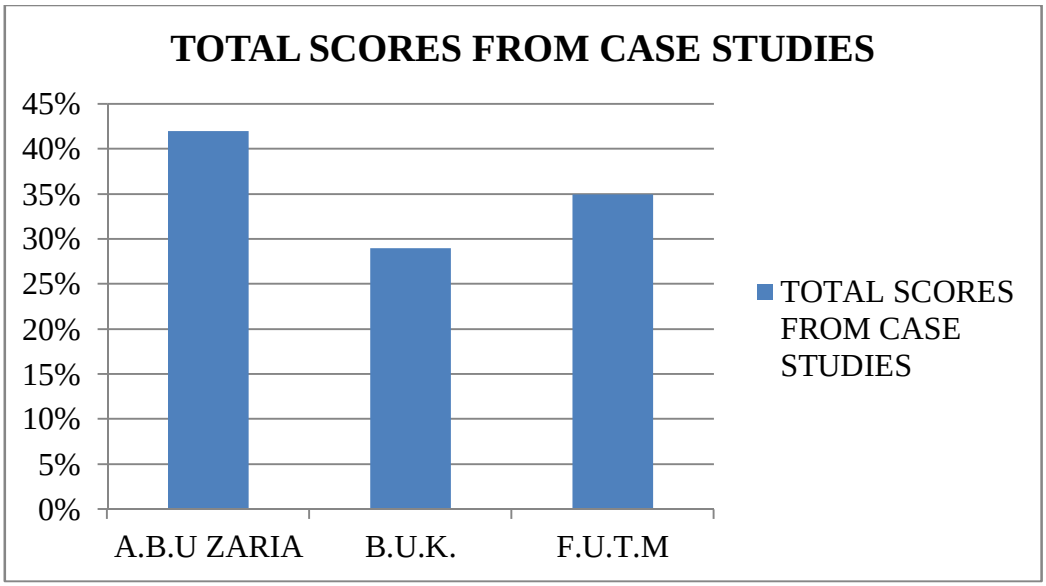


Figure 4.2: Comparison between case studies

Source: Researcher (2015)

4.6 Chapter Summary

This chapter has presented data collected from Faculty of Agriculture A.B.U Zaria, Faculty of Agriculture B.U.K, School of Agriculture and Agricultural Technology F.U.T.M, which are the three cases studied. The objective was to evaluate the level of Passive architecture principles they exhibit under the following principles; Solar Shading, building materials and construction, Induced ventilation techniques, Evaporative cooling, Building form, orientation and renewable energy sources.

Evaporative Cooling has been neglected by all three cases followed by induced ventilation techniques' while Building form, orientation and ‘Solar Shading’ seems to be the most applied. Faculty of Agriculture ABU Zaria emerges with almost all the passive architecture elements under consideration with a score of 42%

5.0 DESIGN REPORT

5.1 Introduction

This chapter is meant to explain the procedure adopted in arriving at the design of the Proposed Faculty of Agriculture, Federal University Gusau. The first part contains a brief description of the site and its features. It further gives a detail report of the proposed Faculty design and the following were properly analyzed; design concept development, student and staff population of the faculty and the facilities to support such population. The last part contains a description of the application of passive architecture principles in the proposed Faculty of Agriculture.

5.2 Site Location

The location of the site for the proposed Faculty of agriculture, Federal University Gusau, as contained in the university's master plan (Figure 5.3), is inside the school's permanent site, in Gusau, Zamfara State. It is to be located behind all the other faculties. According to (NBS, 2014) Zamfara state lies on latitudes 10 degrees 50'' and 13 degrees 10'' to the north, and longitudes 4 degrees 40'' and 7 degrees 10'' east, it shares borders with Sokoto and Kebbi states to the west, Niger state to the southwest, Kaduna to the south, Katsina state to the east and Niger republic to the north (Figure 5.1and 5.2). Zamfara state covers a land mass of approximately 39,792.00 square kilometers, representing 4% of Nigeria. It has fourteen (14) local government areas (NBS, 2014).



Figure 5.1: Map of Nigeria showing Zamfara State

Source**:** www.google.com/images (accessed 12/12/15).



Figure 5.2: Map of Zamfara showing Gusau Local government

Source**:** www.google.com/images (accessed 12/12/15).

The site was selected by the University after careful analysis of a set down criteria and the relevant guidelines for the establishment of Faculty of Agriculture. The following parameters were set down as site selection criteria;

i. Location and accessibility to the users. The ease of ingress and egress to and out of the site for both vehicle and people.
ii. Size of site and possibility for future expansion; enough land to accommodate the various functions as well as give room for future development and expansion
iii. Land use compliance; the site has to be within the land use for educational development.

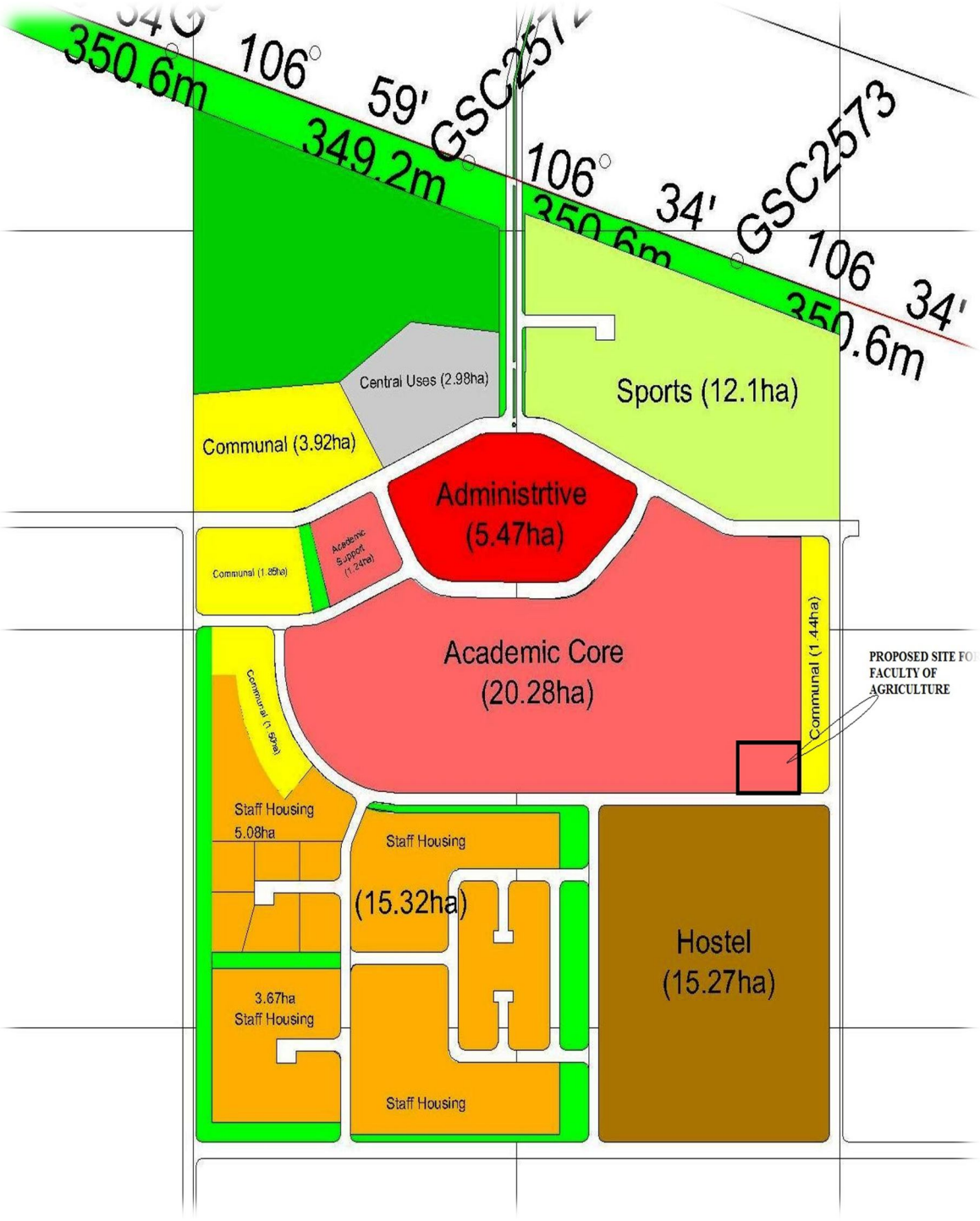


Fig. 5.3: Federal University Gusau Master Plan showing the proposed site.

Source: Department of Works Federal University Gusau (2015)

5.3 Site Topography and Climate

The site has the following features:

5.3.1 Topography

The site is relatively flat, sloping very gently towards its south eastern part (figure 5.4). In order to use the concept of natural gravity, the site drainage would follow this direction of slope, while the site water supply would come from the north western side. Plate 5.1 below shows the main access road to the site and the existing drainage surrounding the site, which flows towards the direction of the slope.

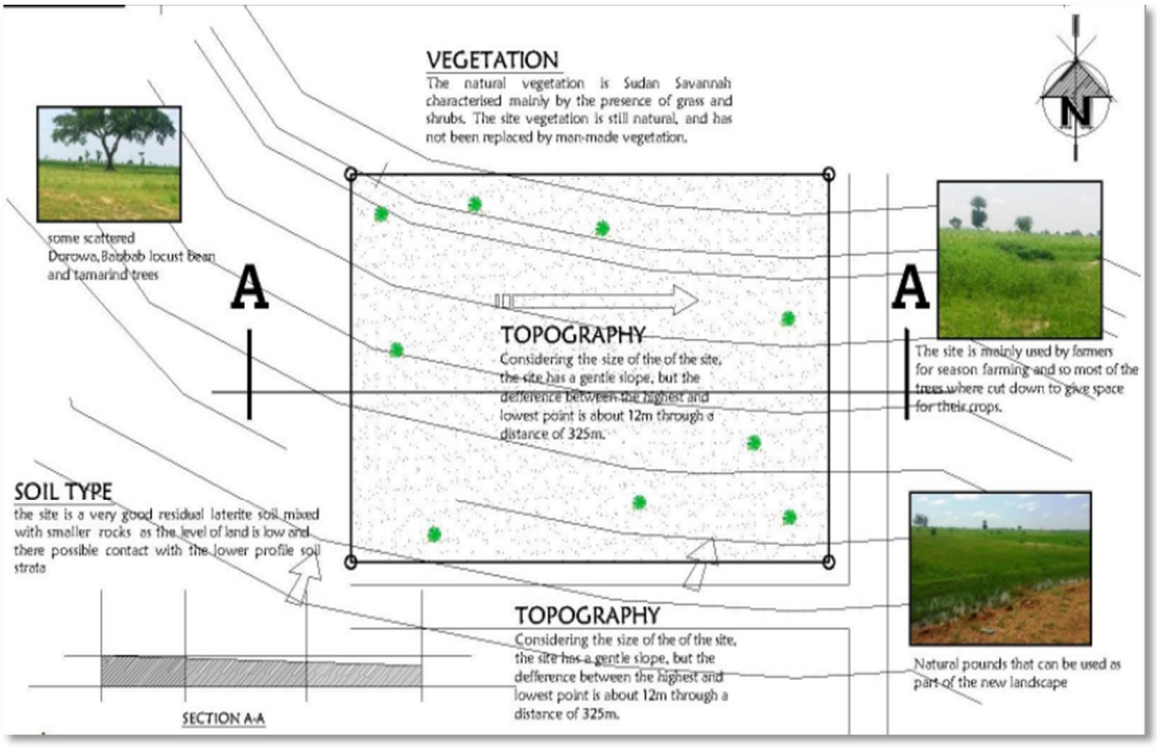


Fig. 5.4: Site Analysis (Topography) for the Proposed Faculty of Agriculture FUGUS.
Source: Researcher (2015)



Plate XIX: Access road to the proposed site.

Source: Researcher (2015)

5.3.2 Vegetation

Gusau falls in the Sudan savannah vegetation zone, which is characterized by short grasses forming a matrix for thorny structures and shrubs. Perennial forest vegetation can be found along the valleys of major rivers and streams that truncate the state together with the several cereal crops grown during the wet season, the vegetation cover moderate the harsh physical landscape.

5.3.3 Climate

The climate of Zamfara State is characterized by wet and dry seasons. The State generally experiences rainfall between May and September. The rain tends to extend to October around the South. The dry season runs through October to April and is usually

accompanied by the harmattan wind with lower temperature. Figure 5.5 below indicates the climatic analysis of the site for the proposed Faculty of Agriculture.

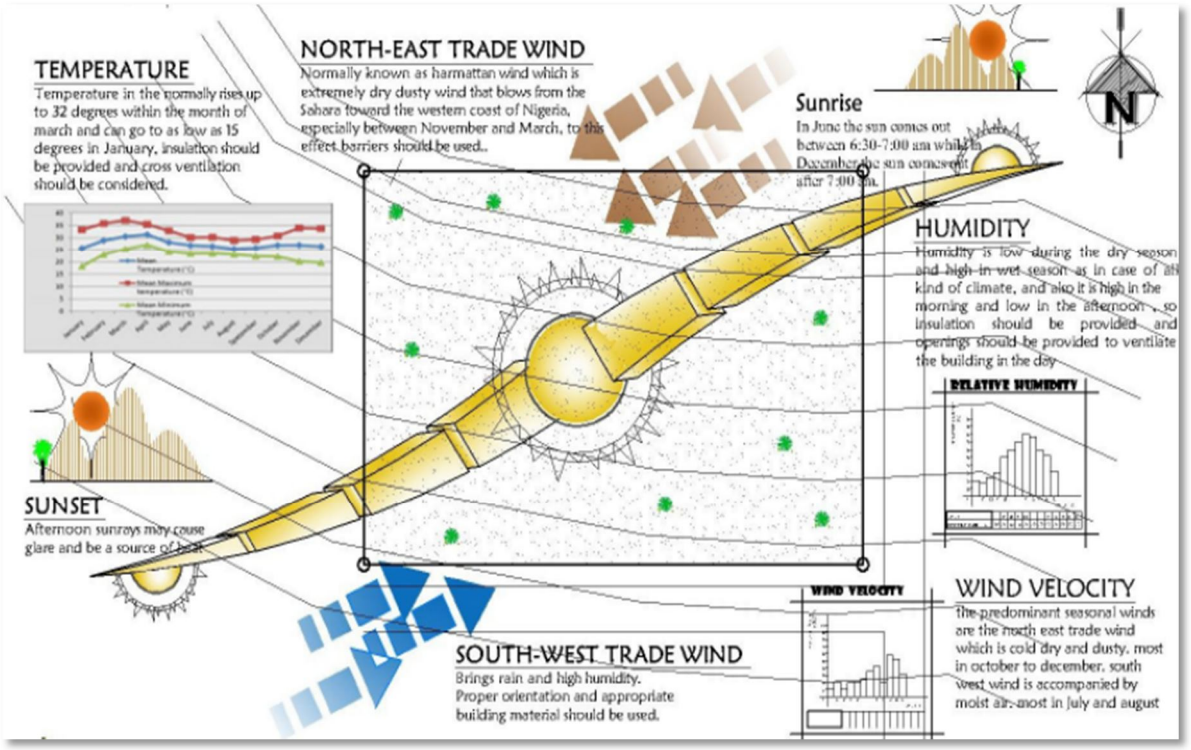


Fig. 5.5: Site Analysis (Climate) for the Proposed Faculty of Agriculture FUGUS.
Source: Researcher, (2015).

5.3.3.1 Precipitation

Records indicates that precipitation in form of rain fall is only experienced between the Months of April to October, with a fluctuation in level from the lowest in April to June to the highest in the months of July to September. Provision will be made for rain water harvesting to be stored in an underground storage facility for use in the site.

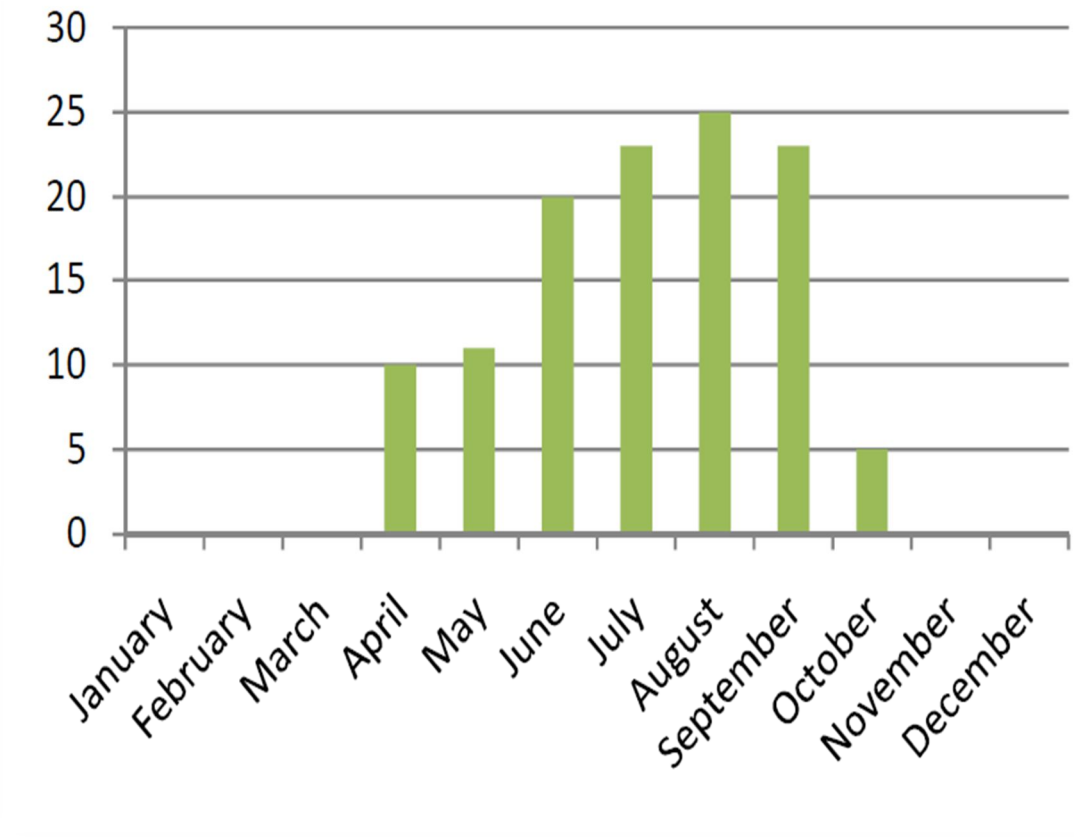


Figure 5.6 Mean Annual Rainfall 2012
Source: (http://www .gaisma.com)

5.3.3.2 Temperature

Zamfara state having fall within the hot dry region of Nigeria records temperatures of up to 40°C in hottest months, with temperature ranging from 32°C to 42°C. January is the coolest month of about 21.66°C. The temperature difference between the two extremes will be tamed by the use of appropriate building material, orientation and shading devices.

