USE OF PASSIVE DESIGN TECHNIQUES IN THE DESIGN OF FACULTY OF ENGINEERING, FEDERAL UNIVERSITY DUTSE (FUD) JIGAWA STATE

BY

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DECLARATION

I hereby declare that the work in this thesis titled "USE OF PASSIVE DESIGN TECHNIQUES IN THE DESIGN OF FACULTY OF ENGINEERING, FEDERAL UNIVERSITY DUTSE (FUD) JIGAWA STATE" was performed by me in the Department of Architecture under the supervision of Dr Babangida Hamza and Dr R. B. Tukur

The information derived from the literature has been dully acknowledged in the text and list of referees provided. No part of this work has been presented for another degree or diploma at any institution.

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Name of student	Signature	Date

CERTIFICATION

This project thesis titled **"USE OF PASSIVE DESIGN TECHNIQUES IN THE DESIGN OF FACULTY OF ENGINEERING, FEDERAL UNIVERSITY DUTSE (FUD) JIGAWA STATE"** meets the regulations governing the award of Master of Science of Ahmadu Bello University, Zaria, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This project is dedicated to the entire members of my family.

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I wish to acknowledge the tireless efforts of my supervisor, Dr Arc Babangida Hamza, who helped and guided me to the successful completion of this work, I also acknowledge the valuable contributions of Arc S.S. Tulpule, Dr Arc R. B. Tukur and Dr Arc Mas'ud Abdulkarim. I thank to other lecturers and staff of the department of Architecture, Faculty of Environmental Design, Ahmadu Bello University (A.B.U.) Zaria who in one way or the other contribute to this work.

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ABSTRACT

Passive Design is a method of construction where a comfortable interior environment can be created using very little energy; simply by eliminating the reliance on active heating or cooling systems. In hot & dry climate an architect‘s aim would be to design a building in such a way that solar gains are maximized in winter and, reduce solar gains in summer.

A comprehensive research which involves the internet, books, past unpublished thesis project, journals, photographs, papers, case studies, the study, analysis and observation of similar facilities from around the world, with a view to understanding their contributions was employed. Analysis of the climatic data was carried out in order to know how to incorporate the passive design techniques to the existing environment.

From the study carry out on the case studies, it can be observed that the most important and frequently occurring Passive design techniques is the solar protection techniques which is easier to apply than Heat modulation or Heat dissipation techniques. The most effective Solar protection techniques used in the case studies are solar control and shading of building surface, landscaping, building form, external finishing and evaporating cooling.

Based on the research carried out, it can be concluded that the most important passive cooling techniques is the solar protection technique then followed by heat dissipation technique. This is because the sun is the major source of heat, so allowing it into building will render the other passive cooling techniques ineffective. So prevention of solar access into building should be the first priority before any other techniques. Let’s encourage the use of architectural solutions based on the observation of natural principles that can reliably supplant mechanical means of cooling the building.

TABLE OF CONTENT

Cover page..... i

Declaration..... ii

Certification..... iii

Dedication..... iv

Acknowledgement..... v

Abstract..... vi

Table of content..... vii

CHAPTER ONE: INTRODUCTION

1.1 Background of study..... 1

1.2 Problem statement..... 2

1.3 Aim and objective 3

1.4 Scope and limitation..... 3

1.5 Justifications..... 4

CHAPTER TWO: LITERATURE REVIEW

2.1 Passive design..... 5

2.2 Principle **of passive design**..... 6

2.3 Passive cooling..... 7

2.4 Principles of passive cooling techniques..... 8

2.5 Classification of passive cooling techniques..... 9

2.6 Types of passive cooling techniques..... 10

2.6.1 Natural ventilation..... 10

2.6.2 Thermal mass..... 12

2.6.3 Thermal insulation..... 17

2.6.4 Buffer spaces..... 19

2.6.5 Evaporative cooling..... 20

2.6.6 Shading devices..... 21

2.6.7 Orientation..... 26

2.6.8 Form..... 28

2.6.9 Landscaping..... 29

2.7 Thermal comfort..... 32

2.7.1 Thermal comfort models..... 33

2.7.2 Thermal balance..... 35

2.8 Education..... 38

2.8.1. Education in Nigeria..... 38

2.8.2. Nigerian education system..... 39

2.9 Engineering studies..... 40

2.9.1 Branches of engineering..... 41

2.9.2. Engineering studies in Nigeria..... 45

2.9.3 Buildings for engineering studies..... 47

CHAPTER THREE: METHODOLOGY

3.1 Methodology to be adopted..... 49

3.2 Sources of data..... 50

3.3 Procedure for data collection..... 50

3.4 Case study selection criteria.....51

CHAPTER FOUR: CASE STUDY

4.1 CASE STUDY ONE..... 52

4.1.1 Background..... 52

4.1.2 Location..... 53

4.1.3 Spatial planning and design: 53

4.2 CASE STUDY TWO..... 59

4.2.1 Background..... 59

4.2.2 Location..... 60

4.2.3 Spatial planning and design..... 60

4.3 CASE STUDY THREE..... 66

4.3.1 Background..... 66

4.3.2 Location. 66

4.3.3 Special planning and design..... 66

4.4 CASE STUDY FOUR..... 72

4.4.1 Background..... 72

4.4.2 Location 72

4.4.3 Special planning and design..... 72

4.5 Conclusion and Observation..... 78

CHAPTER FIVE: SITE

5.1 Dutse town 79

5.2 populations 80

5.3 Site location 80

5.4 Site characteristics and analysis..... 82

5.4.1 Topography..... 82

5.4.2 Infrastructure 83

5.4.3 Vegetation..... 83

5.4.4 Climate 84

5.5 Site analysis..... 89

CHAPTER SIX: DESIGN REPORT

6.1 Purpose of design.....90

6.2 Design brief.....90

6.3 The faculty population.....91

6.4 Schedule of accommodation.....92

6.5 Design concept 94

6.6 Passive cooling techniques applied.....95

6.6.1 Landscaping with vegetation.....95

6.6.2 Orientation.....96

6.6.3 Shading devices.....96

6.6.4 Courtyard system.....97

6.6.5 Water pond.....97

6.6.6 Atrium.....98

6.6.7 Roof garden.....99

CHAPTER SEVEN:

SUMMARY, CONCLUSION AND RECOMMENDATION

7.1 Summary.....100

7.2 Conclusions.....100

7.3 Recommendation.....101

7.4 Original Contribution.....103

REFERENCES.....104

APPENDICIES.....107

LIST OF FIGURES

Figure **Title** **Page**

Fig. 2.1 Principle of passive design..... 7

Fig. 2.2 Passive cooling strategies..... 8

Fig. 2.3 Ventilation air movement..... 12

Fig. 2.4 Use of thermal mass..... 15

Fig. 2.5 Courtyard design with evaporation cooling pond.....21

Fig. 2.6 Basic shading strategies..... 22

Fig. 2.6.1 Basic shading strategies..... 23

Fig. 2.6.2 Basic shading strategies..... 24

Fig. 2.7 Basic shading devices..... 25

Fig. 2.7.1 Basic shading devices..... 25

Fig. 2.8 Landscape design..... 30

Fig. 2.8.1 Landscape design..... 31

Fig. 2.9 Bioclimatic chart..... 34

Fig. 2.10 Ways of thermal exchange by the human body.....36

Fig. 2.11 Diagram of clothing insulation.....37

Fig. 2.12 Stepped pyramid of King Zoser.....42

Fig. 2.13 Machu Picchu, a mountain-top city.....43

Fig. 5.1 Map of Nigeria showing the map and Location of Jigawa State.....78

Fig. 5.2 Map of Jigawa State showing the map and Location of Dutse..... 80

Fig. 5.3 Eastern bye pass road that link the University..... 81

Fig. 5.4 FUD new main Gate.....81

Fig. 5.5 Master plan of of Federal University Dutse (FUD).....82

Fig. 5.6 Infrastructures to the proposed site.....83

Fig. 5.7 Vegetation of the site.....84

Fig. 5.8 Dutse average Temperature.....85

Fig. 5.9 Jigawa average Rainfall.....86

Fig. 5.10 Jigawa average Related Humidity.....86

Fig. 5.11 Jigawa sun path diagram.....87

Fig. 5.12 Jigawa sunrise-sunset-dawn and dust.....87

Fig. 5.13 The climate of the tropical region.....88

Fig. 5.13.1 The climate of the tropical region.....88

Fig. 6.1 Design Concept (Buildings are arrange as a wheel).....94

Fig. 6.2 Elevation showing the shading devices.....96

Fig. 6.3 Part of floor plan showing the courtyard system.....97

Fig. 6.4 Section showing Atrium to discharge hot air.....98

Fig. 6.5 Part of building showing the roof garden.....99

LIST OF TABLES

Table **Title** **Page**

Table 2.1 Thermal mass properties of some common materials..... 16

Table 2.2 Simple shading strategies for different orientation.....27

Table 4.1 Summary of findings in relation to passive design.....58

Table 4.2 Summary of findings in relation to passive design.....65

Table 4.3 Summary of findings in relation to passive design.....71

Table 4.4 Summary of findings in relation to passive design.....76

Table 4.5 Case study Summary sheet..... 77

Table 5.1 Population of Jigawa State and Dutse the State Capital..... 80

Table 5.2 Dutse average weather by Month..... 85

Table 6.1 NUC Academic Students Structure for Engineering..... 91

Table 6.2 NUC Staff / Student ratio for Engineering..... 91

Table 6.3 NUC Minimum Space Requirements for the Deanery.....92

Table 6.4 NUC Minimum Space Requirements for the Department.....93

LIST OF PLATES

Plate **Title** **Page**

Plate 4.1 Enclosed courtyard with a pond, Faculty of Engineering ABU Zaria.....54

Plate 4.2 Part of Landscape, Faculty of Engineering ABU Zaria.....54

Plate 4.3 Side view of the Faculty of Engineering ABU Zaria.....55

Plate 4.4 Department of Civil Engineering ABU Zaria.....55

Plate 4.5 Department of Mechanical Engineering ABU Zaria.....56

Plate 4.6 Department of Electrical Engineering ABU Zaria.....56

Plate 4.7 Interior of the Laboratory in the Faculty..... 57

Plate 4.8 Workshop, Faculty of Engineering ABU Zaria.....57

Plate 4.9 Sign/main entrance gate of the University KUST Wudil.....61

Plate 4.10 Administrative Block KUST Wudil..... 61

Plate 4.11 Sign/ entrance gate of the Faculty KUST Wudil..... 62

Plate 4.12 Workshop, Faculty of Engineering KUST Wudil.....62

Plate 4.13 Main complex and its landscape of the Faculty KUST Wudil.....63

Plate 4.14 Courtyard and surrounding veranda of the Faculty KUST Wudil.....63

Plate 4.15 Interior of the class room of the Faculty KUST Wudil..... 64

Plate 4.16 Part of landscape of the Faculty, KUST Wudil.....64

Plate 4.17 Main entrance gate of the University (BUK New site).....67

Plate 4.18 Approach view of the Faculty of Engineering BUK (New site).....67

Plate 4.19 Side view of the Faculty of Engineering BUK (New site).....68

Plate 4.20 Lecture theatre of the Faculty of Engineering BUK (New site)..... 68

Plate 4.21 Workshop of the Faculty of Engineering BUK (New site).....69

Plate 4.22 Part of Workshop of the Faculty of Engineering BUK (New site).....69

Plate 4.23 Parking spaces of the Faculty of Engineering BUK (New site)..... 70

Plate 4.24 The Faculty buildings on Symonds Street..... 73

Plate 4.25 Use of shading devices in the Faculty, University of Auckland.....74

Plate 4.26 Use of shading devices in the Elevation, University of Auckland..... 74

Plate 4.27 Use of Landscape/courtyard in the Faculty, University of Auckland.....75

Plate 4.28 Interior of the classroom in the Faculty, University of Auckland..... 75

LIST OF APPENDICIES

Appendix 1 FUD Master plan.....107

Appendix 2 Site Analysis (Topography and Vegetation).....108

Appendix 3 Site Analysis (Climatic data and visual impact).....108

Appendix 4 Site plan.....109

Appendix 5 Floor plan on site.....110

Appendix 6 Roof plan.....111

Appendix 7 Sections.....111

Appendix 8 Elevations.....112

Appendix 9 Elevations.....113

Appendix 10 Elevations.....114

Appendix 11 Elevations.....115

Appendix 12 3D.....116

Appendix 13 3D.....116

Appendix 14 3D.....117

Appendix 15

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF STUDY

Incorporation of solar passive techniques in a building design helps to minimize load on conventional systems such as heating, cooling, ventilation & light. Passive strategies provide thermal and visual comfort by using natural energy sources & sinks. Examples: solar radiation, outside air, wet surfaces, vegetation etc means, in hot & dry climate: an architect‘s aim would be to design a building in such a way that solar gains are maximized in winter and, reduce solar gains in summer.

Once the solar passive architectural concepts are applied to design, the load on conventional system (HVAC & lighting) is reduced. Architects can achieve a solar passive design by studying the macro and micro climate of the site, applying bioclimatic architecture design features and taking advantage of the existing natural resources on the site. The solar passive design strategy should vary from one climate to another. Since these buildings can also function independent of mechanical systems, in case of power failure they are still well lit by natural daylight and thermally comfortable.

Energy and architecture form a natural marriage if indoor comfort and respect for environment are secured. Currently, energy constraint and global warming are the

biggest challenges confronting the planet (Nilcon, 2008). Passive design techniques can be used to reduce and in some cases eliminate mechanical air conditioning requirements in areas where cooling is a dominant problem. The cost and energy effectiveness of these options are both worth considering by client and designer. Contained within this section are rules of thumb and an explanation or the essentials of passive cooling systems. Natural ventilation is clearly a valuable tool for sustainable development as it relies only on natural air movement and can save significant amounts of fossil fuel based energy by reducing the need for mechanical ventilation and air conditioning. Reducing electrical energy used for cooling contributes to the reduction of green house gas emission form the electrical generating plant providing the energy (Richard, 2007).

The need to reduce our consumption of energy and to give users more control over their immediate environments are good reasons for designer know to re-evaluate the role of natural ventilation in buildings and to become familiar with the basic principles involve (Richard 2007). University buildings should make students as well as staff life comfortable. External environmental conditions vary seasonally and affect the internal conditions of the building and invariably the level of human comfort on occupants. The factors that determine internal conditions required for comfort are: Environmental and other factors of the site, Occupants activity within the building and duration of occupancy as well as Building location, orientation, envelope, structure and finishes.

1.2 STATEMENT OF PROBLEM

Faculty of engineering buildings requires a comfortable site for the building users to harness the need for high brain-thinking work in the program. Research Institutes and Laboratory buildings including Workshops all require an indoor comfortable condition. Use of passive design technique in hot dry condition could regulate the over-heating of

indoor and outdoor spaces within the academic environment. This problem takes about Six to Eight months of every year. The highly maintenance costs of buildings located in this area and especially where power supply is irregular could also be minimised further.

1.3 AIM AND OBJECTIVES

1.3.1 AIM

The main aim of this thesis is to achieve a passively cooled academic environment with a view to enhancing learning. To achieve this aim, the following objectives are targeted.

1.3.2 OBJECTIVES:

i. To identify key issues in the Principles of passive design techniques.
ii. To identify and incorporate in my proposed design the applicable principles of passive design techniques for hot and dry areas.
iii. To use the guiding principles studied above in the designing of the proposed Faculty of Engineering at Federal University Dutse (FUD), Jigawa State.

1.4 SCOPE AND LIMITATION

Passive design technique is very wide; it involves thermal mass, insulation, landscaping, ventilation, orientation, etc. The focus of this work is how to achieve passive design suitable to the environment in institutional buildings which will be used to provide a conduce environment. This research will be limited in its scope to faculty of Engineering and its ancillary facilities such as library, workshops, lecture theatres and recreational space.

1.5 JUSTIFICATION

Education buildings are crucially important in every body's development. The buildings in which are educated have very special importance in everyone's lives. The new Federal University Dutse (FUD) Jigawa State in a growing State capital Dutse, lacks School of Engineering or Faculty of Engineering that will train the younger people to become Engineers for the state to benefit from them. Jigawa has hot dry climate which required the use of Passive design technique in the design of Faculty of Engineering, hence making this research very important.

Save cost in the long run on running active elements, and contribute our quota in the quest for reduced global warming due to excessive use of energy.

CHAPTER TWO

LITERATURE REVIEW

2.1 PASSIVE DESIGN

Passive design is the key to sustainable building. It responds to local climate and site conditions to maximise building users' comfort and health while minimising energy use. Using passive design can reduce temperature fluctuations, improve indoor air quality and make a home drier and more enjoyable to live in (Oikos, 2008). It achieves this by using free, renewable sources of energy such as sun and wind to provide household heating, cooling, ventilation and lighting, thereby reducing or removing the need for mechanical heating or cooling.

It can also reduce energy use and environmental impacts such as greenhouse gas emissions. Interest in passive design has grown, particularly in the last decade or so, as part of a movement towards more comfortable and resource-efficient buildings.

Passive solar design can also achieve summer cooling and ventilating by making use of convective air currents which are created by the natural tendency of hot air to rise (Oikos, 2008).

The key elements of passive design are: building location and orientation on the site; building layout; window design; insulation (including window insulation); thermal mass; shading; and ventilation. Each of these elements works with others to achieve comfortable temperatures and good indoor air quality. (Stamas, 2008).

The first step is to achieve the right amount of solar access – enough to provide warmth during cooler months but prevent overheating in summer. This is done through a combination of location and orientation, room layout, window design and shading.

Insulation and thermal mass help to maintain even temperature, while ventilation provide passive cooling as well as improving indoor air quality.

All of these elements work alongside each other and therefore should be considered holistically. For example, large windows that admit high levels of natural light might also result in excessive heat gain, especially if they cast light on an area of thermal mass. Similarly, opening windows that provide ventilation will also let in noise. Alongside passive design features, designers should also consider other factors such as views, covenants and local authority restrictions, and building owners' preferences.

2.2 PRINCIPLE OF PASSIVE DESIGN

Passive Design is a method of construction where a comfortable interior environment can be created using very little energy; simply by eliminating the reliance on active heating or cooling systems. Passive Design works on a specific set of principles which are Solar Gain, Solar and Heat protection, Heat Modulation, Heat Dissipation, Thermal Mass, Super Insulation, Airtightness, and MVHR.

The principles use to work on hot-dry climates are Solar and Heat protection, Heat Modulation, Heat Dissipation, Thermal Mass, and Super Insulation. (Figure 2.1) shows the Active Design and Passive Design.

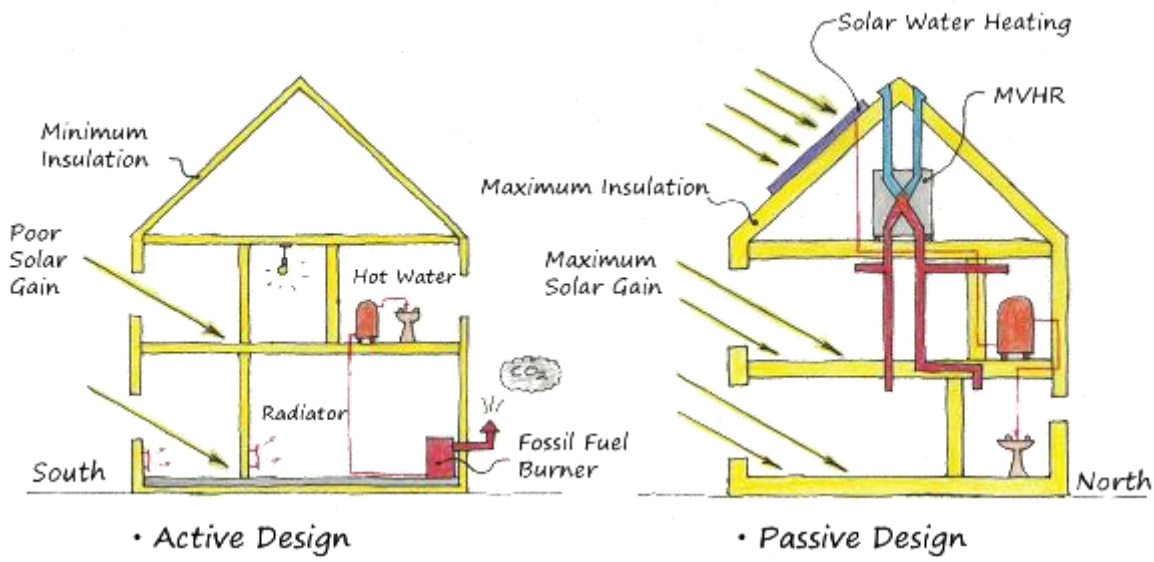


Figure 2.1 Principle of passive design **Source:** Passive design toolkit, (2005)

2.3 PASSIVE COOLING

According to NKBA (2009), passive cooling is a system whereby a building's structure (or an element of it) is designed to permit increased ventilation and retention of coolness within the building components.

