APPLICATION OF PASSIVE COOLING TECHNIQUES IN THE DESIGN OF PROPOSED UNIVERSITY SENATE BUILDING, DUTSIN-MA, KATSINA

BY

ABUBAKAR, AUDI SA'ADU
M.Sc/ENV.DES/06116/2010-2011

BEING A THESIS SUBMITTED TO THE POST GRADUATE SCHOOL,
AHMADU BELLO UNIVERSITY,
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A PROPOSED SENATE BUIDLING FOR FEDERAL UNIVERSITY, DUTSIN-MA, KATSINA

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DEPARTMENT OF ARCHITECTURE
FACULTY OF ENVRONMENTAL DESIGN
AHMADU BELLO UNIVERSITY
ZARIA, NIGERIA

OCTOBER, 2014

DECLARATION

I, ABUBAKAR AUDI SA'ADU hereby declare that the work presented has been a personal academic undertaking executed for the degree of MSc. Architecture and is correct to the best of my knowledge and with prior assistance of my supervisor Arc S.S. Tulpule, that it have not been presented for any other degree or in any other format and all quotations has been duly acknowledged, so also all relevant literature.

.

Abubakar Audi Sa'adu

Student's Name

Student's Signature

DEDICATION

This work is dedicated to Allah for His grace and strength
that saw me through this trying time.
To my beloved father Late Abubakar Audi

CERTIFICATION

This thesis titled ‘APPLICATION OF PASSIVE COOLING TECHNIQUES IN THE DESIGN OF PROPOSED SENATE BUILDING, DUTSIN-MA KATSINA by Abubakar Audi Sa'adu; meets the regulation governing the award of the degree of Master of Science in Architecture and is approved for its contribution to knowledge and literary presentation.

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ACKNOWLEDGEMENT

Glory is to Almighty Allah for seeing me through the successful completion of my course of study.

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God bless you all.

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ABSTRACT

This study aimed at identifying passive design features through extensive literature study that can be incorporated in senate building to make it energy efficient. The study also aimed at identifying changes in the design process that can affect energy efficiency in senate buildings. It has analyzed the design features of typical senate buildings through a case study conducted in different Nigerian Universities.

However, in this thesis an attempt shall be made to evolve design solution with proper consideration of the climate of the site. The climatic variables directly affecting energy usage and user's comfort such as; temperature, humidity, solar radiation and air movement, are to be studied because these are the five constituents of climate that are more important for the purposes of building design.

Within the context of tropical climate, in regards to this proposal, the climatic data of the study area are collected and analysed. The analysed data shall guide us on the selection of building materials, construction method, shape and orientation of building, size and location of fenestrations and the use of soft landscape elements.
These are taken into cognisance by relevant case studies and literature review of building in various climatic regions across the globe with respect to adaptability and response to various environmental variables.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF STUDY

One of the fundamental requirements of buildings is the protection of the people who live and work within from the inclement of weather. The objective of environmental building design is the creation of a comfortable and also energy efficient internal environment. The successful design of buildings relies on an appropriate understanding of the climatic nature of the environment.

Buildings in developing countries are often designed without taking sufficient account of the climate. Factors such as the urban surroundings or site characteristics, orientation and architectural design of the building, choice of building materials, etc. are not given enough importance. Consequently buildings often have a poor indoor climate, which affects comfort, health and efficiency. The problem is found according to Rosenlund, 2000 in dwellings as well as places work and public buildings.

Heating and cooling of buildings account today for high energy consumption. Higher living standards lead to active methods of adjusting the indoor climate of buildings such as offices, hotels, schools and other public buildings as well as residences. Air-conditioning plants are installed without any adaptation of the buildings to these new appliances, which leads to excessive energy consumption and high cost, and may also damage the building (Adamson & Aberg, 1993).

Passive cooling is a term used to encompass a wide range of strategies and options resulting in energy-efficient building design and increased occupant comfort. The concept emphasizes architectural design approaches that minimize building energy consumption by integrating conventional energy-efficient methods, such as

building sitting, an efficient envelope, appropriate amounts of fenestration, increased day lighting design, and thermal mass (Stamas & Sanford, 2008).

Passive design is about ensuring that the fabric of the building and the spaces within it respond effectively to local climate and site conditions in order to maximize comfort for the occupants. Using passive design principles can reduce temperature fluctuations and make a building drier, quieter and more enjoyable to live in. The basic idea of passive design is to allow daylight, heat, and cool airflow into a building when it is needed. The objectives are to control the entrance of sunlight and air flows into the building at appropriate times and to store and distribute the heat and cool air so it is available when needed. Many passive design options can be achieved at little or no additional cost. Others are economically viable over a building's life-cycle.

Passive Cooling refers to those processes of heat dissipation that will occur naturally, that is without the mediation of mechanical components or energy inputs. The definition encompasses situations where the designing of spaces and building elements to lose heat to ambient heat sinks (air, sky, earth and water) by means of natural modes of heat transfer leads to an appreciable cooling effect indoors. The term "passive" implies that energy-consuming mechanical components like pumps and fans are not used.

Passive cooling is based on the interaction of the building and its surroundings. Passive cooling strategies 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.

In general, passive design balances all aspects of the energy use in a building: lighting, cooling, heating, and ventilation. It achieves this by combining, in a single concept, the use of natural sources of energy and conventional, energy-efficient strategies(Rosenlund, 2000).

Passive design means that nature (and the architect) does the work. Passive strategies adjust to environmental conditions primarily through architecture and should be considered before active. This means that the architect must be strategic. It means using the resources on site rather than importing energy from a remote source. Passive cooling is achieved by using ventilation, coupled with the configuration and thermal properties of the building. In addition to cooling, ventilation is necessary to provide for respiration of the occupants, and also to control the level of pollutants inside a building.

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 greenhouse gas emissions from 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 designers now to re-evaluate the role of natural ventilation in buildings and to become familiar with the basic principles involved (Richard, 2007).

Natural ventilation relies on moving air through a building under the natural forces caused by outside wind pressure and the buoyancy effects of temperature

differences. Air paths need to be simple and generous as wind and buoyancy pressures are low.

Energy efficiency in simple terms, means using less energy to perform the same tasks and functions. For office building, this could mean reducing the amount of energy needed for heating by improving insulation of the office building, by introducing lighting control or also regulate space heating and cooling.

1.2 PROBLEM DEFINITION

Most buildings in developing countries are often designed without taking sufficient account of the climate. Consequently buildings often have a poor indoor climate, which affects comfort, health and efficiency. The problem is found in dwellings as well as workplaces and public buildings.

Dutsin-ma climate in Katsina State is characterized as a hot-dry region. The climate is described excessive solar radiation; high daily temperature for a greater part of the year, by which to achieve energy savings and thermal comfort in buildings to be located in such region should be aimed at.

The above reasons make it essential to come up with a design of senate building for Federal University Dutsin-ma that will embark upon the action that is the most energy consumable 'cooling and ventilation' to reduce the carbon emission and cost of operation.

1.3 AIM AND OBJECTIVES

1.3.1 THE AIM OF THIS RESEARCH IS:-

- To design a university senate building that connects the approaches of climate responsiveness in providing thermal comfort and savings in energy for Dutsin-ma Federal University.

1.3.2 THE OBJECTIVES OF THIS ARE:-

- To identify conventional energy consumption techniques for cooling senate building.
- To incorporate energy saving techniques and materials in the design
- To provide a functional and aesthetically design to the university.
- To proposed a design of senate building with minimum consumption of energy for cooling and ventilation

1.4 RESEARCH QUESTIONS

In the cause of this research the following questions are raised to assist in research process:

A. What are the other means available for naturally cooling a senate building?

B. How can these other means be applied in design?

1.5 SCOPE OF THE PROJECT

The scope of this research will be concerned with passive design methods that aid in the cooling of the interior spaces making them comfortable for administrative activities.

The project shall be based on provision of a central administration building which is the senate building for FUD to accommodate the following; the vice-chancellor's office, the registry, the planning unit, students affairs department, bursary and general administration. The senate also houses the senate chamber and the council chamber

1.6 MOTIVATION

People's comfort and health depend on indoor environmental conditions including temperature, humidity, air quality, lighting, and noise levels. These can be managed by careful consideration of passive design techniques in buildings.

The above reasons make it clear in proposing this research topic to make a design proposal for Dutsin-ma Federal University senate building in Katsina State, being it one of the tropical zones that need energy conscious design in which a more successful and well coordinated, effective administrative activities will take place.

1.7 JUSTIFICATION

This thesis is justified by the political decision by the federal government to establish nine federal universities in the country. one of these federal universities is to be located at Katsina.

1.8 RESEARCH METHODOLOGY

The methods of gathering information with regard to this design thesis will be by:

A. Oral/interview with the experienced Architects in the field of sustainable design,
B. Literature and journals review and news paper articles highlighting on the proposed topic,
C. Case studies of existing senate buildings,
D. Personal observations.
E. Analysis of the environmental climatic data of the site shall be carry out to ascertain the a higher and lower temperature of the site.

CHAPTER TWO

LITERATURE REVIEW

2.1 PASSIVE DESIGN

Passive design is a term used to encompass a wide range of strategies and options resulting in energy-efficient building design and increased occupant comfort. The concept emphasizes architectural design approaches that minimize building energy consumption by integrating conventional energy-efficient methods, such as building siting, an efficient envelope, appropriate amounts of fenestration, increased day-lighting design, and thermal mass (Stamas and Sanford, 2008).

Passive design involves collection, storage, distribution and control of energy flow by natural processes of cooling and ventilation. Passive becomes very effective with the use natural energy to conserve conventional energy for achieving thermal comfort. The primary objective of passive design strategies is to reduce or even eliminate the need for active mechanical systems while maintaining or even improving occupant comfort (Oikos 2008).

2.1.1 PASSIVE DESIGN STRATEGIES

Certain passive building elements have inherent synergies and can be combined to produce different and potentially greater improvements in comfort and building energy performance. However, combining elements incorrectly or using certain elements in isolation can negatively impact thermal comfort and building energy efficiency. For example, large south and west facing windows beneficial for passive solar heating must be implemented in combination with high performance windows and external shading to protect the interior from excessive solar heat gains during summer in order to achieve the desired overall building efficiency gains. It is

important to note that these guidelines distinguish between cooling and ventilation (Fergus, 2008).

a. Passive Ventilation

b. Passive Cooling

2.2 PASSIVE COOLING

Passive cooling is considered an "alternative" to mechanical cooling that requires complicated refrigeration systems. By employing passive cooling techniques into administrative building, mechanical cooling and will be eliminated or reduced it to a minimum.

Passive cooling is based on the interaction of the building and its surroundings. Before adopting a passive cooling strategy, matching of local climate must be ensured.

It is evident that the total energy consumption of buildings for cooling purposes varies as a function of the quality of design and climatic conditions (Oikos, 2008).

Passive cooling strategies prevent the building from overheating by blocking solar gains and removing internal heat gains (e.g. using cooler outdoor air for ventilation, storing excess heat in thermal mass). Passive cooling strategies are often coupled with passive ventilation strategies, and the cooling function is achieved by increased passive ventilation air flow rates during periods when the outdoor air temperature is low enough to flush heat from the building (Fergus, 2008).

Passive cooling is the passive design method that is required in hot dry climates as prevalent in Katsina which makes them the system to be considered for the purpose of this thesis.

Heat enters and leaves a home through the roof, walls, windows and floor. Internal walls, doors and room arrangements affect heat distribution within a home.

These elements are collectively referred to as the building envelope. Passive cooling maximizes the efficiency of the building envelope by minimizing heat gain from the external environment and facilitating heat loss to natural sources of cooling:

A useful design strategy for the hot dry climate is to first control the amount of heat from solar radiation and heated air reaching the building, then to minimize the effect of unwanted solar heat within the building skin or at openings, next to reduce internal or casual heat gains from appliances and occupants and finally, where necessary, to use environmental heat sinks to absorb any remaining unwanted heat. In practice a combination of these cooling techniques are almost invariably in operation at the same time.

Fixed or adjustable shading devices, or shading provided by vegetation and special glazing may be used to reduce the amount of solar radiation reaching the building. External heat gains due to solar radiation can be minimized by insulation, reduced window sizes, thermal inertia in the building envelope, reflective materials and compact building layout. Infiltration gains can be reduced by cooling the incoming air and by reducing its infiltration to a minimum necessary for comfort and health.

Several methods of passive/natural cooling, including increased air speeds to maximize perceived levels of cooling, ground and evaporative cooling to reduce the temperature of ventilation air and night-time cooling of the building by radiative heat loss to the sky and enhanced ventilation, can help to maintain comfortable indoor conditions.

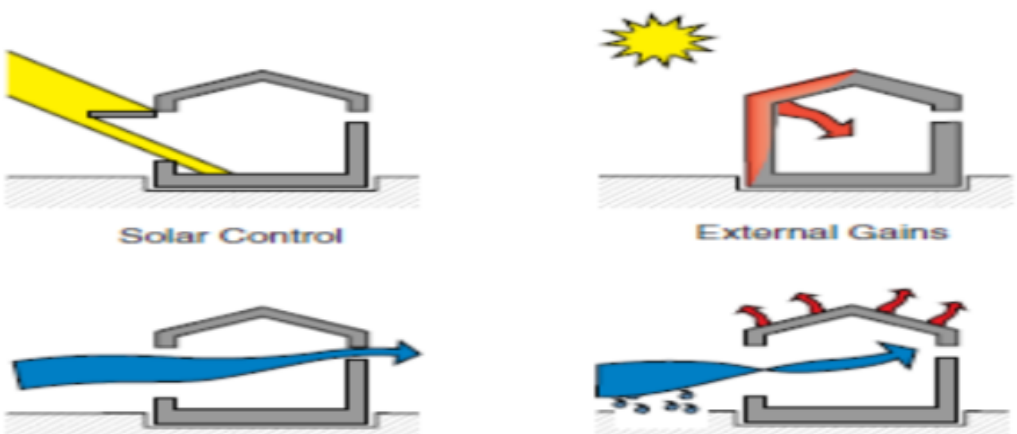


Figure.2.1 Passive cooling strategy,
(**Source** Passive design toolkit, 2005)

2.2.1 PASSIVE COOLING TECHNIQUES

The passive cooling techniques which will aid the cooling of the buildings are as follows:

a) EVAPORATIVE COOLING

Evaporative cooling 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 vapor.

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

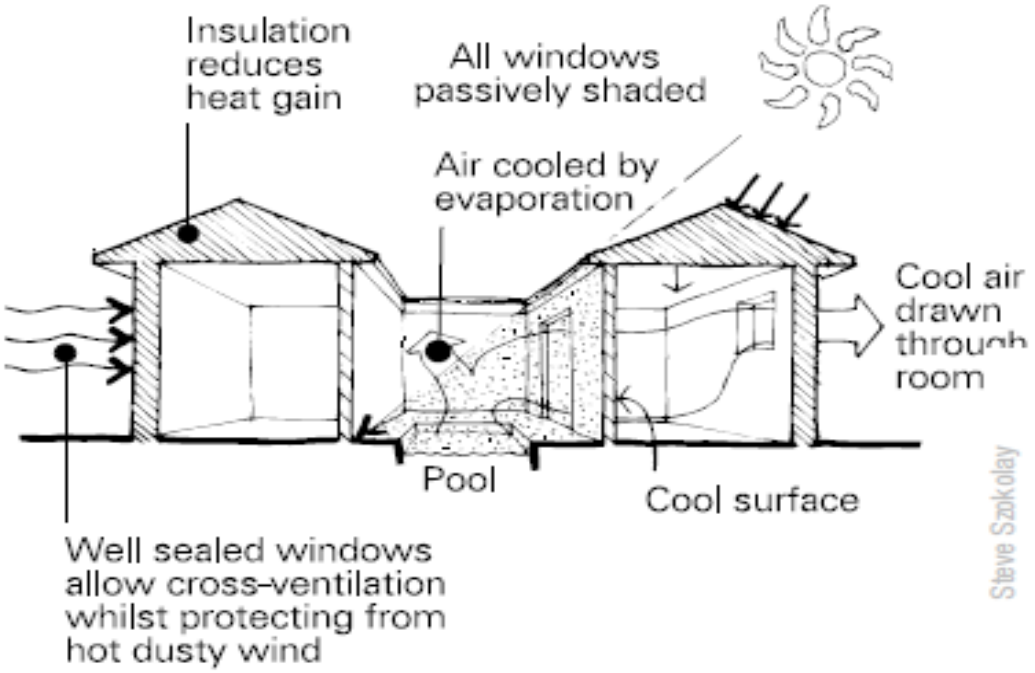


Figure. 2.2: Courtyard design with evaporative cooling pond
(Source: Passive solar design guidance, 2008)

b) CONVECTIVE AER MOVEMENT

Convective air movement relies on hot air rising and exiting at the highest point, drawing in cool air from shaded external areas over ponds or cool

earth. Convection produces air movement capable of cooling a building but has insufficient air speed to cool the occupants.