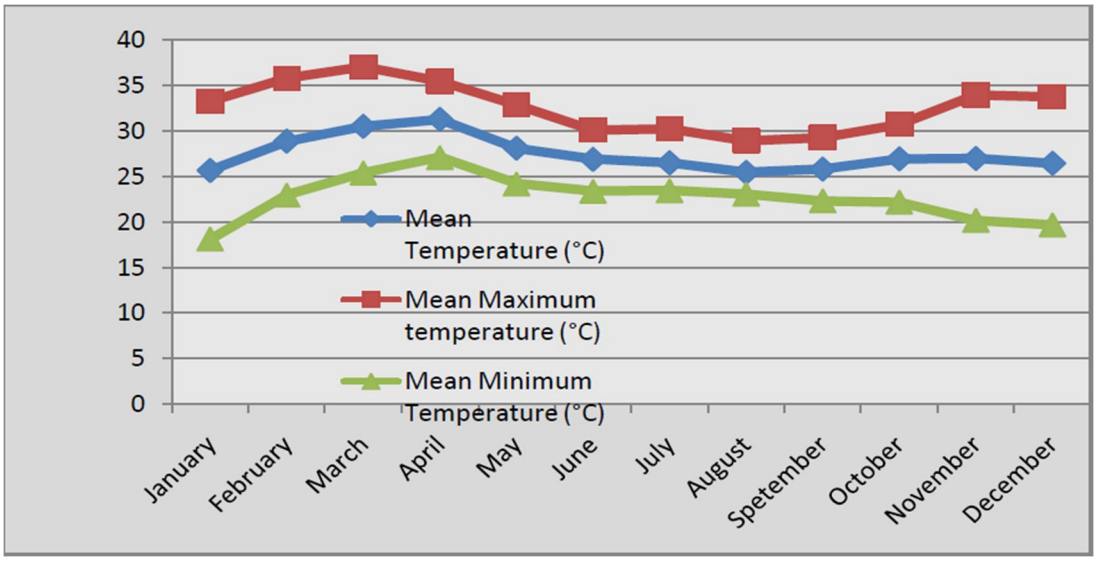


Figure 5.7: Temperature, Gusau

Source: (http://www .gaisma.com)

5.3.3.3 Prevailing Wind and Average Relative Humidity

Figure 5.8 below shows the local prevailing winds: the North East Trade Wind, which is indicated with the dark green color; the South West Trade Wind, which is shown in light green. The Average Relative Humidity of the winds decreases with increase in darkness, that is to say, the average relative humidity is lowest at the end of the north eastern region so that the North East Trade Wind has the lowest moisture content, as shown in the legend. The Faculty of Engineering shall be oriented to take advantage of the South West Trade Wind, which has the highest moisture content.

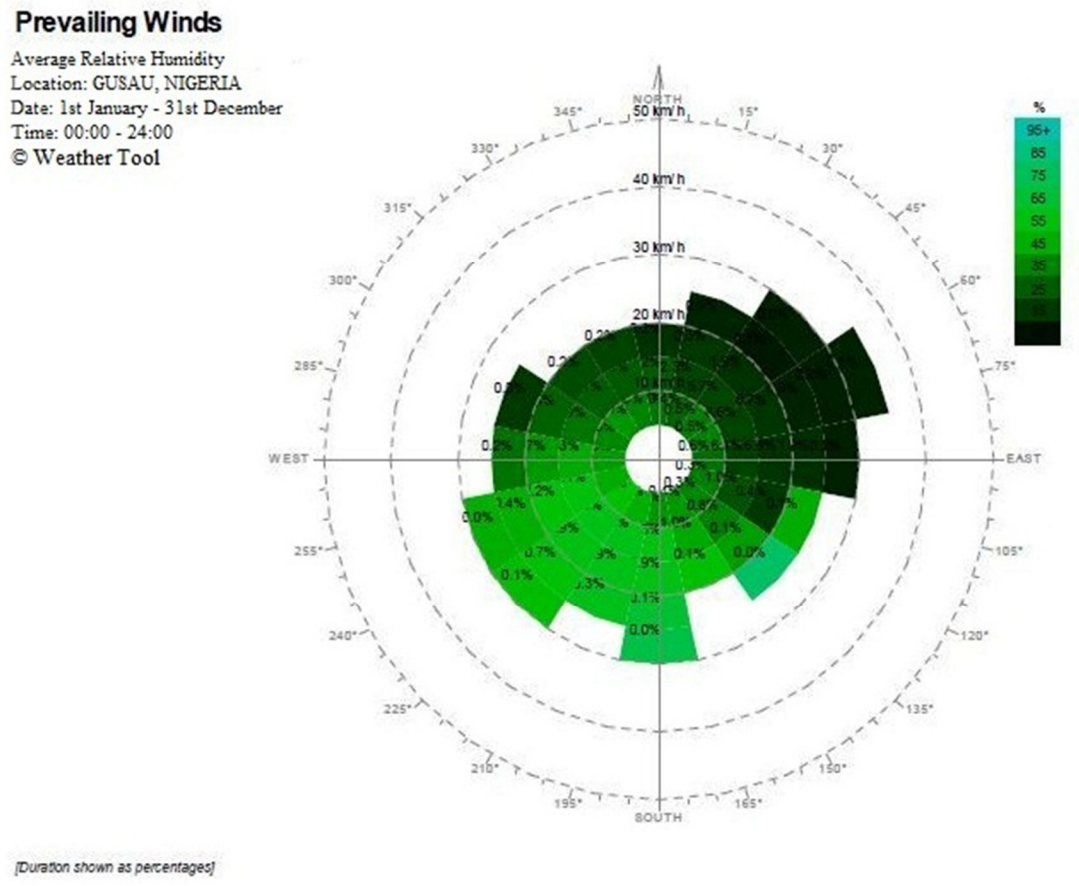


Figure 5.8: Prevailing Winds and Average Relative Humidity
Source: Weather Tool (2015)

5.3.3.4 Sun radiation

Figure 5.9 shows the variation of hours of sunshine with the time of the year, the average ranges from 6.5 hours per day in August to 10 hours per day in December. The approximate elevation angle is 73 at noon. The incidence of Sunshine during the dry season is 8.6hours per day and 6.0hours per day during at cold times. There is relatively high daily radiation which ranges from 19MJ/m in early August when temperatures are a little lower during the wet season and 25MJ/m in April when temperatures are a little higher during the dry (Hot) season. Figure 5.9 below is a Stereographic Diagram of the region that shows the

annual movement of the sun through the sky. It can be used to quickly determine both the direction and time of any solar event throughout the year.

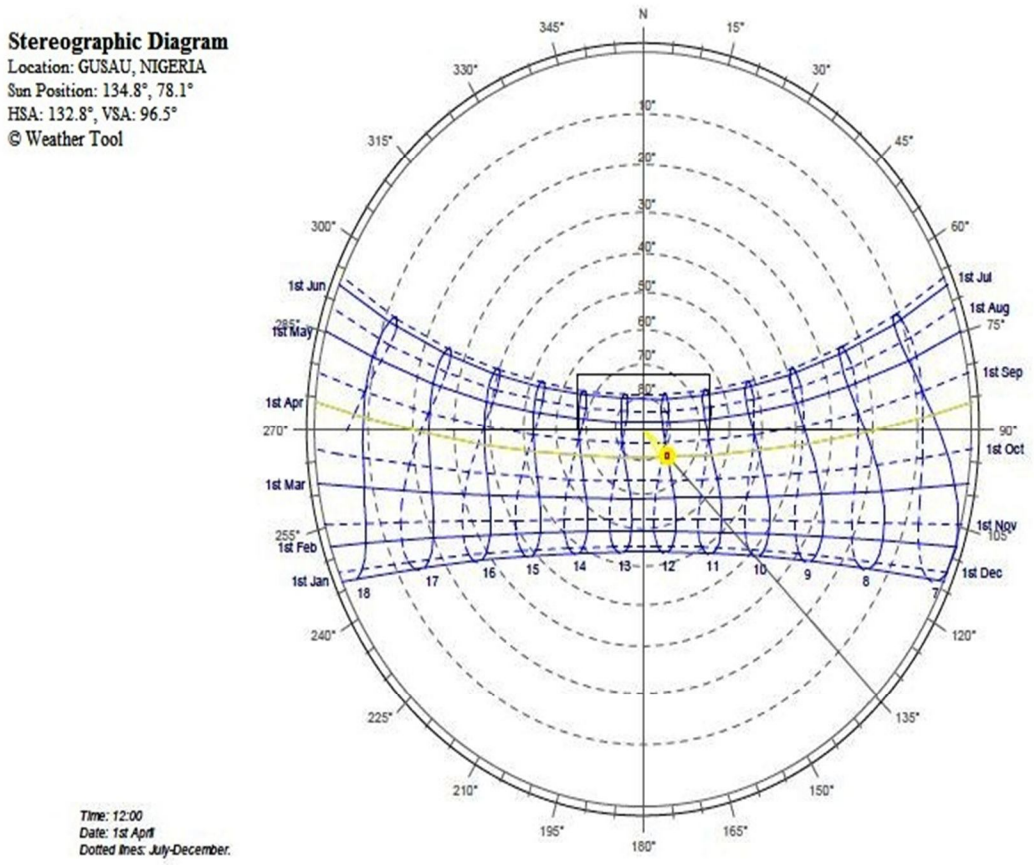


Figure 5.9: Stereographic Diagram of the Site
Source: Weather Tool (2015)

5.3.3.5 Optimum Orientation

Figure 5.10 below shows an optimum orientation based on average daily incident radiation on a vertical surface. The red arrow points to the direction of worst orientation at an incident angle of 92.5 degrees Celsius, meaning that solar radiation is strongest when the sun is at this angle, thus the larger surfaces of buildings should not be oriented at this angle.

The yellow arrow points to the direction of best orientation at an incident angle of 182.5 degrees Celsius, meaning that solar radiation is lowest when the sun is at this angle, hence the larger surface areas of the buildings should be oriented towards this angle.

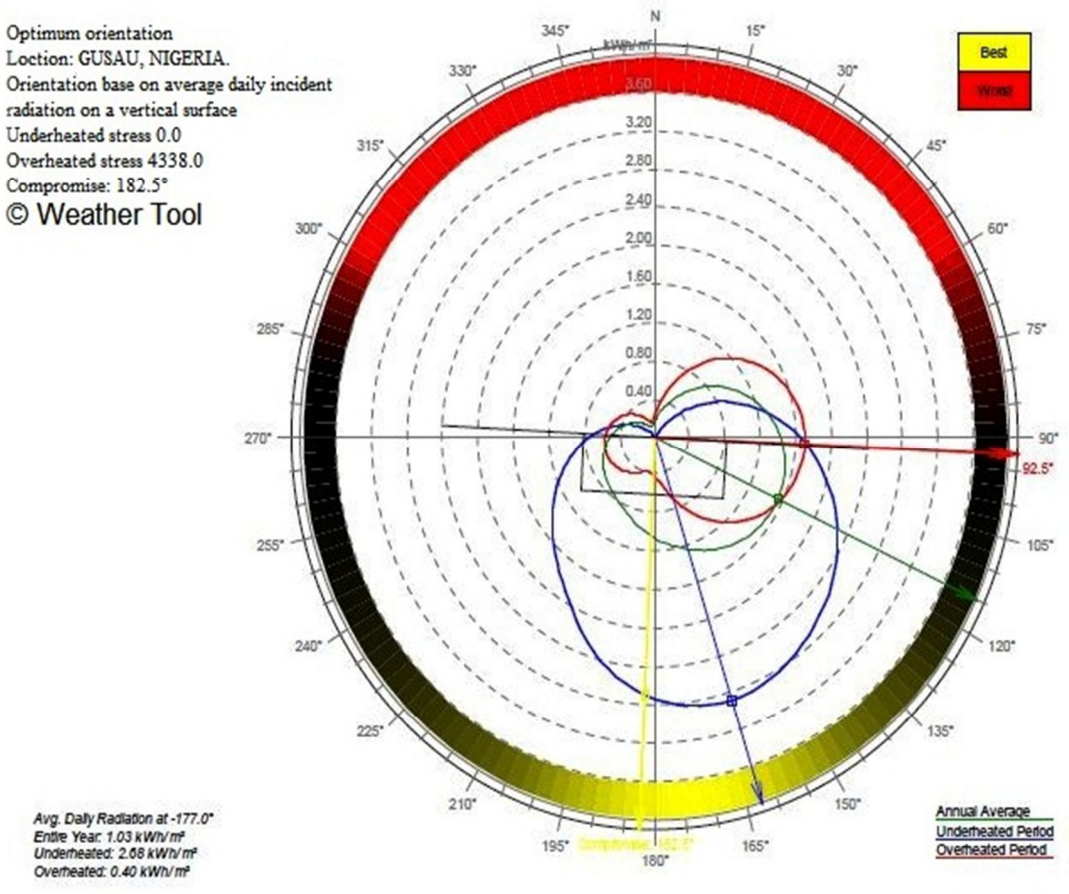


Figure 5.10: Optimum Orientation for the Site
Source: Weather Tool (2015)

5.4 Development of Design Concept

The concept adopted in the design proposal for the Faculty is from Bee honey comb. It is chosen because it fulfills the two requirements or qualities needed for the design of the Faculty of Agriculture, as listed below**.**

I. Design context requirement

II. Passive Architecture requirement

5.4.1 Design Context requirement

In this context the bee honey comb is chosen because it is a product of agriculture and the design proposal is a Faculty of Agriculture. A honeycomb is a mass of hexagonal wax cells built by honey bees in their nests to contain their larvae and stores of honey and pollen (Figure 5.11).



Figure 5.11: Typical honey bee comb
Source: Researcher (2016)

5.4.2 Passive Architecture requirement

The bee honey comb is chosen in this regard because it has the following passive architecture features.

I. **Lower surface – volume (s/v) ratio**: Hexagonal forms are much more compacted than their linear counterparts, making them have lower s/v ratio. Compact forms absorb less heat during the day and release less heat at night. For any given building volume, the more compacts the shape, the less wasteful it is in gaining/ losing heat.

II. **Courtyard system**: the inner part of the hexagonal forms can be landscaped as an open green courtyard, for enhanced natural cooling.

III. **Evaporative cooling**: In the warmer seasons, honey bees use the liquid from the stored nectar as a special type of evaporative coolant to maintain a certain temperature in the honey comb; architecturally this idea can be used in the design proposal using the principle of passive downdraft evaporative cooling towers.

IV. **Natural ventilation**: The modified form enhances natural ventilation. This is because air, being a fluid, is not rigid in nature and would readily assume the shape of the building when it blows around it, thereby easily making its way into the building through the openings to remove internal heat. Furthermore the pores in the comb also allow air to penetrate and reach the bee inside the comb; architecturally this idea can be adopted in design proposal using building skins and openings.

The concept generation is illustrated below in Figure 5.12:

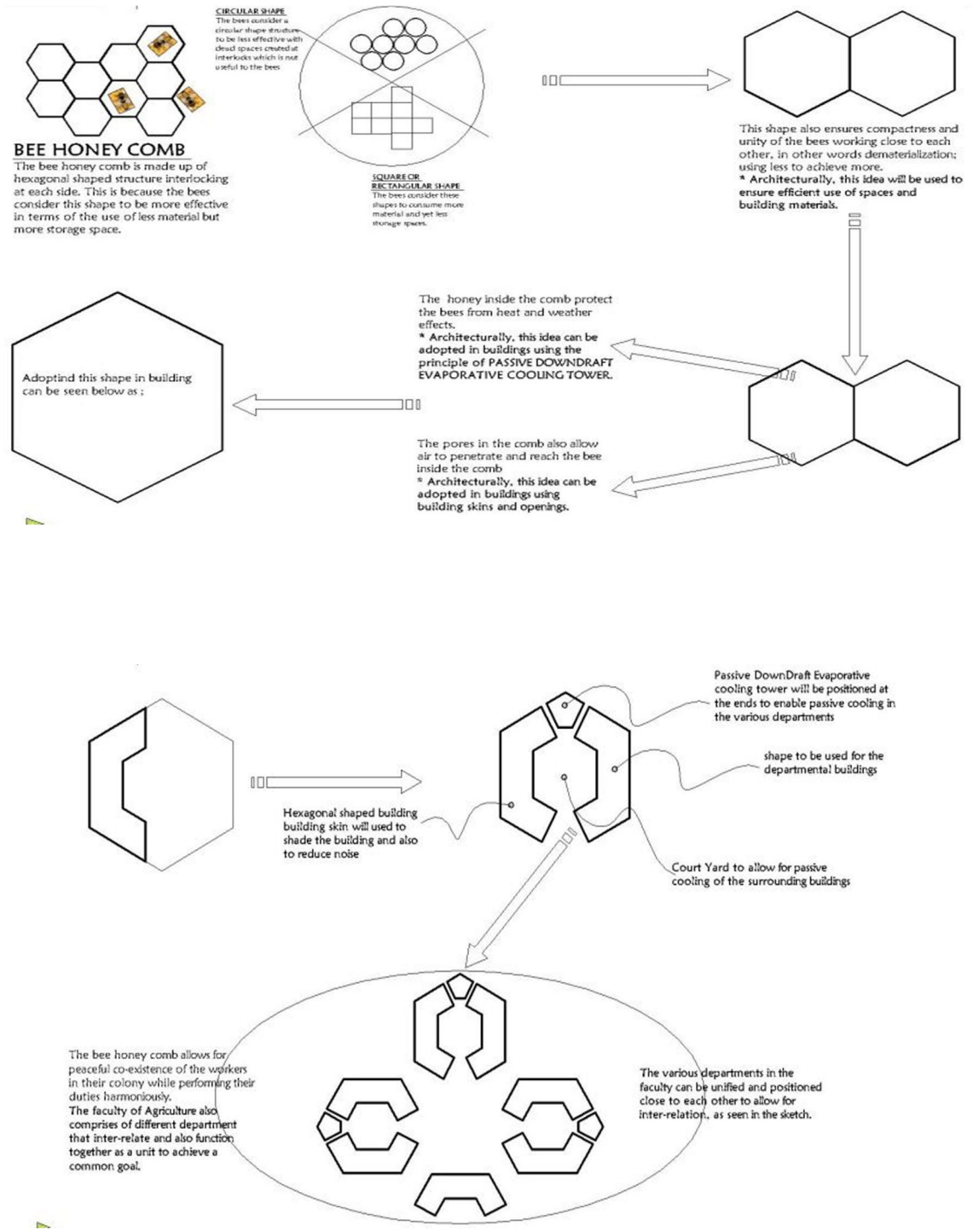


Figure 5.12: Concept generation
Source: Researcher (2016)

5.5 Population of the Faculty

The population of the Faculty can be categorized into four: Students, Academic staff, Technical Staff and Administrative staff.

5.5.1 Population of Students

According to the Nigerian Universities Commission, Benchmark Minimum Academic Standards (NUC BMAS, 2007) for Agriculture, the recommended number of students in a class should be 100. Thus, if the student intake for each programme per academic session is taken as 100, and the duration of each course of study for all departments is 5 years, then the total number of undergraduate students in a department is 5x100=500 students. For the Postgraduate programmes, if the intake is 30 students per academic year, and duration of programme is 2 years, then total number of Postgraduate students in a department is 2x30=60 students. Hence the overall number of Undergraduate and Postgraduate students in a department should be 500+60=560 students.

5.5.2 Population of Academic Staff

The academic staff- student ratio for the Faculty of Agriculture should be maintained at 1:15 (NUC BMAS, 2007). Thus, the number of academic staff for a department is 560/15= 37 academic staff, approximately. There must be at least a Full Time Equivalent of 6 academic staff per programme (NUC BMAS, 2007). A simple way to breakdown the 37 academic staff for each department is by taking 20% of the 37 as Professors/Senior Lecturers; 35% as Lecturers I & II, and 45% as Assistant Lecturers & Graduate Assistant.

5.5.3 Population of Technical Staff

Technical staffs are categorized into Laboratory technologists, Farm officers and Farm attendants. Technical staff to lecturer ratio should be taken as 1:4 (NUC BMAS, 2007). Hence the number of technical staff for each department is 37/4 = 9.

5.5.4 Population of Administrative Staff

The Non-Academic staff to Academic Staff ratio should be taken as 1:4 (NUC BMAS, 2007). Hence number of Non-Academic Staff for each department is 37/4=9.

5.6 Spaces Requirement

The faculty consists of the Faculty Office (Deanery), Twin Lecture Theatres of 500 capacity each, and six Departments which are; Animal science, Crop science, Soil science, Agric. Economics/extension and rural sociology, Forestry/wood technology and Fisheries.

5.6.1 Faculty Spaces Requirement

The following faculty spaces requirement in Table 5.1 are calculated based on the NUC guidelines on user space area.