Green Idea (2009) defined passive cooling as using passive building strategies to relieve the cooling load of a building by capitalizing on such thing as predictable summer breezes or by shading windows from direct summer sunlight.

The term "passive" implies that energy-consuming mechanical components like pumps and fans are not used. Passive cooling is considered an "alternative" to mechanical cooling that requires complicated refrigeration system. By employing passive cooling

techniques into modern building, one can eliminate mechanical cooling or at least reduce the size and cost of the equipment.

Passive cooling is based on the interaction of the building and its surrounding. Passive cooling strategies as shown in (Figure 2.2) are adopted according to the local climate. Also called *natural cooling*, a passive solar energy technique that allows or augments the natural movement of cooler air from exterior, shaded areas of a building through or around a building.

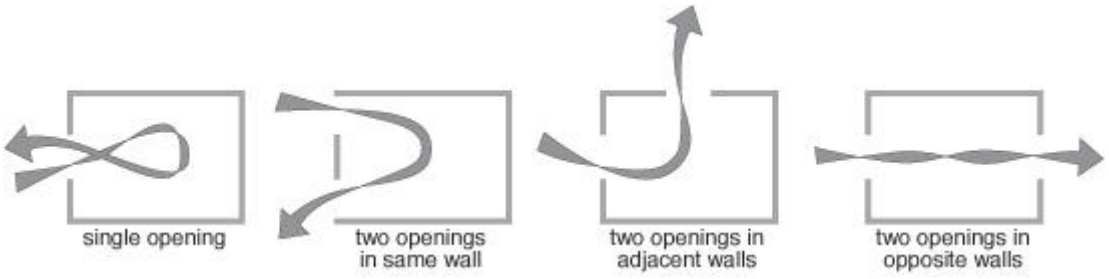


Figure 2.2: Passive cooling strategies

Source: Passive design toolkit, (2005)

2.4 PRINCIPLES OF PASSIVE COOLING TECHNIQUES

Passive cooling techniques in buildings have proven to be extremely effective and can greatly contribute in decreasing the cooling load of buildings. According to Reinhart et al (2001), efficient passive systems and techniques have been designed and tested. Passive cooling has also proven to provide excellent thermal comfort and indoor air quality, together with very low energy consumption. (Reinhart et al, 2001).

When a building's internal and solar gains are sufficiently reduced, a lean *climatization concept* can be developed (Reinhart et al, 2001). The term *lean* signifies that the system

is energy efficient so that only the amount of electricity needed to run fans and circulation pumps is required to maintain comfortable indoor temperatures year-round.

2.5 CLASSIFICATION OF PASSIVE COOLING TECHNIQUES

Passive cooling techniques can be classified in three main categories, (Santamouris & Assimakopoulos, 2002):

a) **Solar and Heat Protection Techniques**. Protection from solar and heat gains may involve: Landscaping, and the use of outdoor and semi-outdoor space, building form, layout and external finishing, solar control and shading of building surfaces, thermal insulation, control of internal gains etc.

b) **Heat Modulation Techniques**. Modulation of heat gain deals with the thermal storage capacity of the building structure. This strategy provides attenuation of peaks in cooling load and modulation of internal temperature with heat discharge at a later time. The larger the swings in outdoor temperature, the more important the effect of such storage capacity. The cycle of heat storage and discharge must be combined with means of heat dissipation, like night ventilation, so that the discharge phase does not add to overheating.

c) **Heat dissipation techniques**. These techniques deal with the potential for disposal of excess heat of the building to an environmental link sink of lower temperature. Dissipation of the excess heat of depends on two main conditions: 1) The availability of an appropriate environmental heat sink; and 2) The establishment of an appropriate thermal coupling between the building and the sink as well as sufficient temperature differences for the transfer of heat. The

main processes of heat dissipation techniques are: ground cooling based on the use of the soil, and convective and evaporative cooling using the air as the sink, as well as water and radioactive cooling using the sky as the heat sink. The potential of heat dissipation techniques strongly depends on climatic conditions. When heat transfer is assisted by mechanical devices, the techniques are known as hybrid cooling.

2.6 TYPES OF PASSIVE COOLING TECHNIQUES

The climate for the location of the thesis proposal is the hot dry type. Some of the passive cooling techniques will now be examined to determine which will be more suitable for the design proposal. The techniques are listed below:

Natural ventilation

Thermal mass

Thermal insulation

Buffer spaces

Evaporative cooling

Shading

Orientation

Form

Landscaping

2.6.1 NATURAL VENTILATION

It depends solely on air movement to cool occupants. Window opening on opposite sides of the building enhance cross ventilation driven by breezes. Since natural breezes can’t be scheduled, designers often choose to enhance natural ventilation using tall

spaces within buildings called stacks. With opening near the top of the stack, warm air can escape, while cooler air enters the building from opening near the ground. Ventilation requires the building to be open during the day to allow air flow.

Convective cooling by ventilation is a very effective method to improve indoor comfort, indoor air quality and reduce temperature. Higher air speeds inside the building may enhance thermal comfort when they do not exceed certain values. The techniques is usually limited to night time ventilation however daytime ventilation may be used when ambient temperature is lower than indoor temperature.

Convective cooling may be natural, mechanical or hybrid. Natural ventilation is due either to wind forces, temperature difference, or both. A serious reduction of the cooling potential is observed in dense urban environments as a result of the dramatic decrease of the wind speed in cities (Geros, et al, 2001). Careful positioning of the openings in naturally ventilated building is a crucial parameter that determines the effectiveness of the process. A review of the sizing methodologies is given by Anthienitis and Santamouris (Athienitis & Santamouris, 2002).

Air movement is the most important element of passive cooling. It increases cooling by increasing evaporation rates. Generally, cross ventilation is most effective for air exchange (building cooling) and fans for air movement (people cooling). Air movement provides useful cooling in all climates but may be less effective in tropical climates during periods of high humidity. However humidity levels in Jigawa is not as high as the coastal areas.

Dominant wind direction on the proposed thesis site is North West, having fenestrations on this side will enhance air movement. According to Reardon (2008) an air speed of 0.5 per second equates to a 3 degree drop in temperature at relative humidity of 50 per

cent. This is a one off physiological cooling effect that occurs when still air is moved at 0.5m per second. (Figure 2.3) shows the air movement. In higher humidity, greater airspeeds are required to achieve the same cooling benefit.

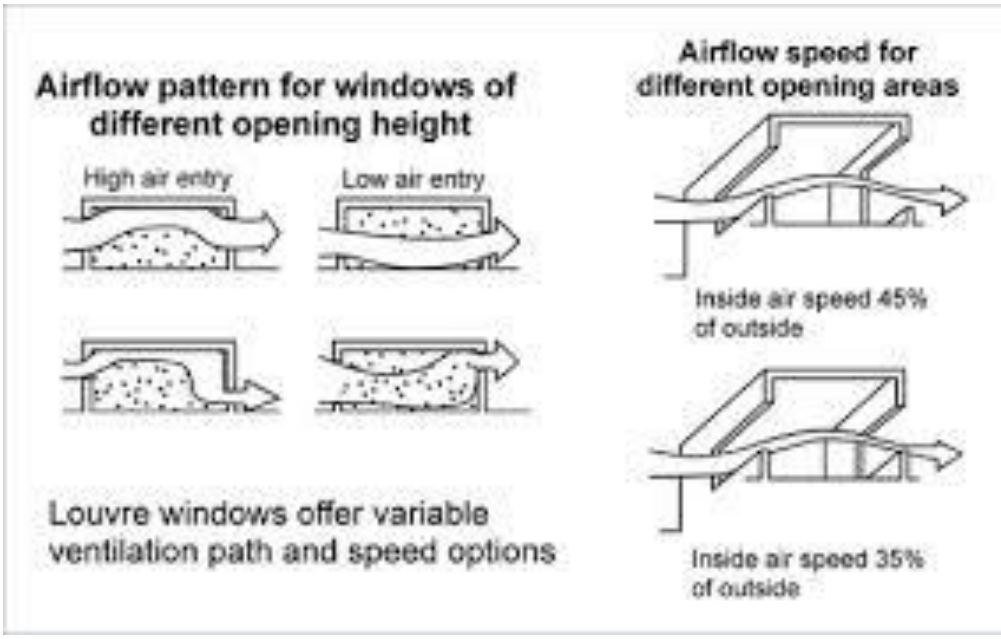


Figure 2.3: Ventilation (air movement)

Source: Reardon, (2008)

2.6.2 THERMAL MASS

Thermal mass is the ability of a material to absorb heat energy. A lot of heat energy is required to change the temperature of high density materials like concrete, bricks and tiles. They are therefore said to have high thermal mass. Lightweight materials such as timber have low thermal mass. Appropriate use of thermal mass throughout a building can make a big difference to comfort and cooling bills. (Reardon, 2008).

Constructed of material with high heat capacity, such as poured concrete, bricks and tiles, it is typically contained in walls, partitions, ceilings and floors.

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

The distribution of thermal mass is based on the orientation of the given surface and the desirable time lag (Lechner, 1991). During the night when outdoor temperatures are lower than indoor temperatures, it is possible to cool the structural mass of the building by natural ventilation. Such a technique, known as 'night ventilation' may contribute in decreasing the cooling load of air conditioned building by up to 60%, or decreasing the overheating hours of "free-heating building", i.e of building not using a cooling system. (No mechanical air conditions) up to 75% (Geros et al, 2001). Each night the mass release heat, making it reedy to absorb heat again next day. To be effective, thermal mass must be exposed to the living spaces.

Phase change materials incorporated in plaster increases the heat storage capacity in the building and thus contribute in decreasing the average indoor temperatures. Correct use of thermal mass moderate internal temperatures by averaging day/night (diurnal) extremes. This increases comfort and reduces energy costs.

Poor use of thermal mass can exacerbate the worst extremes or the climate and can be a huge energy and comfort liability. It can radiate heat all night during a summer heat wave. To be effective, thermal mass must be integrated with sound passive design

techniques. This means having appropriate areas of glazing facing appropriate directions with appropriate level of shading, insulation and thermal mass.

a) How thermal mass works

Thermal mass acts as a thermal battery. During summer it absorbs heat, keeping the house comfortable. In cooler periods the same thermal mass can store the heat from the sun or heaters to release it at night, helping the building to stay warm. (Reardon, 2008). Thermal mass is not a substitute for insulation. Thermal mass stores and re-radiates heat. Insulation stops heat flowing into or out of the building. A high thermal mass material is not generally a good thermal insulator.

A high mass building needs to gain or lose a large amount of energy to change its internal temperature, whereas a lightweight building requires only a small energy gain or loss.

b) Using thermal mass

Thermal mass is most appropriate in climates with a large diurnal temperature range. As a rule of thumb diurnal ranges of less than 6^0C are insufficient; 7^0C to 10^0C can be useful depending on climate; where they exceed 10^0C, high mass construction is desirable. Exceptions to the rule occur in more extreme climates. (Figure 2.4) shows the use of thermal mass.



Figure 2.4 Use of thermal mass

Source: Mike Cleaver, Clever Design, (2013)

In tropical climates with diurnal range of 7-8 high mass construction can cause thermal discomfort unless carefully designed, well shaded and insulated. Thermal mass should always be used in conjunction with good passive design. Since Jigawa has a low diurnal temperature range, building materials with low thermal mass will be used. Where high thermal mass materials like concrete are used, they will be shaded to prevent them from absorbing the suns heat.

c) Thermal mass properties

High density- The more dense the material (i.e the less trapped air) the higher its thermal mass. For example, concrete has high thermal mass, autoclaved Aerated Concrete (AAC) block has low thermal mass, and insulation has almost none.

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

Low reflectivity- Dark, matt or textured surface absorb and re-radiate more energy than light, smooth, reflective surfaces. (If there is considerable thermal mass in the walls, a more reflective floor will distribute heat to the walls).

TABLE 2.1: THERMAL MASS PROPERTIES OF SOME COMMON MATERIALS.

MATERIAL	**THERMAL MASS (volumetric heat capacity, KJ/m^3.k)**
Water	4186
Concrete	2060
Sandstone	1800
Compressed earth Blocks	1740
Rammed earth	1673
FC sheet (compressed)	1530
Brick	1360
Earth wall (adobe)	1300
AAC	550

*(**Source:** Environmental design guide EDG)*

The above (Table 2.1), compare the thermal mass properties of some common materials the volume or quantity of these materials in typical application is also important.

Compressed FC sheet flooring has a higher thermal mass value than brick or earth walls but is usually only present in 20mm thick layers which mean it can't store a lot of heat. Brick wall are 110 to 230mm thick and earth walls are usually minimum 300mm, giving them the capacity to store large amounts of heat.

The amount of useful thermal mass is calculated by multiplying the above figure by the total accessible volume of the material that is the volume of material which has its surface exposed to a heat source. Floor coverings such as carpet, which insulate the mass, reduce the accessible volume. Some thermal mass materials, such as concrete and brick, when used in the quantities required have high embodied energy.

2.6.3 THERMAL INSULATION

The role that insulation plays in the building is determined by its placement. When used in the building envelope, it is preventing heat flow from the inside to outside, either containing heat within the building or preventing it from entering. Insulation can be used to isolate thermal mass, shielding occupied areas from the unwanted effects of thermal mass.

Any building material has an insulating effect. This is most apparent with floor coverings on concrete slabs. Timber or carpet will effectively insulate the slab and reduce (or eliminate) its effectiveness as a heat sink. Internal strapping and lining to wall as will have the same effect, as will acoustic ceiling tiles.

Thermally insulating materials are poor thermal conductors that slow the rate of heat losses and gains to and from the outside. Effective thermal insulation is one of the most critical design parameters of building envelope. The reduction of heat transfer is expressed in term of R-Value and U-Value Minimum R-Value and maximum U-Values

for key building envelop components are prescribed by current ASHRAE 90.1 building energy standards.

Thermal insulation also impacts the surface temperature on the envelope interior, which directly impacts thermal comfort. Interior envelop surface temperatures must remain high enough during winter to avoid condensation and maintain occupant comfort. Cold surface temperatures (i.e windows) affect occupation comfort by both radiation and convection. To achieve consistent thermal insulation of the building envelope, assemblies must be carefully detailed with continuous thermal breaks. Thermal breaks use nonconductive materials to separate conductive materials to avoid degrading the envelope's thermal insulation, a common problem called thermal bridging (Vladimir, 2008).

Insulation can use with respect to floor, roof or wall. Using the appropriate amount and type of insulation such as flexible wood fibre insulation batt, including radiant barriers and bulk insulation to minimize seasonal excessive heat gain will largely improve interior thermal condition of work spaces in hot humid climates.

Flexible wood fibre insulation batt is a medium-density semi-rigid insulation slabs made from wood chipping and 7-10% polyolefin fibres. They are free from Borax and Boric Acid. They can be applied internally and use as insulation material in the hot humid climatic region. It is recommended as a wall insulation material due to the following properties and specifications.

i. Excellent thermal performance in winter
ii. Excellent thermal performance in summer
iii. Excellent acoustic performance
iv. High vapour permeability

v. Hygroscopic (absorbs & release moisture)

vi. Absorbs harmful toxins

vii. Vermin and fungus resistant

viii. Electricity neutral

ix. Non-radioactive

x. Protects the structure from spread of flame

xi. Free from toxins and allergens (Vladimir, 2008).

2.6.4 BUFFER 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 temperature 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.

Buffer spaces are a key component of many passive solar designs when they are oriented on the sunny side of the building.

South- and West-facing buffer spaces can be designed to act as occupied sunspaces, providing both passive solar heat gain and a functional occupied space. Sunspaces function like passive solar collectors, trapping solar gains like a greenhouse. Thermal

storage is most effectively provided in the thermal mass of the floor and/or walls of the sunspace structure itself. Store heat can either reach the building passively through the walls between the sunspace and the interior, or be distributed by an active mechanical system. The design and construction of sunspaces varies widely. In general, they can have open or closed ends, single or multiple slopes, and various arrangements of storage mass in the floor and walls.

Energy savings with reduced heat losses, infiltration at entries and/or preheated ventilation air, improved thermal comfort due to more stable interior space surface temperatures, reduced draft, and increased application of natural ventilation.

2.6.5 EVAPORATIVE COOLING

Evaporative is a technique based on the effect of evaporation as a heat sink. Evaporative cooling lowers the indoor air temperature by evaporating water. The cooling of air is obtained as an amount of sensible heat is absorbed by the water and used as a latent source for evaporation. Evaporative cooling can be direct or indirect. In the direct method which is commonly done directly in the space, the water content of the cooled air increases, being the air in contact with the evaporated water. In the indirect methods, such as roof ponds, which allow evaporative cooling to be used in more temperate climates, the evaporation takes place inside a heat exchanger, without a change in the water content of the air. Modern systems combine the evaporation effects with the movement of the cooled air. This can happen naturally (passive evaporative cooling) or with mechanical integration (hybrid evaporative cooling).

Large amounts of heat are consumed by water as it evaporates. This is called the latent heat of evaporation. This heat is partially drawn from surrounding air, causing cooling. Evaporation is an effective passive cooling method. It works best when relative humidity is lower (70 percent or less during hottest periods) and the air has a greater capacity to take up water vapour. Rates of evaporation are increased by air movement. The surface area of water exposed to moving air is also important. Fountains, mist sprays and waterfalls can increase evaporation rates.

Passive evaporative cooling design solutions include the use of pools, ponds and water. Feature immediately outside windows or in courtyards to pre- cool air entering the house. Carefully located water features can create convective breezes (Chris, 2002).

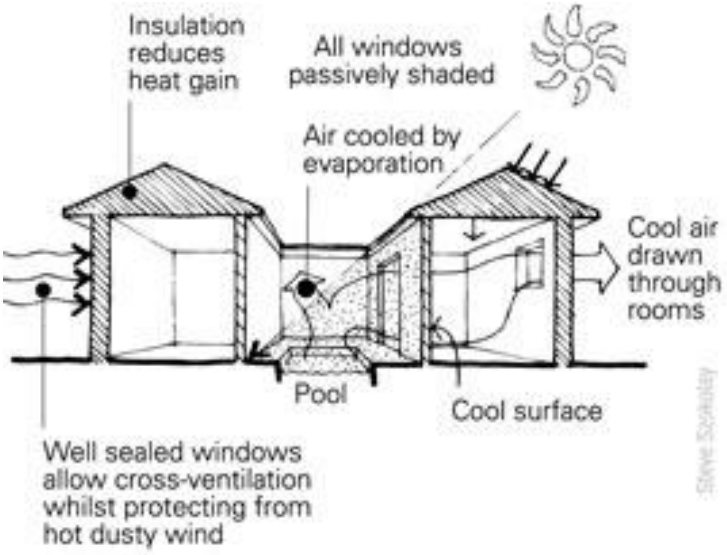


Figure 2.5 Courtyard design with evaporative cooling pond
Source: Passive solar design guidance, (2008)

2.6.6 SHADING DEVICES

In order to control sun penetration to the interior of buildings it is important to provide exterior shading as part of the architectural envelope design. Such shading devices can be attached to the building or can be achieved by the articulation and disposition of the

building floors to create overhangs. Exterior shading is greatly preferred over interior shading as it is important to keep the solar radiation/heat from entering the building.

The north elevation essentially does not require much shading because except in the summer months in the early morning and late evening, no sun penetration occurs. It is best to limit as much as possible fenestration on the north elevation as there will be very little solar heat gain and much direct heat loss from this side. If fenestration is required for day- lighting then it is important to select a highly efficient glazing assembly to reduce energy transfer.

The south elevation allows for the easiest control of solar energy. Shading devices are normally designed as horizontal projections above the windows, the length of the projection is determined as a geometric function of the height of the window and the angle of elevation of the sun at solar noon. Such shading devices can be designed to completely eliminate sun penetration in the summer and allow for complete sun penetration during the winter when such is desired for passive heat gain. (Figure 2.6, 2.6.1 & 2.6.2) shows different method of shading.