Clerestory windows spin away roof ventilators, and vented ridges, eaves and ceilings will allow heat to exit the building in nil breeze situations through convection (Chris, 2002).



and gradually releasing heat (thermal energy). 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 (Chris, 2008).

High thermal mass depends on the ability of materials in the building to absorb heat during the day. Each night the mass releases heat, making it ready to absorb heat again the next day. To be effective, thermal mass must be exposed to the usable spaces. A slab floor would be an easy way to accomplish this in a design.

i) Effects Of Thermal Mass

Thermal mass can have a negative impact on energy performance in some cases, where there is no opportunity to release heat into ambient air (in climates with no diurnal swing) or there is no opportunity for solar gains to be absorbed and stored (in climates with cold temperatures and low solar incidence (Vladimir, 2008).

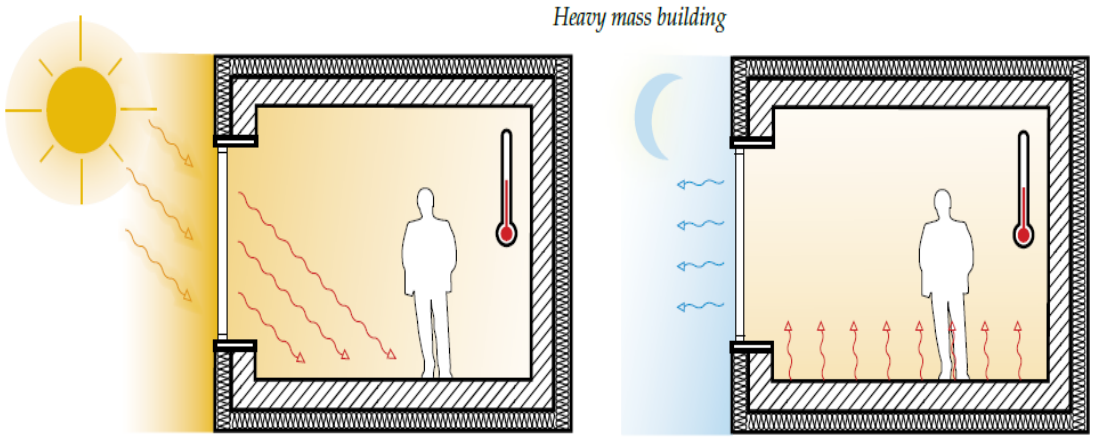


Figure. 2.4a: Effect of thermal mass
(Source: Passive design toolkit, 2008)

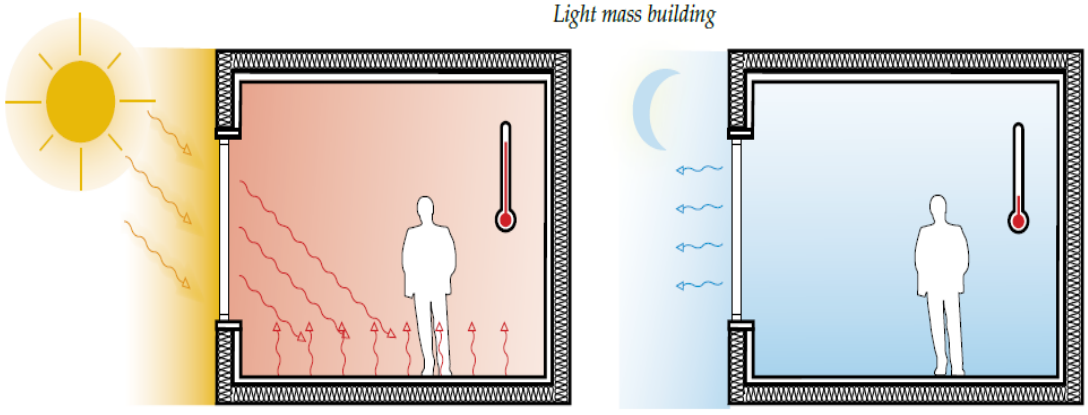


Figure. 2.4b: Effect of thermal mass
(Source: Passive design toolkit, 2008)

ii) High Thermal Mass With Night Ventilation.

In high heat-gain buildings, there may be residual heat at the end of the day which, if retained overnight, can lead to overheating the *next* day. To remove the residual heat, the building is ventilated overnight. The cool night air draws the heat out of the thermal mass or insulated envelope and releases it back outside. With a lower initial temperature at the start of the next day, the building is less likely to overheat, thereby improving comfort and reducing cooling requirements (Vladimir, 2008).

d) THERMAL INSULATION

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. This reduction of heat transfer is expressed in terms of R-Value and U-Value. Minimum R-Values and maximum U-values for key building envelope components are prescribed by current ASHRAE 90.1 building energy standards.

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 walls will have the same effect, as will acoustic ceiling tiles.

Thermal insulation also impacts the surface temperature on the envelope interior, which directly impacts thermal comfort. Interior envelope surface temperatures must remain high enough during winter to avoid condensation and maintain occupant comfort. Cold surface temperatures (i.e., windows) affect occupant 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).

2.2.2 TYPES OF PASSIVE COOLING SYSTEMS

A. COOLING WITH VENTILATION

i. **Comfort Ventilation:** Ventilation during the day and night to increase evaporation from the skin and thereby increasing thermal comfort.

ii. **Night Flush Cooling:** Ventilation to precool the building for the next day

B. RADIANT COOLING

i. **Direct Radiant Cooling:** A building's roof structure cools by radiation to the night sky

ii. **Indirect Radiant Cooling:** Radiation to the night sky cools a heat-transfer fluid, which then cools the building.

D. EVAPORATIVE COOLING

i. **Direct Evaporation:** Water is sprayed into the air entering a building. This lowers the air's temperature but raises its humidity

ii. **Indirect Evaporative Cooling:** Evaporation cools the incoming air or the building without raising the indoor humidity

D. EARTH COOLING

i. **Direct Coupling:** An earth-sheltered building loses heat directly to the earth

ii. **Indirect Coupling:** Air enters the building by way of earth tubes

E. DEHUMIDIFICATION WITH A DESICCANT:

i. **Removal of Latent Heat**

2.2.3 PASSIVE COOLING CONTRIBUTING ELEMENTS

Elements that contribute to achievement of passive cooling include the following:

A. Passive ventilation.

B. Passive evaporative cooling.

C. Thermal mass.

D. High thermal mass with night ventilation.

E. Central atriums and lobbies

F. Wind towers

G. Buffer spaces and double facades

H. Fixed/operable external shading

I. Low window to wall area ratio (S/W).

J. Nocturnal cooling.

K. Earth-tempering ducts.

L. Orientation.

M. Effective shading (including planting)

N. Green roof.

O. Green wall.

P. Landscape.

Q. Ventilated exterior wall

R. Courtyard system.

2.2.4 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. 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 (Matheos, 2005).

2.2.5 CLASSIFICATION OF PASSIVE COOLING TECHNIQUES

Passive cooling techniques can be classified in three main categories and these are as follows:

a) Solar And Heat Protection Techniques.

Protection from solar and heat gains may involve landscaping, the use of outdoor and semi-outdoor spaces, 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 sink of lower temperature.

2.2.6 ARCHITECTURAL APPLICATION OF PASSIVE COOLING PRINCIPLES

The principles of passive cooling can be applied architecturally through following:

A.

B. BUFFER SPACES

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

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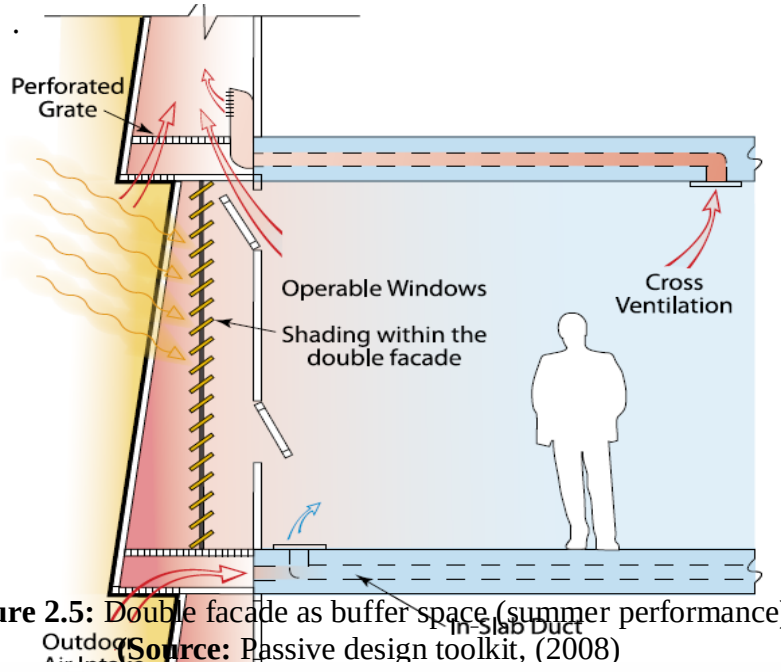


Figure 2.5: Double facade as buffer space (summer performance)
(Source: Passive design toolkit, (2008)

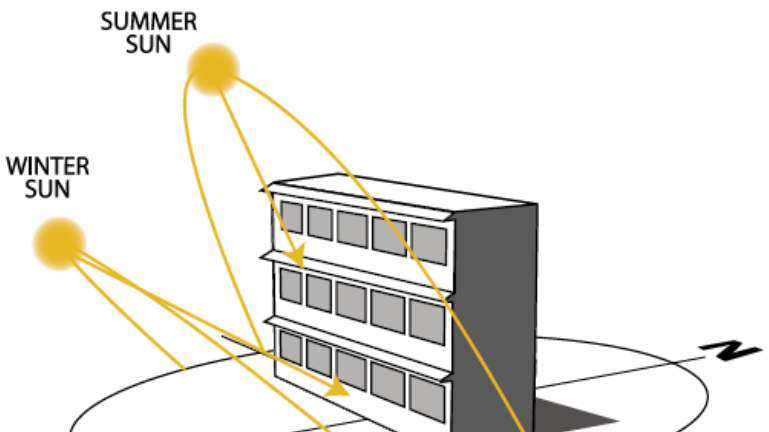


Figure 2.6: illustrating the corridor facade configuration of a double skin façade
(Source: Passive design toolkit, 2008)

C. SITE AND ORIENTATION

Many site considerations can affect the passive design approach, including urban design opportunities and constraints, building orientation on the site, shade from other buildings, wind patterns, proximity to industry, noise, and urban character. These all need to be considered to optimize the integration of passive cooling strategies.

Building facade orientation is one of the key elements for many passive design strategies. Facade orientation affects the energy and comfort implications of solar shading, window to wall area ratio, window position and performance, and choice of exterior colour. A building's orientation determines the amount of solar radiation it receives. The roof surface receives the greatest intensity, but it is normally opaque and well-insulated. Building facades, which can have a significant window to wall area ratio, also receive sun in various amounts.



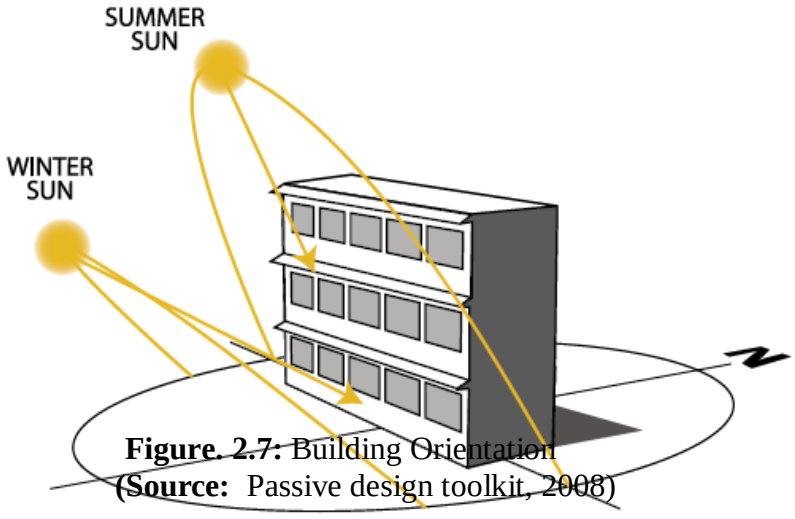


Figure. 2.7: Building Orientation
(Source: Passive design toolkit, 2008)

D. BUILDING SHAPE AND MASSING

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 cost). Certain common building shapes greatly increase envelope area to volume ratio (e.g., thin high rise towers), which can decrease building energy performance in heating dominant buildings. With a similar square footage, buildings with a smaller exterior 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.

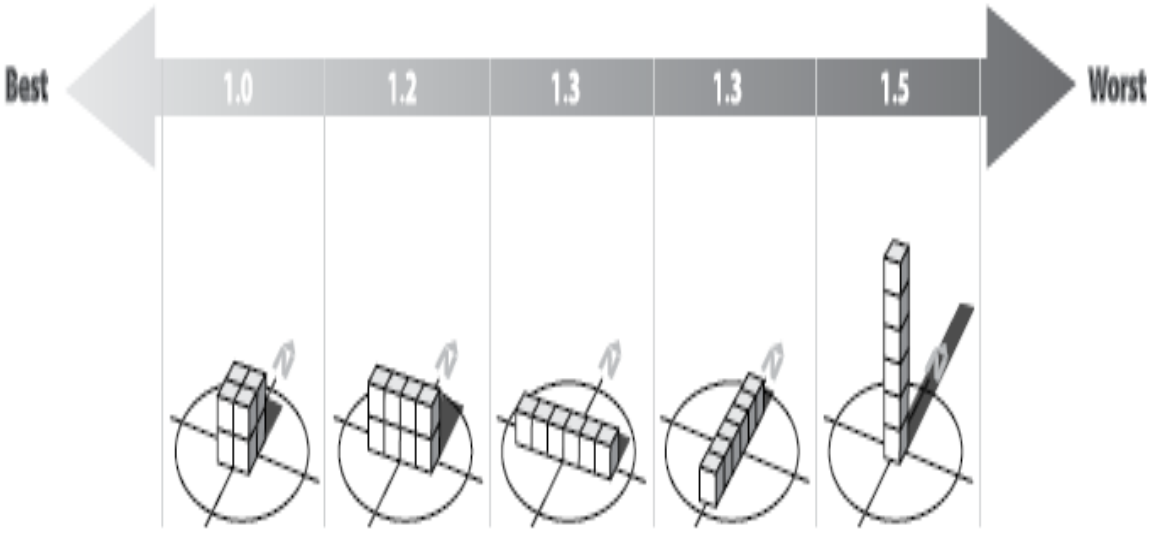


Figure 2.**8** **T**he effect of envelope to volume ratio on energy efficiency
(Source: Passive design toolkit, 2008)

E. LANDSCAPE CONSIDERATIONS

Many landscape considerations happen very early on in the design process. Setbacks, street trees, street alignment and use of landscape buffer zones can be guiding elements of many site planning decisions. Therefore, careful consideration of landscaping is critical to successfully implementing the passive approach at the early stages of design.

Reducing ambient temperature and limiting the heat island effect around buildings, thus reducing the cooling load. Protecting the building from sun, wind and precipitation.

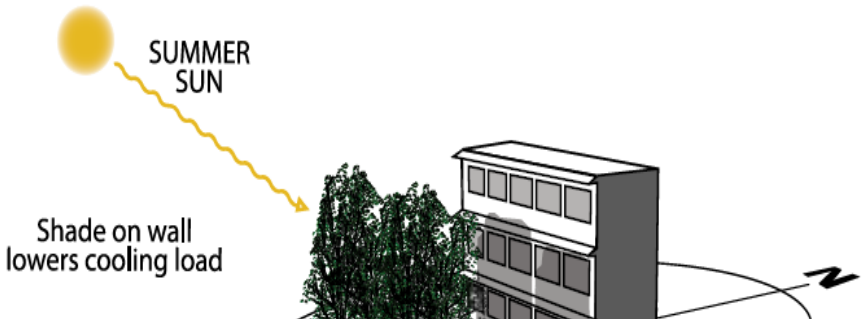


Figure 2.9 Landscape strategies for passive solar heating and day-lighting control

Source: Passive design toolkit, 2008)

F. EARTH COUPLING

This is an advanced passive cooling technique. Earth coupling of thermal mass (floor slabs) protected from external temperature extremes can substantially lower temperatures by absorbing heat as it enters the building or even heat generated by household activities.