Table 5.1 Faculty Spaces Requirement

Location	S/N	DESCRIPTION	SPACE REQUIREMENT (m^2)	QUANTITY
A. OFFICES				
	1.	Deans' office	18.5	1
	2.	Deputy Dean office	13.5	1
	3.	Secretary to Dean office	13.5	1
	4.	Assistant Registrar	7.0	1
	5.	Faculty officer's office	7.0	1
	6.	General office	7.0	1
	7.	Faculty Seminar room	70 person capacity	1
	8.	Faculty Exam Office	7.0	1
	9.	Toilet		10

B. CLASSES		UNDERGRADUATE		
	1.	Faculty Lecture Theatre	500 Students Capacity	2
C. LIBRARY				
	1.	Faculty Digital Library	150 Students Capacity	2

Source: Researcher (2016)

5.6.2 Spaces Requirement for a Typical Department

The following spaces requirements in Table 5.2 are calculated based on the NUC guidelines on user space area.

Table 5.2 Spaces requirement for a typical department

LOCATION	S/N	USER	SPACE REQUIREMENT (m^2)	QUANTITY
A. OFFICES				
	1	H.O.D	24	1
	2	Professor	18.5	6
	3	Senior lecturer	18.5	8
	4	Lecturer I	13.5	5
	5	Lecturer II	13.5	8
	6	Assistant Lecturer	13.5	6
	7	Graduate Assistant	13.5	5
	8	Senior technical staff	12	5
	9	HOD'S Secretary	12	1
	10	Junior technical staff	8	4
	11	Junior administrative staff	8	3
	12	Storage	6	1
	13	Conveniences	4	4
B. CLASSES		UNDERGRADUATE		
	1.	200 Level	100 Students capacity	1
	2.	300 Level	100 Students capacity	1
	3.	400 Level	100 Students capacity	
	4.	500 Level	100 Students capacity	
		POSTGRADUATE		
	1.	Master's Degree Class	30 Students capacity	1
	2.	Postgraduate Seminar Room	60 Students capacity	1

	3. PhD Class	30 Students capacity	1

Source: Researcher (2016)

5.6.3 Laboratories Spaces Requirement

The following space requirements in Table 5.3 are calculated based on the NUC guidelines on user space area.

Table 5.3 Laboratories spaces requirement

S/N	DESCRIPTION	SPACE REQUIREMENT	QUANTITY
Department of Animal Science			
1.	Animal Nutrition and Biochemistry lab.	100 Students Capacity	1
2.	Genetics and Animal Breeding Lab.	100 Students Capacity	1
Department of Crop Science			
1.	Seed production Lab.	100 Students Capacity	1
2.	Genetics and Plant breeding Lab.	100 students Capacity	1
Department of Soil Science			
1.	Soil analysis Lab.	100 Students Capacity	1
2.	Soil Physics and water conservation Lab.	100 Students Capacity	1
Department Of Agric. Economics/ Extension And Rural Sociology			
1.	Agricultural Production lab.	100 Students Capacity	1
2.	Farm management Lab.	100 Students Capacity	1
Department Of Fisheries			
1.	Water Quality lab.	100 Students Capacity	1
2.	Feed production Lab.	100 Students Capacity	1
Department Of Forestry/ Wood Technology			
1.	Wood processing lab.	100 Students Capacity	1
2.	Forest Hydrology and Erosion lab.	100 Students Capacity	1

Source: Researcher, (2016).

5.7 Description of Faculty Facilities

The faculty consists of the Faculty Office (Deanery), Twin Lecture Theatres of 500 capacity each, and six Departments which are; Animal science, Crop science, Soil science, Agric. Economics/extension and rural sociology, Forestry/wood technology and Fisheries (Figure 6.3).

6.7.1 Faculty Shared Facilities

The Faculty shared facilities is made up of the Faculty Office (Deanery), which is the central administration of the whole faculty, and, the Faculty Twin Lecture Theatres of about 500 seats. The toilet facilities behind the Lecture Theatres are meant for the students. The Faculty Office comprises of the ground floor, which accommodates the deanery and the seminar rooms; the first floor, which houses the Faculty Digital Library to cater for the interest of all departments. The staff and students' toilets are located on each floor of the Faculty Office (Figure 5.13).

6.7.2 Departmental Facilities

The departmental Facilities are prototype; a typical department comprises of three floors. The functions provided at each floor is based on descending order of crowd, so that the ground floor gathers the highest number of people, followed by the second up to the least crowded third floor. Facilities common to all departments are described below.

(a) Teaching and Practical Facilities (Ground Floor): The classrooms and laboratories are provided at the ground floor for ease of accessibility and departure by students. The classrooms have sitting capacities of 100 students each. The laboratory varies, depending on the department and type of equipment in the laboratory. The restrooms at the ground floor are for students while those at the subsequent floors are for the use of staff (Figure 5.13).

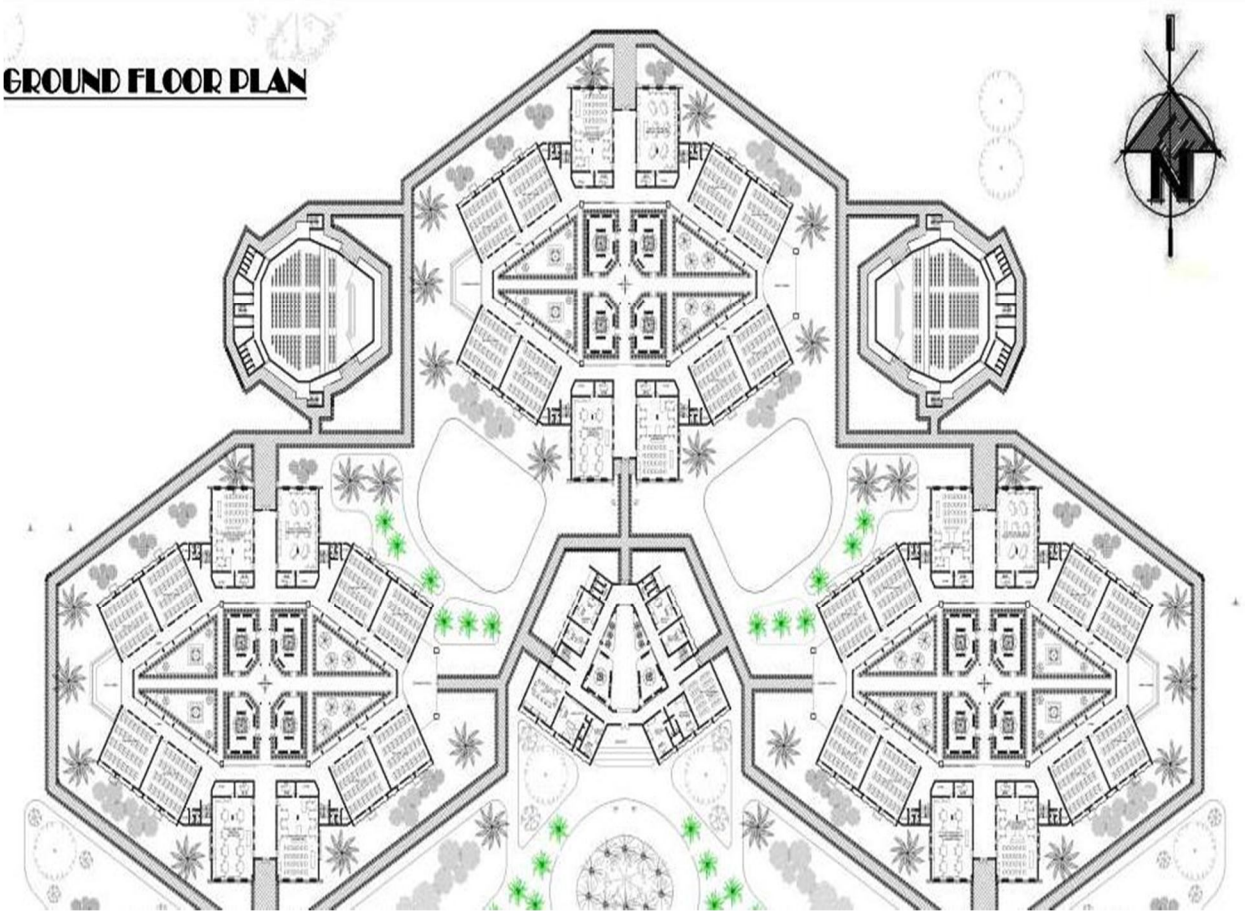


Figure 5.13: Ground floor plan showing teaching and practical facilities
Source: Researcher (2016)

(b) Administrative Staff Offices (First Floor): The administrative facilities for the typical departmental building are located at the first floor. It constitutes the office of the Head of Department, the Undergraduate Coordinator, Postgraduate Coordinator, Exam Officers, postgraduate classrooms, seminar rooms and the departmental library (Figure 5.14).

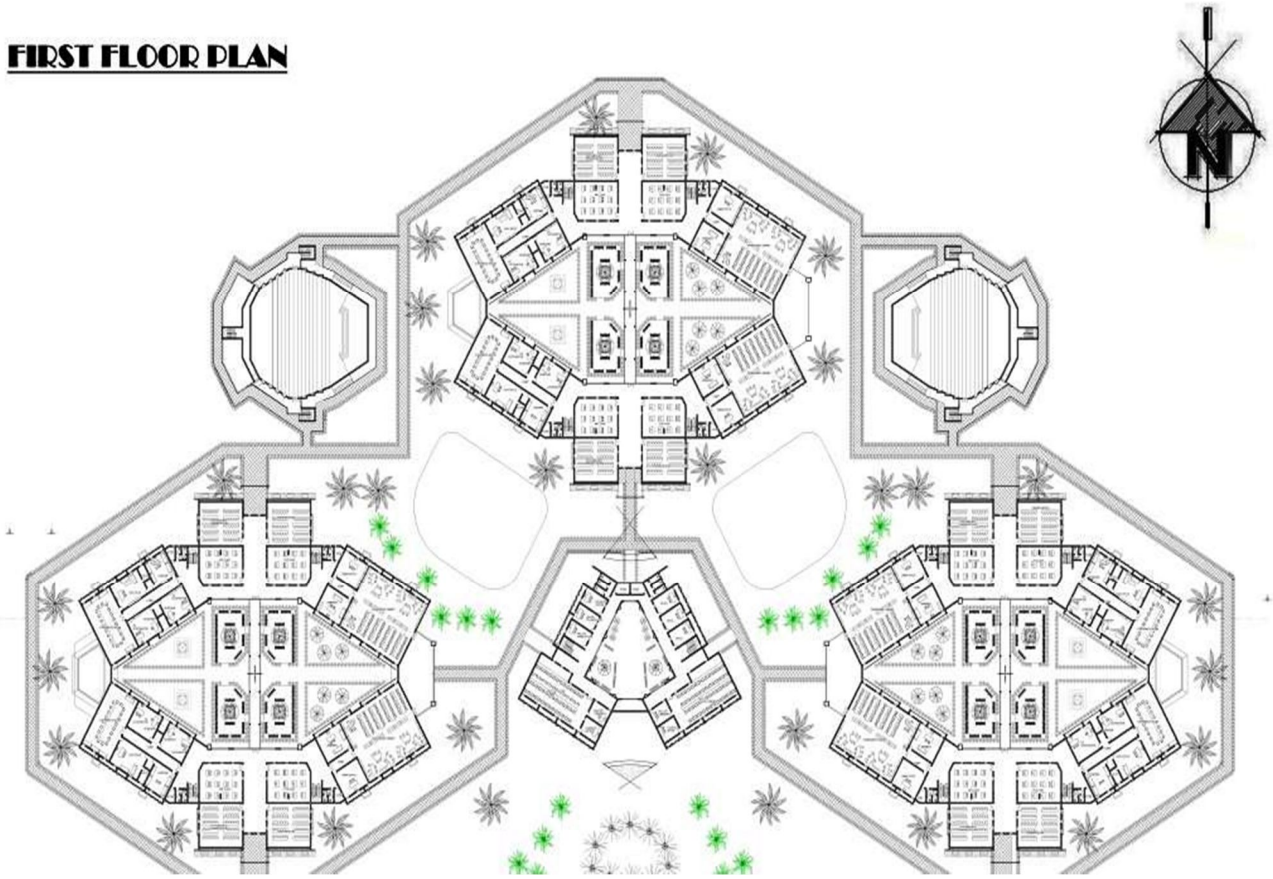


Figure 5.14: First floor plan showing administrative staff offices and departmental library
Source: Researcher (2016)

(c) Academic Staff Offices (Second and Third Floors): The offices for all academic staff are located at the second and third floors (Figure 5.15). The offices are enough to cater for all the 37 academic staff.

(d) Non-Academic Staff Offices: Non-academic staffs include the secretaries to the HOD, Postgraduate and Undergraduate Coordinators. Others are the lab technicians whose offices are in the laboratories.

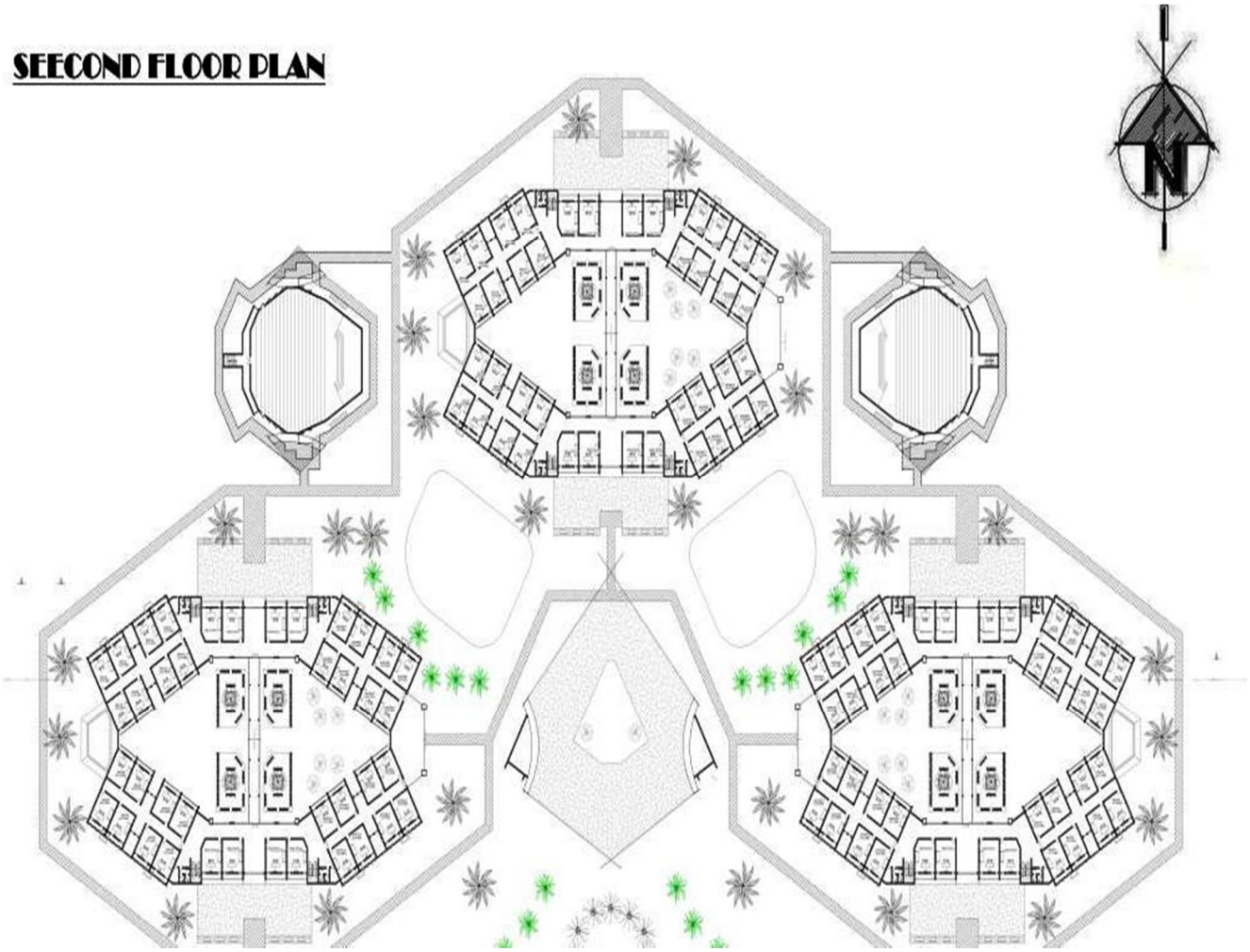


Figure 5.15: Second floor plan showing academic staff offices
Source: Researcher (2016).

5.8 Integration of Passive Architecture Principles

This part of the chapter will briefly explain where and why passive architecture principles were integrated in the design proposal of the Faculty of Agriculture.

5.8.1 Materials and Construction

The building materials used are of high thermal mass, meaning that they have high time lag, or capable of storing heat for a long time. The construction technique employed is also high thermal construction. Since heat can only penetrate a building through the building envelope, then it follows that the best way to stop this heat is by using high thermal construction for the building envelope which are

I. The perimeter walls: All the perimeter walls are design using thick mud brick walls to provide the required time lag. They do not only suit the need of the climatic conditions of the region, but are also economically sustainable (Figure 5.16).

II. Roofs: Green roof is used primarily to repel the effect of the intense solar radiation because it is regard as the best method to insulate a roof. Other benefits of green roofs are; it produces oxygen for the environment, filtering dust from the North East Trade Wind, reducing the heat island effect in the urban environment and reducing air temperature. This is because plants will humidify the air in contact with the roof, thereby keeping the interior space cool (Figure 5.16).

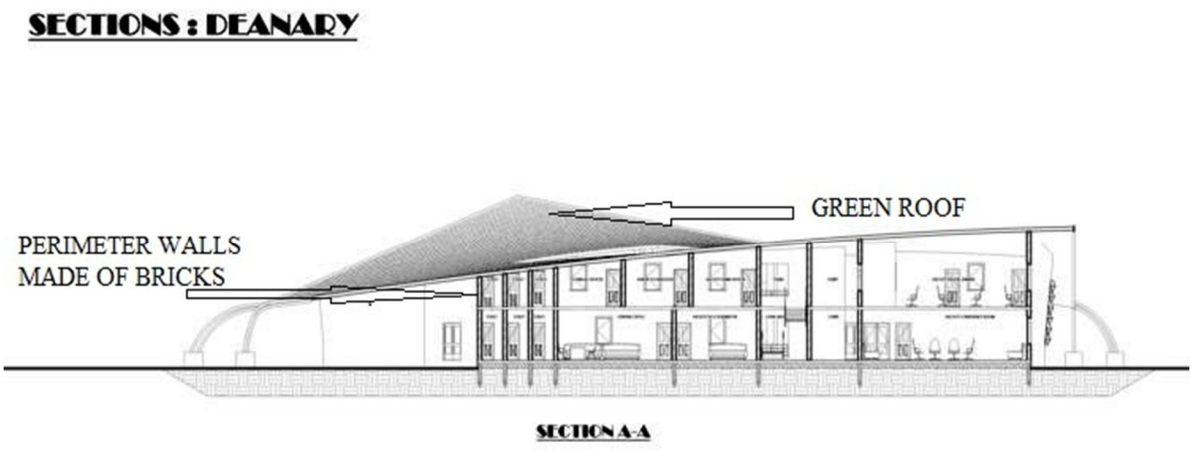


Figure 5.16: Section A-A of Deanery showing High thermal construction
Source: Researcher (2016)

5.8.2 Solar Shading

The techniques employed to provide protection against solar radiation are; shading devices which are positioned in the façade of the building in order to block sun gain in summer and to also allow wind to pass through it and cool the area; deciduous trees were used to shade the windows facing east and west (Figures 5.17 and 5.18). This is because of their ability to develop leaves in rainy season and shade their leaves in dry season. Lastly the external walls are protected by designing the roof so that it extends far beyond the line of walls and has broad overhanging eaves.