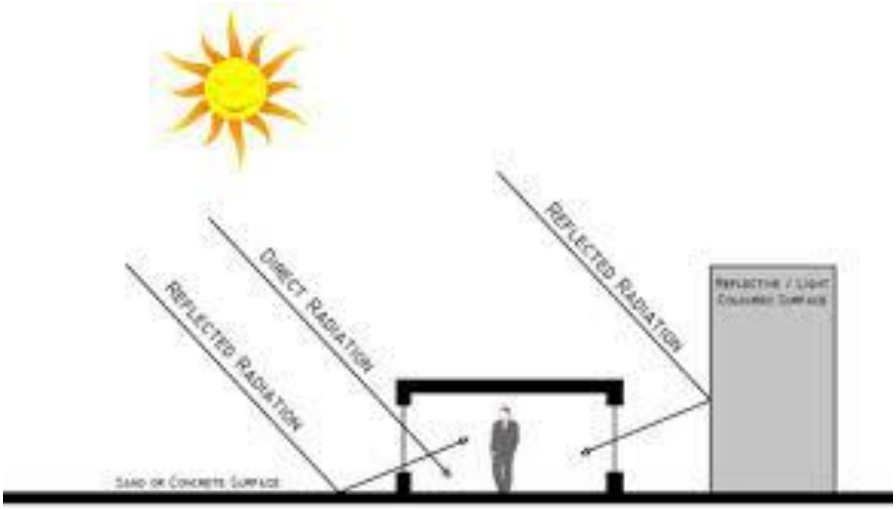


Figure 2.6 Basic shading strategies

Source: Carbon neutral design, (2011)

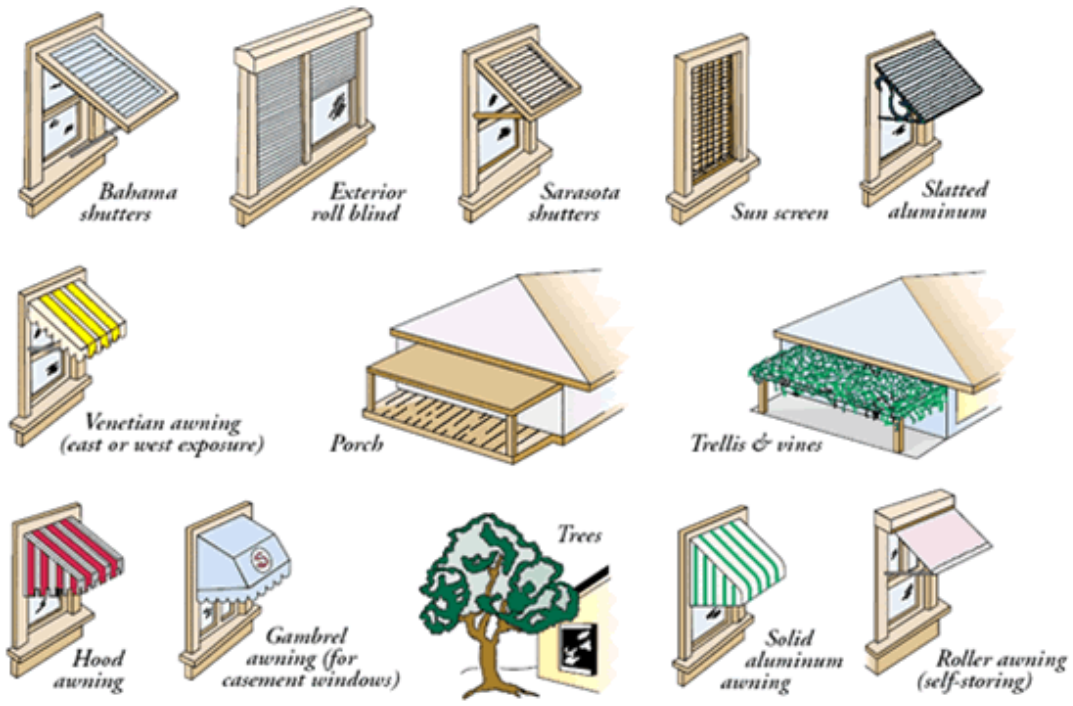


Figure 2.6.1 Basic shading strategies

Source: Window orientation shading, (2011)

The east and west elevations are both difficult to shade "architecturally "the sun angle in the morning and afternoon are low enough to preclude shading using overhangs the morning sun is normally cooler less offensive than the heat and glare of late afternoon sun.

Shading needs to be provided in the way of landscaping and foliage. Deciduous trees are affective as they block the sun in summer when it is not desired and allow sun penetration during the winter. Fences work to block sun and views at all time of the year and so are not so climatically responsive. Vines on more transparent "fence like elements are affective as they too bear leaves to shade in the summer, and keep their leaves until later in the fall when sun is again desired. Vines are often used as well on south facing elevations on trellises to achieve seasonal variation in the opaqueness of the overhangs.

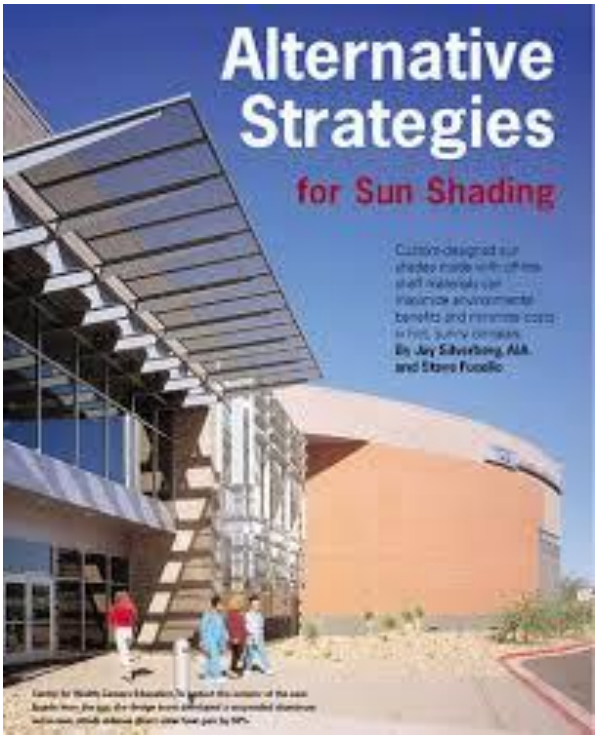


Figure 2.6.2: Basic shading strategies
Source: Alternative strategies for sun shading, (2011)

a) GENERAL TYPE OF SHEDING DEVICES

The basic type of exterior shading devices as shown in (Figure 2.7) can be identified as horizontal, vertical or egg crate. When designing shading devices for heat avoidance it will be important to also weigh the amount of solar penetration that is desired during the heating months. Where the cooling degree days exceed the heating degree day (HOT climates) shading should be affective for the longer period. In some climates this may warrant the virtual elimination of facing windows, with deference to north facing windows to promote day lighting.

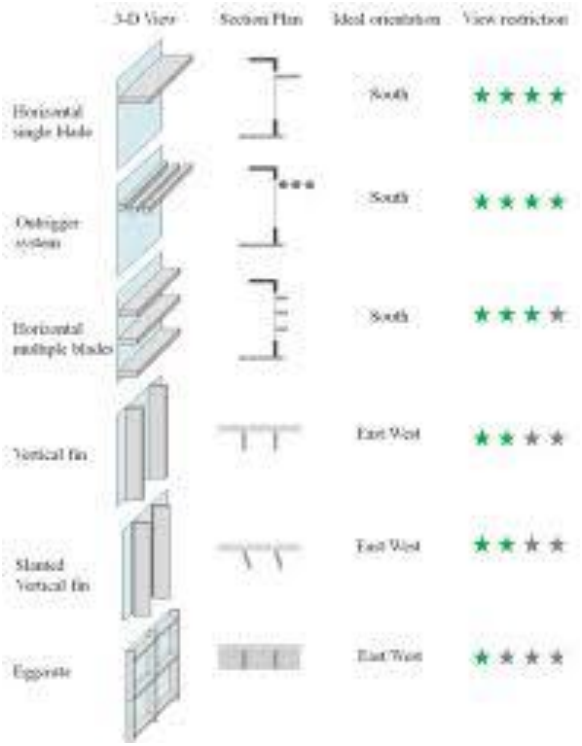


Figure 2.7: Basic shading devices

Source: Carbon neutral design, (2011)

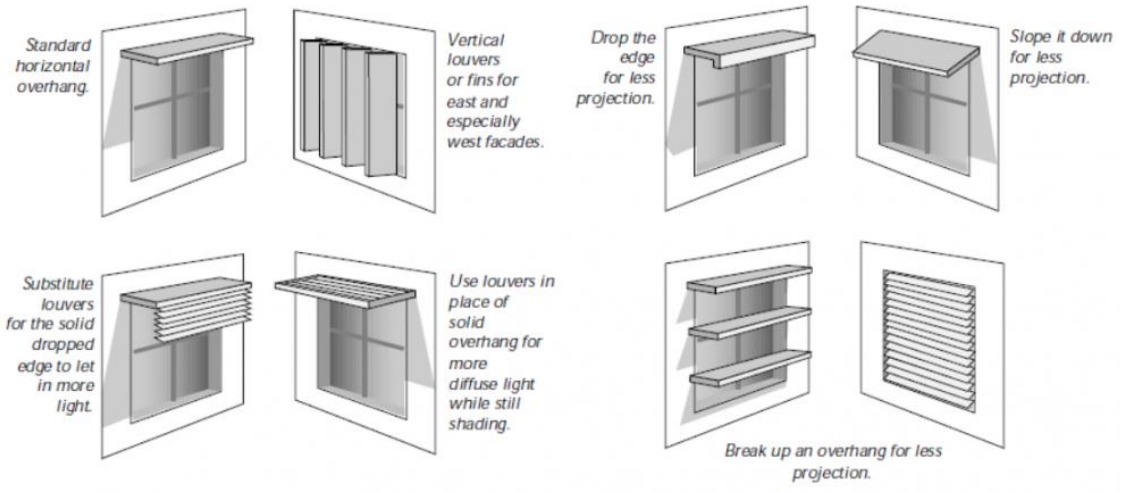


Figure 2.7.1: Basic shading devices

Source: Carbon neutral design, (2011)

i) Horizontal shading devices

Horizontal shading devices are suited to southern exposures. Roof overhangs can also easily be used to shade southern exposures on low rise buildings. This is perhaps the most economical and potentially aesthetically pleasing solution for residential applications.

ii) Vertical and egg- crate shading devices

Where sun is hitting the façade from a south-easterly or south-westerly direction, vertical devices can effectively block the sun. Egg-crates are often used on non-true south facing elevations as well.

2.6.7 ORIENTATION

The main objective in deciding upon a given orientation in hot climate regions is to minimize the impact of the sun on the building in summer. Pattern of solar radiation on different walls results in a clear preference for north-south orientation of the main facades, and especially of the windows. Such orientation enables easy and in expensive shading of the southern window in summer. The heating effect of solar radiation impinging on walls can further be minimized by choosing reflective colours of the walls.

Reardon (2008) stated that with good orientation the need for cooling is reduced, resulting in lower energy bills and reduced greenhouse emission. Buildings should be made to maximize the site's potential and to achieve the best possible orientation for study areas. In hot humid climates orientation should aim to exclude sun year round and maximize exposure to cooling breezes. Where ideal orientation is not possible, as is

often the case in higher density urban areas, *passive cooling can still be achieved with careful attention to design.*

The design of any shading device, particularly horizontal shades, depends greatly on the exact path of the Sun through the sky. Thus, shading device strategies need to be tailored to the orientation of each window. Whilst some orientations are easy to shade, others are much more difficult as the Sun can be almost direct-on at certain times of the day.

The (Table 2.2) below indicates the appropriate types of shading device for use on each orientation of building. These are intended as guidelines only as there are many variations to these basic shading types and some significant room for innovation in the detailed design of shading.

TABLE 2.2:- SIMPLE SHADING STRATEGIES FOR DIFFERENT ORIENTATION.

ORIENTATION	**EFFECTIVE SHADING**
Equator-facing	*Fixed Horizontal Device*
East	*Vertical Device/Louvers (moveable)*
Pole-facing	*Not required*
West	*Vertical Device/Louvers (moveable)*

*(**Source:** Reardon 2008)*

According to Reardon (2008) Orientation should be made for exposure to cooling breeze. It is important to try to avoid windows on the east or west sides, because these sides of a building receive more of the sun's heat. The north side is quite different. East-

and west-facing windows can cause a building to overheat much more so than north-or south-facing windows.

Shade for north-facing windows is relatively easy with a simple overhang: this will still retain the view. East and west-facing windows would need a full cover in which will restrict the view to the outside throughout most of the months. If possible, buildings should be elongated along the east-west axis to maximize the south-facing elevation and the number of south-facing windows that can be incorporated. Buildings with large glass areas can overheat. Reardon (2008) emphasizes on minimizing east-and west-facing windows and sizing shading devices properly.

Orientation issues should be addressed during site planning. To the maximum extent possible, east and west glazing should be reduced. Regardless of building type, most energy that is wasted can be attributed to poor design decisions regarding such factors as orientation, insulation, and glazing. Envelope considerations deal with passive Orientation: Orientation as well as directional emphasis changes with latitude in response to solar angle. Building's main orientation for tropical countries would have a directional emphasis on an axis 50N of E. (Reardon, 2008).

2.6.8 FORM

Building shape and massing have great potential to reduce building energy intensity, but they often fall under the influence of a complex array of factors (planning considerations, building type and use, feasibility and initial). 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, building with a smaller exterior envelope 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.

Massing optimization can significantly improve passive performance, often without increasing the capital cost. As one of the first design considerations, the massing of a proposed building must account for orientation and other site- specific conditions.

2.6.9 LANDSCAPING

Landscaping can be used to enhance a passive cooling system. The use of vegetation to shade a house is a cooling technique that can be very effective. A well-placed plant can deliver effective, cool shade, as well as add to the aesthetic value of a building as well as shade; plants are also effective for cooling because they absorb the heat. Since leaves are generally dark and coarse they reflect very little light, they make ideal solar radiation controllers. Photosynthesis is the way plants convert light into nourishment. During photosynthesis, a process known as evapo-transpiration occurs, in which large amount of water vapour escape through the leaves. That water vapour cools the air passing by it, thus providing a source of cool air for the building. (Givoni, 2001).

Strategy planting of trees, shrubs and vines about a building as shown in (Figure 2.8) and on structures such as pergolas and beam overhangs can, along with urban form, help to modify the microclimate. When correctly applied, the need for internal and external shading devices can be greatly reduced. Selective planting can shade not only windows and other apertures but also whole facades and roofs, reducing conductive as well as radiative heat gains.

Givoni (2001) also stated that by using deciduous trees and vines shading is provided only when needed. Through the use of evergreens, shading can be provided year-round. Vegetation can also be used to reduce ground reflection and, through evapo-transpiration, the ambient air temperature. Evergreen shrubs and ground cover are useful for preventing or reducing reflection from roads, paved areas and buildings. Evergreens are also effectively used as wind barriers. Deciduous species are particularly suitable for temperature climates.



Figure 2.8: Landscape design

Source: Wikipedia org. (2011)



Figure 2.8.1: Landscape design

Source: Wikipedia org. (2011)

The shading effect of vegetation depends heavily on the plant type (tree-shrubs or vines), species, and age. These factors define the leaf type and the density of the vegetation. In the case of deciduous plants, the density changes from season to season. Givoni (2001) records that vegetation affects the internal temperature and cooling load of building in various ways as follows:

1. Tall trees and pergolas situated a short distance from walls and windows will provide shade without significantly reducing ventilation.
2. Vines on walls and high shrubs close to wall provide shade but also reduce the wind speed next to the walls.
3. The air temperature adjacent to the building's external façade is decreased, thus reducing conductive and infiltration heat gains.

4. Vegetative ground cover around a building reduce reflected solar radiation and long wave radiation emitted toward the walls from the surrounding area, thus lowering the solar and long wave heat gain;
5. Vegetation on the eastern and western sides of a building can provide effective protection from solar.

During peak summer days the average temperature of walls shaded by trees or a combination of trees and shrubs can be reduced by up to 60°C. Climbing vines can reduce the temperature by up to 45°C. Givoni's (2001) research has found, however, that the insulating capacity of vegetation may, under certain conditions, negate the cooling effects of its shading function. Even in the Mediterranean region the average external surface temperature of a white all is up to -15°C lower than the average ambient air temperature.

Shading the wall by vegetation may be counterproductive since the wall's long wave heat loss will be reduced. The colour of the wall, and the distance between the wall and the vegetation, are therefore of great importance.

2.7 THERMAL COMFORT

Proper understanding of the parameters around thermal comfort is a critical component of successful building and system design. It is especially important in passive design, where buildings must maintain thermal comfort without the aid of active mechanical systems for as much of the year as possible. According to the Vladimir (2008) Thermal comfort refers specially to our thermal perception of our surroundings. The topic of thermal comfort is a highly subjective and complex area of study. Through passive

design, we can impact four indoor environmental factors that affect thermal comfort. These are listed below:

i. Air temperature

ii. Air humidity

iii. Air velocity

iv. Surface temperatures

Each factors affects thermal comfort differently. The factors most commonly addressed in the conventional design process, air temperature and air humidity, in fact affect only 6% and 18% of our perception of thermal comfort, respectively. To take a more effective comfort-focused approach, we must also consider the temperature of surrounding surfaces and the air velocity, which account for 50% and 26% of thermal comfort perception, respectively.

The effectiveness of passive strategies depends on the range of acceptable thermal comfort parameters set for the project (Vladimir, 2008).

2.7.1 THERMAL COMFORT MODELS

As human thermal comfort perception is extremely complex and subjective, defining acceptable comfort parameters is particularly challenging. Despite these difficulties, several models for quantitatively measuring occupant comfort have been widely used.
The two most relevant in this case are the Fanger and Adaptive Models.

a. The fanger Model

The Fanger Model is most commonly used for typical buildings that rely solely on active mechanical systems. It defines comfort in terms of air temperature and humidity because these parameters are easy to measure and control. It prescribes a relatively

narrow w range of acceptable levels which, in common practice do not vary with outdoor conditions on a daily or yearly basis (Vladimir, 2008).

All these passive cooling strategies rely on daily changes in temperature and relative humidity. Passive cooling strategies that are appropriate for a building site can be assessed by using a bioclimatic chart as shown in (Figure 2.9)

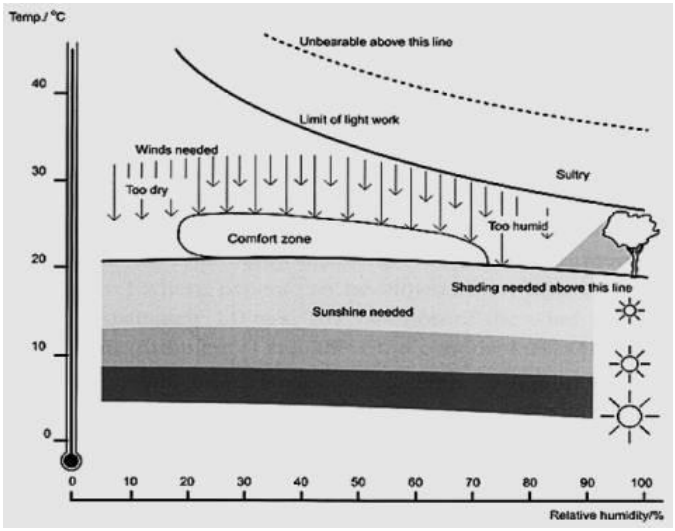


Figure 2.9 Bioclimatic charts,
Source: Climatic responsive building, (2014)

This bioclimatic chart defines four passive cooling strategies based on temperature and relative humidity. This chart can be used to determine which passive cooling strategies are appropriate for the climate at the building site. First, find the following local weather information for each of the months of the year:

i. Average maximum temperature
ii. Average minimum temperature
iii. Average maximum relative humidity
iv. Average minimum relative humidity

Passive cooling strategies are shown on this version of the bioclimatic chart as overlapping zones. When the lines cross zones, it indicates that this strategy may work

for the specified climate. Some months may lend themselves to several different strategies. To reduce cost, choosing one or two strategies that are compatible with each other and the building design is appropriate (Vladimir, 2008).

These passive cooling concepts address getting rid of heat that accumulates in buildings. Certainly, the reduction of heat gains in the first place with high insulation levels, heat blocking windows, proper solar orientation and good shading from building elements and vegetation is a prerequisite for efficient passive cooling of buildings.