Passively shaded areas around earth-coupled slabs keep surface ground temperatures lower during the day and allow night-time cooling. Poorly shaded surrounds can lead to earth temperatures exceeding internal comfort levels in many areas.

F. 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.

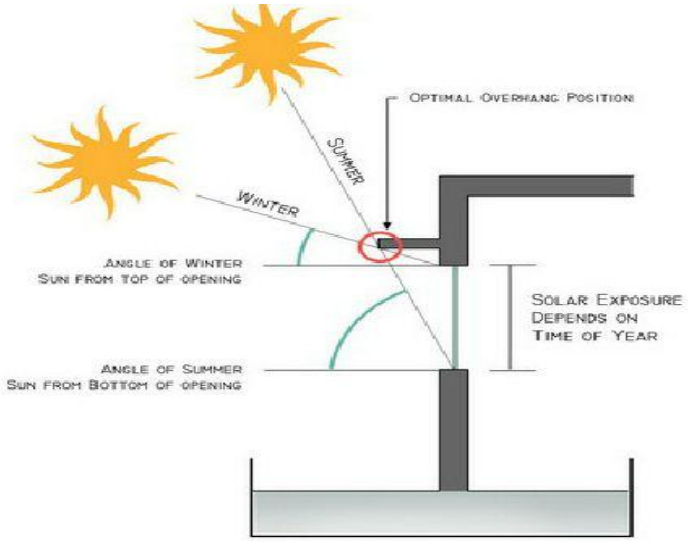
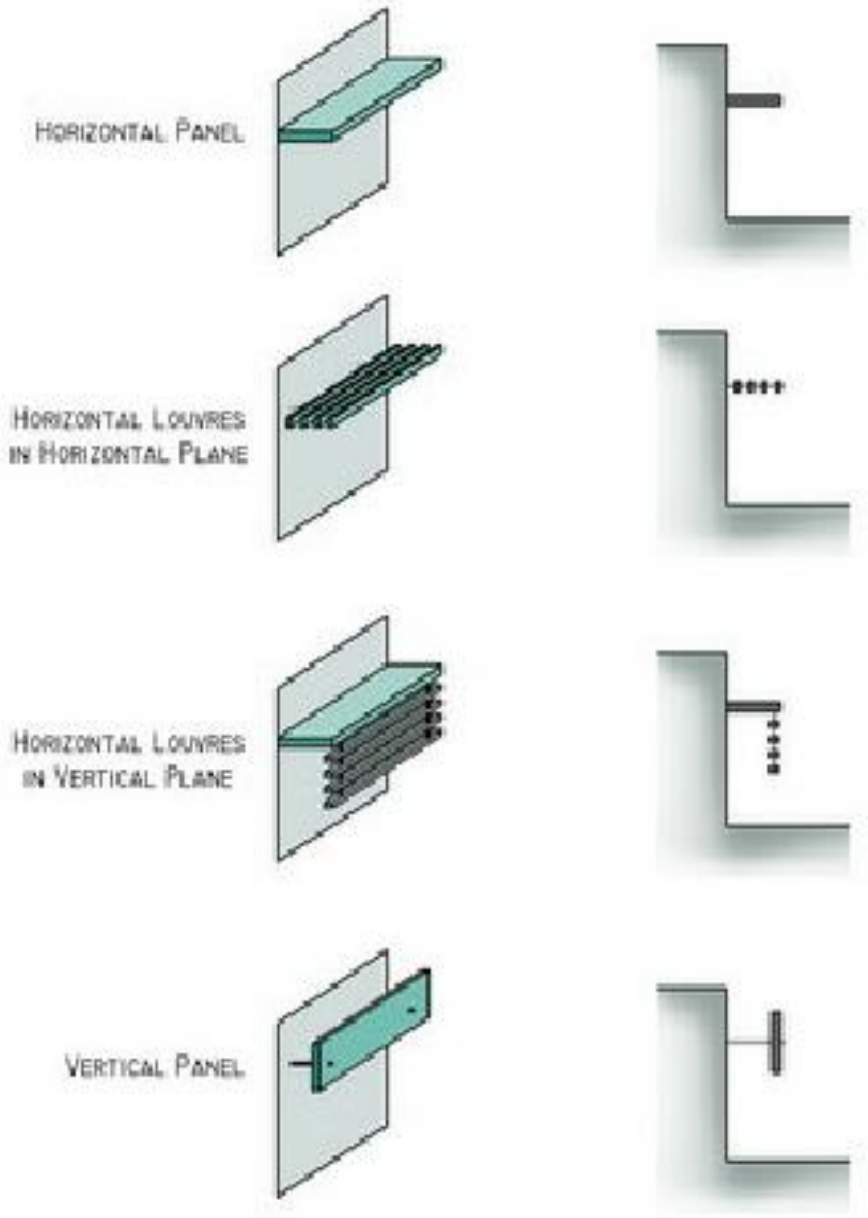


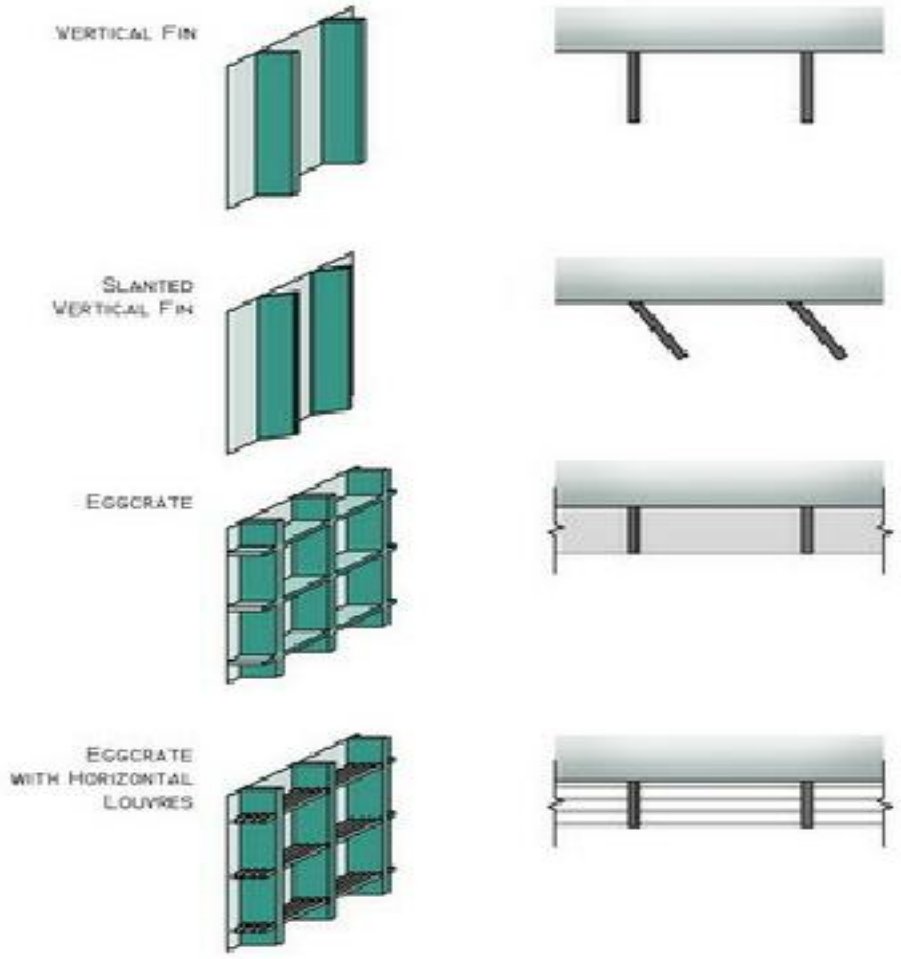
Figure 2.10 Basic Shading Strategies
(Source: Carbon natural Design 2011)

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.



Where sun is hitting the facade 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



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. Thermal comfort refers specifically 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.

A. Air temperature

B. Air humidity

C. Air velocity

D. Surface temperatures

Each factor 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).

A) THERMAL COMFORT MODELS

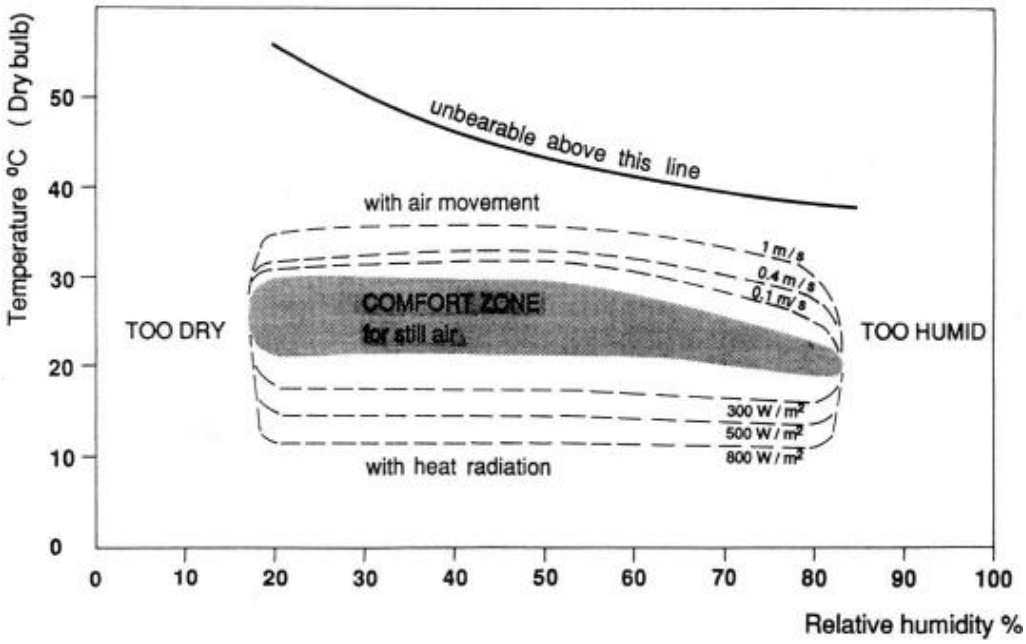
As human thermal comfort perception is extremely complex and subjective, defining acceptable comfort parameters is particularly challenging. Despite these difficulties, several models for quantitatively measuring occupant comfort have been widely used. The two most relevant in this case are the Fanger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

B) 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 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.



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.

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)

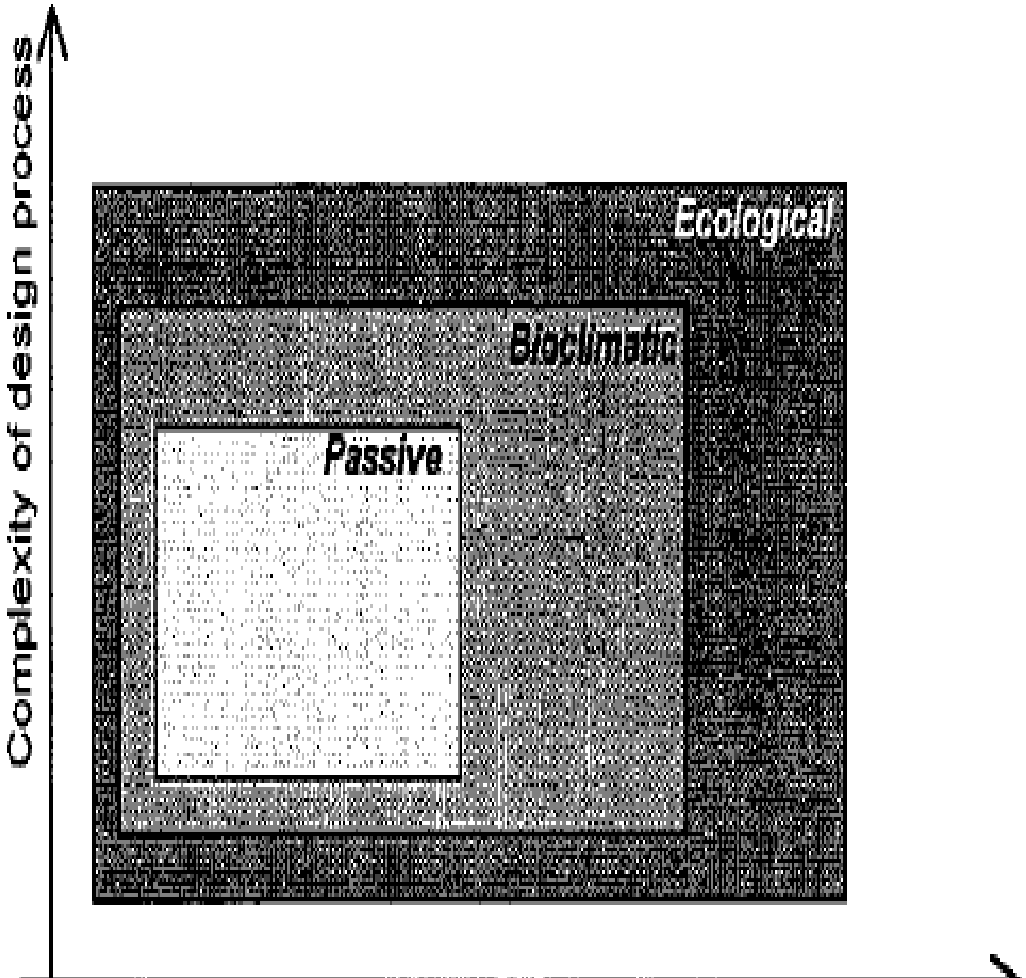
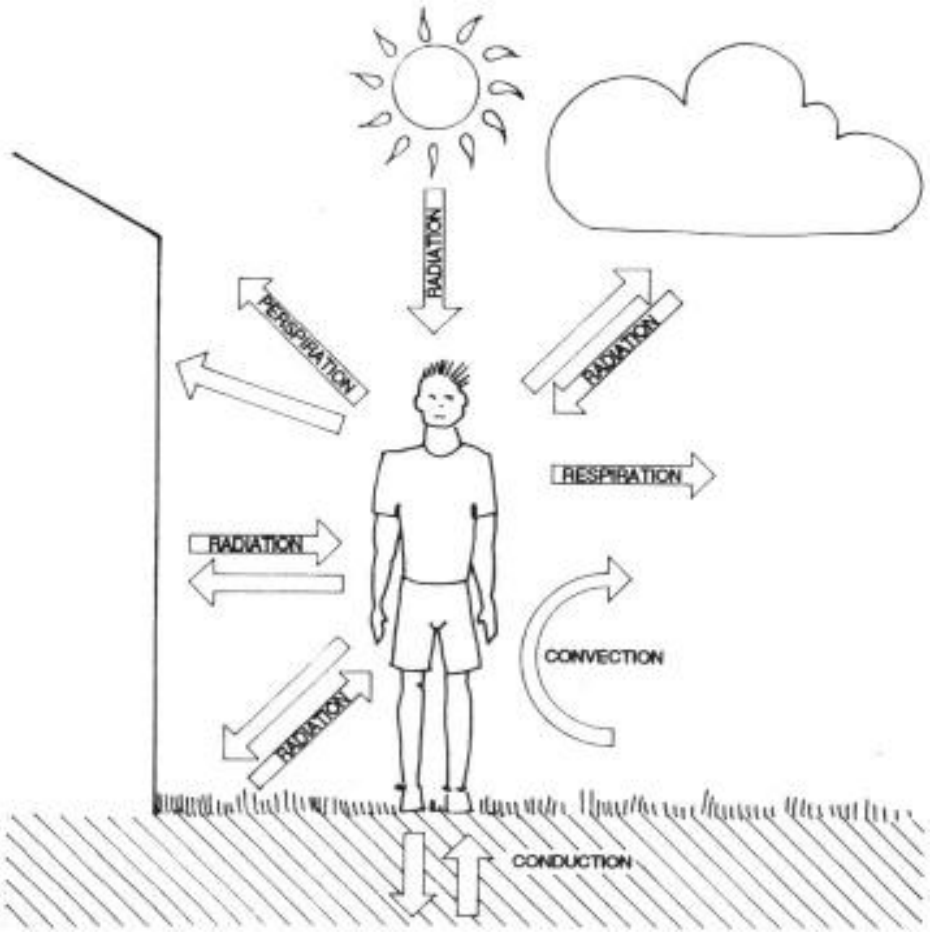


Figure 2.14: Relationship of Passive, Bioclimatic and Ecological approaches (Source: Passive cooling and human comfort, 1994)

C) 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, convection, radiation and evaporation (Paul and Dieter, 2009).