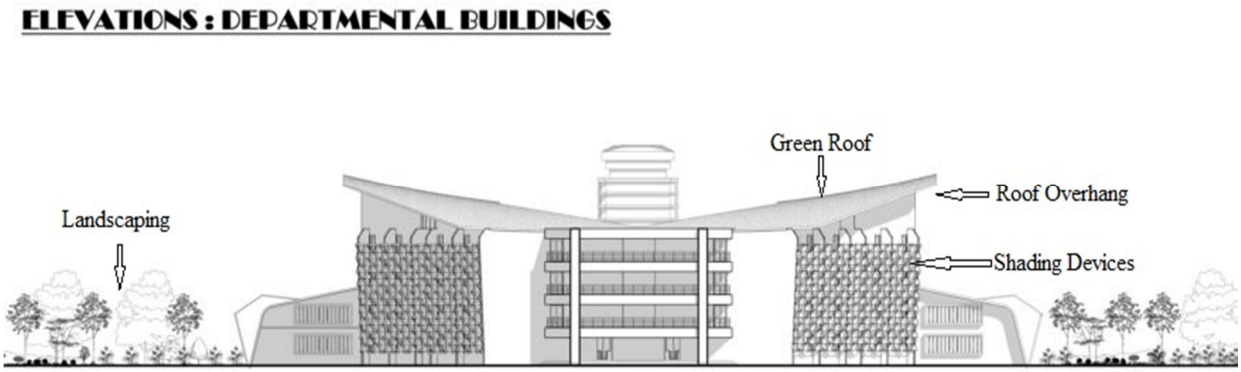


Figure 5.17: Elevations showing Solar Shading Techniques
Source: Researcher (2016).

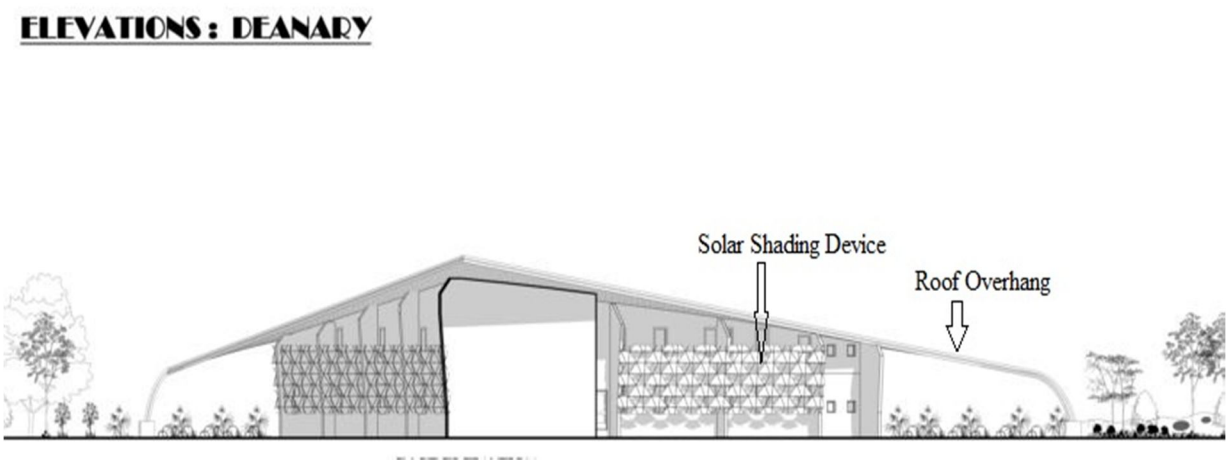


Figure 5.18: Elevations showing Solar Shading Techniques
Source: Researcher (2016).

5.8.3 Induced Ventilation Techniques

Induced Ventilation has been achieved in the departmental building through the provision of ventilation lobbies between two offices (Figure 5.19). As for the faculty office, cross ventilation is by stack effect in the courtyard, openings were provided at the upper and lower levels of the courtyard so that the cool and dense air at the lower level can easily blow in, while the warm and light air can escape at the upper level. Another natural ventilation and thus cooling technique is the use of courtyards (Figure 5.19).

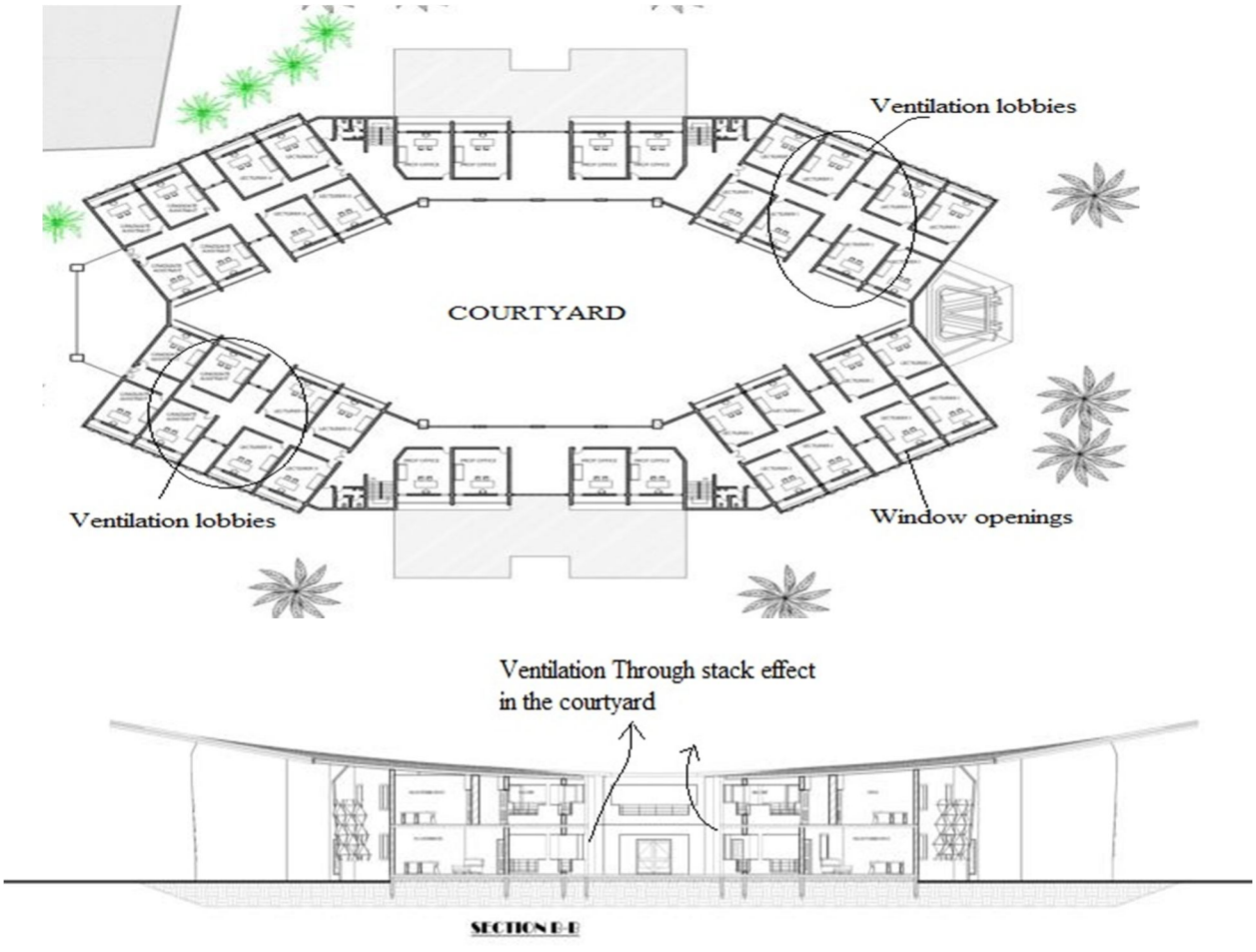


Figure 5.19: Plan and Section showing Induced Ventilation Techniques
Source: Researcher (2016).

5.8.4 Evaporative Cooling

Evaporative cooling lowers indoor air temperature by evaporating water. It is effective in hot-dry climate where the atmospheric humidity is low. In evaporative cooling, the sensible heat of air is used to evaporate water, thereby cooling the air, which in turn cools the living space of the building. Increase in contact between water and air increases rate of evaporation. Evaporative cooling is achieved in the design proposal by the presence of a water body such as fountain in the courtyards (Figure 5.20).

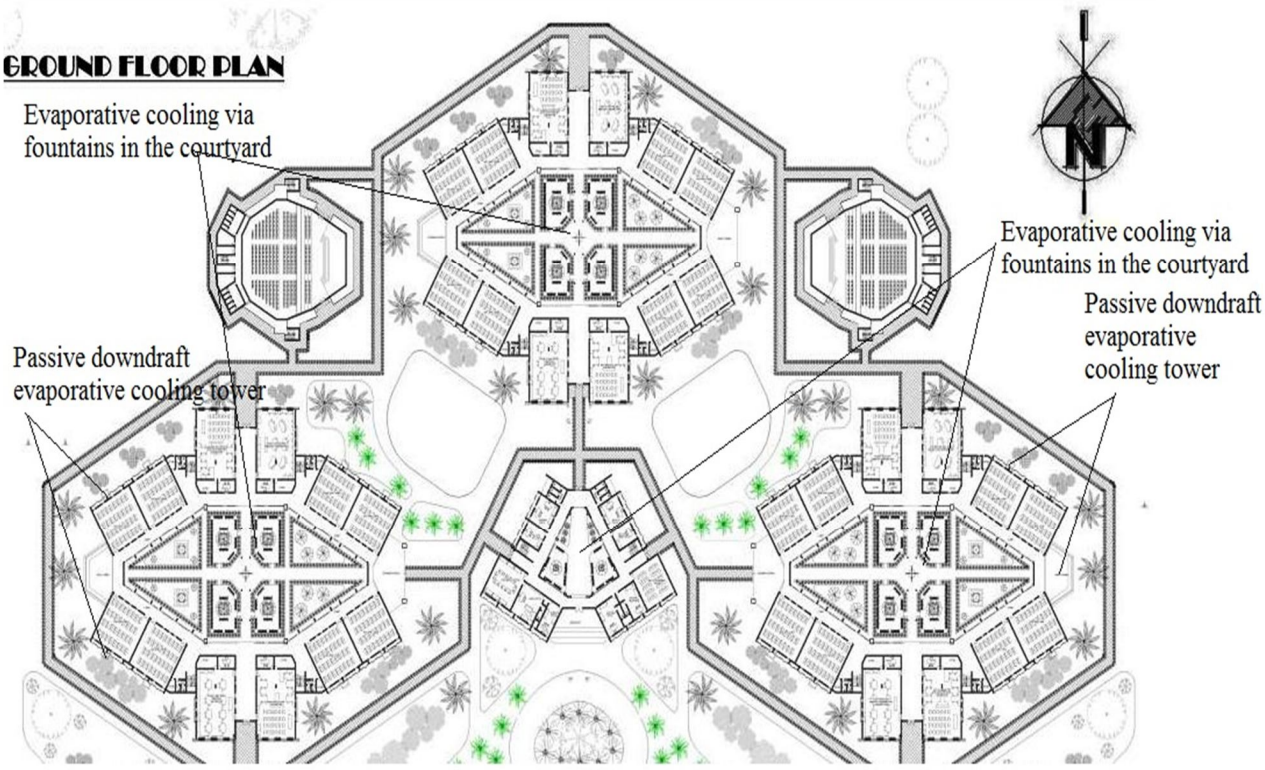


Figure 5.20: Ground Floor Plan showing Evaporative cooling Techniques
Source: Researcher (2016).

Another prominent technique used in the design proposal is the Passive Downdraft Evaporative Cooling Towers (Figure 5.21 and 5.22). In this system Wind Towers guide outside air over water filled pads, inducing evaporation and causing a significant drop in temperature before the air enters the interior.

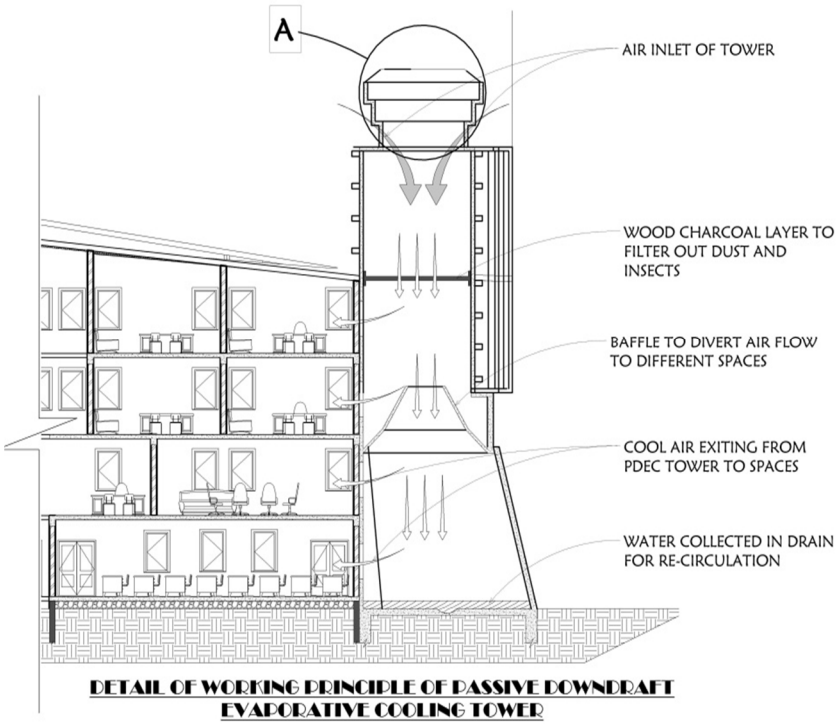


Figure 5.21: Section of a Passive Downdraft Evaporative Cooling Tower
Source: Researcher, (2016).

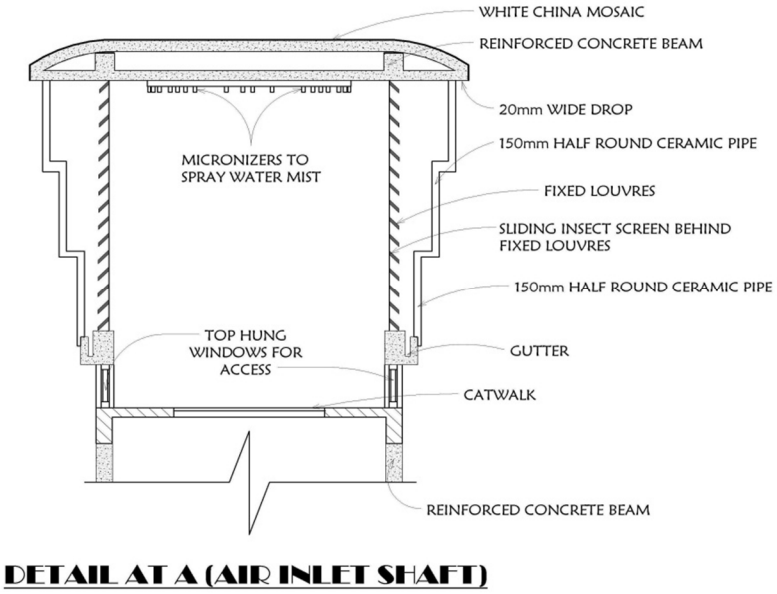


Figure 5.22: Details at air inlet of a Passive Downdraft Evaporative Cooling Tower
Source: Researcher (2016).

5.8.5 Orientation

Thus, orientation has been achieved to a great extent by placing the longer side on the east west axis (Figure 5.23). This is not only to avoid the western sun but also to enable the prevailing wind hit the building at an angle. The service core of the departmental building is positioned at the extreme ends to serve as the first recipient of solar radiation.

5.8.6 Building Form

As earlier explained in the design concept, the hexagonal form adopted for this design is more compacted than their linear counterparts, making them have lower s/v ratio, thereby making it absorb less heat. The inner part of the form can be landscaped as an open green courtyard to enhanced natural ventilation and cooling (Figure 5.23).

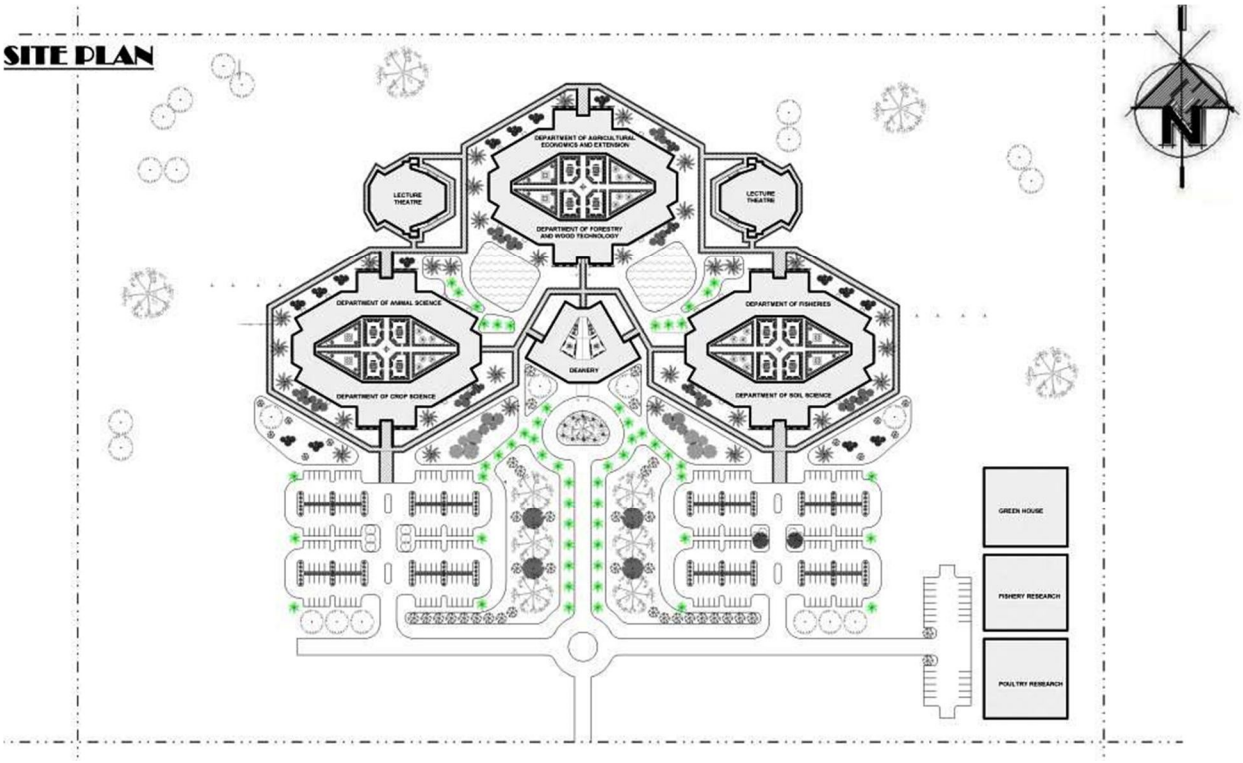


Figure 5.23: Site plan showing Building form and orientation.
Source: Researcher (2016).

5.9 Integration of Renewable Energy Sources

This part of the chapter will briefly explain where and why renewable energy sources were integrated in the design proposal of the Faculty of Agriculture.

5.9.1 Wind Turbines Integration

Building integrated wind turbines, where a separate wind turbine is located on a free-standing tower away from the building itself are used in the proposed design. This type of wind turbine reduces cost and power losses during transmission and distribution. Building integrated wind turbines are likely to be in operation for about 85% of the year, and have a service life of at least 20 years.

5.9.2 Building Integrated Photovoltaic

The building integrated photovoltaic panels (PV) are mounted on the shading devices of the building façade (Figure 5.24). The essence of the PV system is to reduce dependence on non-renewable energy in powering the laboratory machines. In other words, the electricity generated from the PV system can easily be used to power the laboratory equipment and electric bulbs for better economic and energy efficiency.