The passive approach can be seen as a subset of the Bioclimatic, itself a low energy approach. The Bioclimatic, in turn, falls under the broader umbrella of Ecological (Green) design, which embraces issues affecting the environment at large (Fairey, 1994).

2.7.3 THERMAL BALANCE

The body has the ability to balance its temperature by various means. This thermal balance is determined, on the one hand, by the "internal heat load" and on the other, by the energy flow (thermal exchange) between the body and the environment. The thermal exchange between the body and the environment takes place in four different ways: conduction, convention, radiation and evaporation (Paul and Dieter, 2009).

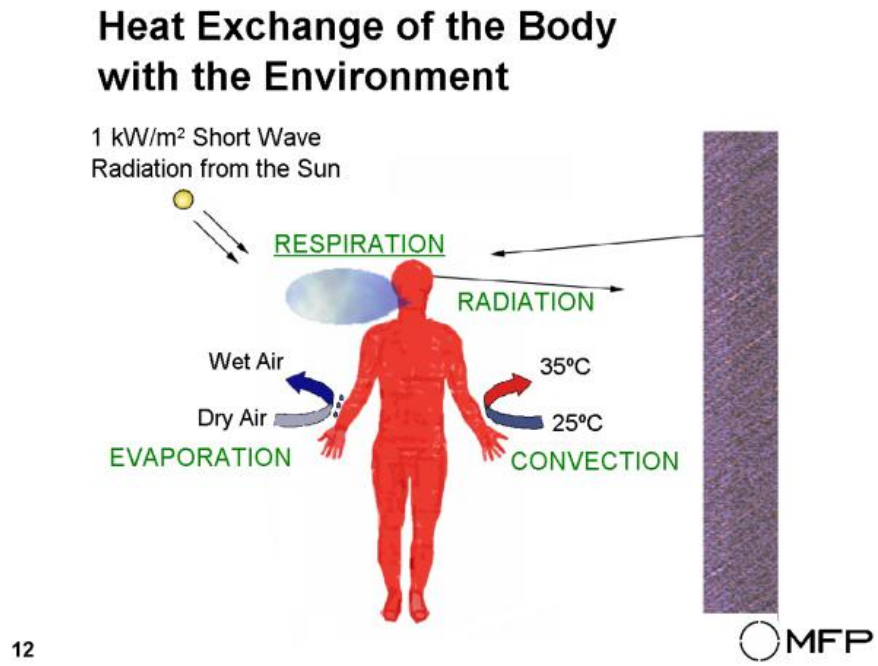


Figure 2.10 Ways of thermal exchange by the human body
Source: Climatic responsive building, 2014

i. CONDUCTION

The contribution that condition makes to the heat exchange process depends on the thermal conductivity of the materials in immediate contact with the skin. Conduction usually accounts for only a small part of the whole heat exchange. It is limited to local cooling of particular parts of the body when they come into contact with materials which are good conductors. This is of practical importance in the choice of flooring materials, especially where people usually sit on the floor (Paul and Dieter, 2009).

ii. CONVECTION

Heat exchange by convection depend primary on the temperature difference between the skin and the air and on air movement. It can, to certain, be controlled by adequate clothing. The insulation effect of clothing can be expressed by a clothing value (clo-value) (Paul and Dieter, 2009). Figure 2.11, shows clothing insulation which can be

given in clo units (1 clo = (.155m^2 - C)/W. Zero clothing equals 0 clo; arctic clothing equals about 4 clo.

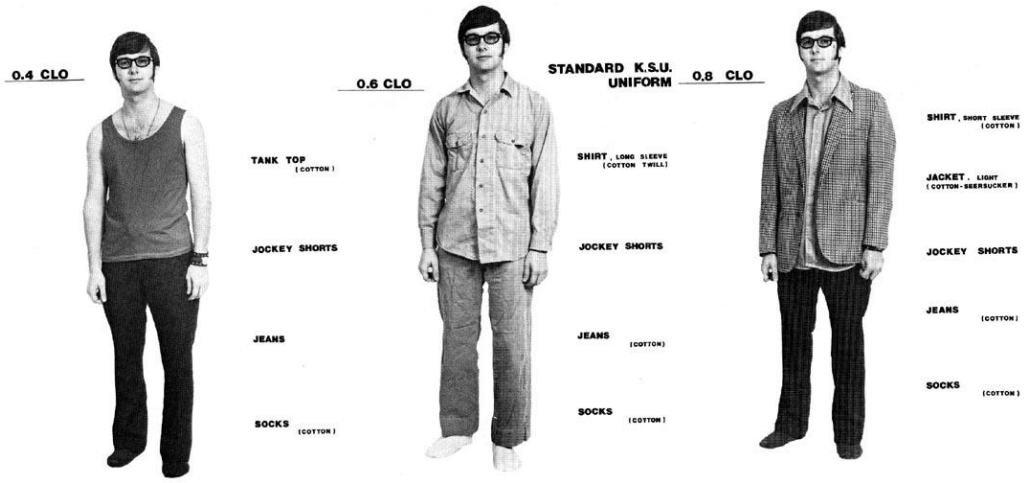


Figure 2.11 Diagram of Clothing Insulation (1 clo = 0.155m^{2}-K/W)
Source: Webdelson.com, (2014)

iii. RADIATION

Radiation takes place between the human body and the surrounding surfaces such as walls and windows, and, in the open air, the sky and sun. In this process temperature, humidity and air movement have practically no influence on the amount of heat transmitted. This amount of heat depends mainly on the difference in temperature between the person's skin and the surrounding or enclosing surface. The body may gain or lose heat by the above-described processes depending on whether the environment is colder or warmer than the body surface. When the surrounding temperature (air and surface) is above 25^{o}C, the clothed human body cannot get rid of enough heat by conduction, convection or radiation (Paul and Dieter, 2009).

2.8 EDUCATION

Education, system of formal teaching and learning as conducted through schools and other institutions. Levels of education in modern societies can go from preschools to colleges and universities. (Encarta encyclopaedia, 2009)

Education or teaching in the broadest sense is any act or experience that has a formative effect on the mind, character or physical ability of an individual. In its technical sense education is the process by which society deliberately transmits its accumulated knowledge, skills and values from one generation to another. (Petronas University, 2009)

Education development from the human struggle for survival and enlightenment, it may be formal or informal. Informal education refers to the general social process by which human beings acquire the knowledge and skills needed to function in their culture. Formal education refers to the process by which teachers instruct students in courses of study within institutions. The types of systems of education are: primary education, Secondary education and Higher education.

2.8.1. EDUCATION IN NIGERIA

Nigeria education has evolved through a number of phases. The education system in Nigeria has been formed by a number of influences, - the colonial influence, the influence of the military rule in Nigeria and then the impact of independence and a new constitution. The progress of education in the southern states of Nigeria reveals the involvement of the Christian missionaries towards the education system in Nigeria during the colonial period. (Petronas University, 2009)

Nigeria education was slowly but soundly developing during the colonial time until the conclusion of World War II. The Christian missionaries introduced the western education system in Nigeria in the mid nineteenth century. Three fundamentally distinct education systems existed in Nigeria in 1990. They were- the indigenous system, the Qur'an schools, and formal European- style educational institutions. Higher education in Nigeria originated with the colonial government launching the Yaba higher college in 1934. (Petronas University, 2009)

Education in Nigeria became the responsibility of the state and local councils according to the 1979 constitution. First six years of primary education was made mandatory, which was a significant factor in the development of education in Nigeria. There has been a noticeable upgrading of educational facilities in Nigeria in the latest year. The apparent rate adult illiteracy in the year 2000 is 35.9%. (Petronas University, 2009)

2.8.2. NIGERIAN EDUCATION SYSTEM

There are many polytechnic colleges and institutions of technology in Nigeria, along with a number of state universities, colleges, and schools. The local and state governments manage primary and secondary education in Nigeria. Higher education is the responsibility of both the federal and the state governments. (NUC, 2004)

Education is free but not compulsory at present in Nigeria. The formal education system includes six years of primary school, three years of junior secondary school, three years of senior secondary school, and four years of university education consequently directing towards a bachelor's level degree in the majority of the subjects. The annual term of school in Nigeria stretch through ten months, and is sectioned into three ten to

twelve weeks periods each at the pre- primary, primary, junior and senior secondary stages. (NUC, 2004)

2.9 ENGINEERING STUDIES

Today, science has a profound effect on the way we live, largely through technology- the use of scientific knowledge for practical purposes. In technology, scientific knowledge is put to practical ends. This knowledge comes chiefly from mathematics and the physical sciences, and it is used in designing machinery, materials, and industrial processes. In general, this work is known as engineering, a word dating back to the early days of the industrial revolution, when an engine' was any kind of machine. The concept of engineering has existed since ancient times as humans devised fundamental inventions such as the pulley, lever, and wheel. Each of these inventions is consistent with the modern definition of engineering, exploiting basic mechanical principles to develop useful tools and objects. Engineering is the discipline, art and profession of acquiring and applying scientific, mathematical, economic, social, and practical knowledge to design and build structures, machines, devices, systems, materials and processes that safely realize a solution to the needs of society. (Olorunfemi, 2004)

Engineering, term applied to the profession in which a knowledge of the mathematical and natural sciences, gained by study, experience, and practice, is applied to the efficient use of the materials and forces of nature. The term *engineer* property denotes a person who has received professional training in pure and applied science, but is often loosely used to describe the operator of an engine, as in the terms *locomotive engineer, marine engineer, or stationary engineer.* In modern terminology these latter occupations are known as crafts or trades. Between the professional engineer and the craftsperson or

tradesperson, however, are those individuals known as sub- professionals or paraprofessionals, who apply scientific and engineering skills to technical problems; typical of these are engineering aides, technicians, inspectors, draftsmen, and the like. (Encarta encyclopaedia, 2009)

The American engineers' council for professional development has defined "engineering" as: the creative application of scientific principles to design or develop structures, machines, apparatus, or manufacturing processes, or works utilizing them single or in combination; or to construct or operate the same with full cognizance of their design; or to forecast their behaviour under specific operating conditions; all as respects an intended function, economics of operation and safety to life and property.

The technical advances of the 19th century greatly broadened the field of and introduced a large number of engineering specialists, and the rapidly changing demands of the socioeconomic environment in the 20th century have widened the scope even further. (Olorunfemi, 2004)

2.9.1 BRANCHES OF ENGINEERING

Engineering is one of the oldest professions in the world. Around 2550 BC, **Imhotep,** the first documented engineer, built a famous stepped pyramid of King Zoser located at Saqqarah as shown in Figure 2.12.



Figure 2.12 Stepped pyramid of King Zoser

Source: Civil Engineering in Canada, (2007)

With simple tools and mathematics he created a monument that stands to this day. His greatest contribution to engineering was his discovery of the art of building with shaped stones. Those who followed him carried engineering to remarkable heights using skill and imagination. Vitruvius' *De archiectura* was published 1AD in Rome and survived to give us a look at engineering education in ancient times.

Engineering, much like other science, is a broad displine which is often broken down into several sub-disciplines. These disciplines concern themselves with differing areas of engineering work. Although initially an engineer will be trained in a specific displace, throughout an engineer's career the engineer may become multi-disciplined, having worked in several of the outlined areas. (Civil Engineering in Canada, 2007) Historically the main branches of engineering are categorized as follows:

i. **Military Engineering** – The first engineers were military engineers, combining military and civil skills. During periods of conflict the engineers made and used

instruments of war such as catapults, battering rams, towers, and ramps to aid in attacking their enemies' forts & encampments and also to defend their own. During the periods of peace, they were involved in many military and civil activities such as building fortifications for defence against further attacks, roads, bridges, aqueducts, canals and cathedrals. The construction and hydraulics techniques used by the medieval engineers in China, Japan, India and other regions of the Far East were far more sophisticated than those of the medieval European engineers.

Machu Picchu, Peru is considered a civil engineering marvel. It was built high in the Andes Mountains assisted by some of history's most ingenious water resources engineers. The people of Machu Picchu built a mountain-top city (figure 2.13) complete with running-water, drainage systems, food production and stone structures so advanced that they have endured for over 500 years. (Civil Engineering in Canada, 2007)



Figure 2.13: Machu Picchu, a mountain-top city

Source: Civil Engineering in Canada, (2007)

ii. **Civil Engineering** – Civil engineering is the oldest of the main disciplines of engineering. The first engineering school, the National School of Bridges and Highways in France, was opened in 1747. John Smeaton was the first person to actually call himself a "Civil Engineer". These civil engineers built all types of structures, designed water-supply and sewer systems, designed railroads and highways, and planned cities. In 1828 the world's first engineering society came into being, the Institution of Civil Engineers in England. (Civil Engineering in Canada, 2007)

iii. **Mechanical Engineering** – Mechanical engineering was the second branch of engineering to emerge in the last part of the 1700s. The invention of the steam engine was the starting point for the Industrial Revolution. All types of machinery were being developed now and so a new kind of engineer, one dealing with tools and machines, was born. Mechanical engineers received formal recognition in 1847 with the founding of the Institution of Mechanical Engineers in England. (Civil Engineering in Canada, 2007)

iv. **Electrical Engineering** – A very broad area that may encompass the design and study of various electrical & electronic systems, such as electrical circuits, generators, motors, electromagnetic/electromechanical devices, electronic devices, electronic circuits, optical fibres, optoelectronic devices, computer systems, telecommunications. (Civil Engineering in Canada, 2007)

v. **Chemical Engineering –** In the 1800's, industry started using more and more chemical processes in many areas such as metallurgy, food production and textiles. At the end of the 19th century, the increased use of chemicals in the manufacturing industry eventually created a new industry, an industry whose main function was the production of chemicals. The new chemical engineer was involved in the design and

operation of these new chemical producing plants. Around 1900, the term "Chemical Engineer" was being used, but it wasn't until the development of the petroleum industry that chemical engineering became recognized as a unique engineering discipline. (Civil Engineering in Canada, 2007) With the rapid advancement of technology many new fields are gaining prominence and new branches are developing such as material engineering, computer engineering, software engineering, nanotechnology, teratology, molecular engineering, mechatronics, etc. these new specialties sometimes combine with the traditional field and form new branches such as mechanical engineering and mechatronics and electrical and computer engineering.

2.9.2. ENGINEERING STUDIES IN NIGERIA

Today technology has permeated every aspect of social life and virtually everything revolves around it. Engineering is a key driver of human development. Sub- Saharan African in particular has very small engineering capacities which result in many African nations being unable to develop crucial infrastructure without outside aid. For a developing country like Nigeria, engineering education thus assumes vital importance in the development of relevant technology for social growth.

This kind of education is obtained by attendance at a tertiary institution, a university, college or polytechnic. Since technology is constantly being updated and improved in other parts of the world, the challenge of this millennium for engineering education in Nigeria requires our learning system to undergo changes so that engineering graduates will be equipped to cope with these global changes and societal needs. (Alabe, 2008)

In Nigeria, engineering is taught in the universities, which award degrees at both undergraduate and graduate levels, and in polytechnics, which award diplomas. Historically, the first Nigerian engineers to receive formal training attended the old higher college, Yaba, in the 1940s. With the establishment of the university college Ibadan (now university of Ibadan) in 1948, Nigerians were sponsored to British universities to train as engineers, on completion of a two year pre degree program at Ibadan. Later, more universities such as Ahmadu Bello University, university of Lagos, etc were established in the 1940s making it possible to train engineers locally.

Engineering education in Nigeria must seek to contribute to the development of Nigeria by maintaining flexibility in our educational programs and continually adapting them to technological changes. Our programs must provide intensive course work that gives students a solid theoretical background, and research projects that involve the application of modern scientific techniques to practical, local problems. (Alabe, 2008)

It is important that engineering curriculum, course content and teaching methods evolve in partnership with changes in environment and technology. Extensive educator-practitioner interaction is a vital element in maintaining the currency of the engineering program and ensuring that it achieves the needs of industry, government and society.

Advisory groups and professional activities should be a vehicle for the development of programs which enable engineering faculty and engineering practitioners to work at the student level, so that engineering education will truly be educating engineers for doing engineering.

Programs must be developed in which student work on real engineering project provided local engineering firms (industry) this will expose student to all aspects of design from initial concept to the finished product.

Computer technology has led to the evolution of new fields of study and it is very like that this trend will continue. Engineering programs in Nigeria universities must equip engineering students with necessary computer skills by making computer available at all levels for teaching, instruction and research.

There is a need to expand the horizons the engineering graduate, in technical leadership areas. In recent years there has been increased demand for masters level education, so it is suggested that preferential attention should be give to improving programs at this level. This will be very appropriate for two classes of current engineering graduate: the student with a broad undergraduate program that lacks sufficient depth, and student who are deeply interested in increase technical competence, as a result of having spent some post- BSc time in practice. (Alabe, 2008)

2.9.3 BUILDINGS FOR ENGINEERING STUDIES

Education buildings are crucially important in every body's development. They are the scenes on which some of the most critical passages of our lives are played out- hence the vital necessity of making them as webs of places. Education takes almost all of us out of our families for the first time. We move from the home to general society through schools: we change from adolescence to adulthood at college. So the buildings in which we are educated have very special importance in everyone's lives. Can you ever recover from your first classroom? Can you forget your first days in an educational institution: lonely, unsure, excited, and dazed by the strange mixture of new people, ideas and influences. (Alabe, 2008)

An engineering educational facility is an interactive teaching tool, with the capability to expose, monitor and manipulated the many engineering inside. This capability help to educate both engineering students and the general public about the multidisciplinary

science and engineering technology found in today's structures. Faculty of engineering buildings are where engineering education that requires brain- thinking work and maximum concentration for extensive research and laboratory experiments takes place.

CHAPTER THREE

3.0 METHODOLOGY

There are various means through which data for this project was sourced. The following methods have been adapted for source working data:

a. **Field work:** This involves site visit and taking case studies from the existing similar faculty within and outside the country.
b. **Data reviews:** This involves the review of literature relating to the field of study by the use of journals, published and unpublished papers and texts.
c. Relevant guidelines of National University Commission in the design of University buildings were found to be relevant.
d. Reference was made to the guidelines of State development control Authority and Ministry of Land.

3.1 METHODOLOGY ADOPTED

Information or data of the research was gathered through primary and secondary sources. Primary sources was encompass of comparative case study analysis used for buildings that show elements of passive design techniques within and outside Nigeria.

Basic data from the master plan of the University of Dutse has been of utmost importance and also guidelines of National University Commission were relevant. A comprehensive research which involves the internet, consultation of books, past unpublished thesis project, architectural journals, photographs, papers, case studies, the study, analysis and observation of similar facilities from around the world, with a view to understanding their contributions was employed. A rigorous field research was

carried out which involves site visitation and studying the existing site condition and carrying out relevant surveys, photographs and personal observations were recorded. Analysis of the climatic data was carried out in order to know how to incorporate the passive design techniques to the existing environment.

3.3 SOURCES OF DATA

a. PRIMARY SOURCES

The primary sources of data in this research are:

i. Architectural drawings and specifications.

ii. Directly observe the workings of such elements that interface between users.

iii. To expose elements that may not be discover from floor plans.

b. SECONDARY SOURCES

The secondary sources of data in this research are:

i. Books

ii. Journals

3.3 PROCEDURE FOR DATA COLLECTION

The procedure for the data collection involved visits to three local case studies and taking a visual analysis base on the use of passive design techniques in their design. These buildings were then evaluated on the created field forms.

However, the foreign case studies were gotten through the internet and their analysis based on the use of passive design techniques are evaluated on the field forms as well.

3.3.1 CASE STUDY

Sample survey of related Universities with Faculty of Engineering was carried out. Case studies have always been a valuable mechanism to bring a sense of reality to a design process. It is helpful to be able to study examples of buildings that are known to perform well and to see how and why they do so. It is also helpful to be able to see where certain strategies will produce limitations of the design in other ways.

3.4 CASE STUDY SELECTION CRITERIA

The case studies were purposely selected on the basis of being Faculties of Engineering and encompass principles of passive design techniques. Those techniques were examined to determine which will be more suitable for the design proposal. The techniques are listed below:

- Natural ventilation
- Thermal mass
- Thermal insulation
- Buffer spaces
- Evaporative cooling
- Shading
- Orientation
- Form
- Landscaping

CHAPTER FOUR

CASE STUDY

4.0 OVERVIEW

There is need to study existing works related to a research area for the research work to be successful. This thesis is taking an in depth study of Engineering studies buildings both locally and internationally in relation to academic buildings and the use of passive design techniques in such buildings. As this would help the researcher to make improvements where there are pitfalls in the design.