The contribution that conduction 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 depends primarily on the temperature difference between the skin and the air and on air movement. It can, to a certain extent, be controlled by adequate clothing. The insulation effect of clothing can be expressed by a clothing value (clo-value) (Paul and Dieter, 2009).

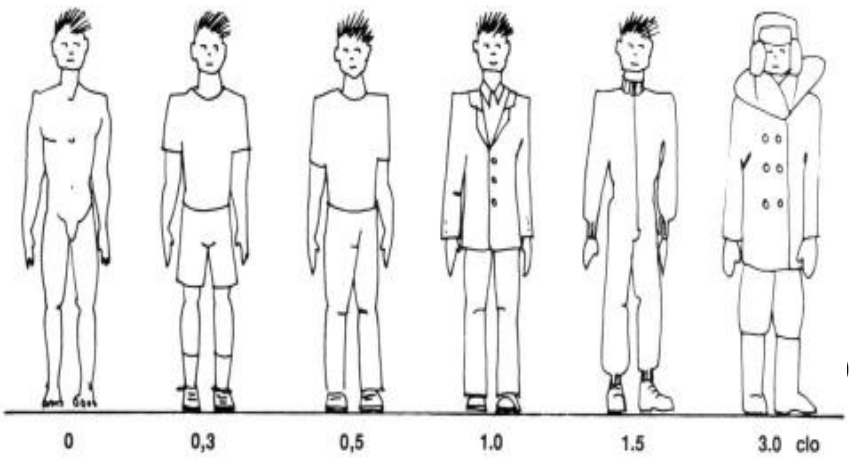


Figure 2.16: Ins

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 surfaces) is above 25°C, the clothed human body cannot get rid of enough heat by conduction, convection or radiation (Paul and Dieter, 2009).

2.2.8 NATURAL VENTILATION.

Natural ventilation is an important and simple technique that when appropriately used may improve thermal comfort conditions in indoor spaces, decrease the energy consumption of air conditioned buildings, and contribute to fight problems of indoor air quality by decreasing the concentration of indoor pollutants.

It must be recognized that natural ventilation is not just an alternative to air conditioning. Instead it is a more effective instrument to improve indoor air quality, protect health, provide comfort, and decrease unnecessary energy consumption.

Given the great inequalities in terms of income and energy use in the world, what natural ventilation may offer is a function of the actual needs, the

characteristics of the building as well as the type of energy used, and the services and systems employed. Thus, three main clusters of possible uses/contributions may be defined as a function of income and the corresponding energy use (Matheos. 2005).

In very low income households natural ventilation can greatly contribute in avoiding indoor air pollution problems caused by combustion processes. Almost 2 billion people are living under these specific conditions, without access to electricity and modern fuels. High concentrations of indoor pollutants pose a tremendous health threat to the population of the less developed countries.

Natural ventilation may greatly contribute in improving indoor air quality and indoor thermal conditions for about three billion people of low and medium income. Most of these people live in poorly designed buildings suffering from high indoor temperatures during summer. This population doesn't have the means to use any cooling equipment and relies fully on natural systems and techniques. Design and integration of efficient natural ventilation systems and components like wind and solar towers, can greatly assist in improving indoor thermal comfort. As it concerns indoor air quality, high levels of outdoor air pollution and its impact on the indoor environment, is a major problem for this part of urban population.

Also, natural ventilation can greatly contribute in improving thermal comfort, decrease the needs for air conditioning, and improve indoor air quality in the developed world. As previously explained, a serious limitation of natural and night ventilation application in dense urban environments has to do with the severe reduction of wind speed in urban canyons. Outdoor

pollution is also a grave limitation for natural ventilation in urban areas (Matheos, 2005).

A. PRINCIPLES OF NATURAL VENTILATION

The principles of natural ventilation in buildings are relatively few and straightforward, relying on wind, thermal buoyancy or both as driving forces. There is, however, a whole range of subtle and sophisticated ways to take advantage of the natural driving forces to promote the ventilation principles. This is exemplified in a number of both new and old buildings that utilise natural driving forces for ventilation (Klieven,2003).

B. NATURAL VENTILATION CONCEPT

The driving force is the first aspect to be applied which can be wind, buoyancy or a combination of both. While the second aspect is ventilation principle used to exploit the natural driving forces to ventilate a space. This can be done by single-sided ventilation, cross ventilation, or stack ventilation. The third aspect is the characteristic ventilation element used to realise natural ventilation. The most important characteristic elements are wind towers, wind scoops, chimneys, double façades, atria, and embedded ducts.

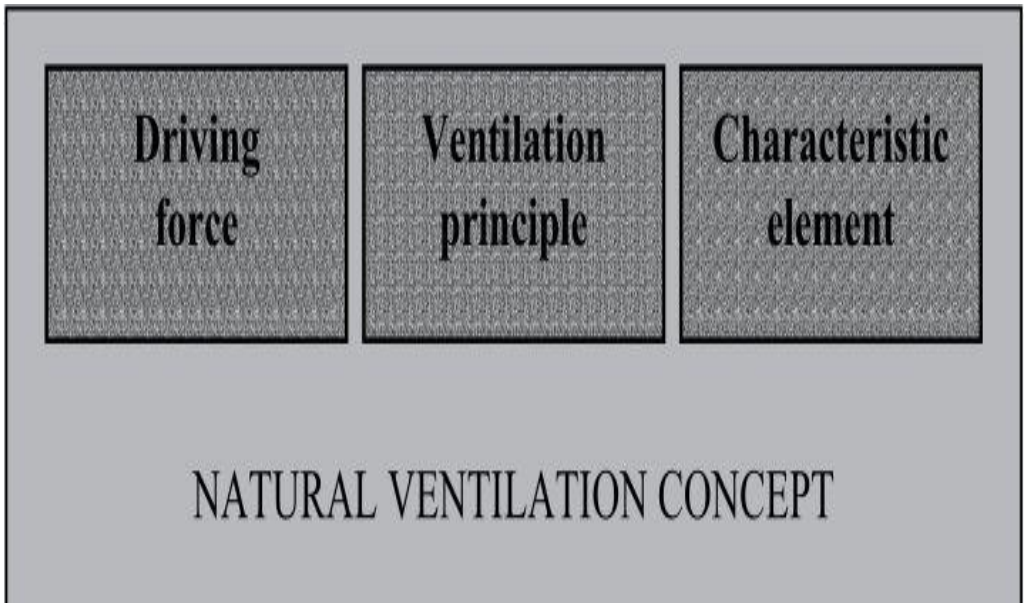


Figure 2.17: The concept of natural ventilation
(Source**:** Klieven, 2003)

C. NATURAL DRIVING FORCE

According to Klieven, (2003), There are only two fundamentally different types of natural driving forces available; thermal buoyancy and wind.

i. Thermal Bouyancy

Thermal buoyancy driven ventilation occurs when there is a density difference between the internal and external air, which again is caused by temperature differences between the inside and outside. Thermal buoyancy is sometimes referred to as the stack effect or the chimney effect.

The difference in density creates pressure differences that pull air in and out of a building through suitably placed openings in the building envelope. When the indoor air temperature exceeds the outdoor temperature, an over-pressure is built up in the upper part of the building and an under-pressure is formed in the lower part. At a certain height, the indoor and outdoor pressure equals each other, and this level is referred to as the neutral plane. An over-pressure above the neutral plane drives air out through openings in the building envelope, and an under-pressure under the neutral plane pulls air in through openings in the building envelope (Klieven, 2003).

ii. Wind

Wind driven ventilation occurs as a result of various pressures created on the building envelope by wind. These pressure differences drive air into the building through openings in the building envelope's windward side, and drive air out of the building through openings in the building envelope's leeward side (Klieven, 2003).

iii. Thermal Bouyancy And Wind In Combination

The two driving forces can occur separately but most likely they occur at the same time. Thermal buoyancy will typically be the dominating driving force on a calm cold day with practically no wind, whereas pressure differentials created by wind will typically be the dominating driving force on a windy hot day. Their forces can oppose or complement each other depending on the placement of the inlet and outlet openings in relation to the wind direction (Klieven, 2003).

D. TYPES OF NATURAL VENTILATION OPENINGS

There are several types of ventilation opening but the common ones are:

i. Single Sided Ventilation

Single sided ventilation relies on opening(s) on only one side of the ventilated enclosure. Fresh air enters the room through the same side as used air is exhausted. A typical example is the rooms of a cellular building with operable windows on one side and closed internal doors on the other side. With a single ventilation opening in the room, the main driving force in summer is wind turbulence. In

cases where ventilation openings are provided at different heights within the façade, the ventilation rate can be enhanced by the buoyancy effect. The contribution from thermal buoyancy depends on the temperature difference between the inside and the outside, the vertical distance between the openings, and the area of the openings. The greater vertical distance between the openings, and the greater temperature difference between the inside and the outside, the stronger is the effect of the buoyancy. Compared with other strategies, lower ventilation rates are generated, and the ventilation air does not penetrate so far into the space (Klieven, 2003).

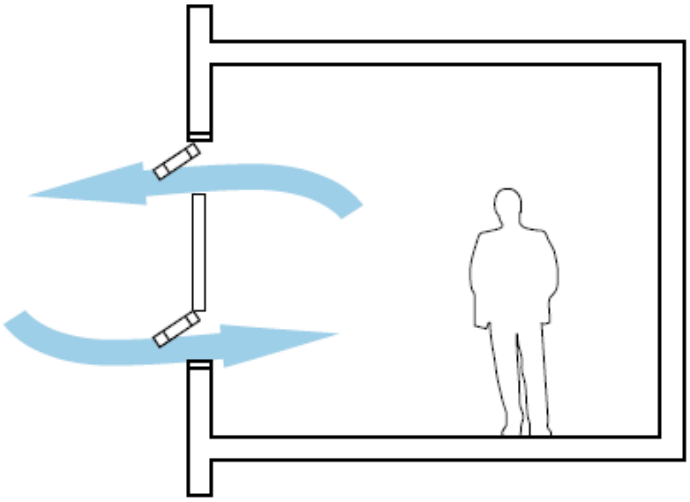


Figure 2.18: Single-Sided Ventilation
(Source: Passive design toolkit, 2008)

ii. Cross Ventilation

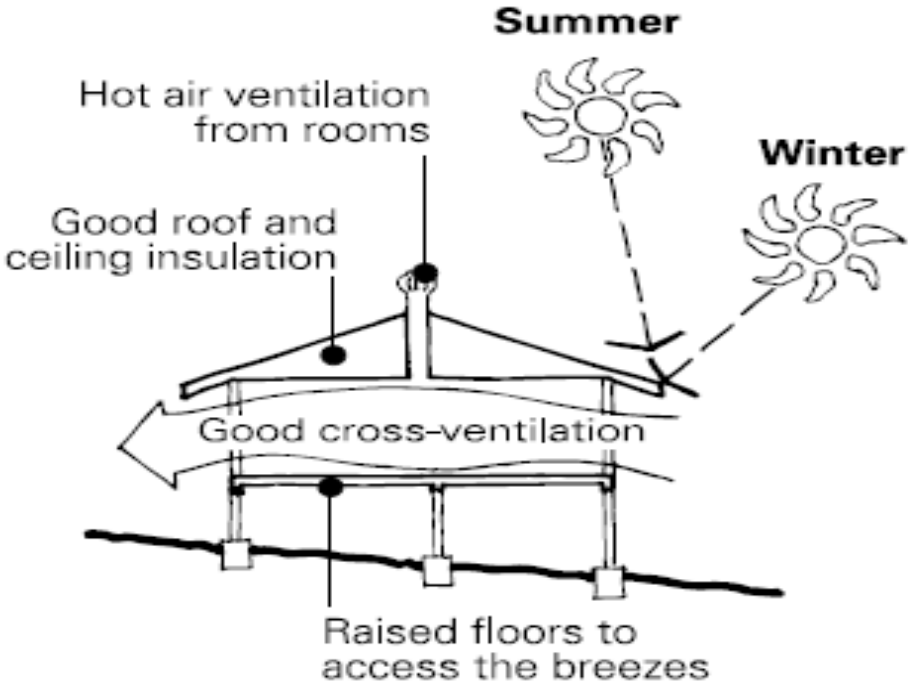
Cross-ventilation is the case when air flows between two sides of a building envelope by means of wind-induced pressure differentials between the two sides. The ventilation air enters and leaves commonly through windows, hatches or grills integrated in the façades. The ventilation air moves from the windward side to the

leeward side. A typical example is an open-plan office landscape where the space stretches across the whole depth of the building. The airflow can also pass through several rooms through open doors or overflow grills. The term cross-ventilation is also referred to when considering a single space where air enters one side of the space and leaves from the opposite side. In this case the ventilation principle on the system level can be either cross- or stack ventilation. As the air moves across an occupied space, it picks up heat and pollutants. Consequently, there is a limit to the depth of a space that can be effectively cross-ventilated (Klieven, 2003).

Cross ventilation establishes a flow of cooler outdoor air through a space; this flow carries heat out of a building. Cross ventilation is a viable and energy-efficient alternative to mechanical cooling under appropriate climate conditions. The design objective may be direct cooling of occupants as a result of increased air speed and lowered air temperature or the cooling of building surfaces to provide indirect comfort cooling. The effectiveness of this cooling strategy is a function of the size of the inlets, outlets, wind speed, and outdoor air temperature. Air speed is critical to direct comfort cooling; airflow rate is critical to structural cooling.

Buildings are typically best naturally ventilated when they are very open to the breezes yet shaded from direct solar radiation. Building materials in a cross ventilated building may be light in weight, unless night ventilation of mass is intended—in which case thermally massive materials are necessary.

Successful cross ventilation requires a building form that maximizes exposure to the prevailing wind direction, provides for adequate inlet area, minimizes internal obstructions (between inlet and outlet), and provides for adequate outlet area. An ideal footprint is an elongated rectangle with no internal divisions. Sitting should avoid external obstructions to wind flow (such as trees, bushes, or other buildings). Cross ventilation for occupant comfort may direct airflow through any part of a space if the outdoor air temperature is low enough to provide for heat removal. At high outdoor air temperatures, cross ventilation may still be a viable comfort strategy if airflow is directed across the occupants (so they experience higher air speeds).



Stack ventilation occurs where the driving forces promote an outflow from the building, thereby drawing fresh air in via ventilation openings at a lower level. Fresh air typically enters through ventilation openings at a low level, while used and contaminated air is exhausted through high-level ventilation openings (a reversed flow

can occur during certain conditions). Designing the outlet to be in a region of wind-induced under-pressure can enhance the effectiveness of stack ventilation. A typical example is a building with an elevated central part, in which warm and contaminated air from the surrounding spaces rises to be exhausted through wind towers located on the roof (Klieven, 2003).

Due to its physical nature, the stack effect requires a certain height between the inlet and the outlet. This can be achieved by e.g. increasing the floor to ceiling height, tilting the profile of the roof, or applying a chimney or an atrium. By its nature, stack ventilation resembles cross-ventilation as far as some individual spaces are concerned, in that air enters one side of the space and leaves from the opposite side1. The air may flow across the whole width of the building and be exhausted via a chimney, or it may flow from the edges to the middle to be exhausted via a central chimney or atrium.

To work well, a stack needs to generate a large temperature difference between exhaust air and incoming air. This can be done in several ways, including increasing stack height. A typical stack will provide effective ventilation for areas within the lower half of its total height.

This implies that stacks be double the height of the building if they are to serve all floors of a building, or that they only serve a portion of the total floor area. Stacks may be integrated or exposed. This is a question of expression: placing a stack on the building perimeter for solar access or integrating it into an atrium are very

different architectural solutions. This decision will hinge not only upon aesthetics, but also upon climate conditions, cooling loads, and zoning and building codes. Exterior finishes and landscaping (plants, misting, and ground covers) can lower the incoming air temperature. Inlet (and outlet) sizing is critical to system performance. Inlet location, quantity, and size can affect building security, building facade appearance, and the quality of the incoming air.