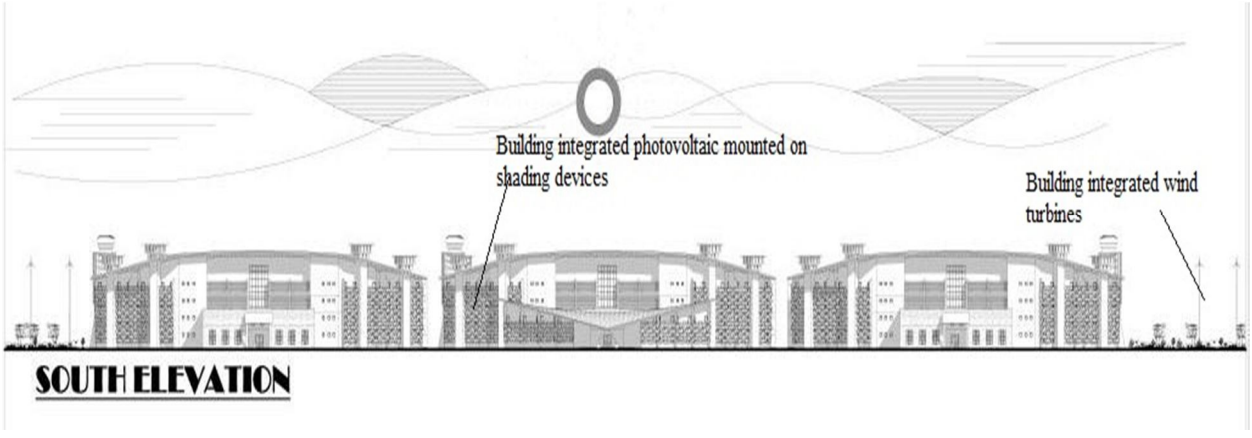


Figure 5.24: Elevation showing integration of renewable energy sources
Source: Researcher (2016).

6.0 CONCLUSION

6.1 Summary of Major Findings

The research work was aimed at investigating the potentials of integrating passive architecture principles and in the design of educational buildings in Gusau (Hot Dry Climate) with a view to enhancing self sustained buildings that will facilitate learning and overcome the state of discomfort with minimum energy utilization. Findings from the case studies show that Evaporative Cooling has been neglected by all three cases followed by induced ventilation techniques while Building form, orientation and Solar Shading seems to be the most applied. Faculty of Agriculture ABU Zaria emerges with almost all the passive architecture elements under consideration with a score of 42%

6.2 Conclusion

The research was able to conclude that adapting Passive architecture design principles in educational buildings can improve the indoor thermal comfort and alleviate the need for mechanical cooling. Out of the numerous passive design principles that have been adopted by others in different climates, only those principles discussed in this study were adopted to meet the purpose of this study and were applied in the context of hot dry climate of Nigeria. The principles selected were only related to possible energy savings and enhancing low energy architecture in hot dry climate. By adopting the above mentioned passive design principles the proposed design would reduce the energy demand for cooling.

6.3 Recommendation

Based on the conclusions drawn, the following recommendations are made

1. There is the need to explore more affordable renewable energy technologies, so that designers can easily choose the one that suits the requirements of the climate they are designing for.
2. Professional institutions of the Built Environment, such as Nigerian Institute of Architects (NIA) and the Architect Registration Council of Nigeria (ARCON) should organize workshops and seminars to retrain and sensitize their members on the need for energy savings and enhancing low energy architecture.
3. Tertiary Education Institutions like the Polytechnics and Universities that train practitioners of the built-environment should introduce courses on low energy architecture.

The Recommendations for furthers studies are

1. Testing the principles of passive architecture discussed in this study in other building typologies. This was tested in Educational building. Other public and private buildings such as hostels, offices, resort and others would be benefit to research.
2. Testing the principles of passive architecture in educational buildings in other climatic regions of Nigeria is also encouraged.

6.4 Contribution to Knowledge

I. The research identifies passive architecture design principles which are; Solar shading, Materials and construction technology, Induced ventilation techniques, Evaporative cooling, Building orientation and Building form that can be adopted in hot dry climatic region to minimize the use of energy for cooling, improve occupant's comfort and enhance low energy architecture.

II. The study was able to identify the honey bee comb form as one of the forms that enhances the following passive architecture strategies; Lower surface- volume (s/v) ratio (Building Form) and Evaporative cooling.

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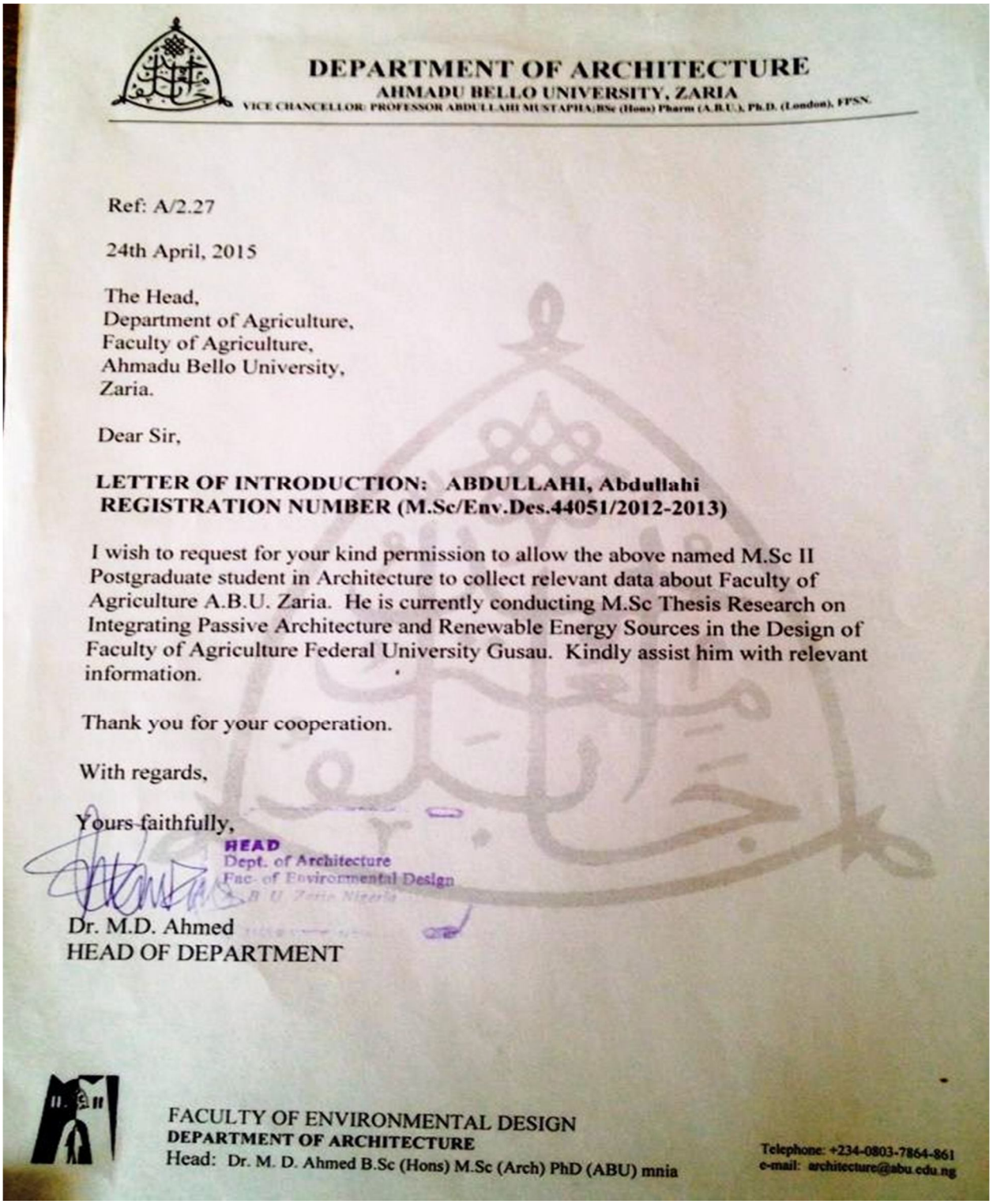
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APPENDIX 1: LETTER OF INTRODUCTION I



DEPARTMENT OF ARCHITECTURE
AHMADU BELLO UNIVERSITY, ZARIA
VICE CHANCELLOR: PROFESSOR ABDULLAHI MUSTAPHA,BSc (Hons) Pharm (A.B.U.), Ph.D. (London), FPSN.

Ref: A/2.27

24th April, 2015

The Head,
Department of Agriculture,
Faculty of Agriculture,
Ahmadu Bello University,
Zaria.

Dear Sir,

LETTER OF INTRODUCTION: ABDULLAHI, Abdullahi
REGISTRATION NUMBER (M.Sc/Env.Des.44051/2012-2013)

I wish to request for your kind permission to allow the above named M.Sc II Postgraduate student in Architecture to collect relevant data about Faculty of Agriculture A.B.U. Zaria. He is currently conducting M.Sc Thesis Research on Integrating Passive Architecture and Renewable Energy Sources in the Design of Faculty of Agriculture Federal University Gusau. Kindly assist him with relevant information.

Thank you for your cooperation.

With regards,

Yours faithfully,

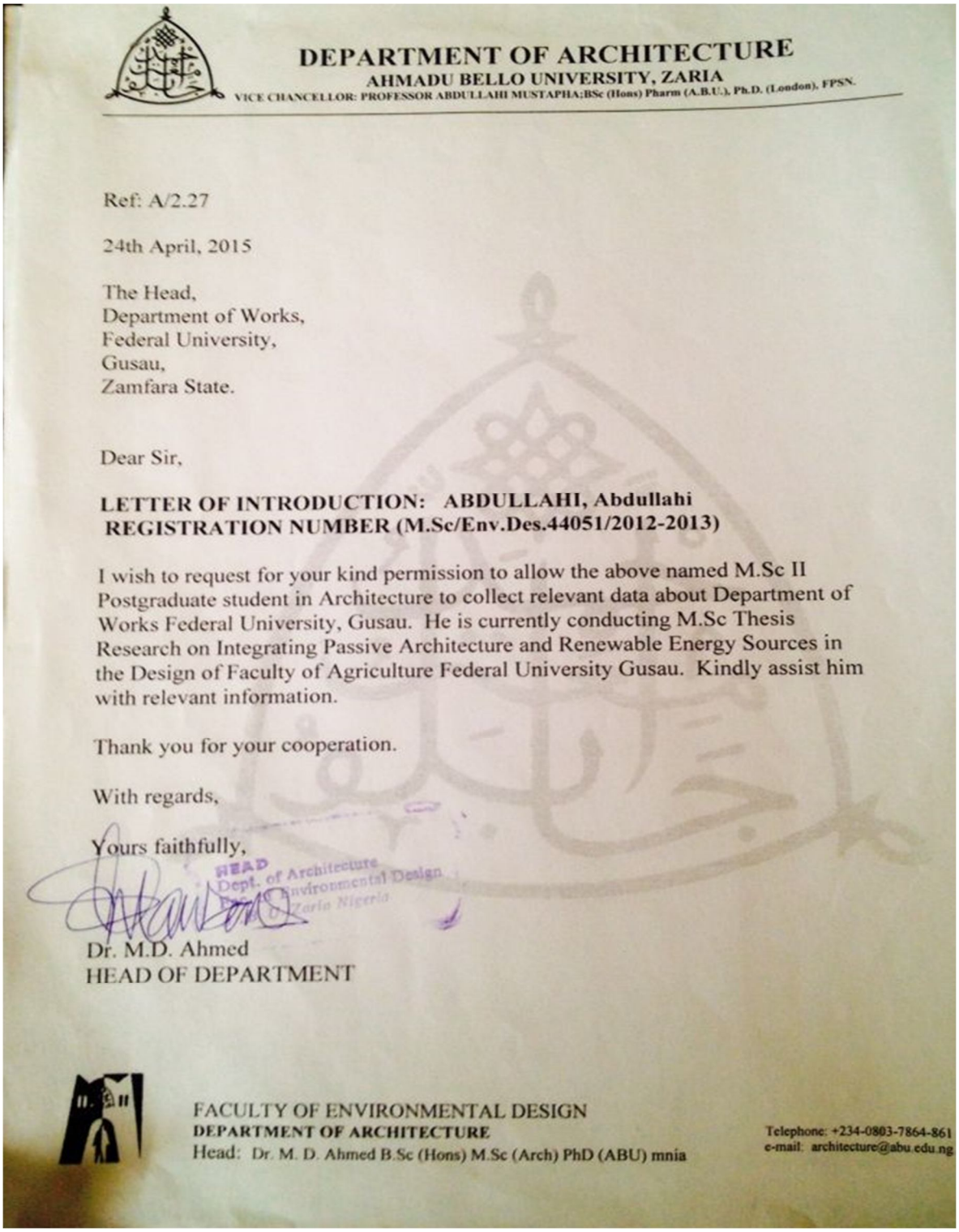
HEAD
Dept. of Architecture
Fac. of Environmental Design
A.B.U. Zaria Nigeria

Dr. M.D. Ahmed
HEAD OF DEPARTMENT

FACULTY OF ENVIRONMENTAL DESIGN
DEPARTMENT OF ARCHITECTURE
Head: Dr. M. D. Ahmed B.Sc (Hons) M.Sc (Arch) PhD (ABU) mnia

Telephone: +234-0803-7864-861
e-mail: architecture@abu.edu.ng

APPENDIX 2: LETTER OF INTRODUCTION II



DEPARTMENT OF ARCHITECTURE
AHMADU BELLO UNIVERSITY, ZARIA
VICE CHANCELLOR: PROFESSOR ABDULLAHI MUSTAPHA;BSc (Hons) Pharm (A.B.U.), Ph.D. (London), FPSN.

Ref: A/2.27

24th April, 2015

The Head,
Department of Works,
Federal University,
Gusau,
Zamfara State.

Dear Sir,

LETTER OF INTRODUCTION: ABDULLAHI, Abdullahi
REGISTRATION NUMBER (M.Sc/Env.Des.44051/2012-2013)

I wish to request for your kind permission to allow the above named M.Sc II Postgraduate student in Architecture to collect relevant data about Department of Works Federal University, Gusau. He is currently conducting M.Sc Thesis Research on Integrating Passive Architecture and Renewable Energy Sources in the Design of Faculty of Agriculture Federal University Gusau. Kindly assist him with relevant information.

Thank you for your cooperation.

With regards,

Yours faithfully,

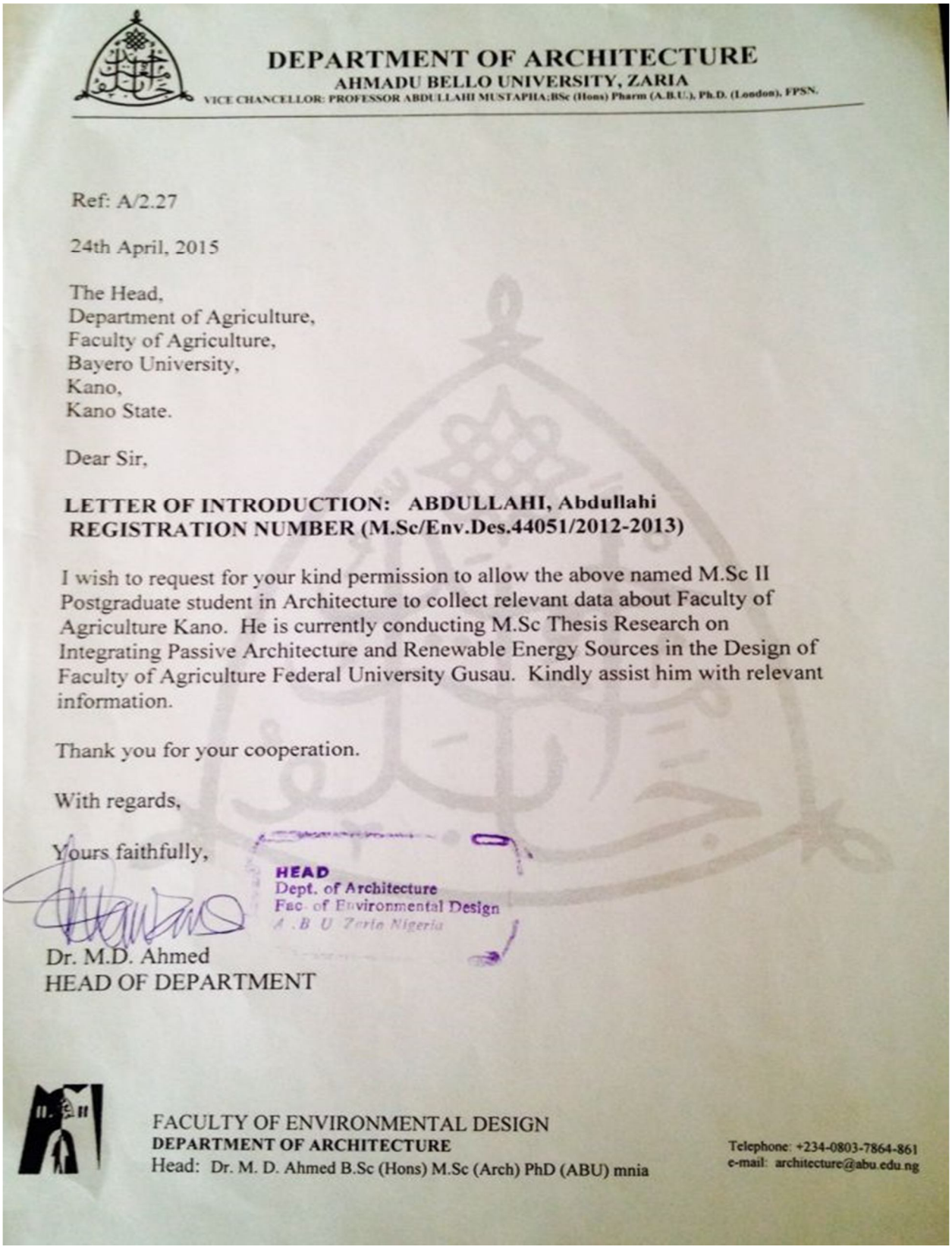
HEAD
Dept. of Architecture
Faculty of Environmental Design
A.B.U. Zaria Nigeria

Dr. M.D. Ahmed
HEAD OF DEPARTMENT

FACULTY OF ENVIRONMENTAL DESIGN
DEPARTMENT OF ARCHITECTURE
Head: Dr. M. D. Ahmed B.Sc (Hons) M.Sc (Arch) PhD (ABU) mnia

Telephone: +234-0803-7864-861
e-mail: architecture@abu.edu.ng

APPENDIX 3: LETTER OF INTRODUCTION III



DEPARTMENT OF ARCHITECTURE
AHMADU BELLO UNIVERSITY, ZARIA
VICE CHANCELLOR: PROFESSOR ABDULLAHI MUSTAPHA;BSc (Hons) Pharm (A.B.U.), Ph.D. (London), FPSN.

Ref: A/2.27

24th April, 2015

The Head,
Department of Agriculture,
Faculty of Agriculture,
Bayero University,
Kano,
Kano State.

Dear Sir,

LETTER OF INTRODUCTION: ABDULLAHI, Abdullahi
REGISTRATION NUMBER (M.Sc/Env.Des.44051/2012-2013)

I wish to request for your kind permission to allow the above named M.Sc II Postgraduate student in Architecture to collect relevant data about Faculty of Agriculture Kano. He is currently conducting M.Sc Thesis Research on Integrating Passive Architecture and Renewable Energy Sources in the Design of Faculty of Agriculture Federal University Gusau. Kindly assist him with relevant information.

Thank you for your cooperation.