4.1 CASE STUDY ONE: FACULTY OF ENGINEERING, AHMADU BELLO UNIVERSITY, ZARIA

4.1.1 BACKGROUND

The Faculty of Engineering, Ahmadu Bello University, Zaria, is the oldest and one of the leading Engineering Schools in Nigeria and in the West African Sub-region. It started in 1955 as a Faculty of Engineering of the University College, Ibadan and was based in the then Nigerian College of Arts, Science and Technology (N.C.A.S.T.), Zaria. The Faculty offered courses leading to the external degrees of Bachelor of Science of London University in Civil, Electrical and Mechanical Engineering. Following the recommendations of the Ashby Commission on higher education, a Provisional Council was created in 1961 and Ahmadu Bello University was opened in October, 1962. In that year, the University took over responsibility for engineering education from N.C.A.S.T. and the Faculty of Engineering of Ahmadu Bello University was born.

4.1.2 LOCATION

Ahmadu Bello University, Zaria, is situated along Katsina road, Samaru, and the Faculty of Engineering is located in the Samaru campous close to the Faculty of Environmental Science at South and surrounded with access roads at North and West.

4.1.3 SPACIAL PLANNING AND DESIGN

The Faculty of Engineering comprised of the following departments:

i. Civil Engineering
ii. Mechanical Engineering
iii. Electrical Engineering
iv. Agricultural Engineering
v. Metallurgical Engineering
vi. Surveying
vii. Chemical Engineering
viii. Water Resources & Environmental Engineering

The Faculty of Engineering consist of two main complexes. The main complex is comprised of department of Mechanical, Electrical and Civil Engineering, along with the Administrative offices and two lecture theatres. There is an enclosed rectangular courtyard with a pond and outdoor sitting area. The new complex is comprised of a large, u-shaped building, housing the departments of Metallurgical Engineering, Water Resources & Environmental Engineering as well as various workshops. The department of Chemical Engineering is located in the faculty of Sciences. The structure is of reinforced concrete frame with sand-crate block walls and concrete floors, there are vertical, horizontal and egg-grate shading devices in the elevations, the roof are a combination of concrete flat roof and pitched with long span aluminium roofing sheets.



Plate 4.1: Enclosed courtyard with a pond, Faculty of Engineering ABU Zaria

Source: Field work, (2014)



Plate 4.2: Part of Landscape, Faculty of Engineering ABU Zaria

Source: Field work, (2014)

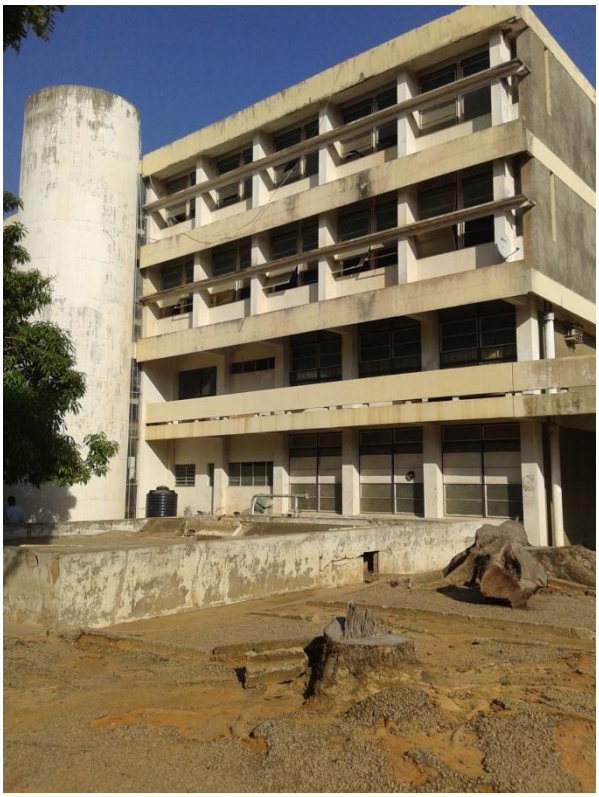


Plate 4.3: Side view of the Faculty of Engineering ABU Zaria

Source: Field work, (2014)



Plate 4.4: Department of Civil Engineering ABU Zaria

Source: Field work, (2014)



Plate 4.5: Department of Mechanical Engineering ABU Zaria

Source: Field work, (2014)



Plate 4.6: Department of Electrical Engineering ABU Zaria

Source: Field work, (2014)



Plate 4.7: Interior of the Laboratory in the faculty

Source: Field work, (2014)



Plate 4.8: Workshops, Faculty of Engineering ABU Zaria

Source: Field work, (2014)

TABLE 4.1: SUMMARY OF FINDINGS IN RELATION TO PASSIVE DESIGN

VARIABLES	FEATURES	METHOD OF APPLICATION	REMARK
Windows	Various sizes of windows Base on required amount of air ventilation and evaporating cooling	Located in class rooms and administrated spaces high level windows in workshop	Positive
Courtyard	Open space serving as medium for exchange of generated hot air with the fresh cool air	Provide at main complex building in order to bring coldness to the interior to the building	Positive
Atrium	Atrium with ventilation windows	Atrium with window opening at the highest level to dissipate the generated to the surrounding sink.	Positive
Shading devices	Vertical and Horizontal shading devices in the most of the building	Provision of vertical and horizontal shading devices on east-west and south-north	Positive
Landscaping	Landscaping elements surrounding the buildings to absorb solar radiation rays	Applied on the surrounding environment of the building for solar radiation rays absorbance	Positive

Source: Field survey, (2014)

4.2 CASE STUDY TWO: FACULTY OF ENGINEERING, KANO STATE UNIVERSITY OF SCINCE AND TECHNOLOGY (KUST) WUDIL

4.2.1 BACKGROUND

The major process of establishing Kano University of Technology Wudil (KUT) started in 1988 when Kano State Government set up a Task Force Committee. The Committee recommended the establishment of the University at Bagauda Lake Hotel. Subsequent to the report, the Kano State Government set up a Technical Committee to study, in detail, the Report of the Task Force Committee.

As a result of the Report of the Technical Committee and with the Minimum Academic Standards of the National Universities Commission (NUC) being met, the Honorable Minister of Education, in 17th December, 1991, granted the approval for the establishment of the University.

On 27th December, 1991, a Governing Council was appointed by the then Military Government to take charge of the affairs of the University. The new Council carried out various activities for the take-off of the University up to March, 1995. In January, 2000, a Committee on the revival of the University project was set up by the Kano State Executive Council. The Committee submitted a report to the Executive Council recommending the immediate reactivation of the project.

The Kano State Executive Council accepted the recommendation. Subsequently, His Excellency, the former Executive Governor of the State, Dr. Rabiu Musa Kwankwaso, appointed another 11-member Implementation Committee. Consequent upon the 13-month effective and articulated activities of the Implementation Committee, the University took off successfully in April, 2001.

4.2.2 LOCATION

The Kano State University of Science and Technology (KUST) Wudil situated along Kano – Maiduguri road, (north to the road) in Wudil town, about thirty kilometers approximately thirty minutes journey from Kano and one hundred kilometers (one hour journey) from Dutse, Jigawa State capital.

The Faculty of Engineering located at North/East to the Administrative Block of the University and West to Faculty of Agriculture, it is not up to One kilometer from the main gate.

4.2.3 SPATIAL PLANNING AND DESIGN:

The faculty of Engineering comprised of the following departments:

i. Civil Engineering
ii. Mechanical Engineering
iii. Electrical Engineering

The faculty consist of two parts: the main complex and workshops block, the main complex comprising the whole departments of electrical, mechanical and civil engineering along with administrative offices and lecture theatres. The complex is two stories building. The ground floor consists of class rooms and lecture theatres while the first floor comprised of class rooms, laboratory and studio.

The workshop block is in south to the main block immediately after the parking space the block comprised applied mechanics, solid workshop and thermolab. The block is in rectangular shape and is double volume in height. It is located at east to the parking, the parking space is wide enough, but is not well identify as parking area with little landscape surrounding the parking area. The landscape at south part to the faculty is

green and beautiful which shows the element of passive design. The complex has courtyards and surrounding verandas which bring cool to the interior of the building.





Plate 4.9: Sign/Main entrance gate of the University KUST Wudil

Source: Field work, (2014)



Plate 4.10: Administrative Block KUST Wudil

Source: Field work, (2014)





Plate 4.11: Sign board / Faculty of Engineering, KUST Wudil

Source: Field work, (2014)



Plate 4.12: Workshop Block, KUST Wudil

Source: Field work, (2014)



Plate 4.13: Main complex and its landscape, KUST Wudil

Source: Field work, (2014)



Plate 4.14: Courtyard and surrounding veranda, KUST Wudil

Source: Field work, (2014)



Plate 4.15: Interior of the class room, KUST Wudil
Source: Field work, (2014)



Plate 4.16: Part of Landscape of the Faculty, KUST Wudil
Source: Field work, (2014)

TABLE 4.2: SUMMARY OF FINDINGS IN RELATION TO PASSIVE DESIGN

VARIABLES	FEATURES	METHOD OF APPLICATION	REMARK
Windows	Various sizes of windows Base on required amount of air ventilation and evaporating cooling	Located in class rooms and offices high level windows in workshop	Positive
Courtyard	Open space serving as medium for exchange of generated hot air with the fresh cool air	Provide at main complex building in order to bring coldness to the interior to the building	Positive
Orientation	Orienting most of the buildings on east-west axis	Orienting the longer side of the buildings to east-west direction while the shorter side to north-south direction	Negative
Shading devices	No shading devices in the most of the building	Only the projection of the vertical columns in the workshops and in un completed building	Negative
Landscaping	Landscaping elements surrounding the buildings to absorb solar radiation rays	Applied on the surrounding environment of the building for solar radiation rays absorbance	Positive

Source: Field survey, (2014)

4.3 CASE STUDY THREE: FACULTY OF ENGINEERING, BAYERO UNIVERSITY KANO (BUK)

4.3.1 BACKGROUND

Bayaro University (BUK) Is a University situated in Kano, Kano State, Nigeria. It was founded in 1977, when it was renamed from Bayaro University College and upgraded from University College to University; in 1980 it ceased functioning as a faculty of the Ahmadu Bello University. It has faculty of Agriculture, Arts, Law, Medicine, Science, Social and Management Science and Technology.

4.3.2 LOCATION

The Bayero University Kano (BUK) new site situated along Kabuga - Gwarzo road, (north to the road) in Rijiyar Zaki, Kano about five kilometres and approximately ten minutes journey from kofar Kabuga, Kano.

The faculty of engineering located at South/East to the University and West to the Faculty of Art and Social Science.

4.3.3 SPACIAL PLANNING AND DESIGN

The Faculty of Engineering comprised of the following departments:

i. Civil Engineering
ii. Mechanical Engineering
iii. Electrical Engineering

The Faculty is a single building that has north-light roofing. The special organization of the faculty is such that there is a centralized circulation hall with offices, classrooms and

other services on one side and the workshops and laboratories are on the other side. The building consists of three floors, on the ground floor; one side occupies the workshops while the other consists of the deanery, cafeteria and some offices while the upper floors consist of more offices, classrooms, lecture theatres and laboratories. The workshops are a large span of open plan segregated by gates. The building is beam and column concrete structure with sand-crate block walls and concrete floors.



Plate 4.17: Main entrance gate of the University (new site)

Source: Field work, (2014)



Plate 4.18: Approach View of the Faculty of Engineering BUK (new site)

Source: Field work, (2014)



Plate 4.19: Side View of the Faculty of Engineering BUK (new site)

Source: Field work, (2014)

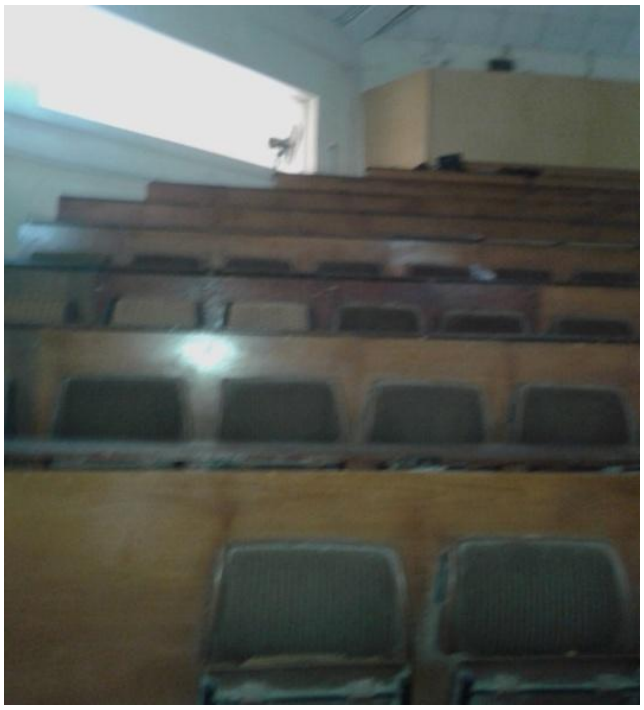


Plate 4.20: Lecture theatre, Faculty of Engineering BUK (new site)

Source: Field work, (2014)



Plate 4.21: Workshop, Faculty of Engineering BUK (new site)

Source: Field work, (2014)



Plate 4.22: Part of Workshop, Faculty of Engineering BUK (new site)

Source: Field work, (2014)



Plate 4.23: Parking spaces, Faculty of Engineering BUK (new site)

Source: Field work, (2014)

TABLE 4.3: SUMMARY OF FINDINGS IN RELATION TO PASSIVE DESIGN

VARIABLES	FEATURES	METHOD OF APPLICATION	REMARK
Windows	Various sizes of windows Base on required amount of air ventilation and evaporating cooling	Located in class rooms and offices high level windows in workshop	Positive
Courtyard	Open space serving as medium for exchange of generated hot air with the fresh cool air	Provide at main complex building in order to bring coldness to the interior to the building	Positive
Orientation	Orienting most of the buildings on north-south axis	Orienting the longer side of the buildings to north-south direction while the shorter side to east-west direction	Positive
Shading devices	Vertical shading devices in the most of the building	Provision of vertical shading devices on east-west of the main complex building	Positive
Landscaping	Landscaping elements surrounding the buildings to absorb solar radiation rays	Few landscape element applied on the surrounding environment of the building for solar radiation rays absorbance	Negative
Atrium	Atrium with ventilation windows	Atrium with window opening at the highest level to dissipate the generated to the surrounding sink.	Positive

Source: Field Survey, (2014)

4.4 CASE STUDY FOUR: FACULTY OF ENGINEERING, UNIVERSITY OF AUCKLAND, NEW ZEALAND

4.4.1 BACKGROUND

The faculty was made famous for its role in Team New Zealand's America's Cup victory in 1995 and 2000, instrumental in its contribution was the world's first Twisted Flow Wind Tunnel built in 1994 at the Tamaki Campus that allows better simulation of the flow of wind over yacht sails by varying the angle of attack with height. The smaller DeBray wind tunnel situated at the city campus is used for a variety of research and teaching purposes, but is primarily used commercially to provide pedestrian wind environment tests for new building consents for the Auckland City Council using its 1:400 scale model of the Auckland City central business district.

4.4.2 LOCATION

The **University of Auckland, Faculty of Engineering** is one of nine faculties that make up the University of Auckland. Located on Symonds Street, Auckland, it has been consistently rated as the best Engineering School in New Zealand for quality of research.

4.4.3 SPACIAL PLANNING AND DESIGN

The Faculty of Engineering comprised of the following departments:

i. Department of Chemical and Materials Engineering
ii. Department of Civil and Environmental Engineering
iii. Department of Electrical and Computer Engineering
iv. Department of Engineering Science
v. Department of Mechanical Engineering

The faculty itself is based at the University of Auckland city campus, with many research groups based at the Tamaki Campus, including the Centre for Advanced Composite Materials (CACM), and the Yacht Research Unit (YRU). The Faculty has been undergoing recent renovation at its city Campus, including a modern atrium area with café, updated library, four new computer labs, two new large lecture theatres, and updates to equipment and seating in many smaller lecture rooms.



Plate 4.24: The Faculty buildings on Symonds Street.

Source: http://www.engineering.auckland.ac.nz/, (2014)



Plate 4.25: Use of shading devices in the faculty buildings

Source: http://www.engineering.auckland.ac.nz/, (2014)



Plate 4.26: Use of shading devices in the Elevation of the faculty building

Source: http://www.engineering.auckland.ac.nz/, (2014)



Plate 4.27: Use of Landscape and courtyard in the faculty
Source: http://www.engineering.auckland.ac.nz/, (2014)



Plate 4.28: Interior of the classroom in the faculty

Source: http://www.engineering.auckland.ac.nz/, (2014)

TABLE 4.4: SUMMARY OF FINDINGS IN RELATION TO PASSIVE DESIGN

VARIABLES	FEATURES	METHOD OF APPLICATION	REMARK
Windows	Various sizes of windows Base on required amount of air ventilation and evaporating cooling	Located in class rooms and administrated spaces	Positive
Courtyard	Open space serving as medium for exchange of generated hot air with the fresh cool air	Provide at main complex building in order to bring coldness to the interior to the building	Positive
Atrium	Atrium with ventilation windows	Atrium with window opening at the highest level to dissipate the generated to the surrounding sink.	Positive
Shading devices	Vertical and Horizontal shading devices in the most of the building	Provision of vertical and horizontal shading devices on east-west and south-north	Positive
Landscaping	Landscaping elements surrounding the buildings to absorb solar radiation rays	Applied on the surrounding environment of the building for solar radiation rays absorbance	Positive

Source: Field Survey, (2014)

Table 4.5: CASESTUDY SUMMARY SHEET

VARIABLES	**CASESTUDY ONE A.B.U. ZARIA**	**CASESTUDY TWO KUST WUDIL**	**CASESTUDY THREE BUK KANO**	**CASESTUDY FOUR UNIVERSITY OF AUKLAND New Zealand**
Ventilation/Air movement	Good	Satisfactory	Good	Good
Courtyard	Good	Good	Satisfactory	Good
Orientation	Satisfactory	Satisfactory	Satisfactory	Satisfactory
Shading devices	Good	Bad	Satisfactory	Good
Landscaping	Satisfactory	Satisfactory	Bad	Good
Atrium	Good	-	Good	Satisfactory
Water body	Good	-	-	Good
SUMMARY	**Good**	**Satisfactory**	**Satisfactory**	**Good**

Source: Field Survey, (2014)

4.5 CONCLUSION AND OBSERVATION

From the study carry out on the case studies it can be observed that the most important and frequently occurring Passive design techniques is the solar and heat protection techniques which is easier to apply than Heat modulation or Heat dissipation techniques. The most effective Solar and heat protection techniques used in the case studies are solar control and shading of building surface, landscaping, building form, external finishing and evaporating cooling, while the heat modulation techniques used basically is thermal mass. It will be observed that High thermal mass is suitable where temperature diurnal range is larger than 10^0C.

Jigawa climate has low diurnal range 7-8, high thermal mass construction can cause thermal discomfort unless carefully design, well shaded and insulated. Since Jigawa has low diurnal range, building materials with low thermal mass will be used. Where high thermal materials such as concrete are used, they will be shaded to prevent them from overheating.

Evaporation cooling, using water for indoor cooling was used in Ahmadu Bello University (ABU) and University of Auckland, New Zealand. Rain water can be reserved and utilize where there is no constant water supply as is used in rain water harvest. Heat dissipation method used in BUK Kano Case study is the use of a thermal chimney shaped to evacuate hot above the building that is stack effect. Provision Courtyards and cross ventilation where also used in case like ABU Zaria and University of Aurckland to achieve ventilation.

CHAPTER FIVE

5.0 SITE

5.1 DUTSE TOWN

Dutse is located at about 130 kilometres south-East of Kano and some 25 kilometres to the North of Kwanar Huguma (a junction village of the Kano – Maiduguri highway). It lies at 11.76^{o} North latitude, 9.34^{o}East longitude and 460 metres elevation above the sea level. Dutse town has an important link to Potoskum and Damaturu in Yobe State and Jama'are and Azare in Bauchi State (See Fig. 5.1/5.2). The town is also located some 7 kilometers to the Shuwarin junction, the junction that links Gaya-Kano road and Shuwarin-Potuskum up to Maiduguri road.



Fig. 5.1: Map of Nigeria showing the map and Location of Jigawa State

Source: Nigeria Gallery Media, (2014)



Fig. 5.2: Map of Jigawa State showing the map and Location of Dutse
Source: Nigeria Gallery Media, (2014)

5.2 POPULATION

In the 2006 National Census conducted by the National Population Commission (NPC), Jigawa State recorded a total population of about 4.4 Million while Dutse and its satellite villages recorded a population of 251.135, as shown in the (Table 5.1) below.