Figure 2.20: Various Stack Ventilation Configurations
(Source: Kate Beckley 2008)

E. TYPES OF VENTILATION METHOD

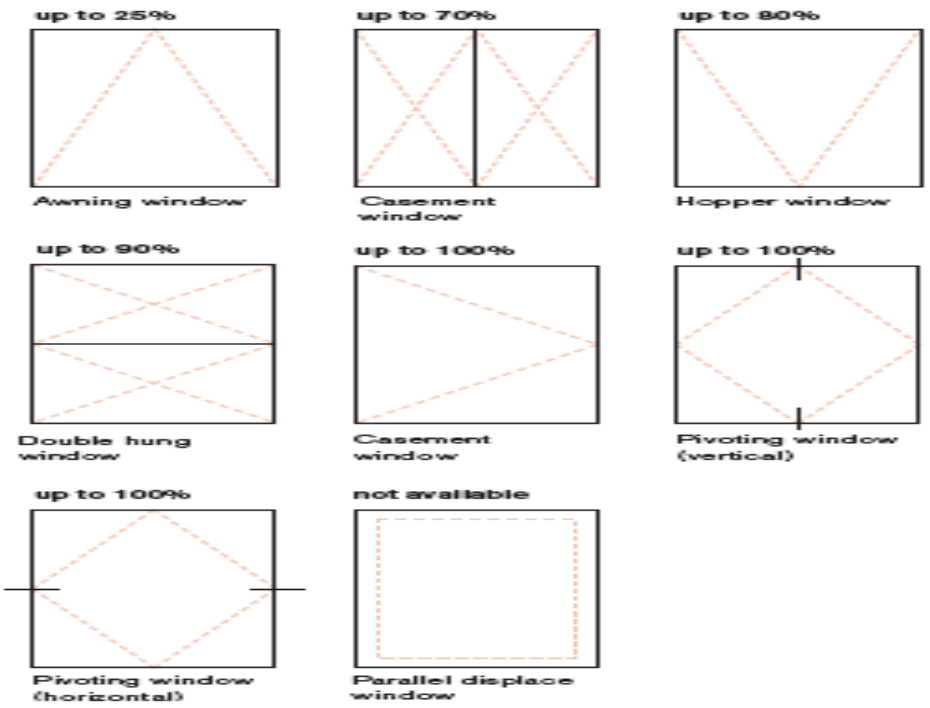
The types of ventilation method may include the following

1. Gap Ventilation

Self or gap ventilation is the exchange of air in a room occurring when windows, exterior doors and roller shutter housings are closed but air penetrates through their joints due to the drop of pressure between the interior and the exterior, caused by temperature differences and wind incidence. Modern windows typically no longer permit gap ventilation since they are well sealed but some models comprise small operable flaps.

2. Window Ventilation

The most common method of natural ventilation is window ventilation whereby different types of hardware and fittings have an impact on the efficiency of the ventilation efficiency is also influenced by the wind pressure exerted on the façade. If ventilation is only provided through one side of the façade, it can be achieved for rooms about 2.5 times deeper than high. Cross ventilation causing 'draught' is more efficient, since sufficient ventilation can be achieved for rooms 5 times as deep as they are high. Today, motorised windows are available that provide automatic ventilation depending on the actual requirement or to facilitate opening windows that are difficult to access.



Shaft ventilation is primarily used to exchange high volumes of air. Fresh air flows into the room through the windows, is then exhausted

through a shaft, usually located in the centre of the building, and exits through the roof. Shaft ventilation is widely used in apartment buildings and, in earlier times, was often used to allow large building depths. Shaft ventilation is also very reliable in winter because the shaft's wind-protected location within the building prevents the exhaust air from cooling rapidly and therefore maintains the ventilation's functionality.

Nowadays, exhaust shafts are often situated within the façade: the shaft-box façade is one example. With this type of façade the exhaust air is heated by solar radiation and therefore rises more quickly.

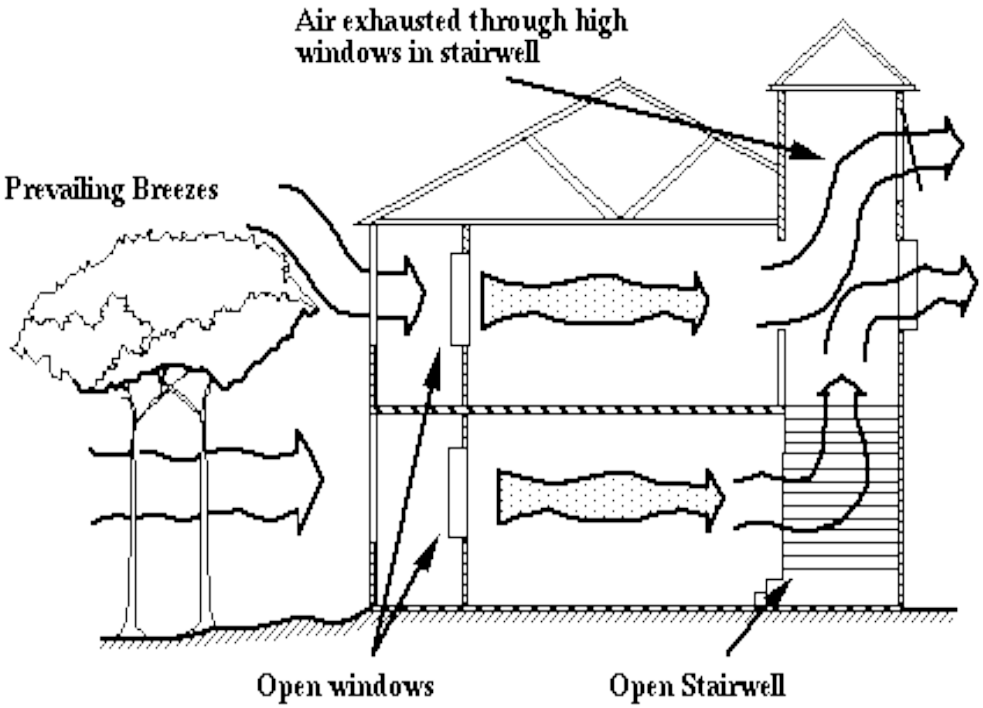


Figure 2.22: Thermal Chimney Effect Built into Home
(Source**:** Klieven, 2003)

F. ARCHITECTURAL IMPLICATIONS OF NATURAL VENTILATION

The architectural implications of natural ventilation are summarized below:

1) Airflow is governed by three guiding principles:

- Air has inertia, i.e., air does not necessarily travel in the shortest path between an inlet and an outlet in an adjacent wall.
- Moving air produces friction in contact with bodies and as a result slows down or forms into eddies.
- Air moves due to pressure differences.

2) Local topographical conditions, landscaping and adjacent buildings can dramatically influence winds at the site. Thus, recorded wind speeds and direction data at a nearby meteorological station may be of little value.

3) A study of the external airflow patterns is necessary to determine the best locations for windows or other apertures. Inlets should be placed in the high pressure regions and outlets in the low pressure regions.

4) Window inlets must be so designed and placed as to provide maximum airspeeds at the desired locations (sitting level in living rooms, just above the bed level in bedrooms).

5) Window types greatly influence the airflow direction in a room. One of the best types of window for natural ventilation purposes seem to be awning or louvered windows which can be manually rotated to direct the

wind to desired locations inside the room. Such windows will also generally provide the maximum aperture area, afford protection from the rain and allow installation of bug screens. Although window types affect the airflow direction, they do not significantly affect the overall ventilation rate.

6) The best location for an inlet is near the vertical and longitudinal centre of a wall which is perpendicular to the wind. This is where the pressure is the highest. If the inlets are too high or are near to the side edge of a wall, overhangs or wing walls should be provided to induce a high pressure zone.

7) The outlet should be exposed to the eddy or wind shadow which is the low pressure zone. The outlet may be placed high, near the ceiling, to take advantage of the stack effect, if any. However, it may be ill advised in locations without a prevailing wind direction, or in some coastal areas where the prevailing wind fluctuates between two opposite directions.

8) In many cases, oblique winds at 45° provide better or equally well ventilation as normal winds. Consider a cross-ventilated room with inlet and outlet windows directly in line with each other. Winds normal to the windows will have a tendency to move through the building without mixing well with the room air. Therefore, regions near the wall will not be well ventilated. Whereas, oblique winds will create a circulating airflow pattern in the entire room providing greater ventilation rates and lower local airspeeds. This has profound design implications in those

humid areas where the prevailing summer breezes are easterly or westerly, the direction most difficult to shade and ventilate at the same time. If the prevailing breeze is easterly, one can orient the inlet wall to face south east or north-west, directions which are easier to shade with long overhangs. Thus simultaneous shading and ventilation are possible.

9) For cross-ventilated rooms, both inlet and exit window sizes need to be increased to increase ventilation rates. However, making the inlet smaller than the outlet creates higher wind speeds near the inlet wall, which may be desirable.

10) The effect of indoor partitions is greatest when they are close to the inlet window. But on the average, the ventilation rate is not greatly reduced.

2.2.9 ADVANTAGES OF PASSIVE COOLING STRATEGIES TO BUILDING

Adoption of passive cooling strategies in design of buildings gives the following advantages:

a) **Economic:** The installation of mechanical equipment means a capital cost and also the recurrent cost of energy consumed and system maintenance.

b) **Ecological/environmental:** Passive buildings impose the least load on the ecosystem, consume less energy and produce less amount of waste such as carbon emission.

c) **Aesthetic:** Passive buildings are more likely to be in sympathy with their environment, and more likely to increase diversity and interest

2.3 CLIMATE

The climate or average weather is primarily a function of the sun. The word "climate" comes from the Greek "klima," which means the slope of the earth in respect to the sun. The Greeks realized that climate is largely a function of sun angles (latitude) and, therefore, they divided the world into the tropic, temperate, and arctic zones.

Through the ages, climate, culture and economy have been the determinants of architecture and building. The art of building and the quality of the architecture of a place have always reflected a people's adaptation to local materials and methods to their economic, social and cultural needs. People have also learned by habit and custom, to provide buildings that will help to modify the external climate, satisfy the functional, religious and social needs, and be affordable to their economic capacity. But, there cannot be a good architecture if it does not respect or relate to the particular climate, or the physical, social or economic environment of the people to whom it relates

Accordingly, the tropical and subtropical regions can be divided into many different climatic zones; however these climatic zones can be generalized into three main climate zones:

A. The hot-arid zone, including the desert or semi desert climate and the hot- dry maritime climate.

B. The hot-humid zone, including the equatorial climate and the warm-humid climate

C. The temperate zone, including the monsoon climate and the tropical upland zone

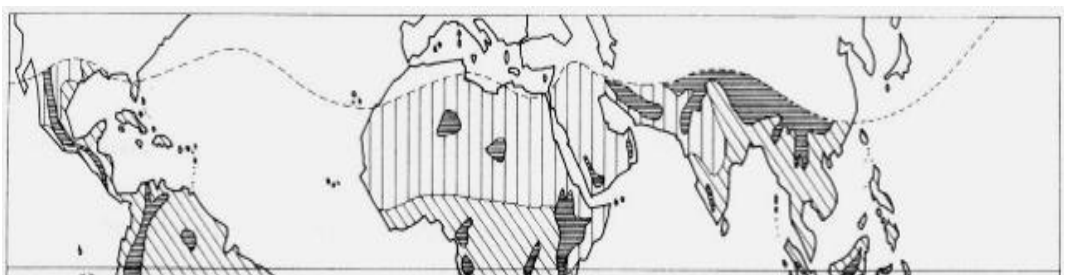


Figure. 2.23: World map showing different Climatic zones
(Source: Design with Climate,1963)

2.3.1 DIFFERENCES BETWEEN CLIMATE AND WEATHER.

Climate is what you expect, and is a statistical composite of weather conditions for some places viewed over long period of time (e.g, usually duration of at least 20 or 30 years). Climate described the atmospheric conditions that have existed over a much longer time (Dean 2004).

Weather is what you get, and collection of atmospheric phenomena that occur over some place for a short period of time (i.g, for a short an interval as a few hours to as long a duration as perhaps a week or more). The phenomena include such action as the movement of air (relative to the ground), the presence of water vapor in clouds or as precipitation, the magnitude of the pressure of the atmosphere over the ground, and the transfer of thermal energy to or away from the ground. (Dean 2004).

2.3.2 MICROCLIMATE

For a number of reasons, the local climate can be quite different from the climate region in which it is found. If buildings are to relate properly to their environment, they must be designed for the microclimate in which they exist. The following factors are mainly responsible for making the microclimate deviate from the macro-climate

a) **Elevation above sea level:** The steeper the slope of the land, the faster the temperature will drop with an increase in elevation. The limit, of course, is a vertical ascent, which will produce a cooling rate of about 3.6°F per 1,000 feet.

b) **Form of land**: South-facing slopes are warmer than north-facing slopes because they receive much more solar radiation

c) **Size, shape, and proximity of bodies of water:** Large bodies of water have a significant moderating effect on temperature, they generate the daily alternating land and sea breezes, and they increase the humidity.

d) **Soil types:** The heat capacity, color, and water content of soil can have a significant effect on the micro-climate. Light-colored sand can reflect large amounts of sunlight, thereby reducing the heating of the soil, and, thus, the air, but at the same time greatly increases the radiation load on people or buildings

e) **Vegetation:** By means of shading and transpiration, plants can significantly reduce air and ground temperatures. They also increase the humidity whether or not it is already too high. In a hot and humid climate.

F. **Manmade structures:** Buildings, streets, and parking lots, because

2.3.3 TYPES AND ATTRIBUTES OF NIGERIAN CLIMATIC ZONES

Climate, that is macro - and micro - climate, is the sum of characteristic meteorological phenomena in the atmosphere. These are modified by topographic conditions of the earth and by the changes which civilization has made to its surface. Micro-climate is found in a more limited space like a room, a street, town or small landscape, while macro-climate is that found in a much larger space such as over a country, a continent or on oceans.

Climatic conditions include weather observations over the longest possible period of time, and must consist not only of temperatures and precipitation values, but also humidity, cloud, wind, air pressure and solar

radiation. The Nigerian macro-climate may be classified into four zones according to Komolafe (1988) namely:

a) Hot - dry,

b) Temperate dry

c) Hot humid and

d) Warm humid.

2.3.4 HOT DRY CLIMATE

This zone is situated in two belts at latitudes between approximately 15° and 30° North and South of the equator. Its main characteristics are the very hot summer season and a cooler winter season, and the great temperature difference between day and night.

CHAPTER THREE

RESEARCH METHODOLOGY

3.0 RESEARCH METHODOLOGY

The research methodology and methods of data collection in conducting this thesis is qualitative analysis of case studies and review of some relevant literature from documented past work of published and unpublished literature.

3.1 SAMPLING TECHNIQUE

Purposive sampling technique is to be adopted in this research work. However, variants of this sampling technique would be applied at different levels of the study. Sample survey of related and relevant universities with senate building will be carried out. Case studies have always been important means to bring a sense of reality to a design process. It is helpful to be able to study example of buildings that are known to perform well and to be see how and why they do so. It is also helpful to be able to see where certain strategies will produce limitations to the design in other ways.

3.1.1 SOURCES OF DATA

A. PRIMARY SOURCES

The primary sources of data to be use in this research are:

1. Architectural drawings and specifications
2. Manufacturer's Catalogues
3. Direct observation
4. Photographs

B. SECONDARY SOURCES

The secondary sources of data to be use in this research are:

1. Books

2. Journals
3. Web documents

3.2 METHOD OF DATA ANALYSIS

Analyses of data during this thesis include the following

3.2.1 ANALYTICAL STRATEGY

This relies on the hypothesis that passive means of cooling will reduce the energy consumption in senate buildings. The point is to develop a descriptive framework for organizing the study.

3.2.2 MODE OF ANALYSIS

The mode of analysis adopted in this thesis is the pattern matching which involves comparison of the expected results with the obtained results to know the extent of the problem in order to come up with the better solution of that particular problem

3.3 INSTRUMENTS OF DATA COLLECTION.

The instruments of data collection are the tools that assist in carrying out the research, for assessment of the variables used in the research. The instruments of data collection applied in this research are listed below:

3.3.1 PHOTOGRAPHS

Photographs of relevant case studies are to be taken to determine the passive cooling techniques and the extent, to which they were applied, that is to say, if their extent of application was strong, weak or non-existent.

3.3.2 SKETCHES

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

3.3.3 NOTES

These notes where in form of field forms outlining the variables of passive cooling techniques as they relates to senate buildings and some other public building types.

3.4 PROCEDURES FOR DATA COLLECTION

These involved visits to two local case studies and taking a visual analysis based on application of passive cooling techniques in then* 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 application of passive cooling techniques are evaluated on the field forms as well.

3.4.1 CASE STUDIES

Case study research in Architecture goes beyond the documentation and description of the physical characteristics of the built environment (Oluigbo, 2010).

In architectural research a case study is the most prepared mode of assessing a particular phenomenon or group of phenomena which enables the research to see the situation of a particular sample of the similar phenomenon thereby assessing and analysing it. The case studies selected for this thesis were sampled purposively.