With regards,

Yours faithfully,

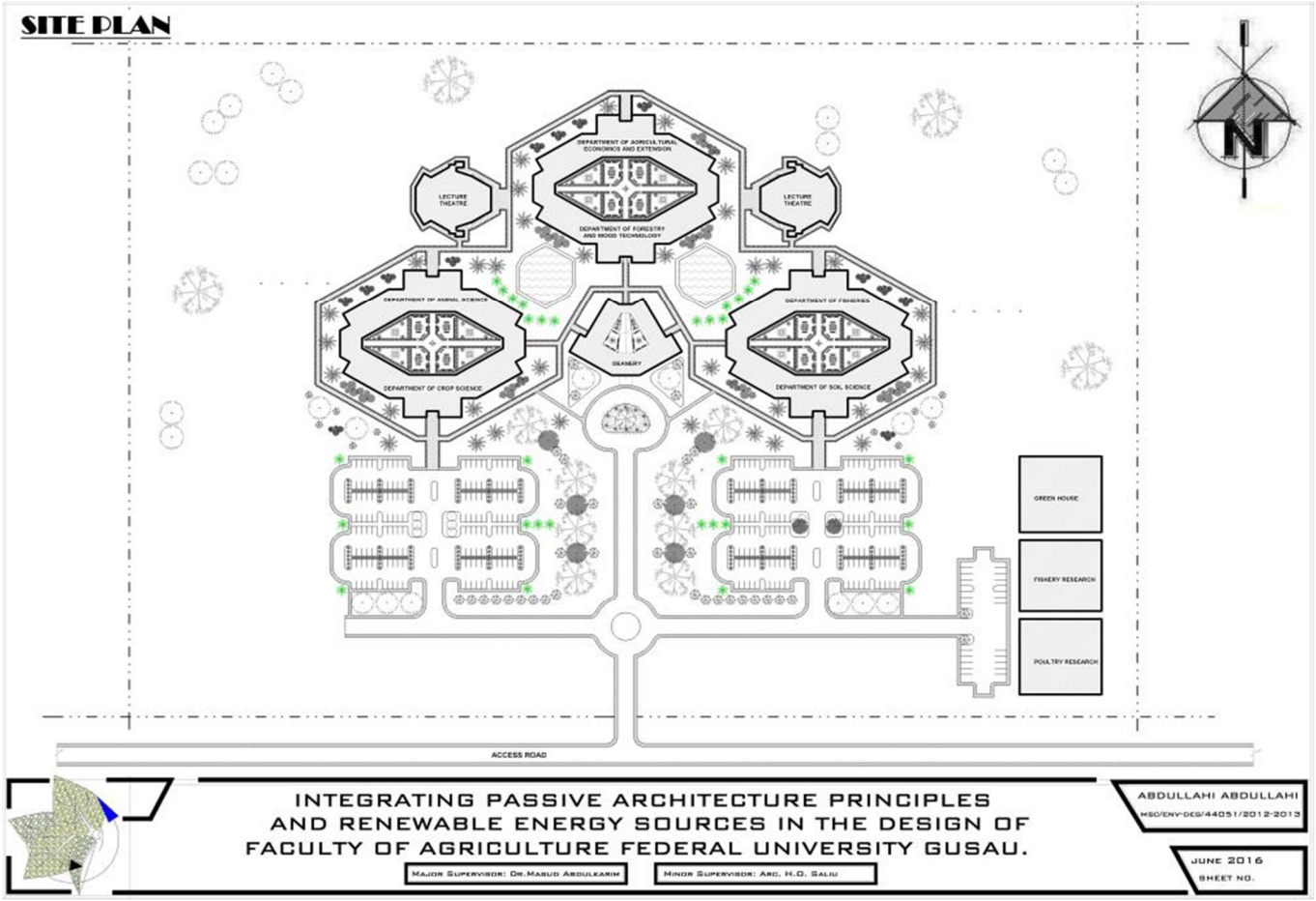
HEAD
Dept. of Architecture
Fac. of Environmental Design
A.B.U. Zaria Nigeria

Dr. M.D. Ahmed
HEAD OF DEPARTMENT

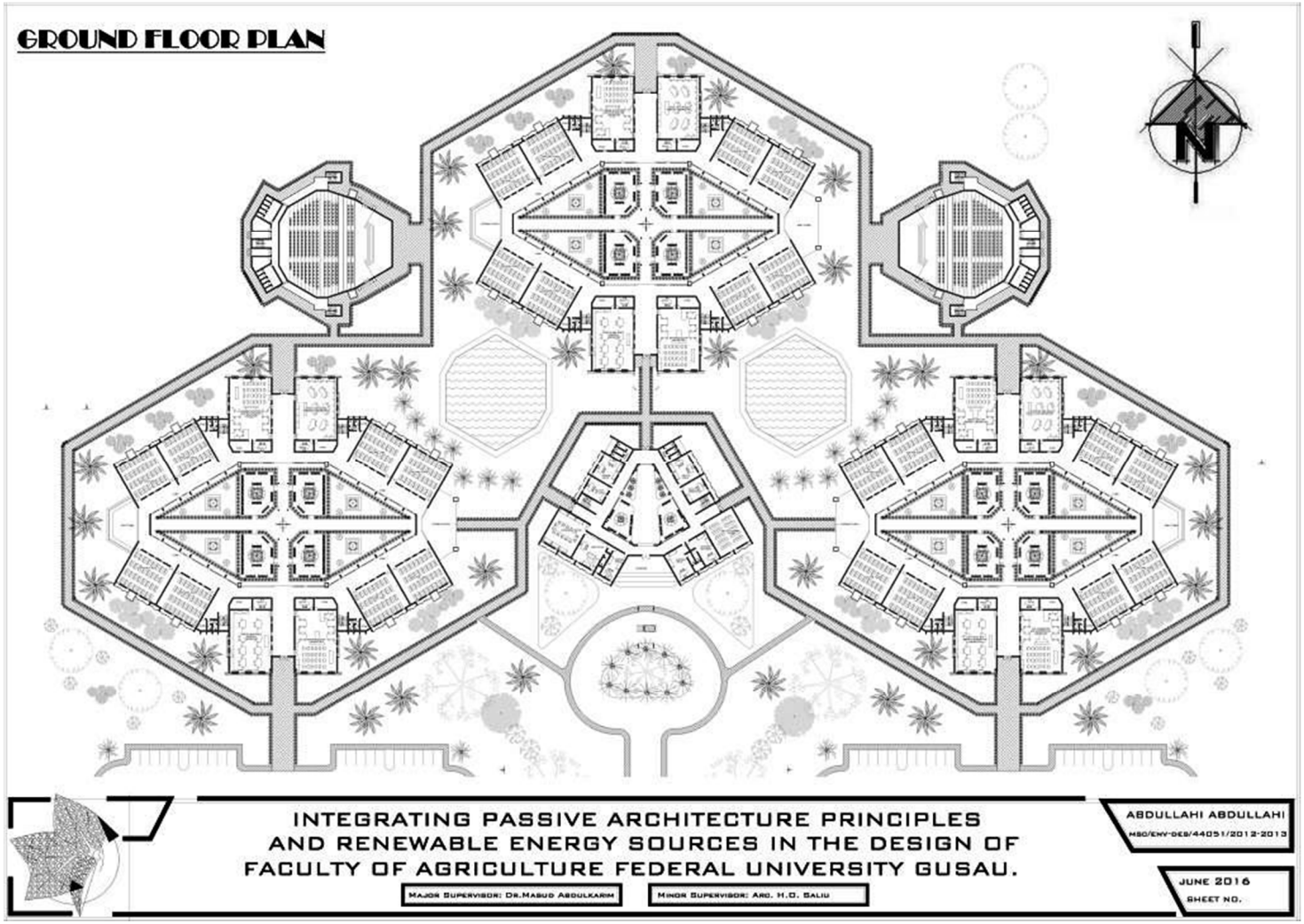
FACULTY OF ENVIRONMENTAL DESIGN
DEPARTMENT OF ARCHITECTURE
Head: Dr. M. D. Ahmed B.Sc (Hons) M.Sc (Arch) PhD (ABU) mnia