TABLE 5.1: POPULATION OF JIGAWA STATE AND DUTSE THE STATE CAPITAL

STATE / LOCAL GOVT.	BOTH SEXES	MALE	FEMALE
Jigawa State	4,361,002	2,198,076	2,162,926
Dutse	251,135	125,773	125,362

Source: Jigawa State Population Commission (NPC) Dutse, (2009)

5.3 SITE LOCATION

The site for the thesis proposal is located at the permanent site of the Faculty of Engineering within Federal University Dutse, (FUD) Jigawa State. The University itself is located along Eastern bye pass road, the road that links the Huguma-Kiyawa road. Figure 5.3 and 5.4 shows the Eastern bye pass road and the new main Gate respectively.



Fig. 5.3: Eastern bye pass road that link the University
Source: Field work, (2014)



Fig. 5.4: FUD new main Gate
Source: Field work, (2014)

The site is bounded to the North/West by Faculty of Law, South/West by Faculty of Science Education, North/East by Student Hostel and South / East by Staff club. Fig. 5.5 is the Master plan showing the location of the site.

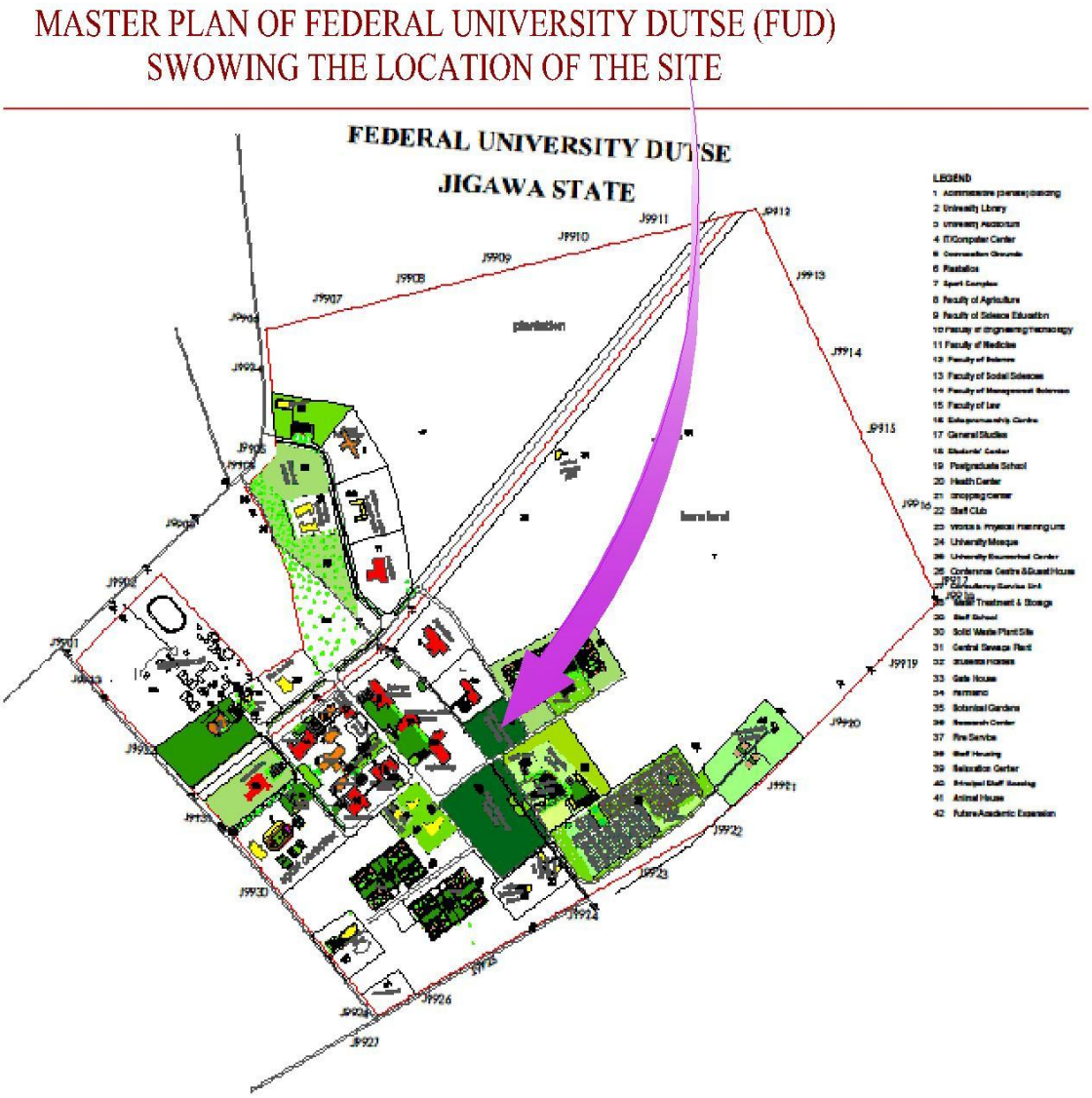


Fig. 5.5: Master plan of Federal University Dutse (FUD)
Source: FUD Physical Planning Department, (2014)

5.4 SITE CHARACTERISTICS AND ANALYSIS

5.4.1 TOPOGRAPHY

The slop of the site is negligible; therefore the topography of the site is relatively flat with good natural drainage. The direction of the slope should be used for drainage, because it is easier due to natural force of gravity.

5.4.2 INFRASTRUCTURE

The site is served with adequate utilities and facilities like electricity, telephone and water services, Fig. 5.6 show some of infrastructure such as road and electricity to the site. The availability of these services to the site makes it convenient and less expensive for erecting new structure.

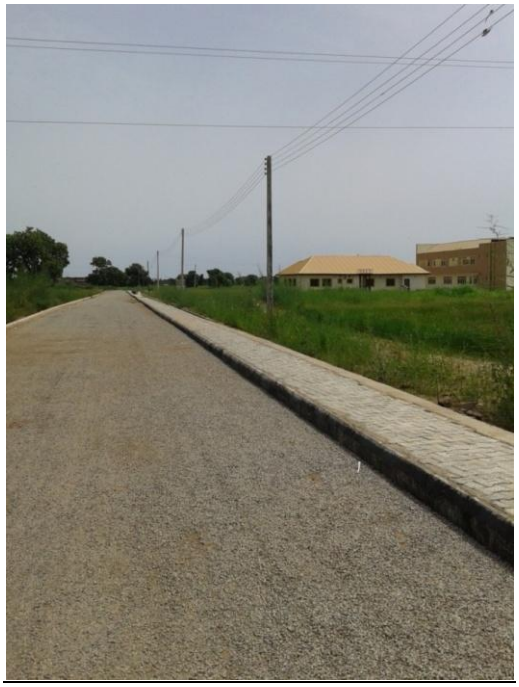


Fig. 5.6: Infrastructures to the proposed site
Source: Field work, (2014)

5.4.3 VEGETATION:

The area is covered by the savannah vegetation type which consist of scattered trees and shrubs in a matrix of short grasses that grow in tuffs both having replaced by secondary vegetation. Figure 5.7 show the vegetation of the site.



Figure 5.7: Vegetation of the site.

Source: Field work, (2014)

5.4.4 CLIMATE:

The climate is typical of hot and dry lasting for the greater part of the years. Jigawa can be broadly divided into two season, they are the wet season from March to October, and the dry season from November to early March. A specific type of prevailing wind characterizes each season. The wet season brings with it South-Western wind originating from equatorial rain belt and blowing from the high-pressure zones which occur over the Atlantic Ocean during their period. The dry season is accomplished by Hamrmattan, a dust-laden wind blowing from the Sahara desert.

(i) **TEMPERATURE:** Day temperature often rise to as high as 33^{o}C (110^{o}F**)** in the dry season and could be as low as 21^{o}C (65^{o}F) during harmatan period (December – February). The graph in (figure 5.8) and (table 5.2) shows the Dutse average Temperature.

YEAR TEMPERATURE IN AVERAGE

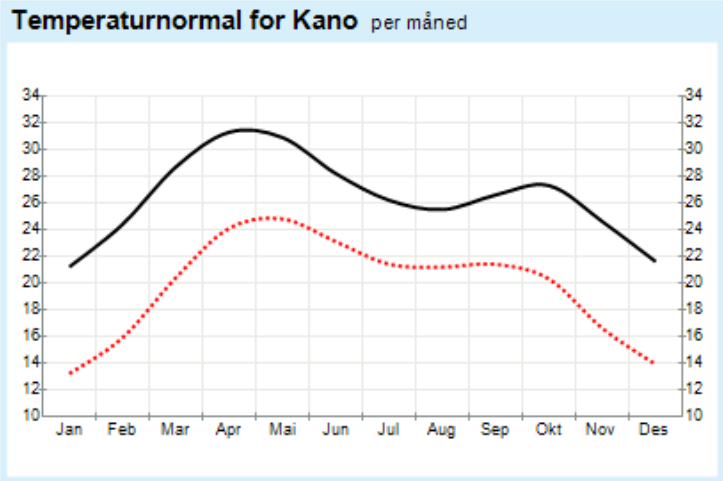


Fig. 5.8: Dutse average Temperature
Source: www. meoweather. Com, (2014)

Table 5.2: DUTSE AVERAGE WEATHER BY MONTH

	Temperature			Precipitation
Months	**Normal**	**Warmest**	**Coldest**	**Normal**
January	21.2°C	-	13.2°C	0
February	24.4°C	-	15.9°C	0
March	28.7°C	-	20.4°C	0
April	31.3°C	-	24.1°C	0
May	30.9°C	-	24.8°C	3
June	28.2°C	-	23.1°C	8
July	26.2°C	-	21.4°C	13
August	25.5°C	-	21.2°C	14
September	26.6°C	-	21.4°C	8
October	27.3°C	-	20.3°C	1
November	24.6°C	-	16.6°C	0
December	21.6°C	-	13.9°C	0

Tabular view for temperature and precipitation per month

Source: Nigeria Route. Com, (2014)

(ii) **RAIN FALL:** Rain fall is concentrated from June to September. The rainy season is associated with the equatorial maritime (or south west trade winds). The south-easterlies are rain-bearing and are dominant in the Dutse area from May/June. The average rain fall in the area as shown in figure 5.9 is 762mm per year.

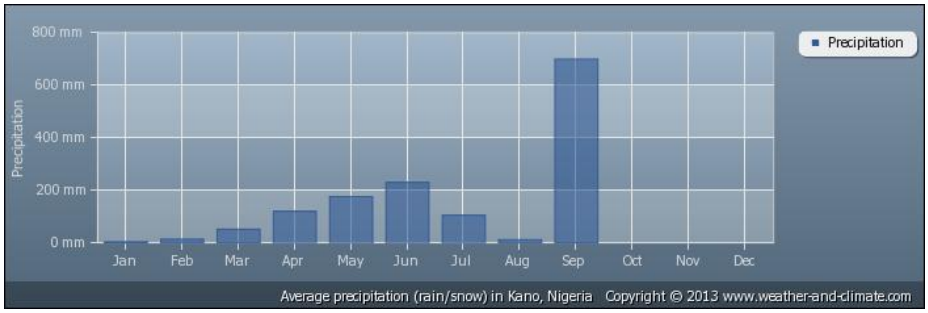


Fig. 5.9: Jigawa average Rainfall

Source: www.weather-and-climate. Com, (2014)

(iii) **VEGETATION:** The area is covered by the savannah vegetation type which consists of scattered trees and shrubs in a matrix of short grasses that grow in tuffs.

(iv) **RELATIVE HUMIDITY:** There is low humidity during the dry season, coupled with high afternoon temperature. This accounts for the effective of the day season. During rainy season the relative humidity is high and the temperature is slightly lower which create heat traps there by making the place uncomfortably hot. Also the interplay of temperature and humidity factors that determine how comfortable a building could be. Figure 5.10 shows the Jigawa State average Related Humidity

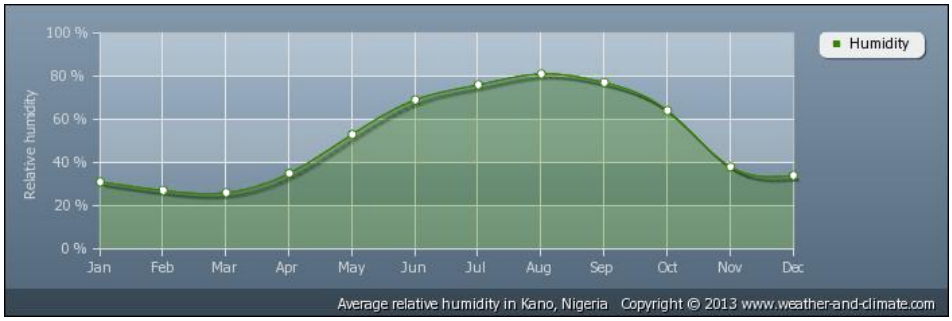


Fig. 5.10: Jigawa average Related Humidity

Source: www.weather -and- climate. Com, (2014)

(v) **SUNSHINE AND RADIATION:** There is an average range of hours of sunshine in Jigawa of between 6.0 hours per day in August and 9.8 hours per day in November. The sunshine and its radiation for Jigawa can be seen and discussed using the diagram below in figure 5.11

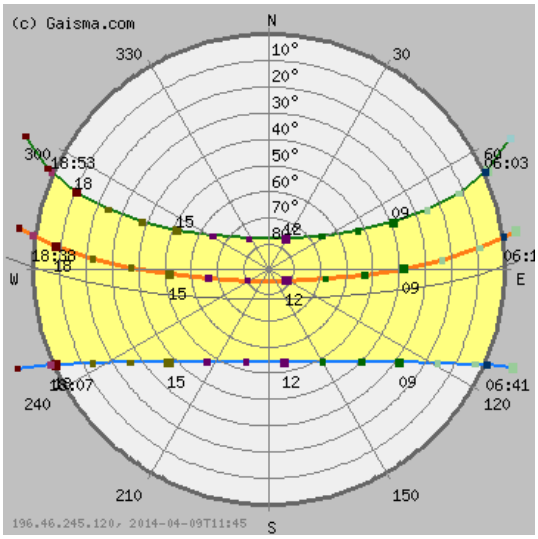


Fig. 5.11: Jigawa sun path diagram

Source: www. gaisma. Com, (2014)

The elevation angle is approximately 75 degrees at noon. The incidence of Sunshine in summer months is 8.1 hours per day and 5.9 hours in the winter. Daily radiation is high and it ranges from 23MJ/m^2 in the summer and 18MJ/m^2 in July. Figure 5.11 shows the Jigawa State sunrise-sunset-dawn and dust.

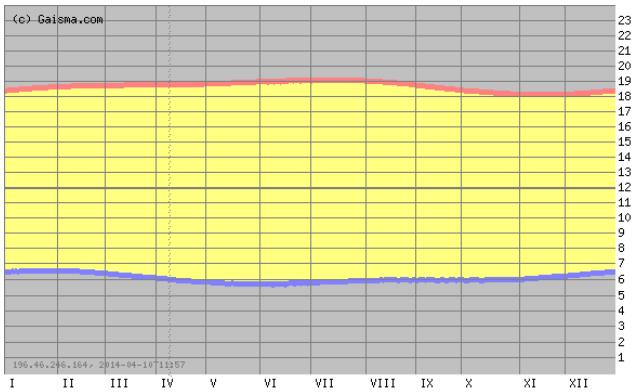


Fig. 5.12: Jigawa sunrise-sunset-dawn and dust

Source: www. gaisma. Com, (2014)

(vi) **WIND:** On average, the wind speeds vary from 2.0m/s most of the wind comes from the South-West and the direction of the prevailing winds is 108^{o}S. The presence of South-West and North-East winds is attributed to the displacement of the inter-tropical convergence zone. There are variations in the wind speed at different times of the day, lower speeds occurring in the mornings and afternoon. On average the strongest winds occur around 15,00h, fortunately at the time when ventilation is mostly desirable for cooling purposes. Figure 5.13 shows the Climate of the Tropical Region.

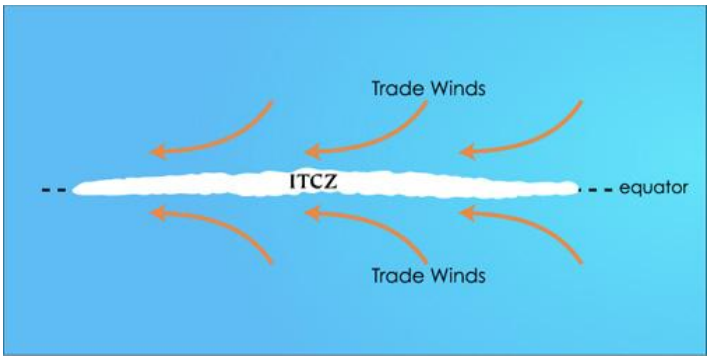


Fig. 5.13: The Climate of the Tropical Region

Source: thebritish geographer.weebly. Com, (2014)

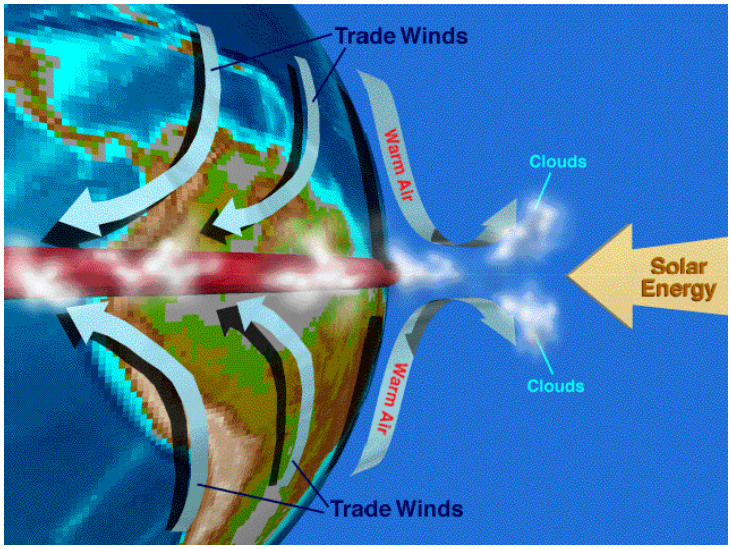


Fig. 5.13.1 The Climate of the Tropical Regions

Source: thebritish geographer.weebly. Com, (2014)

5.5 SITE ANALYSIS

The type of the soil on the site is sandy land; it falls within the Sudan savannah vegetation. It is covered, with short trees and scattered grasses. The site slopes gently towards the south-west direction and drains out easily.

The site is bounded by two roads at the Northern, Southern and Eastern direction and bounded by Entrepreneurship Centre at Western direction.

A 17KVA (PHCN) line passes by the site from which power can be tapped. Water will be tapped from the main water supply pipe. However bore holes would be sunk on site to ensure continuous supply of water.

The two major winds that affect the site are:

a- South-West trade wind which is cool and moist wind that brings rain and good for ventilation, it originates from the Atlantic Ocean.

b- North- East trade wind which is dry, hot and dusty. It brings harmattan and it originates from the Sahara desert.

The sun rises around 6:00-6:30am and sets at about 6:30pm. The solar heat intensity is a bit favourable for human activities in the morning hours, while it gets unfavourable for human activities from noon. Shading devices shall be provided in appropriate places.

CHAPTER SIX

6.0 DESIGN REPORT

6.1 PURPOSE OF DESIGN

The proposed Faculty of Engineering shall be viewed as a thesis proposal for the design of a faculty building which will house the required facilities to cater for the educational requirements of the specified fields of engineering. This research is on Engineering School with respect to passive design. It is a proposal for various buildings to house engineering designers of the build environment.

The main objective of the proposed faculty is to use passive design techniques suitable for the hot-dry climate. Achievement of this major goal is through analysis of the various passive design techniques and using those that are suitable for that environment.

6.2 DESIGN BRIEF

The faculty of engineering complex shall house departments for the four most basic engineering disciplines. The departments are:

i. Civil Engineering
ii. Mechanical Engineering
iii. Electrical Engineering
iv. Chemical Engineering

The faculty complex will provide facilities for both academic and administrative functions for both staff and students. The academic facilities shall include leaning studios, classrooms, seminar rooms, workshops, as well as laboratories. The administrative facilities shall include departmental offices, as well as the office of the dean. The ancillary facilities shall include parking spaces, library, and lecture theatres.