3.5 CASE STUDY SELECTION CRITERIA

The case studies were purposely selected on two bases which are:

A. For being administrative building. and also

B. for being passive cooling design

3.6 ASSESSMENT OF PASSIVE COOLING TECHNIQUES

The assessment of passive cooling techniques is carried out using the following:

3.6.2 PASSIVE COOLING VARIABLES

The passive cooling variables are those variables responsible for cooling the senate building without much energy consumption. These variables include the following:

A. Windows and vents
B. Courtyards
C. Orientation
D. Roof overhangs
E. Shading devices
F. Materials specification
G. Insulation
H. Roof garden
I. Landscaping

CHAPTER FOUR

CASE STUDIES

4.1 INTRODUCTION

In an attempt to provide a functional and befitting administrative office for Federal University Dutsin-ma (FUD), the study of existing similar, relevant and related facilities around the world, becomes very essential.

The case studies were carried out on three existing Senate buildings in Nigerian Universities which are;

A. Ahmadu Bello University Senate Building.

B. Ummaru Musa Yaradua University Katsina Senate Building.

C. Adamawa State University Senate Building

The following criteria were tag on in the selection of case studies;-

4.1.1 DESIGN APPRAISAL

a) EXTERIOR IMAGE AND ARCHITECTURAL EXPRESSION :

This takes account of the site context and general architectural expression in terms of scale form and concept.

b) PHYSICAL ORGANISATION AND DESIGN :

This includes the zoning of related functional spaces, 3-dimensional massing of offices and other support facilities.

c) INTERIOR IMAGE:

This includes lobbies, lounges, Adjacencies of spaces

and ergonomics

d) INTERACTIVITY:

This includes the provision of social spaces like atria, nodes, stairways, built-in seats designed for formal and structured interaction

e) CLIMATE RESPONSIVENESS/PASSIVE COOLING - VARIABLES:

How well the building envelope and its attendant elements respond to the climatic and micro-climatic conditions in which it is located. The passive cooling variables are those variables responsible for cooling the senate building without much energy consumption. These variables include windows and vents, courtyards, orientation, roof overhangs, shading devices, materials specification, insulation, landscaping.

4.2 CASE STUDY ONE: AHMADU BELLO UNIVERSITY SENATE BUILDING

Ahmadu Bello University Zaria operates two Campuses, Samaru and Kongo. Samara main campus house the Senate building, built in early 1980s and the structure is eight storey floors of integrated podium and tower, and senate chamber located between the podium and tower.

4.2.1 LOCATION

The senate building located at the centre of the University, and accessible straight from the main gate of the University. Located south of Sir Kashim Ibrahim library, east of convocation square.

4.2.2 DESIGN APPRAISAL

a) EXTERIOR IMAGE AND ARCHITECTURAL EXPRESSION:

The external walls have non-structural shading devices. The building is square in form with a central core tower. Its corridors are single banked which enhances ventilation flow. The senate building is the most dominant structure within the campus.

b) PHYSICAL ORGANISATION AND DESIGN:

- The structure is a typical office building. It has a square plan and recesses were use to introduce shade. It is the tallest building in the university signifying its importance.
- The reception lobby is double volume concept with staircase at both side and three (3) numbers lifts for vertical transportations.
- Adequate conveniences have been provided
- Scattered parking spaces provided.

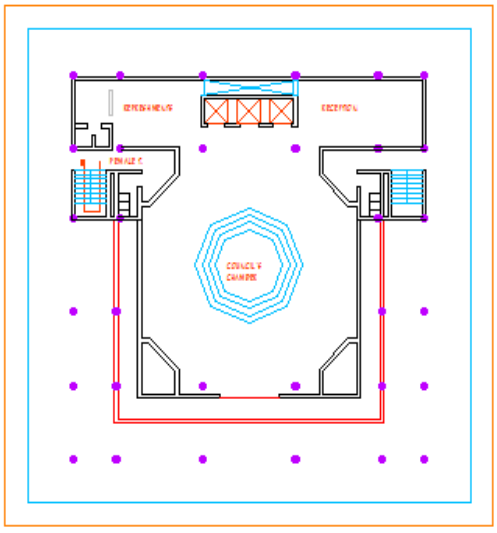


Figure 4.1: ABU Senate building Side View,
(Source: Author's field work, Jan 2013)



GROUND FLOOR PLAN

Figure 4.2a: Sketch of ABU senate building, ground floor plan
(Source: Author's field work, Jan, 2013)



2ND FLOOR PLAN

Figure 4.2a: Sketch of ABU senate building, second floor plans
(Source: Author's field work, Jan, 2013)

c) INTERIOR IMAGE

The senate has two staircases from the ground floor to the mezzanine and two separate ones from the ground floor up to the last floors. It also has three elevators centrally placed in the waiting area for the ease of traffic flow.



Figure 4.3:. View through Courtyard,
(Source: Author's field work Jan, 2013)

d) INTERACTIVITY:

Stairways and elevators which were located at strategic places are to ensure ease in traffic flow and enhance interactivity between spaces.

e) CLIMATE RESPONSIVENESS/PASSIVE COOLING VARIABLES:

- Recesses were used to prevent direct heating up of the external walls by solar radiation allowing the interior to remain cool even at the hot periods of the year. Also fenestrations were deliberately made to be large so as to allow adequate in-flow of air unto the building.

- Square shape was adopted considered as appropriate design approach to overcome solar radiation.
- External vertical and horizontal shading devices were observed on the tower. Also veranda was in cooperated round the entire podium, observed to be adequate.
- Wall-wall windows adopted on the podium and normal windows size on the tower, which are all adequate air floor especially for this region.
- Reinforced concrete roofing style was adopted for this structure, which minimizes effect of roof blown away.
- Orientation of the existing Senate building is adequate, which provide optimum cross ventilation and minimize wind effects.
- Trees were adequately planted around the building which also protect the wind effect especially in the lower floors.
- The problem of noise has been considered by placing public office at the lower floors.
- The building was planned and designed in such a way that it is in conformity with surrounding environment. To further enhance the eco-system, trees and shrubs were planted around the building; this also absorbs the solar radiation thereby reducing the amount of heat generated around and within the building.

TABLE 4.1 ASSESSEMENT OF SOME PASSIVE COOLING VARIABLES

PASSIVE COOLING VARIABLES			
VARIABLES	**FEATURES**	**METHOD OF APPLICATION**	**REMARK**
Windows and vents	Various, sizes of windows based on required amount of air for stack effect ventilation and evaporative cooling.	Providing each category of window to its respective space based on the requirement of the offices as well as the other Spaces	Positive
Courtyards	Open space serving as medium for exchange of generated hot air with the fresh cool air	Void space from 2nd floor to the preceding floors so as to provide exchange of generated hot air with the fresh air	Positive
Orientation	Orienting the buildings on north-south axis	The building is square in nature, so any of the axes is appropriate to be at the north-south direction as well as east-west direction to minimise solar heat gain.	Positive
Roof overhangs	Long roof eave projections to serve as shading device	Projection of roof eaves to shade the incident rays of solar.	Negative
Shading devices	Vertical shading devices on the north-south direction and horizontal and egg-crate shading	Introduction of verandas and recesses helps in shading of	Positive

	devices for east-west direction	excessive solar radiation	
Materials Specification	Building components that reflects heat back to the surrounding sink.	Provided on the exterior part of the building to prevent the heat gain from the solar radiation. They can be inform of cladding or walling material	Positive
Insulation	Void in the roofs, ceiling and wall.	Provided in the roof to insulate the building from the solar heat gam from roof and also in the ceiling and the walls to insulate heat gain to the interior part of the building.	Positive

(Source: Authors field survey, Jan. 2013)

4.3 CASE STUDY TWO: UMMARU MUSA YARADUA UNIVERSITY KATSINA SENATE BUILDING.

Ummaru Musa Yaradua University Katsina (UMYUK) Senate building built in early 2007 and the structure is three (3) storey floors, The University was initiate by late president Ummaru Musa Yaradua during his tenure as governor of Katsina state.



Figure 4.4: Picture showing frontage of UMYU senate building,
(Source: Author's field work, Jan, 2013)

4.3.1 LOCATION

The University is Located in the main campus of Ummaru Musa Yaradua University, accessible directly from the main gate.



Figure 4.5: Picture Showing main access to UMYU Senate building
(Source: Author's field work**,** Jan, 2013)

4.3.2 DESIGN APPRAISAL

a) EXTERIOR IMAGE AND ARCHITECTURAL EXPRESSION:

The senate building is the most dominant structure within the main campus of the university. The external walls have non-structural shading devices. The design adopted a courtyard system and the corridors are single banked which enhances ventilation flow, presence of fountain hi the courtyard provided evaporative cooling so as to make the building cooler.

b) PHYSICAL ORGANISATION AND DESIGN:

- The building is a very massive one. The building houses offices, administrative units and reception hall.
- The structure is a typical office building with spider form concept.
- The reception lobby is spacious enough to accommodate student crowd
- Adequate conveniences have been provided at strategic points
- The parking spaces provide is well defined.

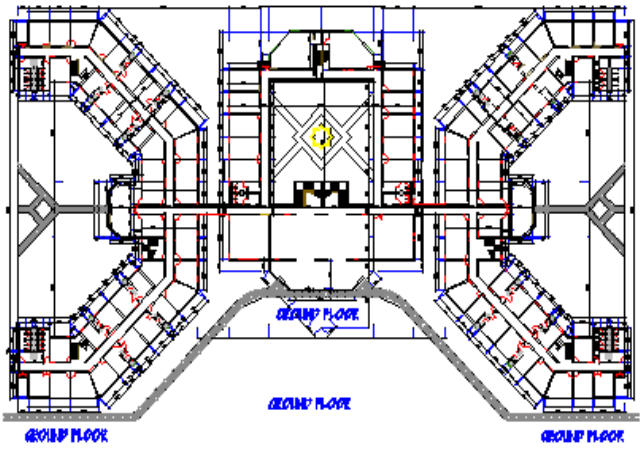


Figure 4.6a: Picture Showing ground floor plan of UMYU Senate building
(Source: Author's field work, Jan, 2013)

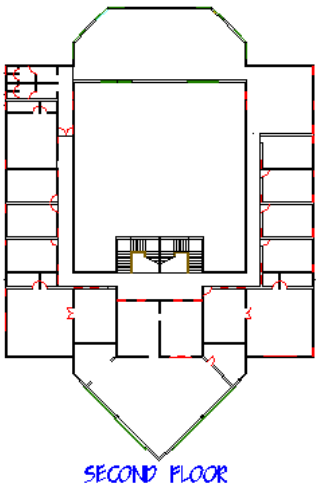


Figure 4.6a: Picture Showing second floor plan of UMYU Senate building
(Source: Author's field work, Jan, 2013)

The building has a total of eight staircases. It also has a courtyard that is located near to the entrance. Offices within the building were zoned according to the functions they perform.



Figure 4.7: Picture Showing reception/Security Point of UMYU senate building
(Source: Author's field work Jan, 2013)

d) INTERACTIVITY:

Due to the lengthy nature of the building, staircases were introduced at strategic intervals to enhance ease of traffic flow between the floors.

e) CLIMATE RESPONSIVENESS/PASSIVE COOLING VARIABLES:

- Building technique and materials that are suitable for the environment were adopted. Reinforced concrete gutters were introduced to effectively eliminate water from the roof also to minimize effect of roof blown away.
- The shape of the building is considered as appropriate design approach to reduce direct penetration of solar radiation.

- Smaller windows were used which are more desirable in hot dry climate in order to minimize the direct penetration of solar radiation into the interior.
- Orientation of the existing Senate building is adequate, which provide optimum cross ventilation and minimize wind effects.
- Trees and shrubs were planted around the building and within the courtyard to absorbs the solar radiation thereby reducing the amount of heat generated around and within the building.



Figu

TABLE 4.2: ASSESSEMENT OF SOME PASSIVE COOLING VARIABLES

PASSIVE COOLING VARIABLES			
VARIABLES	FEATURES	METHOD OF APPLICATION	REMARK
Windows and vents	Various" sizes of windows based on required amount of air for stack effect	Providing each category of window to its	Positive

	ventilation and evaporative cooling.	respective space based on the requirement of the offices as well as the other Spaces	
Courtyards	Open space serving as medium for exchange of generated hot air with the fresh cool air	Provided at the centre of the building serving as medium for	Positive
		generated hot air with the fresh cool air.	
Orientation	Orienting the buildings on north-south axis	Orienting the longer side of the buildings to north-south	Positive
		direction while the shorter side to east-west direction to minimise solar heat gain.	
Roof overhangs	Long roof eave projections to serve as shading device	Projection of roof eaves to shade the incident rays of solar.	Negative
Shading devices	Vertical shading devices on the north-south direction and horizontal	Provision of vertical shading devices on south-north sides and devices for east-	Negative

		west direction.	
	and egg-crate shading devices for east-west direction		
Materials specification	Building components that reflects heat back to the surrounding sink.	Provided on the exterior part of the building to prevent the heat gain from the solar radiation. They can be inform of cladding or walling material Negative	Negative
Insulation	Void in the roofs, ceiling and wall.	Provided hi the roof to insulate the building from the solar heat gain from roof and also in the ceiling and the walls to insulate heat gain to the interior part of the building.	Positive
Roof garden	Planting at the roof of the building to absorb solar radiation rays.	Provided at the top of the roof of the buildings.	Negative
Landscaping	Landscaping elements surrounding the buildings to absorb solar radiation rays	Applied on the surrounding environment of the	Positive

	for their photosynthesis process.	building for solar radiation rays absorbance.	

(Source: Authors field survey, Jan. 2013)

4.4 CASE STUDY 2: ADAMAWA STATE UNIVERSITY SENATE BUILDING.

4.4.1 LOCATION:

Located in the main campus of Adamawa state university, Mubi.. (Northern Adamawa State).



State University senate building
(**Source:** Author's fieldwork, Jan, 2013)



Figure 4.9b: Picture showing rear view of Adamawa State University senate building
(Source: Author's fieldwork, Jan, 2013)

4.4.2 DESIGN APPRAISAL

a) EXTERIOR IMAGE AND ARCHITECTURAL EXPRESSION :

The building is the most dominant and centralized structure within the campus

b) PHYSICAL ORGANISATION AND DESIGN :

The functions performed by the spaces were properly zoned. The building is located in such a way that it serves a central role to other support facilities.

c) INTERIOR IMAGE:

The senate building has three staircases from the ground floor to the top-most floor. It also has an escape staircase that is accessible to the V.C. It has a central courtyard.

d) INTERACTIVITY:

Staircases were used to ensure efficient circulation of traffic flow between floors. Private staircase was introduced to enhance security.

e) CLIMATE RESPONSIVENESS:

A lot of climate responsive design techniques were employed by the designers of this building. The use of central courtyard helps to aid ventilation. The introduction of verandas and recesses helps in shading of excessive solar radiation.

TABLE 4.3: ASSESSEMENT OF SOME PASSIVE COOLING VARIABLES

PASSIVE COOLING VARIABLES

VARIABLES	FEATURES	METHOD OF APPLICATION	REMARK
Windows and vents	Various" sizes of windows based on required amount of air for stack effect	Providing each category of window to its	Positive
	ventilation and evaporative cooling.	respective space based on the requirement of the offices as well as the other spaces	
Courtyards	Open space serving as medium for exchange of generated hot air with the fresh cool air	Provided at the centre of the building serving as medium for	Positive
		generated hot air with the fresh cool air.	
Orientation	Orienting the buildings on north-south axis	Orienting the longer side of the buildings to north-south	Positive
		direction while the shorter side to east-west direction to minimise solar heat gain.	
Roof overhangs	Long roof eave projections to serve as shading device	Projection of roof eaves to shade the incident rays of solar.	Negative

Shading devices	Vertical shading devices on the north-south direction and horizontal	Provision of vertical shading devices on south-north sides and devices for east-west direction.	Negative
	and egg-crate shading devices for east-west direction		
Materials specification	Building components that reflects heat back to the surrounding sink.	Provided on the exterior part of the building to prevent the heat gain from the solar radiation. They can be inform of cladding or walling material Negative	Negative
Insulation	Void in the roofs, ceiling and wall.	Provided hi the roof to insulate the building from the solar heat gain from roof and also in the ceiling and the walls to insulate heat gain to the interior part of the building.	Positive
Roof garden	Planting at the roof of the building to absorb solar radiation rays.	Provided at the top of the roof of the buildings.	Negative
Landscaping	Landscaping elements	Applied on the	Positive

	surrounding the buildings to absorb solar radiation rays for their photosynthesis process.	surrounding environment of the building for solar radiation rays absorbance.	