Telephone: +234-0803-7864-861
e-mail: architecture@abu.edu.ng

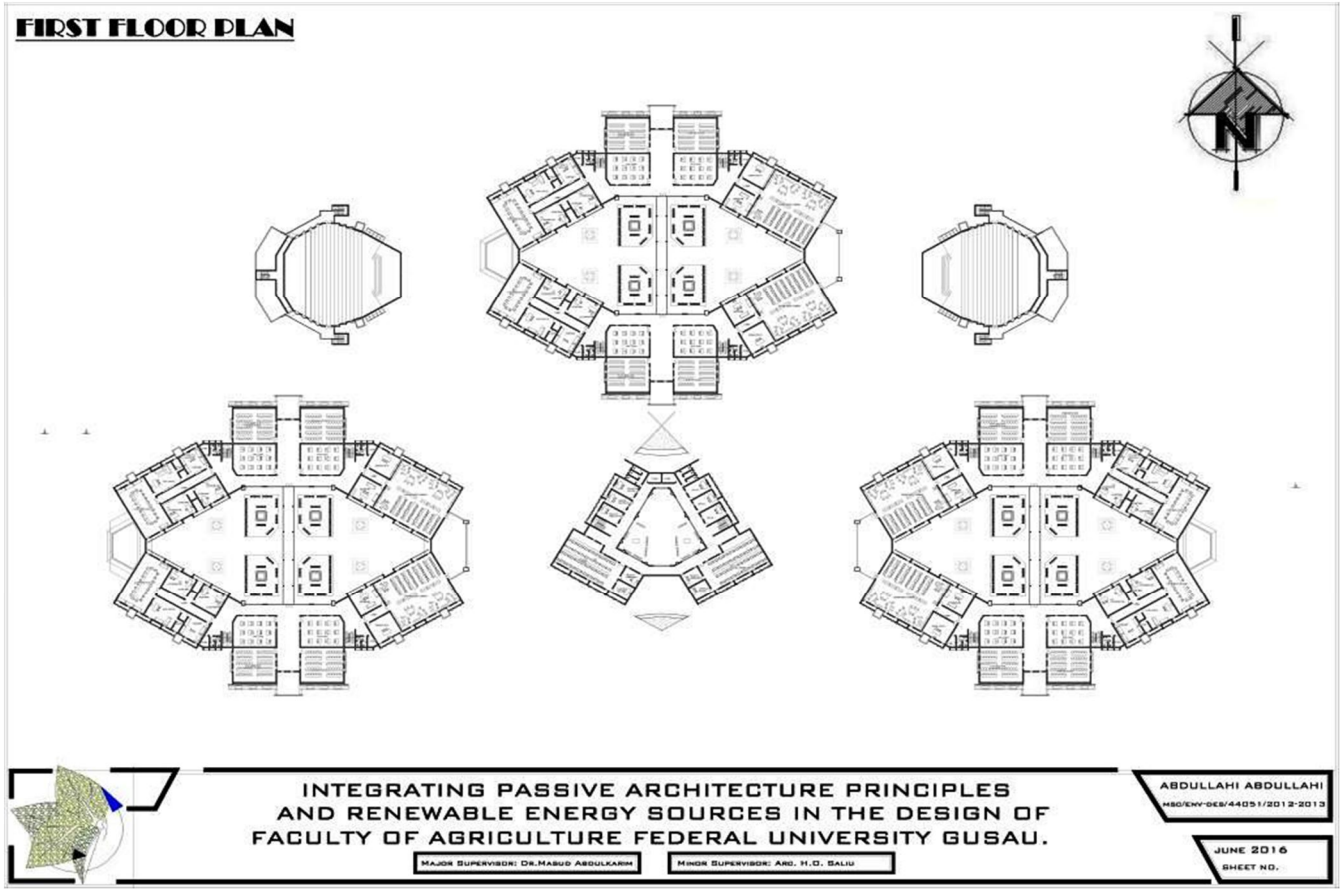
APPENDIX 4: SITE PLAN



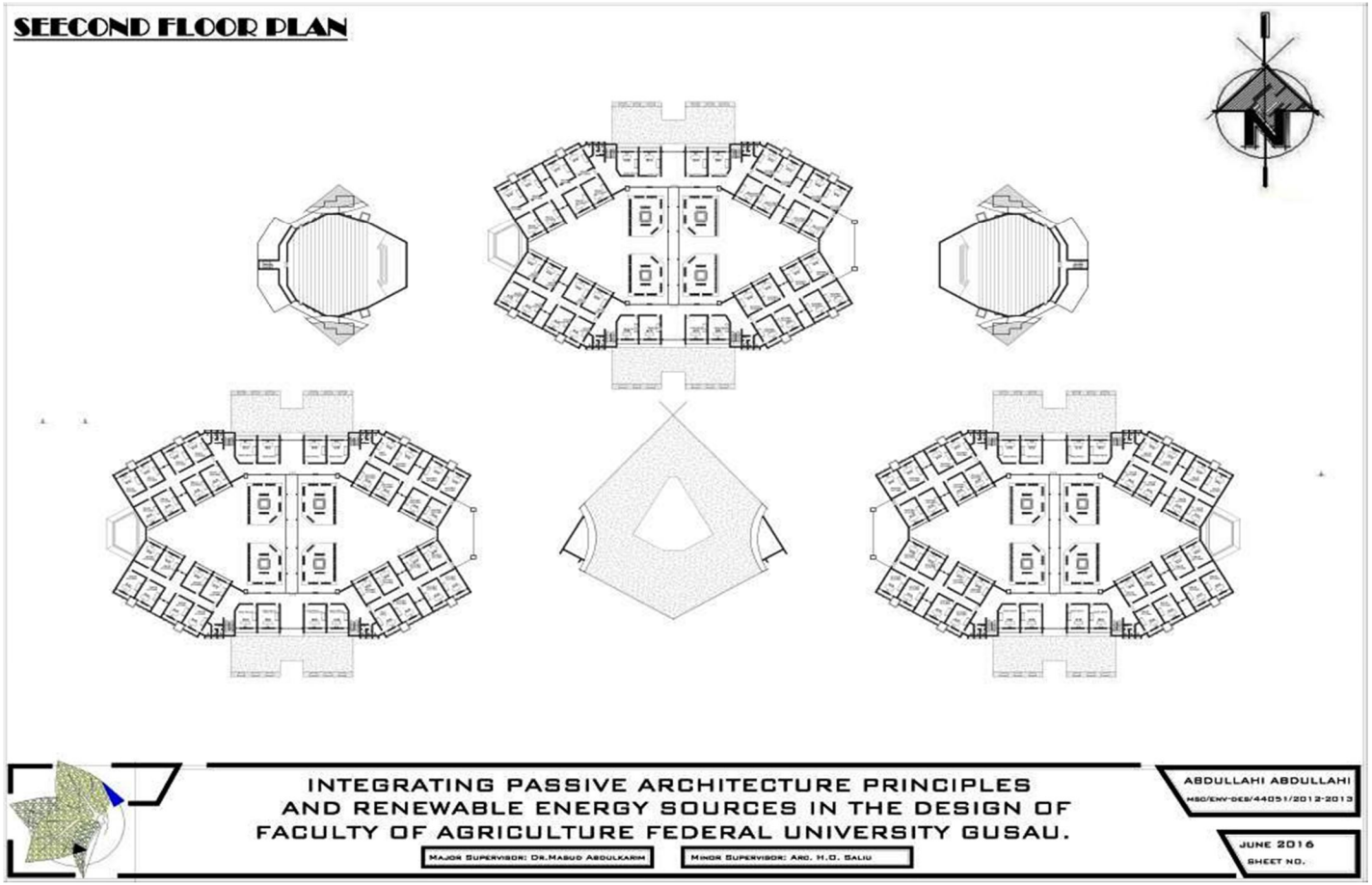
APPENDIX 5: GROUND FLOOR PLAN



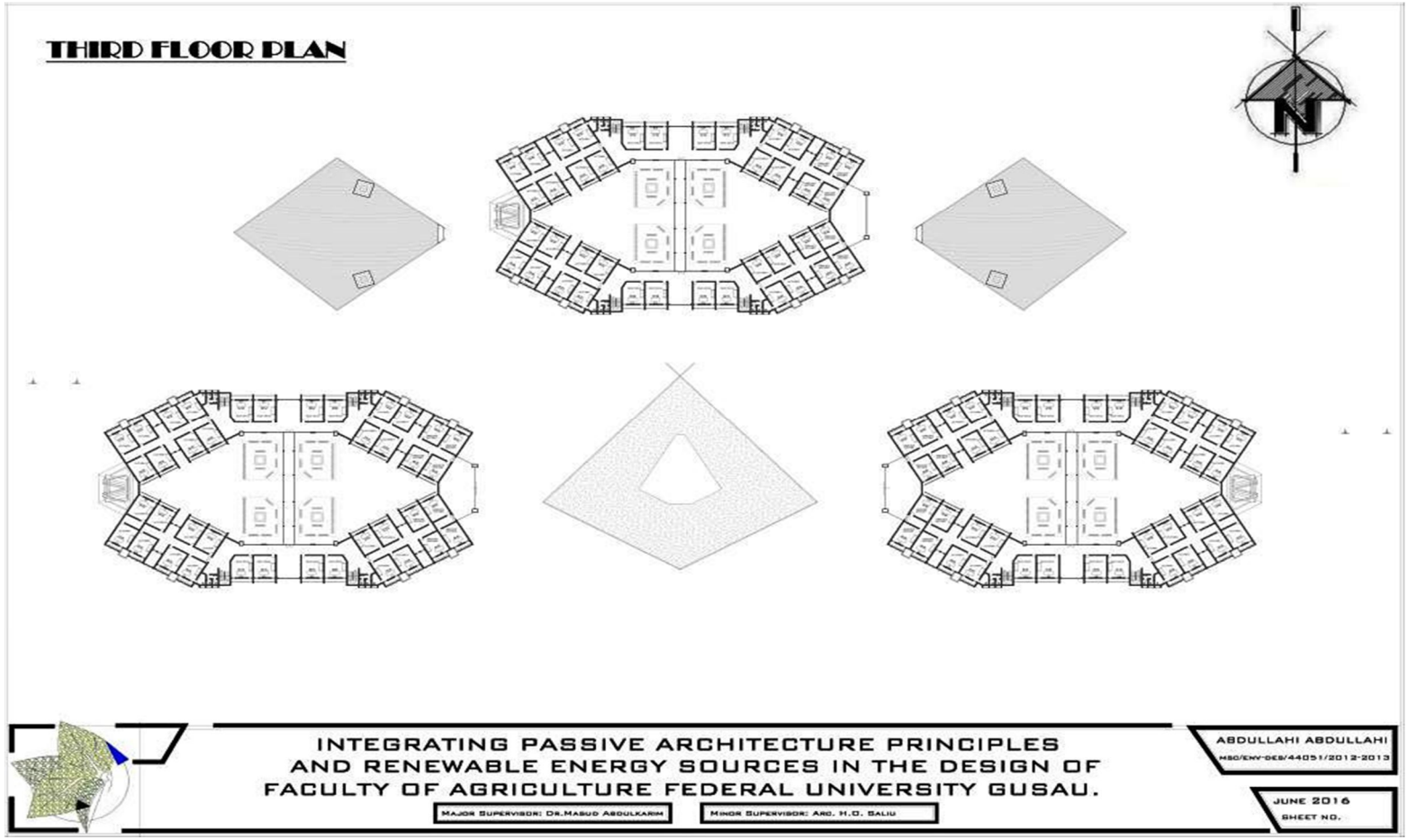
APPENDIX 6: FIRST FLOOR PLAN



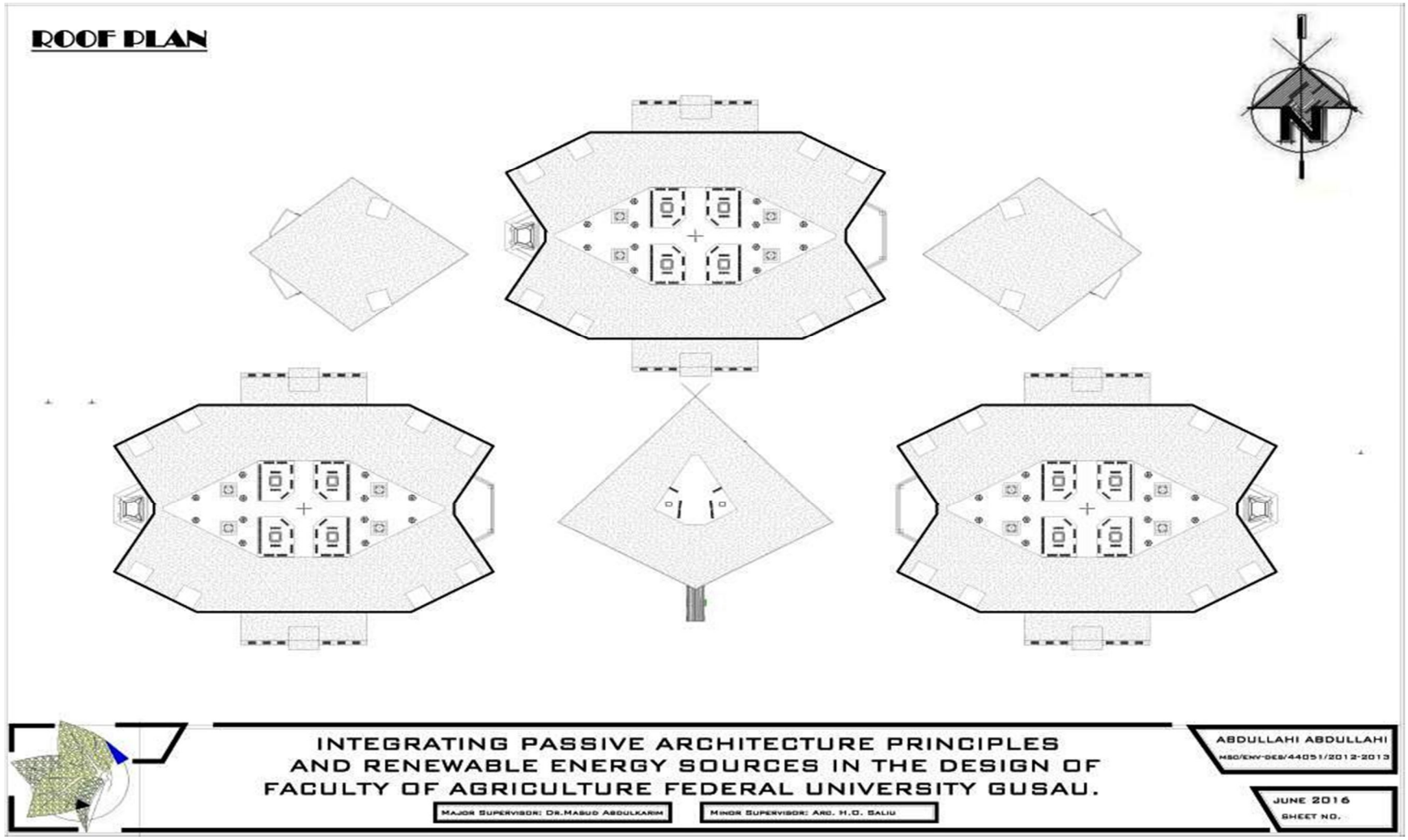
APPENDIX 7: SECOND FLOOR PLAN



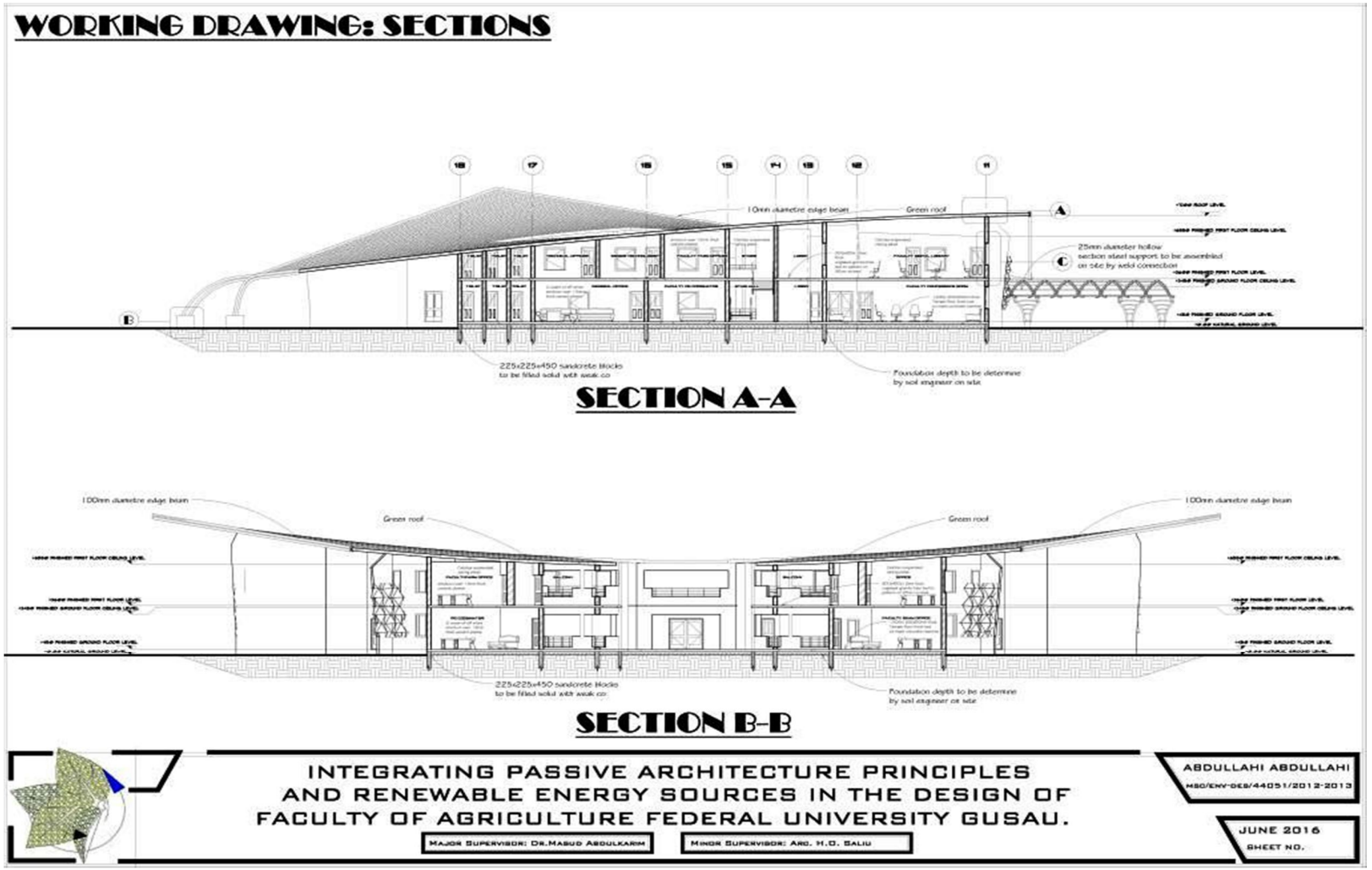
APPENDIX 8: THIRD FLOOR PLAN



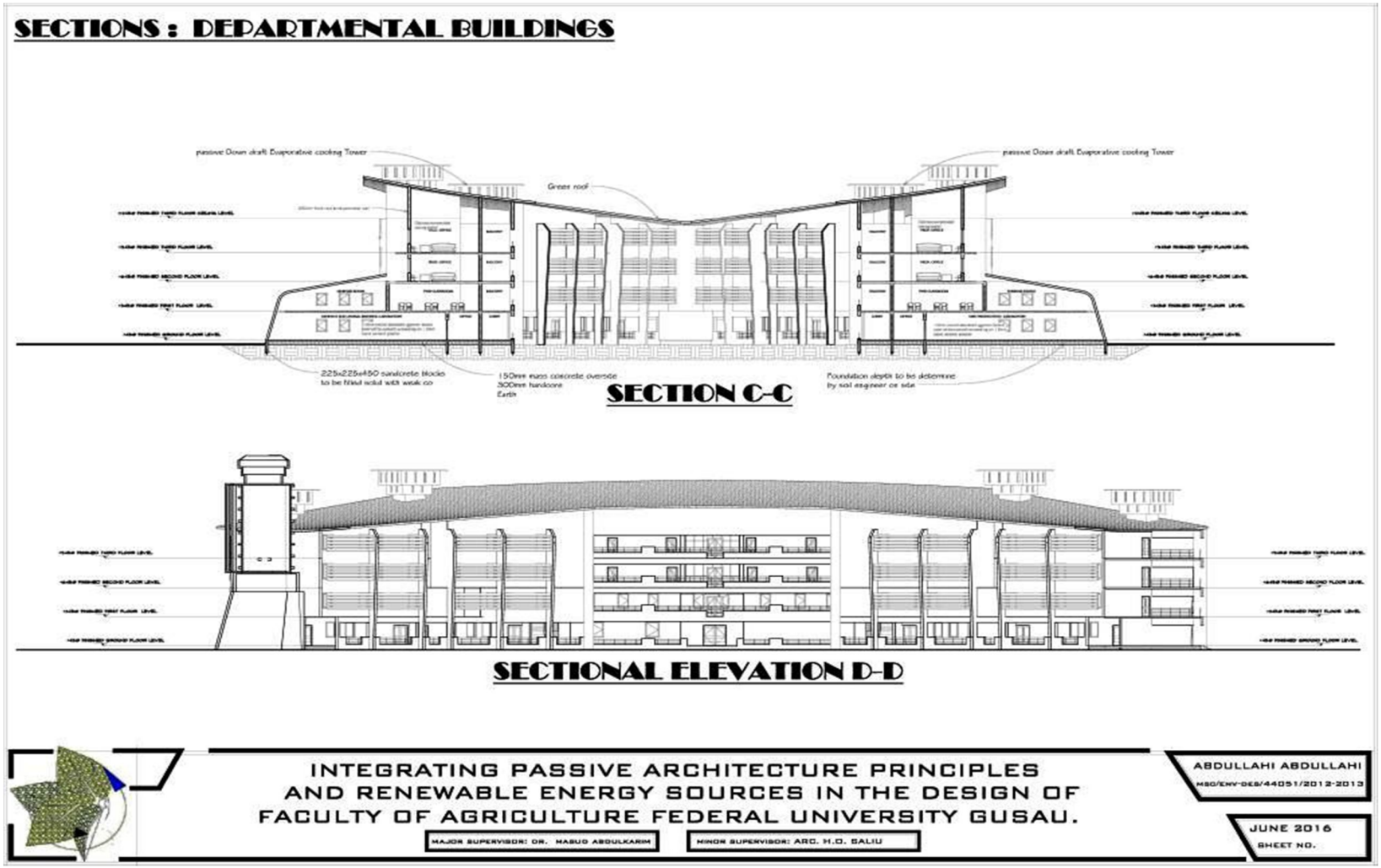
APPENDIX 9: ROOF PLAN



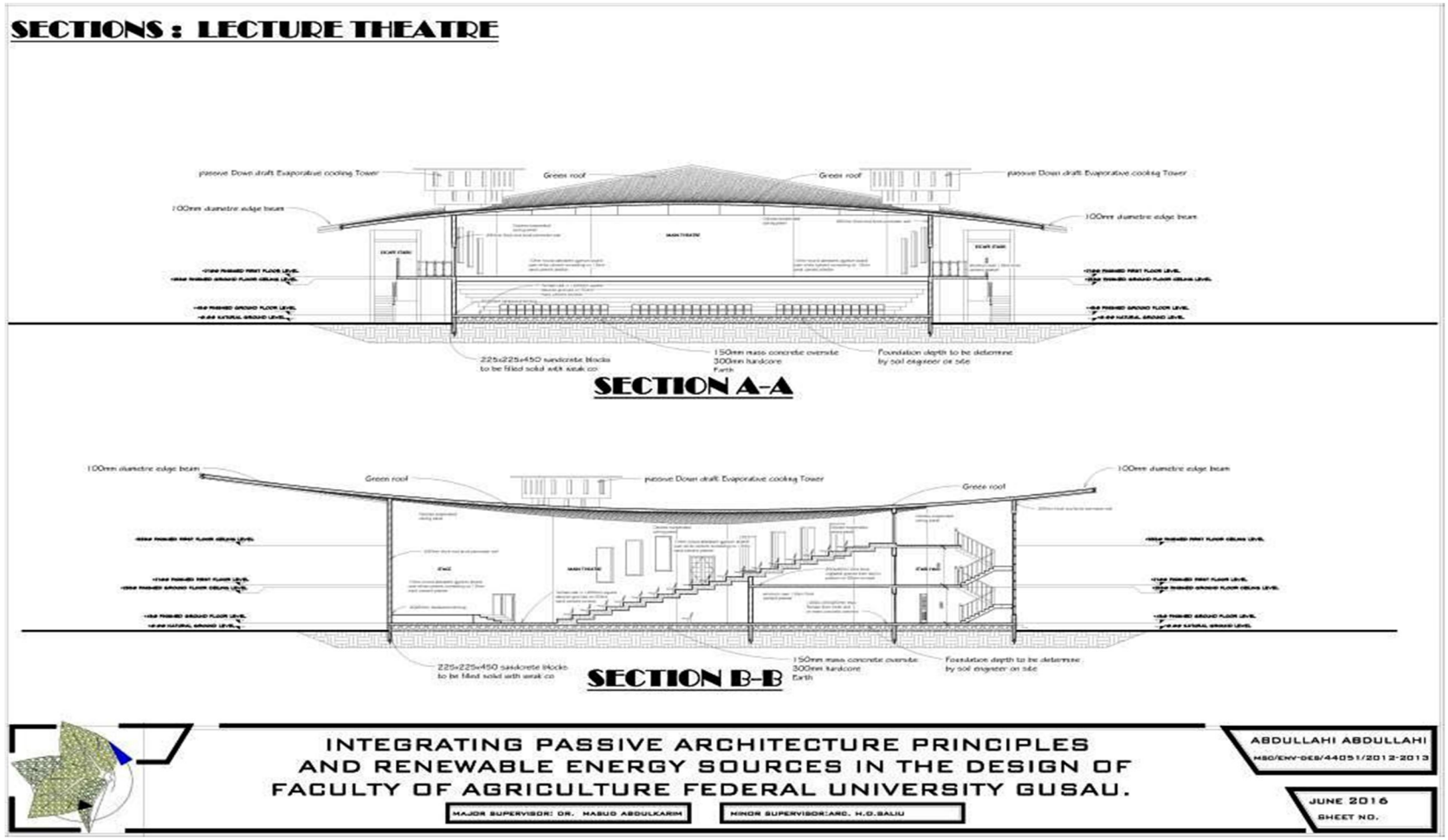
APPENDIX 10: SECTION A-A AND B-B



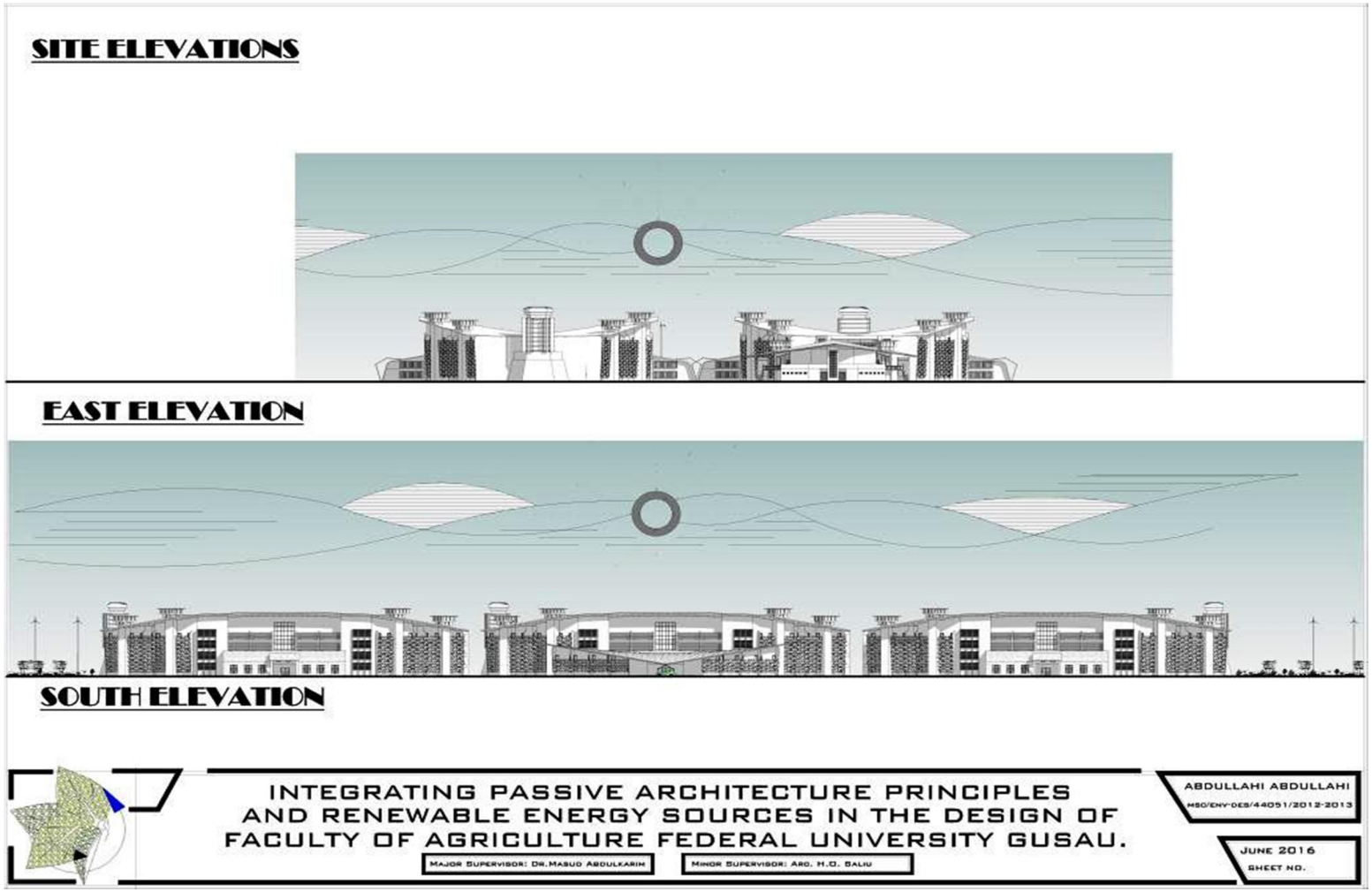
APPENDIX 11: SECTION C-C AND D-D



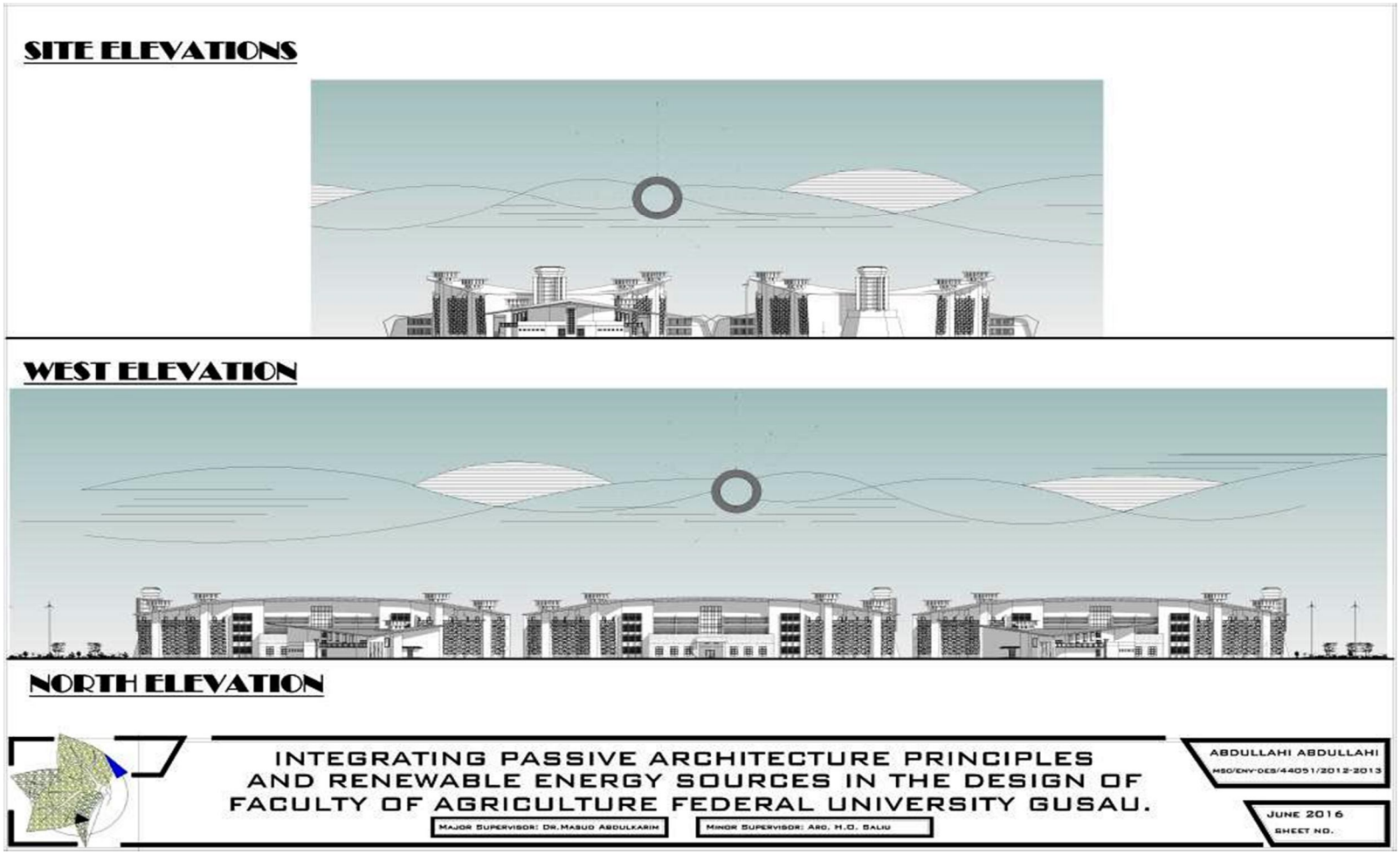
APPENDIX 12: LECTURE THEATRE SECTION A-A AND B-B