6.3 THE FACULTY POPULATION

The population of the faculty comprises mainly of staff and students and it is difficult for one to predict with much degree of certainty the number of students who may attend the school in future years, therefore the National Universities Commission (NUC) standard as shown in Table 6.1 and 6.2 is going to be used as a guide. All the programmes at the Faculty consist of a five years curriculum of the studies leading to the Bachelor of Engineering after successful completion. Based on the NUC guidelines, there should be a minimum of six full time equivalent staff in each program or department. There should be a reasonable number of staff with doctoral degree as well as sufficient industrial experience and also to recruit very competent senior technical staff to maintain teaching and research equipment.

Table 6.1: NUC Academic Students Structure for Engineering

COURSE	DURATION	STUDENT INTAKE	ULTIMATE CAPACITY	TOTAL
Electrical Engineering	5	50	80	400
Mechanical Engineering	5	50	80	400
Civil Engineering	5	50	80	400
Chemical Engineering	5	50	80	400

Source: NUC Minimum Academic Standards for Engineering & Technology, (2005)

Table 6.2: NUC Staff/ Student ratio for Engineering

DEPARTMENT	STAFF/STUDENT RATIO	STUDENT POPULATION	NO. OF STAFF
Electrical Engineering	1 : 10	400	40
Mechanical Engineering	1 : 10	400	40
Civil Engineering	1 : 10	400	40
Chemical Engineering	1 : 10	400	40

Source: NUC Minimum Academic Standards for Engineering & Technology, (2005)

6.4 SCHEDULE OF ACCOMMODATION

This is the space allocation for the different teaching, leaning and social spaces. In arrival at the space requirements and schedule of accommodation, the standards are those enumerated from the National Universities Commission (NUC) guidelines and also accepted standards that are not given by NUC. For the good administration of each discipline, adequate facilities were provided for the office of the dean and each of the departments. The required minimum standard for the deanery in Table 6.3 includes: Dean Space, Deputy Dean, and Secretary to the Dean, Assistant Registrar, and Administrative Secretariat, General Office, Conference Room and Faculty Office. And for each of the department in Table 6.4 includes: Seminar Rooms, Studios, Workshops, Laboratories, Library, Parking, Office accommodation, and Classrooms.

DEANERY

Table 6.3: NUC Minimum Space Requirements for the Deanery

DESCRIPTION	NO. OF PERS.	AREA PER PERS. NUC MIN. STD.(m^2)	TOTAL AREA (m^2)
Dean	1	24	24
Deputy Dean	1	20	20
Secretary	2	12	24
Assistant Registrar	1	16	16
Admin Secretariat	1	20	20
General Office	4	4	16
Conference Room	40	2	80
Faculty Office	4	2	8
Students Affairs	10	0.76	10
Staff Common Room	200	0.35	70

ICT centre	40	2	80
Toilets	3	2	6
Storage space	50	0.1	5

Source: NUC Benchmark Min. Academic Standards for Engineering & Tech. (2005)

DEPARTMENTS

Table 6.4 NUC Minimum Space Requirements for the Department

DESCRIPTION	**CAPACITY**	**AREA PER PERS. NUC MIN. STD.(m^2)**	**TOTAL AREA (m^2)**
Head of Department	1	24	24
Professor	6	24	144
Secretary	1	7	7
Teaching staff	20	16	320
Technical staff	9	7	63
Administrative staff	3	6	18
Seminar Room	80	1.85	148
Exam Office	2	7	14
Library	100	1.25	125
Classrooms	400	0.65	260
Laboratory	20	7.5	150
Toilets	3	2	6
Storage	50	0.1	18

Source: NUC Benchmark Min. Academic Standards for Engineering & Tech. (2005)

6.5 DESIGN CONCEPT

The concept of engineering has existed since ancient times as humans devised fundamental inventions such as the pulley, lever, and wheel. Each of these inventions is consistent with the modern definition of engineering, exploiting basic mechanical principles to develop useful tools and objects.

Zanzan (2002) defines Concept as basically the process of obtaining an explicable vocabulary of architectural forms and special relationship that is a true reflection of the goals and objectives of the client as sought to be represented by the building.

The building of this faculty is conceived as an engineering tool, a tool to achieve the goal of a sound engineering education. The building is thus, developed as an instrument, with its main focus being its efficiency in achieving its said goal. The building form concept of this faculty is thus conceived as a mass, generated from an arrangement of wheels, (figure 6.1) as well as a controlled revolution of a wheel, all arranged together.

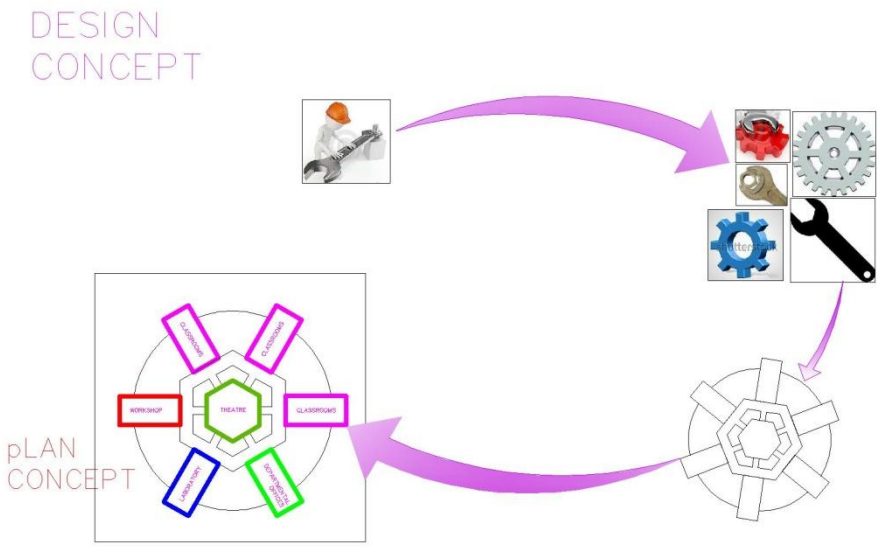


Fig. 6.1 Design Concept (Buildings are arranged as a wheel)

Source: Authors sketch, (2014)

6.6 PASSIVE DESING TECHNIQUES APPLIED

Usually the climate of hot-dry zones is characterized by hash weather. The temperature is relatively high at around 30 – 35°C. The major design objectives and response is protecting the building from unwanted heat. The solar radiation is intense and to a great extent diffuses due to haze. It therefore demands generous shading devices to be used. Large shading devices reduces sky glare which may be caused by haze.

Vegetation is rich and provides an excellent means of improving the climatic conditions. Its surface does not heat up and it provides efficient shading at low cost. However, it will be arranged in a way that does not impede air circulation.

The main considerations in planning and design the School is:

- Arrangement of vegetation around the buildings.
- Generous and well distributed areas of vegetation were used to help improve the microclimate.
- External public spaces, roads and footpaths were protected from the sun by planting of trees.
- Orientation to minimize sun radiation impact.
- Large courtyard between the buildings to enhance air movement.
- Water pond
- Atrium
- Roof garden

6.6.1 LANDSCAPING WITH VEGETATION

High trees with wide shading crowns provide significant protection from solar radiation and were incorporated as much as possible into the landscape planning. High shrubs

were avoided near buildings because the space between the ground vegetation and the crowns of the trees have to remain open, to provide free access for the wind at the level of the living space.

6.6.2 ORIENTATION

The orientation of the building is a variable considered when designing with passive design principles. The longer side should be facing north-south direction to reduce the heat gain through solar radiation. The majority of the openings should be on these sides to reduce the cost of shading the building from the solar radiation intensity. The shorter sides should face east-west direction with enough shading devices to prevent the effect of solar radiation intensity.

6.6.3 SHADING DEVICES

The shading devices shown in figure 6.2 are used in passive design to shade the building from solar radiation heat gain through the openings. There are three types of shading devices which include vertical, horizontal and egg crate (combination of the first two). In the cause of this design, vertical shading device is used by introduction of fins to shade the sides from the solar radiation intensity.



Fig. 6.2: 3D showing the shading devices in the design

6.6.4 COURTYARD SYSTEM

The courtyard system is serving as medium for bringing in fresh air to the interior of the buildings and releasing the warm air to the atmosphere. It serve as a medium to locate the water pond to serve as a cooling system as shown in figure 6.3 in the next page.

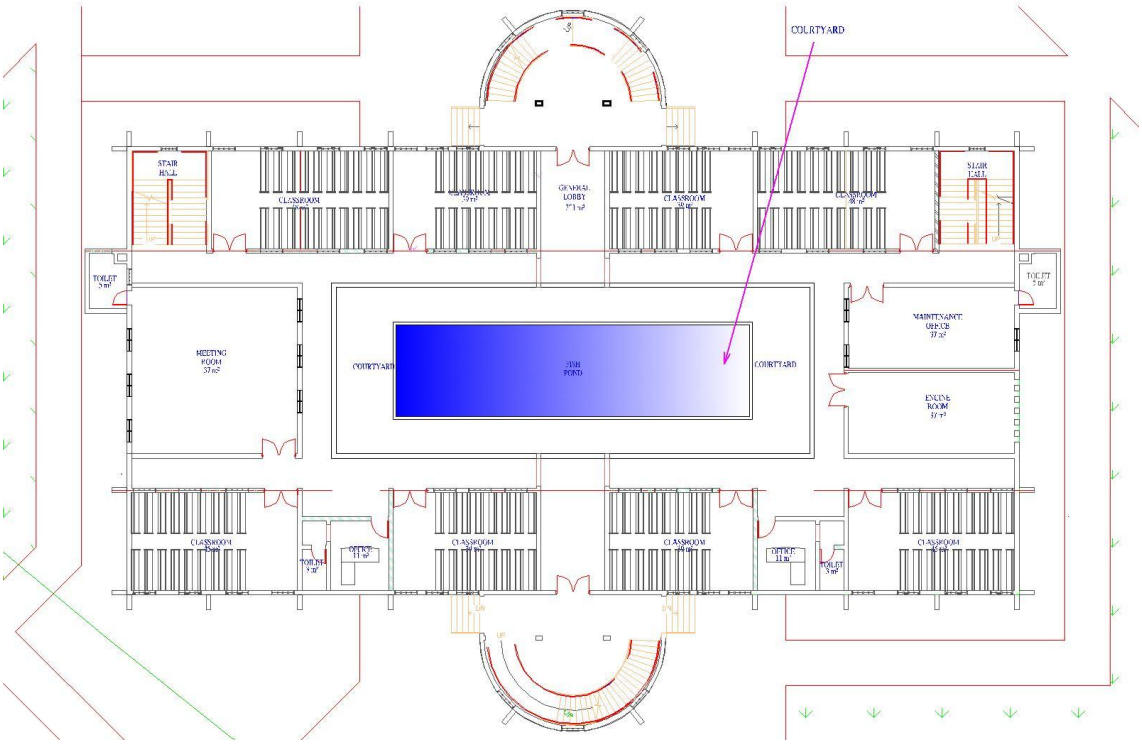


Fig. 6.3 Part of floor plan of the Proposed FUD Faculty of Engineering showing the courtyard system

6.6.5 WATER POND

The use of water pond in figure 6.3 above contributes to evaporative cooling where the water cools the hot air by inducing moisture in to the air and the air cool the interior of the building.

6.6.6 ATRIUM

The atrium is provided to serve as the collector of the warm air from the building and discharging it through the vent as that air is light since it is warm, it will move up and escape to the atmosphere through the vents as shown in the fig. 6.4 below.

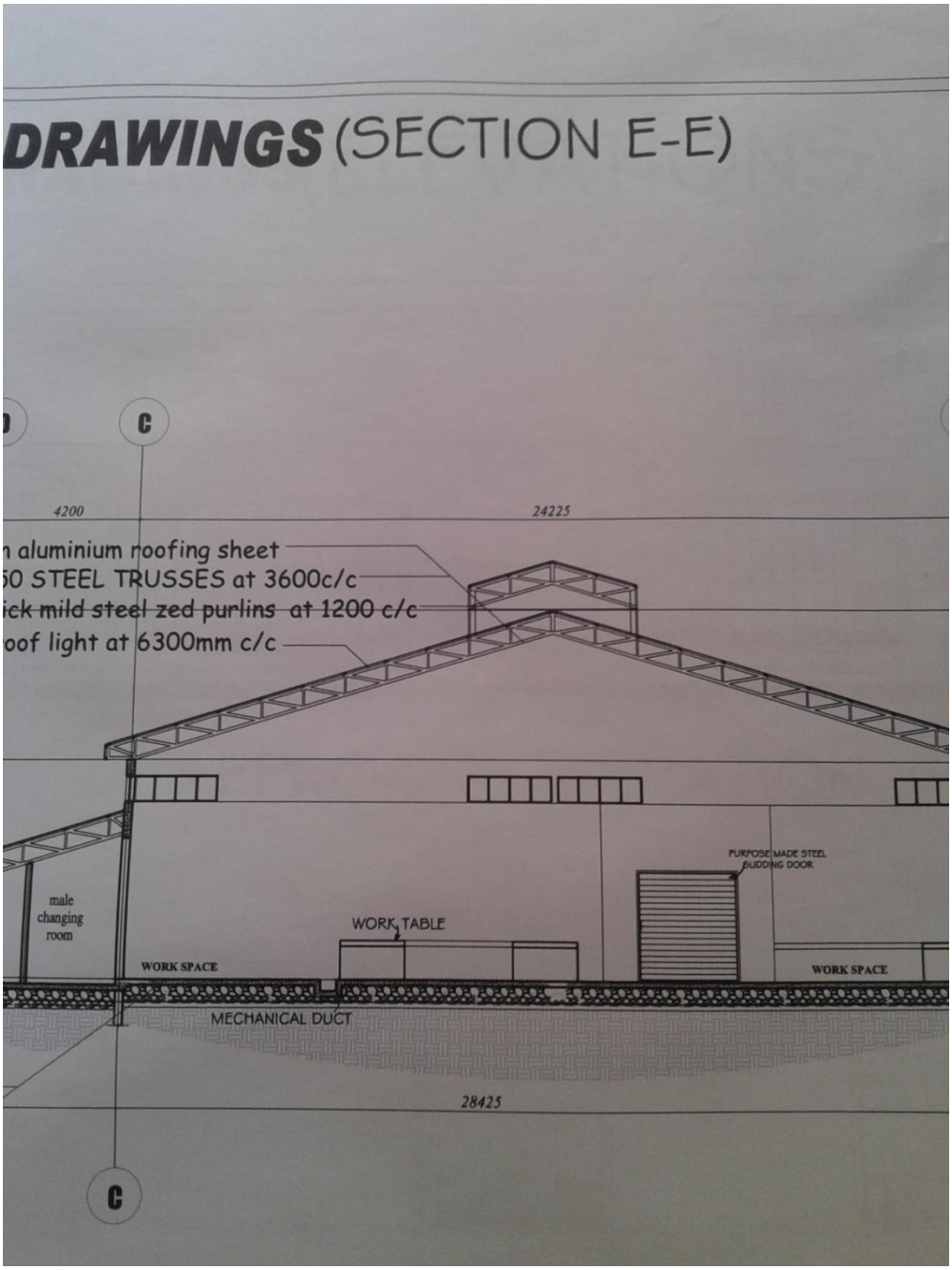


Fig. 6.4 A Section showing Atrium for discharging hot air from interior of the building

6.6.7 ROOF GARDEN

The roof garden as shown in figure 6.5 is incorporated in the design to serve as an absorbent of the radiant heat from the solar on the roof of the building. The use of roofing sheets is minimised to reduce solar heat gain in the building and the environment. The plants absorb the rays as part of their photosynthesis process and release fresh air to the surrounding environment.



Fig. 6.5 Part of 3D showing the roof garden in the design

CHAPTER SEVEN

SUMMARY, CONCLUSION AND RECOMMENDATION

7.1 SUMMARY

This research established the principle of passive design and explored various passive design techniques for hot- dry climates and engineering education in Nigeria. The objective, which is to study, analyzes and applies the appropriate techniques to suit the proposed school building as a means of minimizing the energy consumption which is threat to the environment or the fact that, it emits carbon that is responsible for global warming. Heat modulation, heat dissipation, solar and heat protection techniques all discussed in relation to the sites climatic data.

The research attempted to set forth some of the practical standards that may cushions the effects of Jigawa's harsh (hot - dry) climate in the Faculty of Engineering.

7.2 CONCLUSIONS

Based on the research carried out, it can be concluded that the most important passive cooling techniques is the solar protection technique then followed by heat dissipation technique. This is because the sun is the major source of heat so allowing it into building will render the other passive cooling techniques ineffective. So prevention of solar access into building should be the first priority before one can move down to the other techniques.

For heat dissipation air movement is the most important, large openings facing wind directions with large shading devices protecting then. Openings for ventilation will become a problem if they are not protected from the sun.

Heat modulation techniques like evaporative cooling is very complex and is more suitable for dryer climates, it also needs constant supply of water and frequent maintenance especially when using roof ponds. The water bodies also attract mosquitos which is very undesirable.

7.3 RECOMMENDATION

Education buildings are crucially important in every body's development. They are the scenes on which some of the most critical passages of our lives are played out- hence the vital necessity of making them as webs of places. Education takes almost all of us out of our families for the first time. We move from the home to general society through schools: we change from adolescence to adulthood at college. So the buildings in which we are educated have very special importance in everyone's lives.

It is very necessary to get the climate data of a site before any design for the site will commence this will guide the designer.

Using optimal orientation (orientation for both Solar protection and wind access simultaneously) is recommended for low rise building. In the case of high rise structures, orientation should be strictly for solar protection.

The intensity of radiation is normally less than in hot-dry regions, it is nevertheless a significant source of heat, therefore its entry into the building should be prevention. In

hot-dry climates the radiation is mostly directional and the shadow angles can be established with a high degree of accuracy.

Shading device should therefore provide great coverage, obstructing most of the sky and not just the sun. Furthermore, the openings should be far larger than in hot-dry climates. This is another reason why the shading devices should be much larger.

The proper arrangement of vegetable, mainly of shade-providing trees, within the surrounding space is an important aspect for the improvement of the indoor climate.

Another efficient solution is to grow a green cover roofs and walls. This cover functions as a second by the features, skin which provides:

The flow of air can be influenced by topographical features, by the orientation of the building and by the position of surrounding buildings and other obstructions. Such obstructions may be built intentionally to divert the wind in a desired direction. Anthienitis and Santamouris (2002) recommend that designers should enhance natural ventilation using tall spaces within building called stacks since natural breezes can't be scheduled. With openings near the top of the stack, warm air can escape, while cooler air enters the building from openings near the ground. Ventilation requires the building to be open during the day to allow air flow.

Let's encourage the use of architectural solutions based on the observation of natural principles that can reliably supplant artificial or mechanical means of cooling and ventilating the building.

It is also recommended that, further research should be carried out to explore the sufficiency of the passive means of cooling faculty of Engineering.

7.4 ORIGINAL CONTRIBUTION: The Study:

i. Established that, the incorporation of various building components such as ventilated exterior wall, and others reduce the solar heat gain of the indoor spaces.

ii. Demonstrated how evaporative cooling techniques like Water bodies, soft landscaping can be integrated into the design to reducing the cost of cooling in hot-dry climate like that of Jigawa.

iii. Established that, Xyrophytric and Deciduous trees do well in hot-dry climate in providing shading and cooling.