Source: Authors field survey, Jan. 2013

4.5 SUMMARY OF FINDINGS

Table 4.4: ANALYSIS OF CASE STUDIES.

Classification	Case study one	Case study two	Case study three

Exterior image	4	3	3
Interior image	3	3	3
Interactivity	3	3	3
Organization and design	4	3	3
Climatic Responsiveness	4	3	2

Table 4.5 LEGEND

Case study one	Ahmadu Bello university Zaria
Case study Two	Ummaru Musa Yaradua University, Katsina State.
Case Study Three	Adamawa State University

Table 4.6 RANKING

5	Excellent
4	Very Good
3	Good
2	Averagely Good

CHAPTER FIVE
SITE ANALYSIS

5.0 SITE LOCATION

The site for the proposed senate building is located at permanent site of federal university Dutsin-ma along Dutsin-ma - Kankara road, Katsina State. Dustin-ma local government is one of the hot dry parts of the savannah to the north. is located about 1126 kilometers away from the sea. Katsina (12°58 'N-7°45 'E).

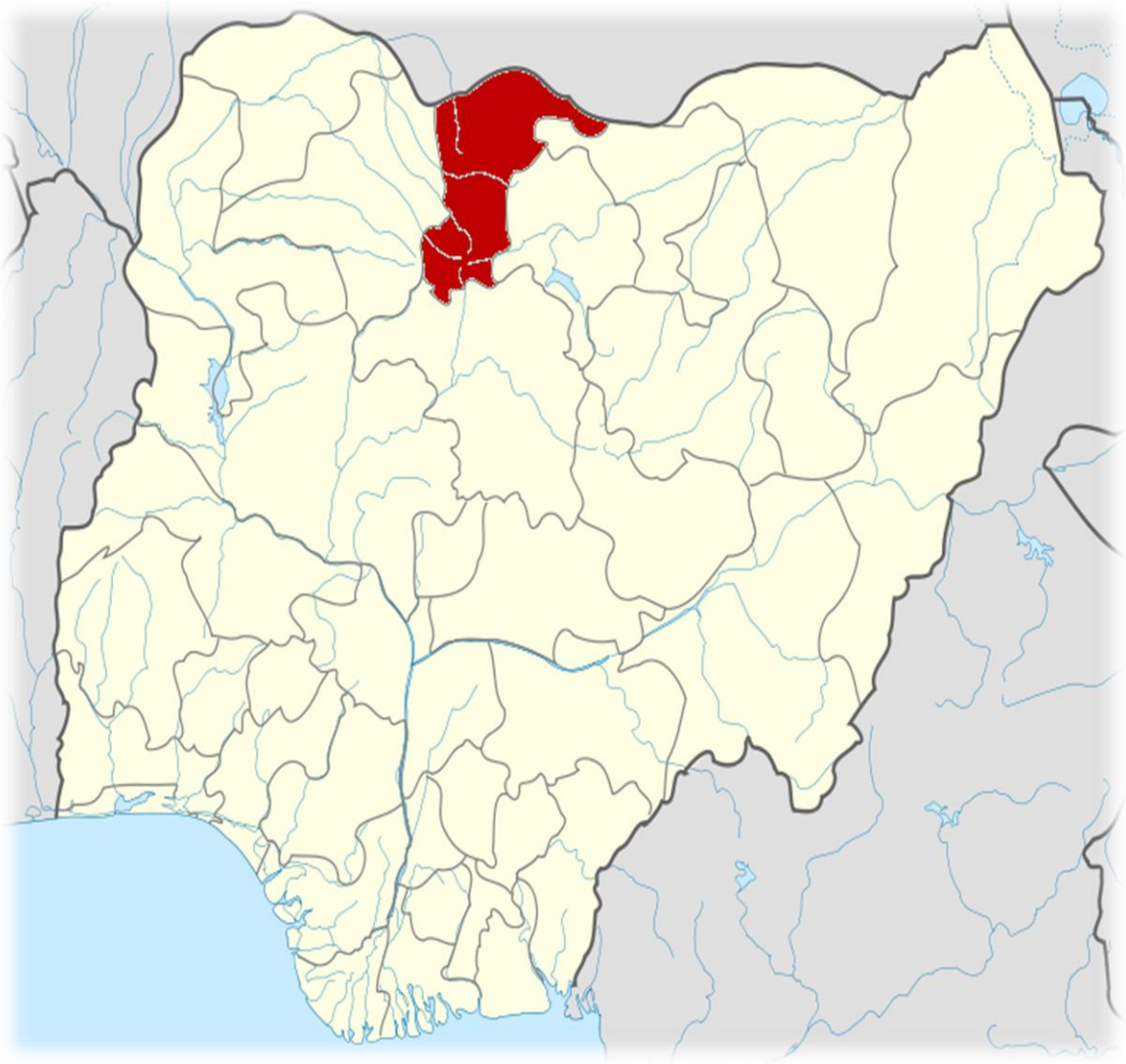
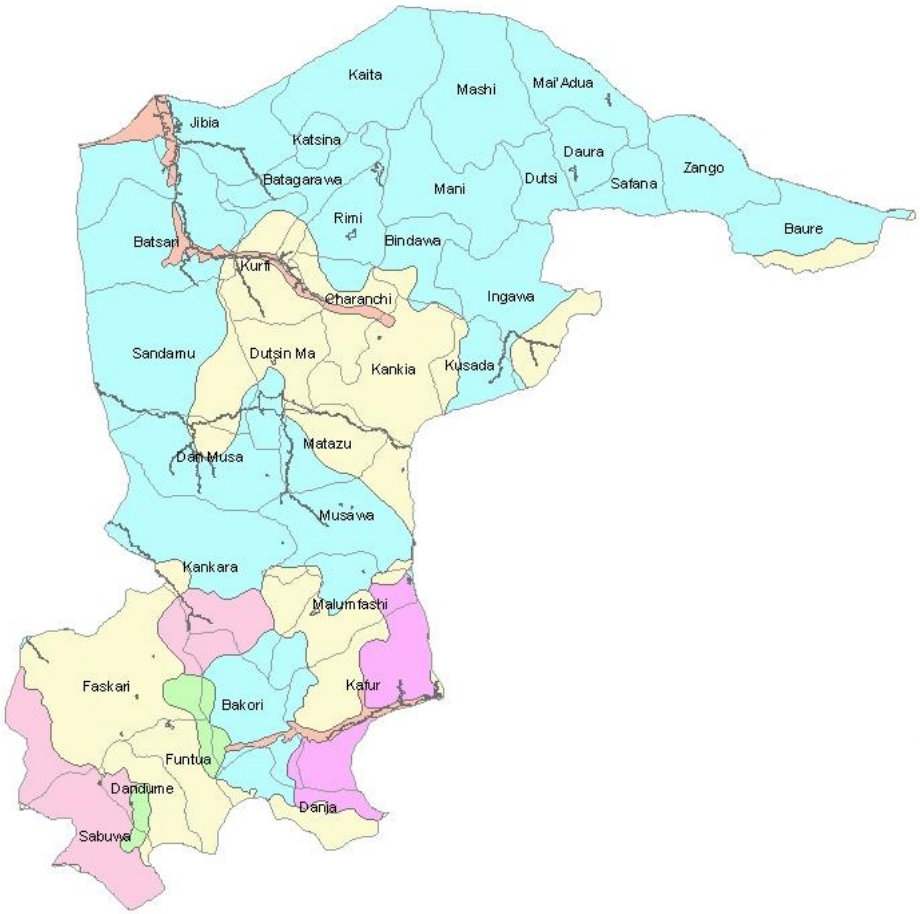


Figure 5. 1: Picture Showing Map of Nigeria,
Source: Wikimedia Commons (2010)



(Source: Wikimedia Commons 2010)

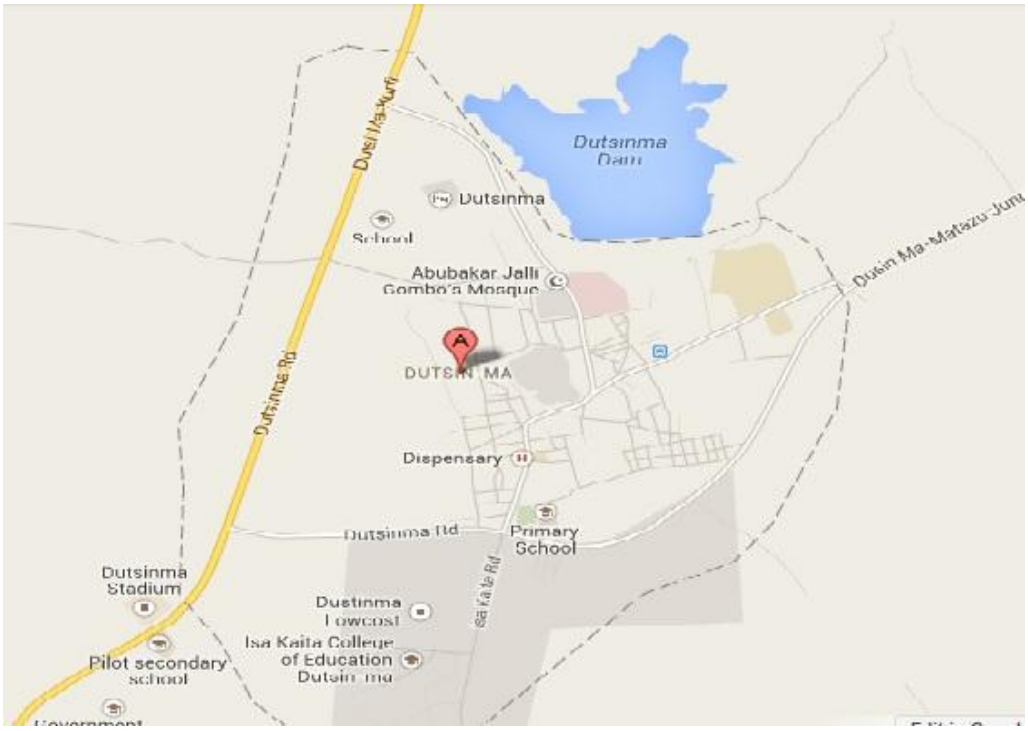


Figure 5.3: Picture Showing Dutsin-ma,
(**Source:** Google map 2014)

5.0.1 TOPOGRAPHY

The area is characterized by a relatively flat gently sloping to the north-western part of the site. Site drainage would take this direction in order to use the concept of natural gravity. While the water supply should come from south-western direction in order to also use the principle of natural gravity.



Figure 5.4: topographical nature of the site
(Source: Author's field work, Jan, 2013)

5.0.2 SOILS

The soils underlying the Dutsin-ma local government of Katsina state are the brown and reddish soils. Their suitability for development land uses varies with depth, texture, run-off potential and drainage. Severe constraints for foundations, streets and underground utilities occur when soils are shallow, strong, locally high in swelling clays or poorly drained.



Figure 5.5: Soil nature of the site
(**Source:** Author's field work, Jan 2013)

5.0.3 VEGETATION

The area is easily identified by the broad band of mainly Neem trees that encircle the town immediately outside the mud-built walls, the natural vegetation consists of the Sudan and the guinea savannah both having been replaced by secondary vegetation.



Figure 5.6: The vegetation of the site
(**Source:** Author's field work. Jan 2013)

5.0.4 GEOLOGY

Dutsin-ma is underlain by sedimentary rocks of cretaceous age, comprising the Gundumi formation. Lithologically they consist chiefly of coarse, purple and mottled, feldspathic grits. Impersistant intercalations of blueish and purplish clay are occasionally present in the grits, while lands or horizons of quartz pepples are common at certain levels.

5.1 CLIMATic condition

Dutsin-ma Katsina possesses a tropical continental climate with distinct wet and dry season. This is generally classified as semi-arid.

Generally the weather is cool in the morning, hot in the afternoon, cool again in the evening. Between November and January the Harmattan lowers the temperature. The wind is dry in January to April.

5.1.1 TEMPERATURE

Temperature is generally high throughout the year. The average maximum daily temperature reached is 29.4°C. The average minimum daily temperature reached is 12.5' C. The temperature varies from season to season, but the total average hours receiving sunshine in a day is 8.3 hours.

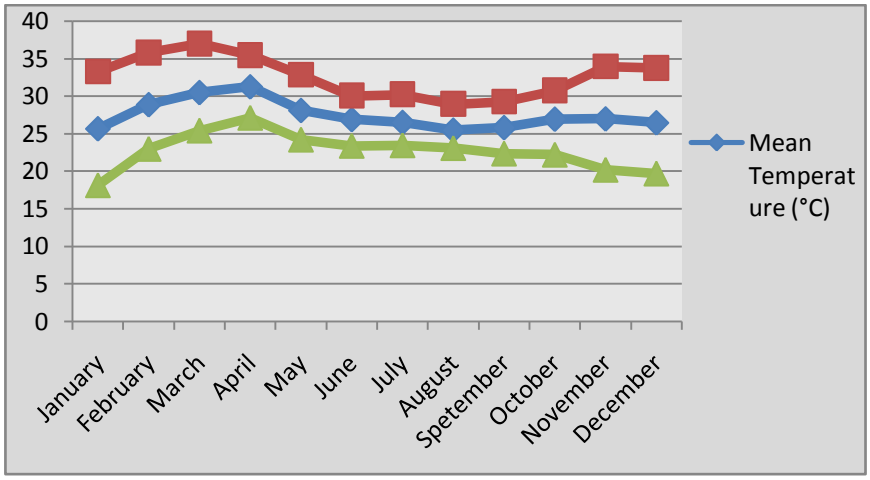


Plate 5.1: Temperature
(**Source**: http//www.gaisma.com, Oct.26th, 2010)

5.1.2 RAINFALL

The rains usually start in June or July during these rainy months the south-westerly winds are dominant winds and are heavy with moisture. They produce zones of intense convectional rainfall. The month of August has the highest amount of rainfall each year.

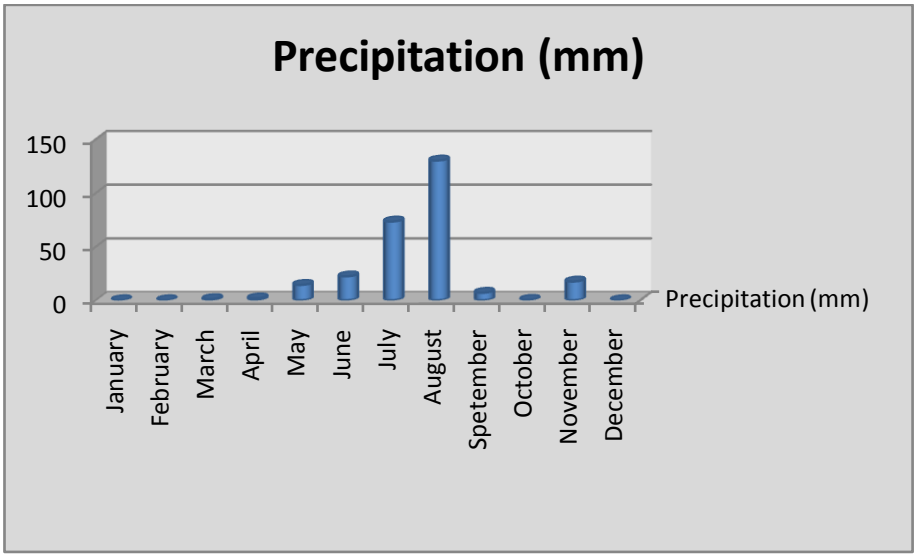


Plate. 5.2: Precipitation
(Source: http//www.gaisma.com, Oct. 26th, 2010)

5.1.3 EVAPORATION

The rate of evaporation usually increases during the dry season. During the rainy, season the rate of evaporation decreases due to increase in the atmospheric pressure. The daily vapour evaporation is 13.4mL

5.1.4 WIND

In Katsina the wind direction follows the two reasons; the wet and dry seasons. The type of air masses prevailing in Katsina are the dust laden harmattan from the north east winds (November to March) and the moisture laden south-west trade winds from the Atlantic Ocean. The wind run in Katsina is 197.81 km/s.