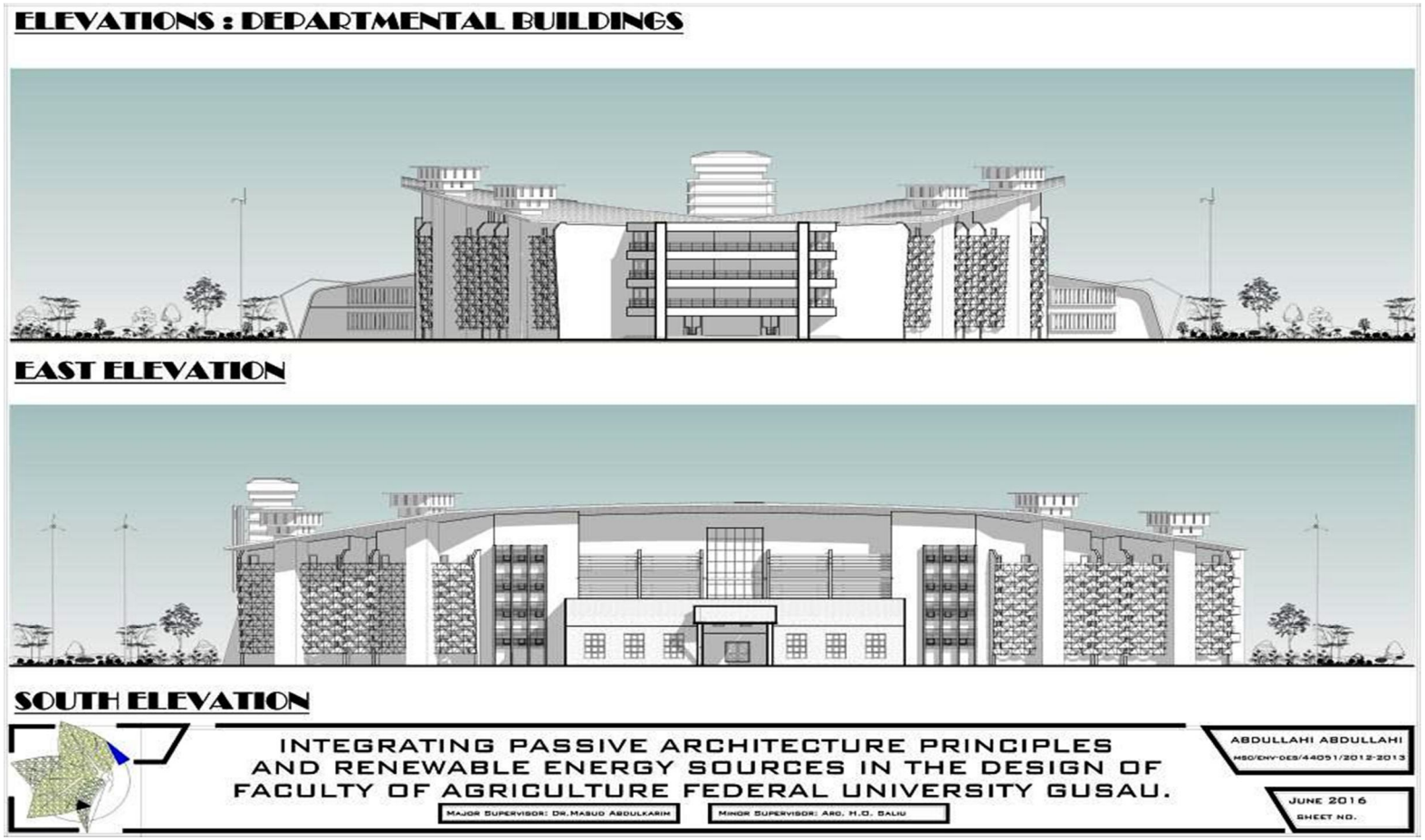
APPENDIX 13: SITE ELEVATIONS I



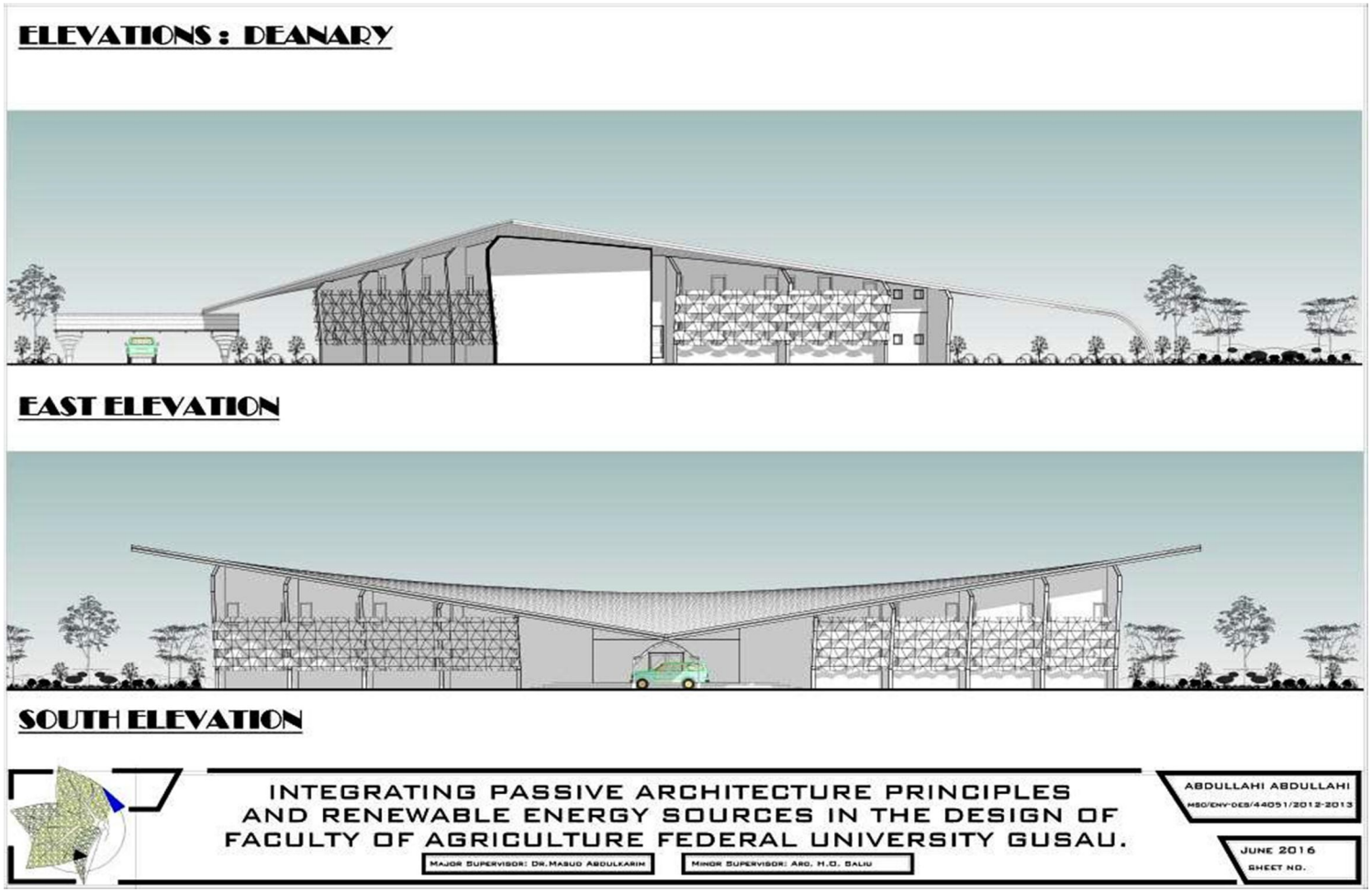
APPENDIX 14: SITE ELEVATIONS II



APPENDIX 15: ELEVATIONS DEPARTMENTAL BUILDINGS



APPENDIX 16: ELEVATIONS DEANERY

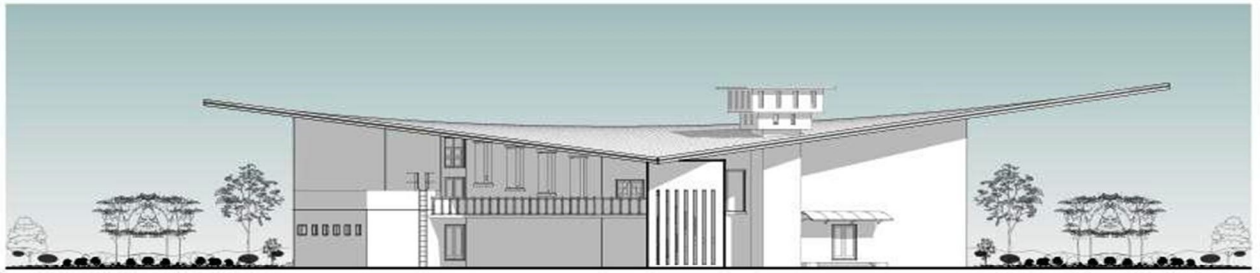


APPENDIX 17: ELEVATIONS LECTURE THEATRE

ELEVATIONS: LECTURE THEATRE



WEST ELEVATION



NORTH ELEVATION

INTEGRATING PASSIVE ARCHITECTURE PRINCIPLES AND RENEWABLE ENERGY SOURCES IN THE DESIGN OF FACULTY OF AGRICULTURE FEDERAL UNIVERSITY GUSAU.

MAJOR SUPERVISOR: DR.MASUD ABDULKARIM

MINOR SUPERVISOR: ARC. H.O. SALIU

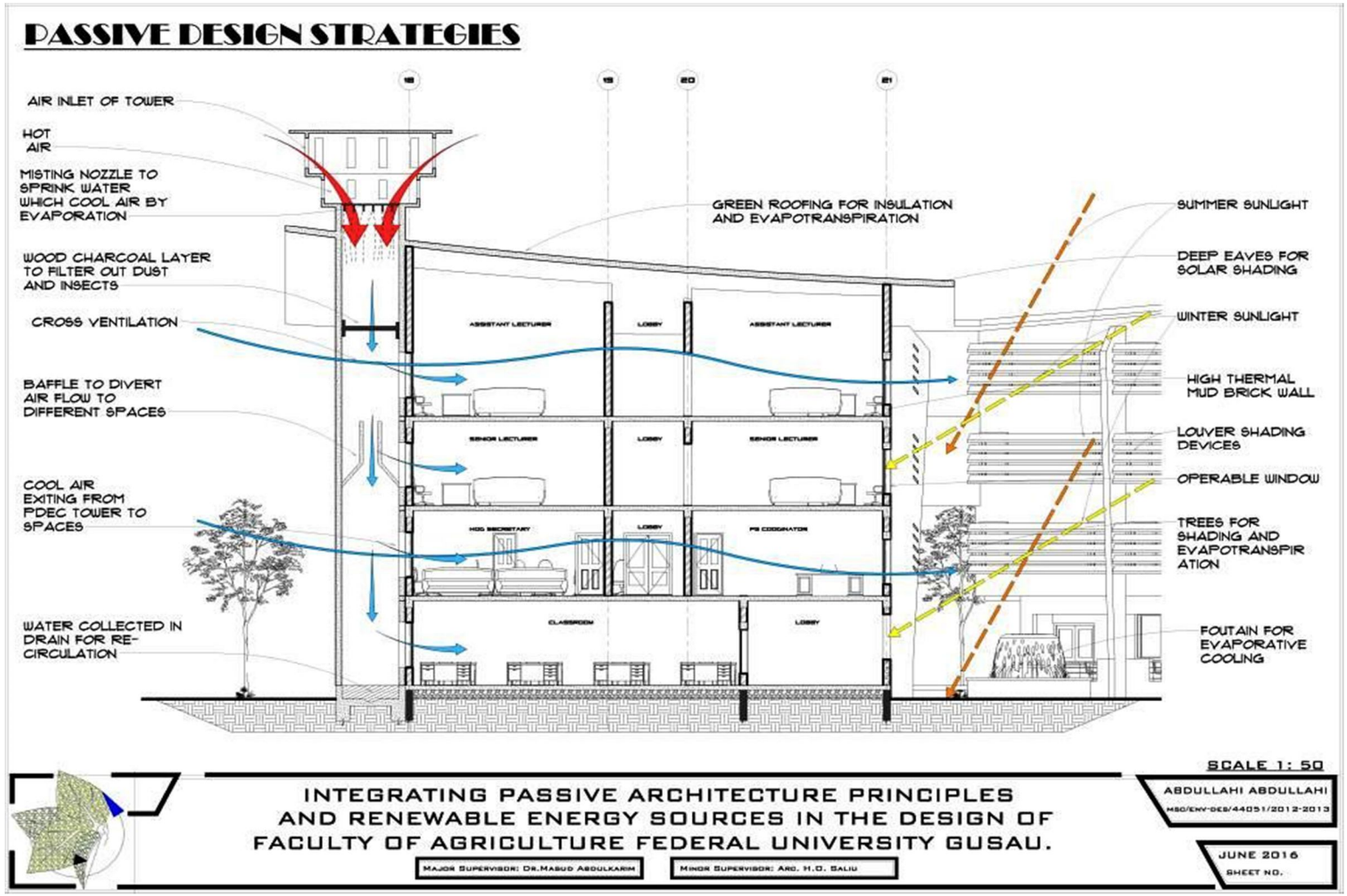
ABDULLAHI ABDULLAHI

HSC/ENV-DES/44051/2012-2013

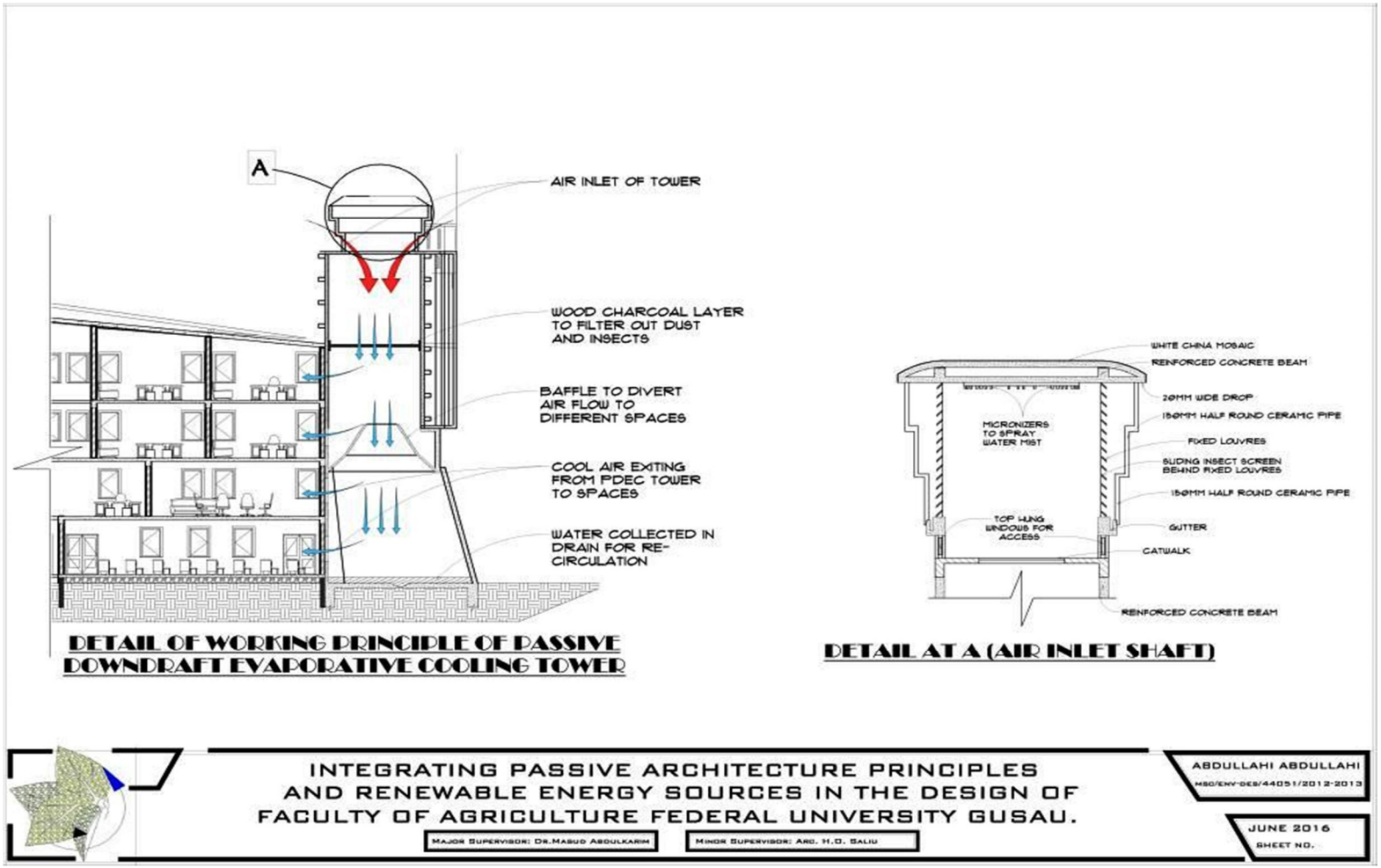
JUNE 2016

SHEET NO.

APPENDIX 18: PASSIVE DESIGN STRATEGIES



APPENDIX 19: PASSIVE DOWNDRAFT EVAPORATIVE COOLING TOWER



APPENDIX 20: 3D VIEWS