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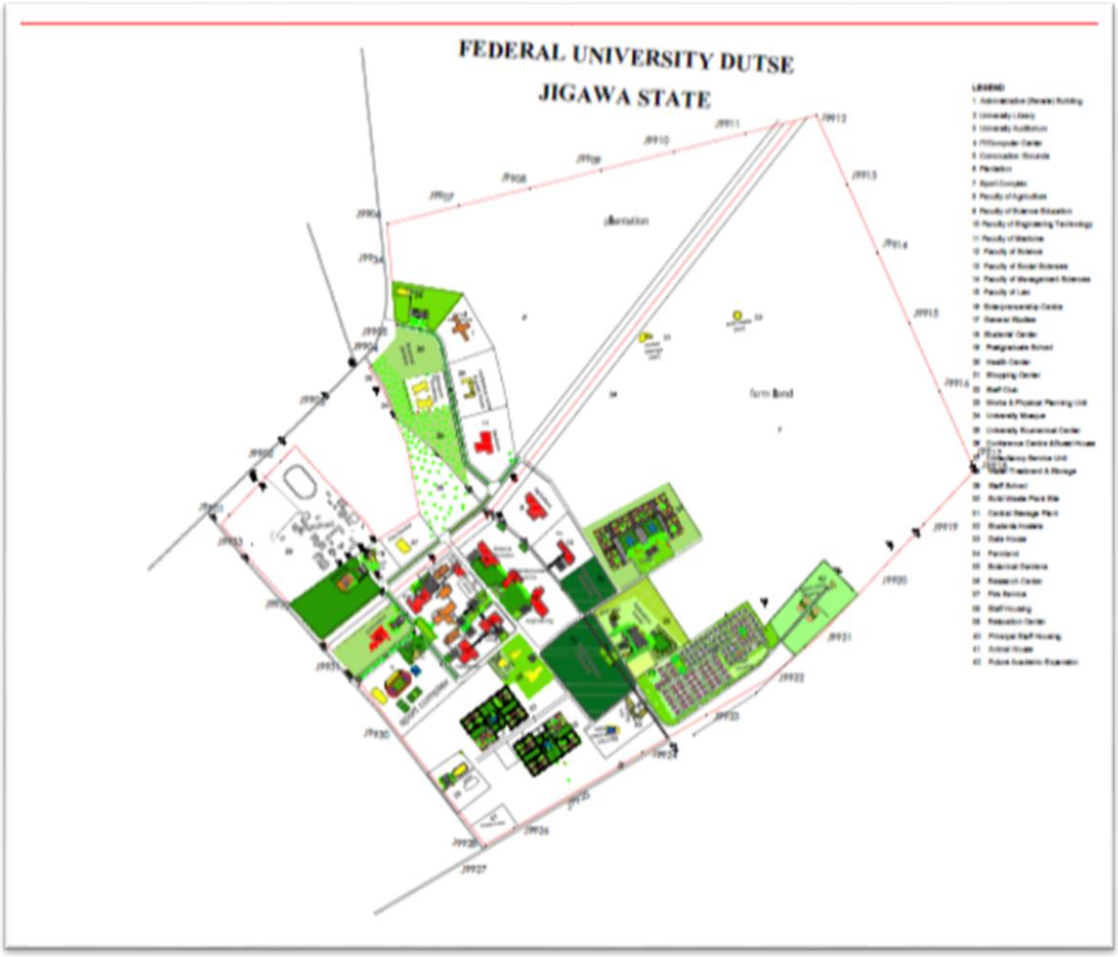
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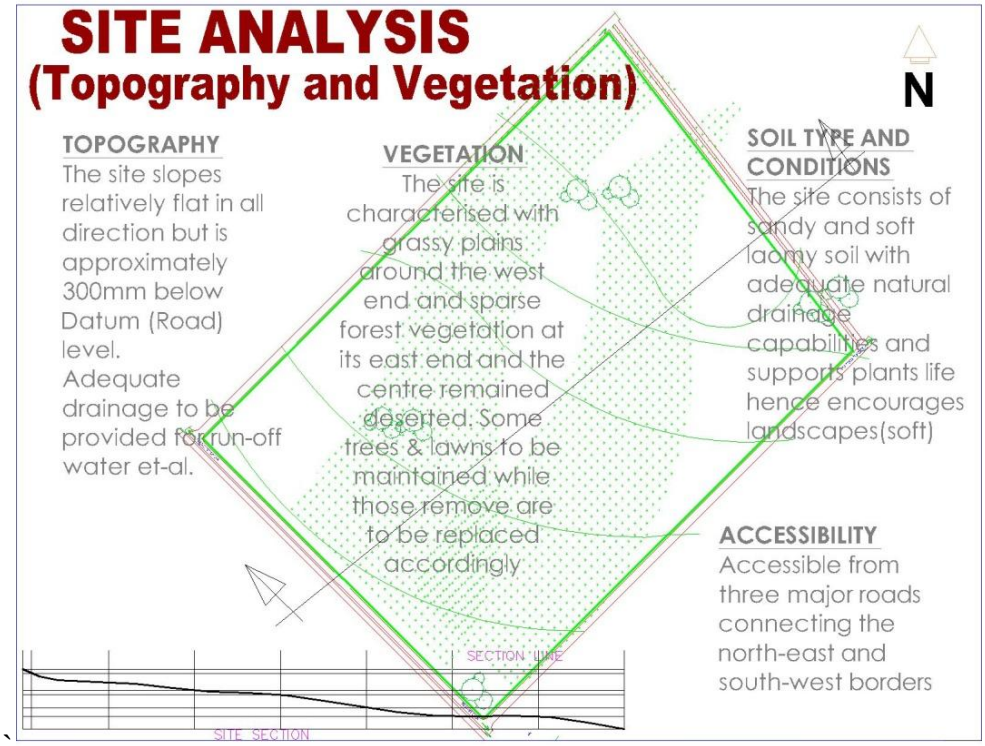
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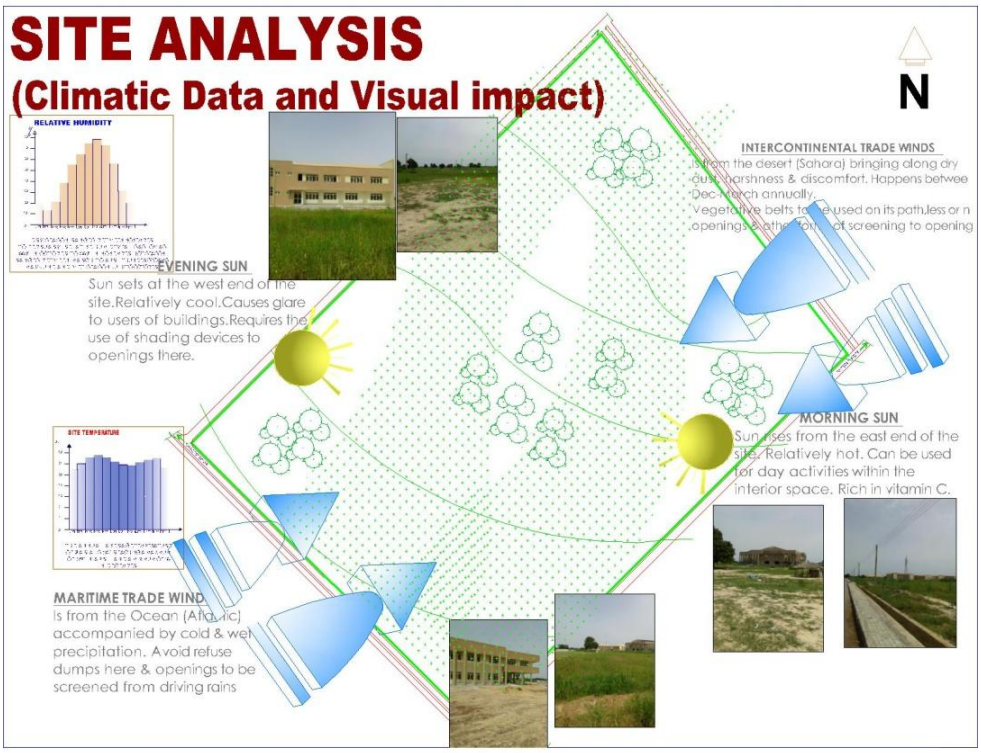
APPENDIX



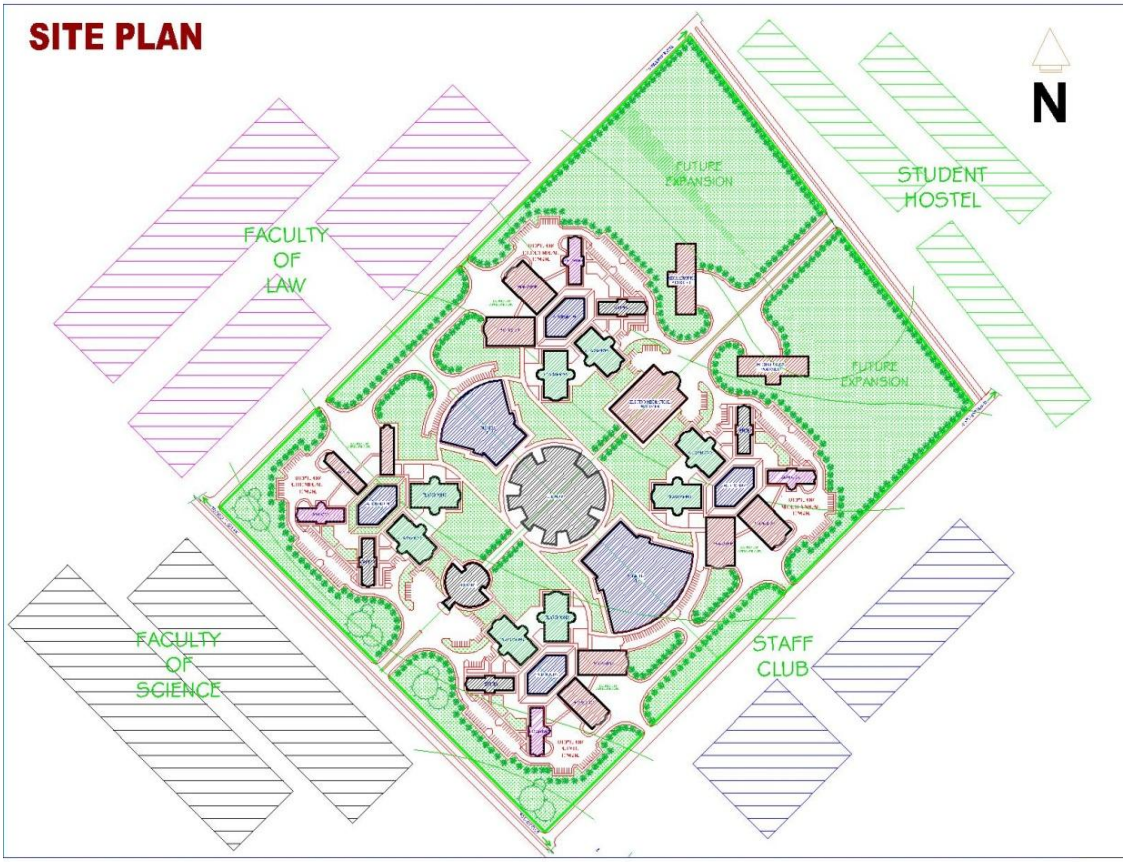
Appendix 1: Master plan of Federal University Dutse (FUD)



Appendix 2: Site Analysis (Topography and Vegetation)



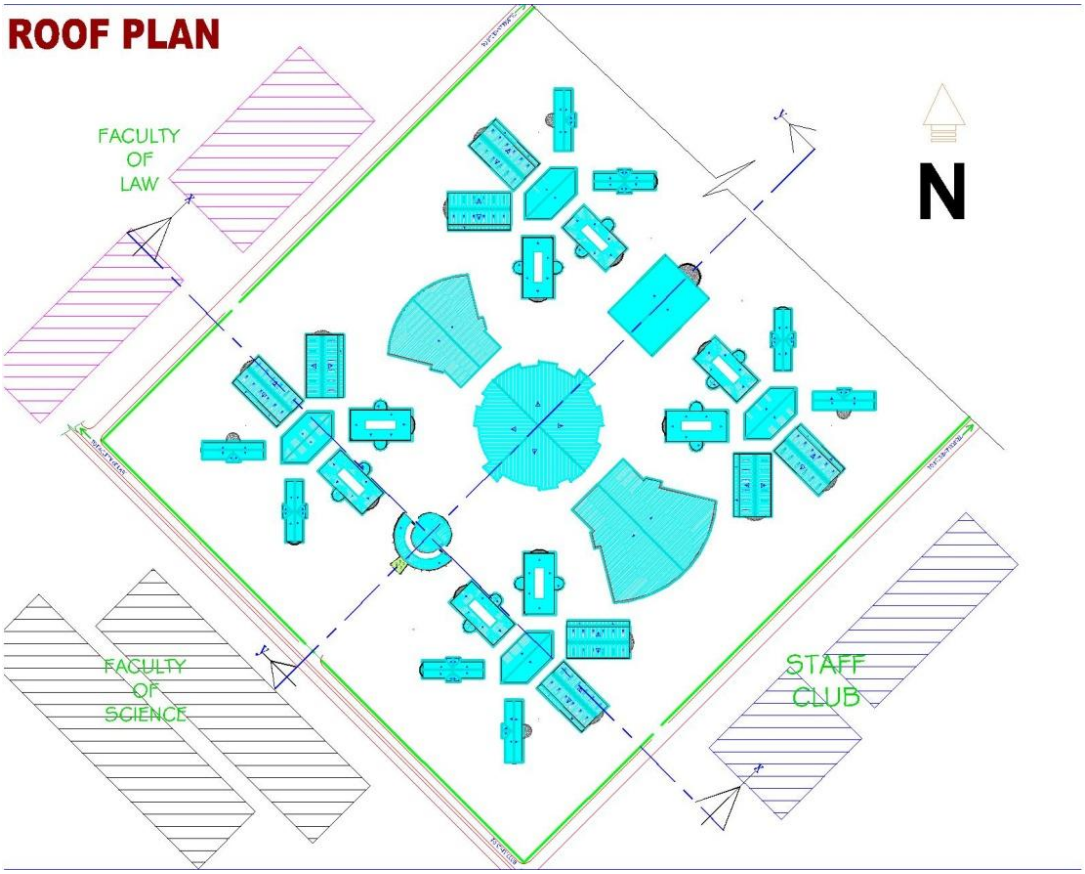
Appendix 3: Site Analysis (Climatic Data and Visual impact)



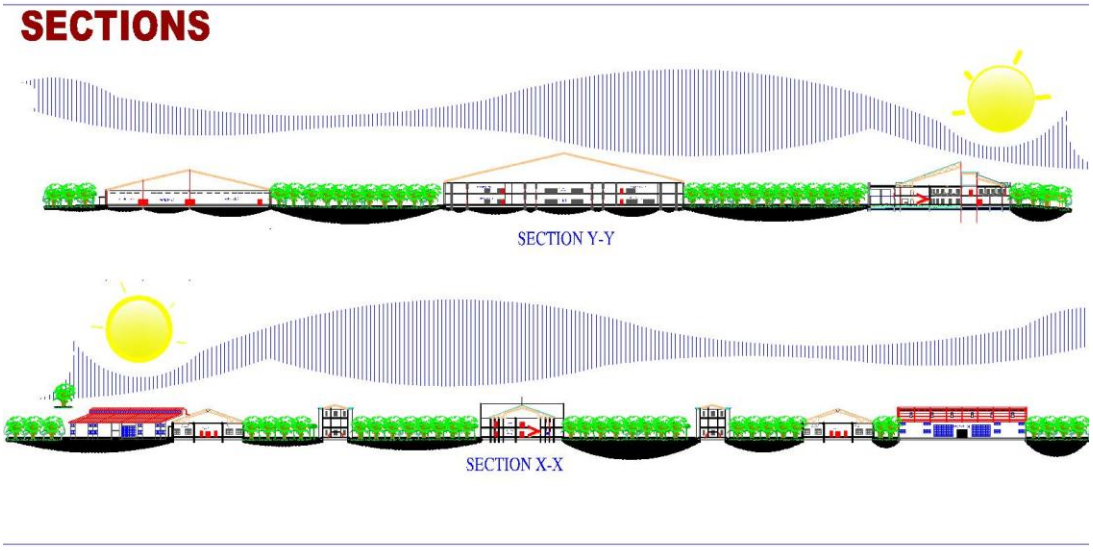
Appendix 4: Site plan



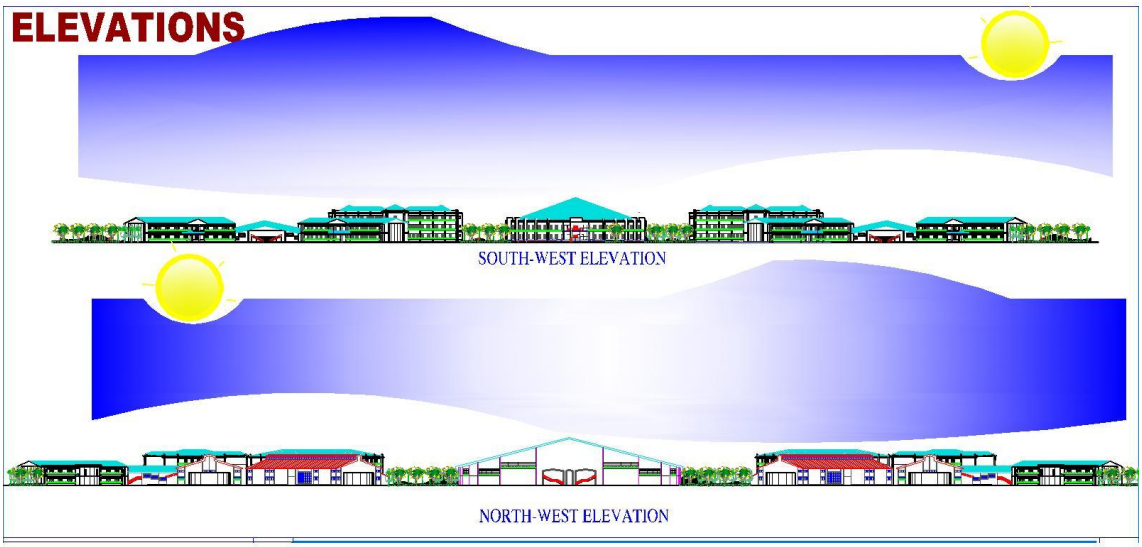
Appendix 5: Floor plan on site



Appendix 6: Roof plan



Appendix 7: Sections



Appendix 8: Elevations



Appendix 9: Elevations



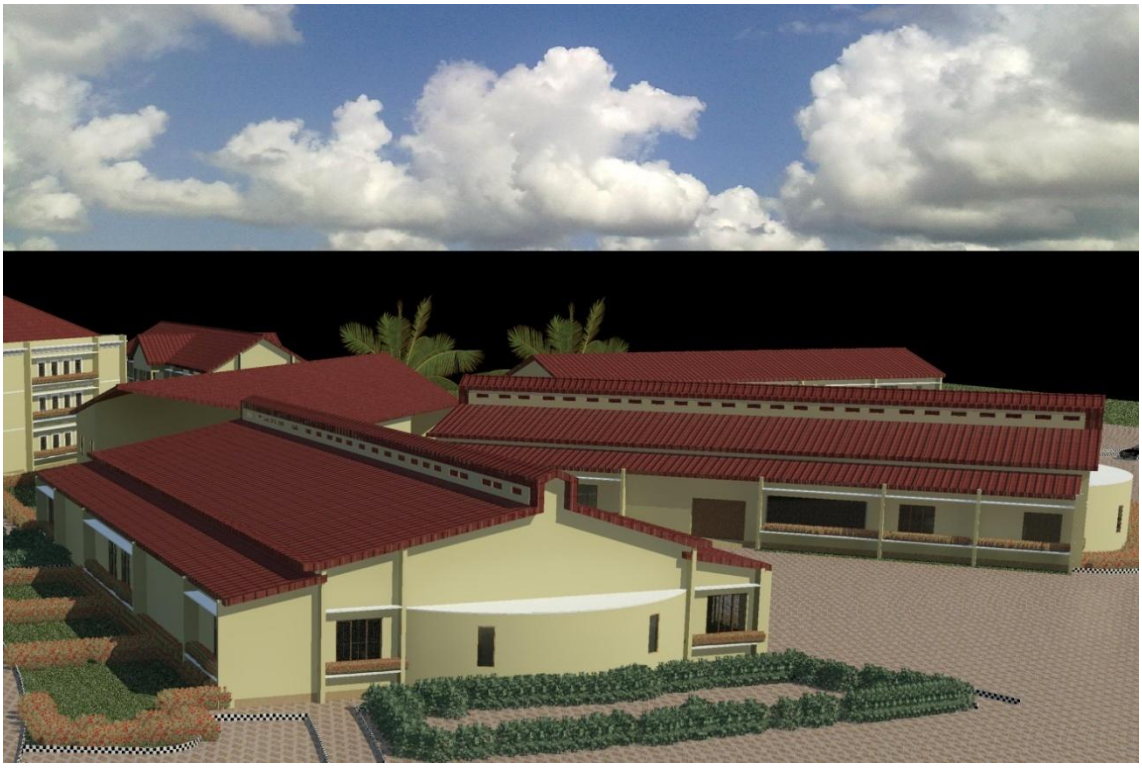
Appendix 10: Elevations



Appendix 11: Elevations



Appendix 12: 3D



Appendix 13: 3D



Appendix 14: 3D



Appendix 15: 3D