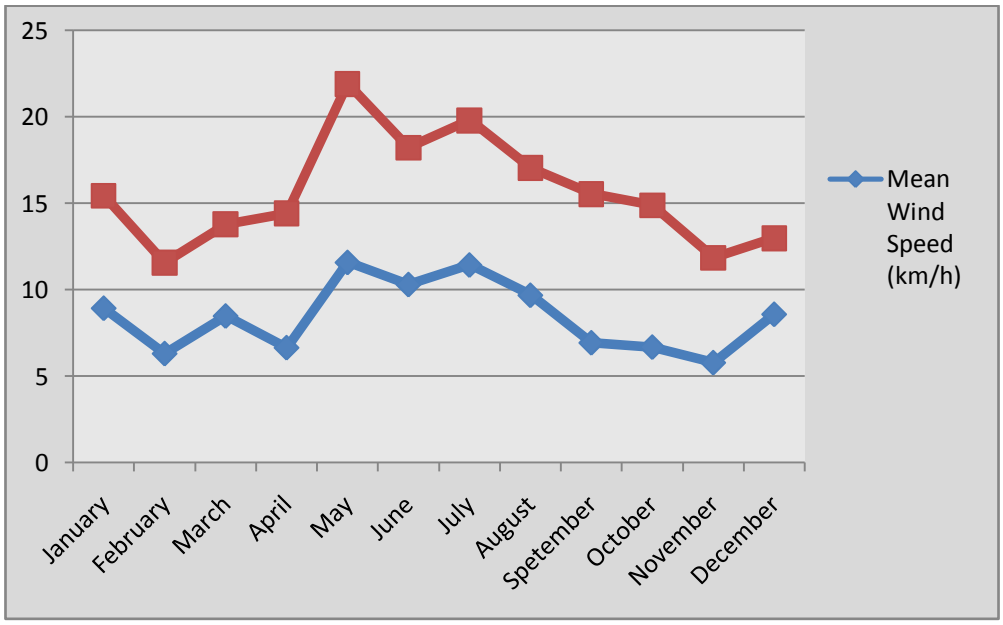


Plate 5.3 Wind speed
(Source: http//www.gaisma.com, Oct.26th, 2010)

5.1.5 RELATIVE HUMIDITY

The relative humidity is always very low. The average humidity is 22 %.

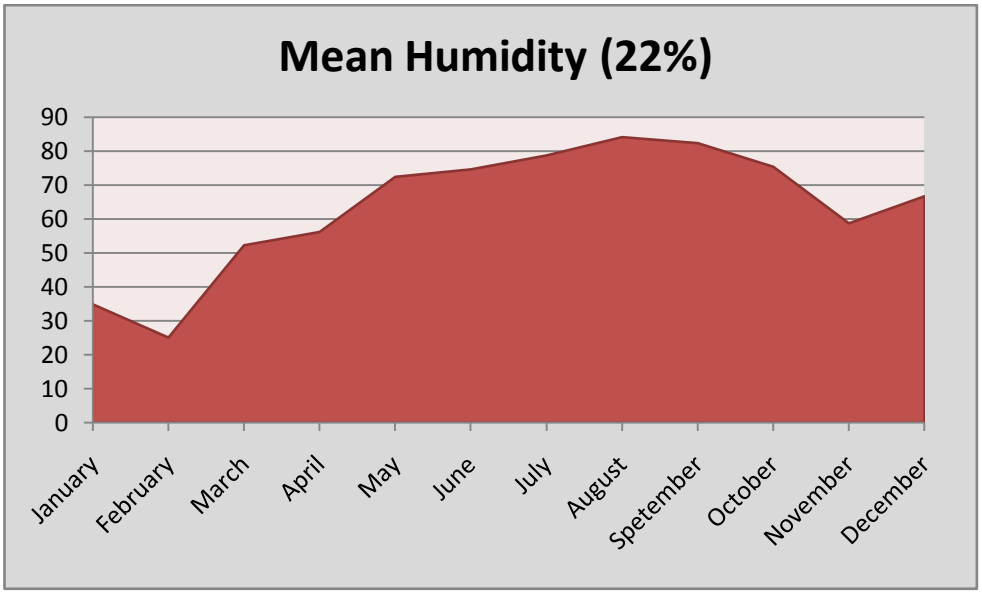


Plate 5.4: Mean Humidity
(Source: http//www.gaisma.com, Oct. 26th, 2010)

5.2 SITE ANALYSIS

A. AIR MOVEMENT:

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

ii) South West Trade Winds: Blowing north east across the site with rain and humid air from the Atlantic Ocean. Wind pressure to be created through small external openings and large internal openings.

B. ORIENTATION OF BUILDINGS:

Longer side of the building should face north-east direction to reduce hot discomfort.

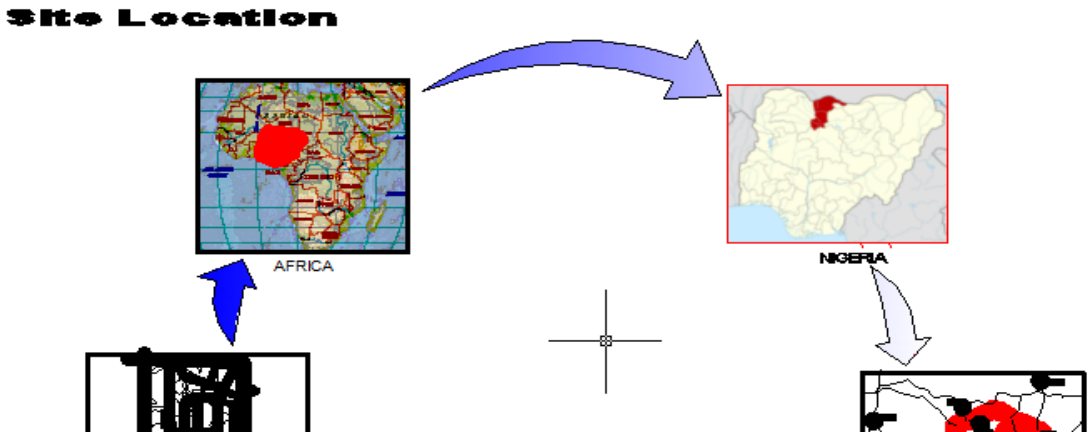


Figure 5.7: Site Location
(**Source:** Author's Design)

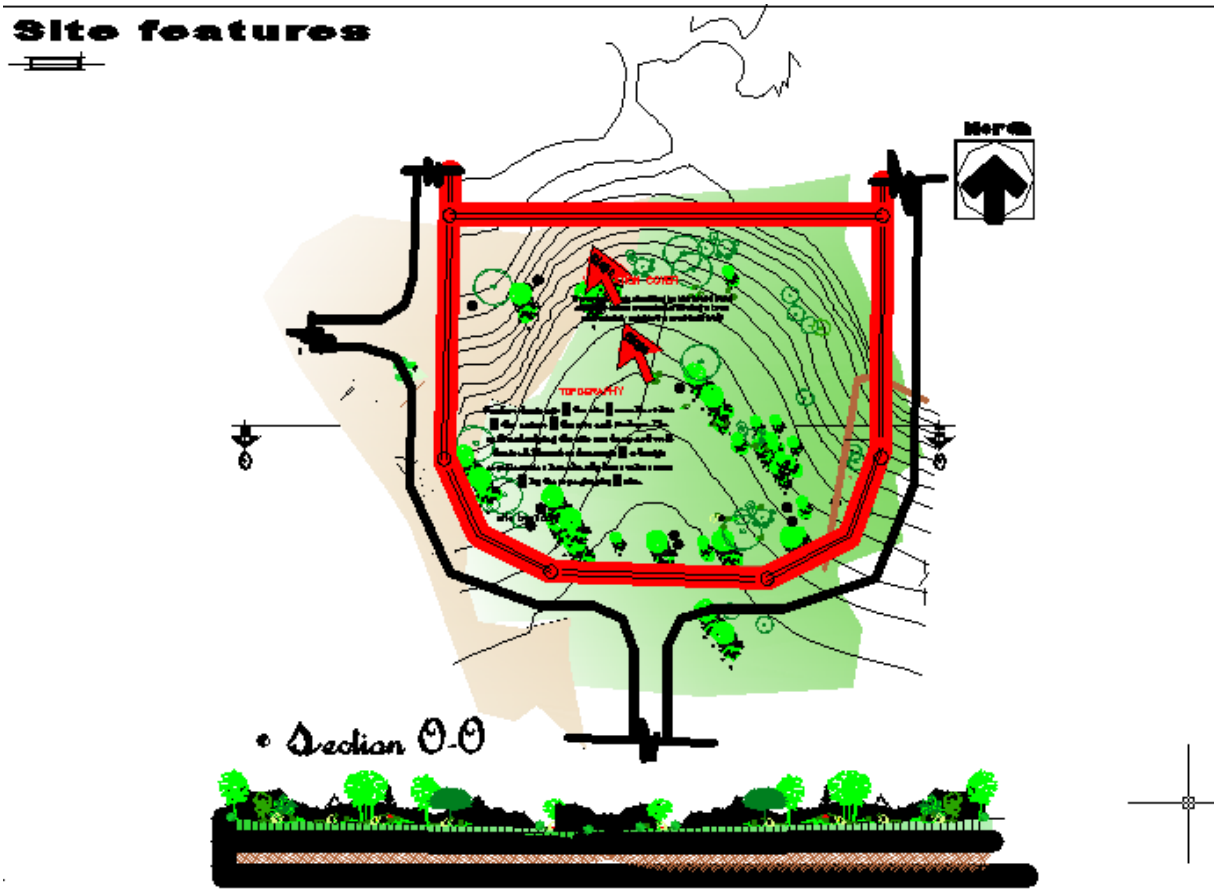


Figure 5.8: Site Analysis showing Site vegetation
(**Source**: Author's Design)

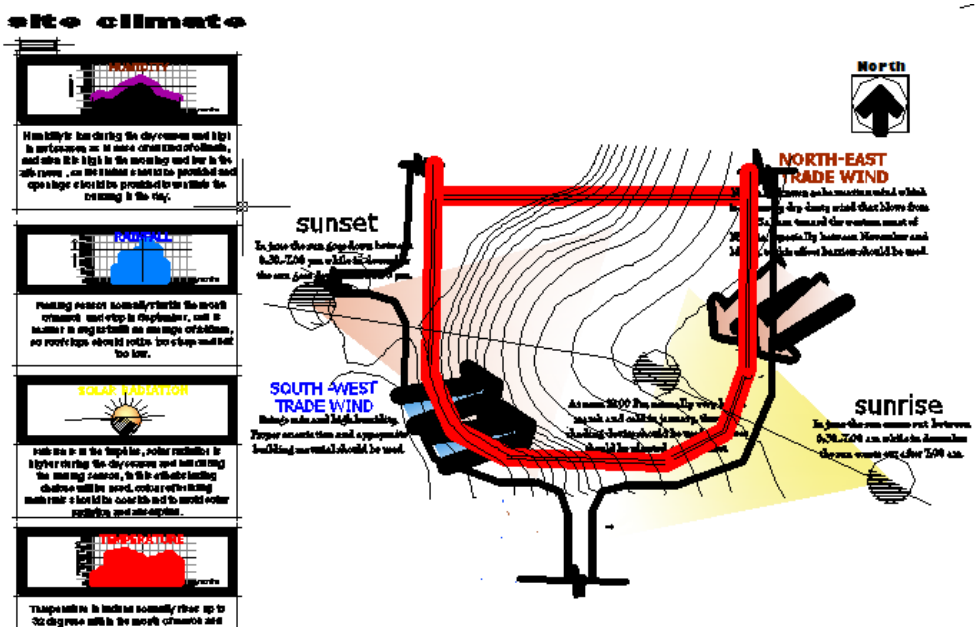
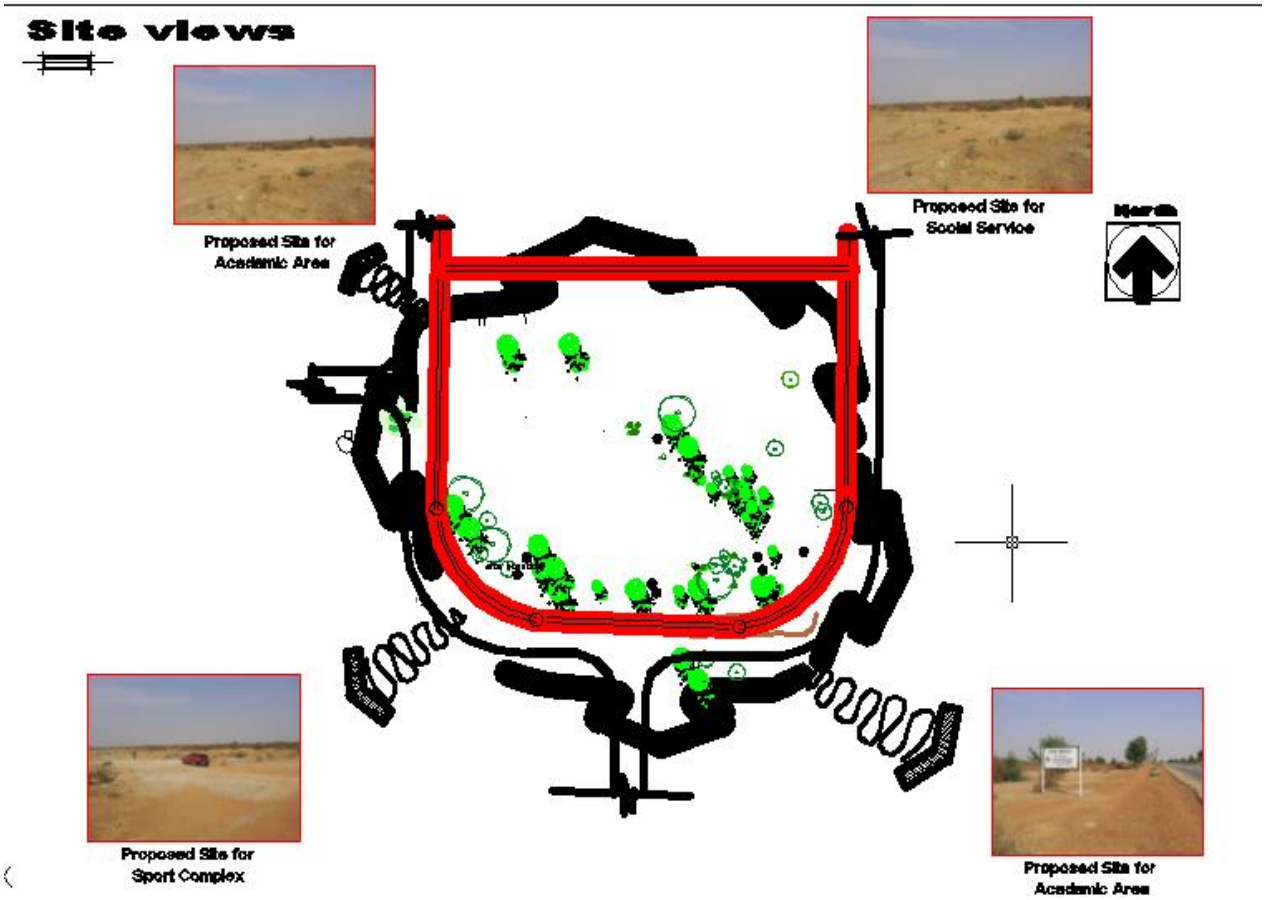


Figure 5.9: Site Climatic Data analysis
(**Source:** Author's Design)



CHAPTER SIX

DESIGN REPORT

6.1 DESIGN BRIEF

The main administrative building shall be the focal point of campus and should be centre of attraction and the most dominant structure. The admin building shall extend up to sixth floors consist of podium and tower. The brief for the senate building evolved from a number of factors, the master plan for the Campus, the site, and the microclimate, culture and life style. The research called for a number of issues to be addressed in the design approach. These issues utilizing low maintenance materials and passive design principles for lighting and cooling.

6.2 PLANNING CONCEPT

In the planning concept of Federal University Dutsin-ma , the four constituents of a university were duly considered and which are The central administration (Senate Building), academic core (teaching/research areas), accommodations for both staff and students, and the recreational areas.

To enhance the accessibility to basic amenities, circulation, services, functional relationships and expected interaction among the users of the facilities, the senate building is to be located in such a way that it plays a central role to other facilities.

Below is the summary of the functional requirements:

A.

B. VICE CHANCELLOR'S OFFICE:

- Vice chancellor's office with support facilities including waiting room, office for secretary, personal assistant, typing/computer room.
- Boardroom for board of trustees meeting which should be an extension of the Vice chancellor's office with provision for tea room and toilet.
- Office for the university chancellor, secretary, waiting-room, typing/computer room.
- Senate chambers as an extension of the chancellor's office to accommodate at least eighty senate members, with provisions for lounge/tea room and toilet.

C. ADMINISTRATIVE UNIT

- Office of the vice-chancellor Administration.
- Secretary to the vice chancellor Admin., waiting room and computer/typing room.
- A committee room with conference facilities as an extension of the vice-chancellor Administration's office.
- Office of the registrar, secretary and waiting.
- Two executive offices for directors and head of units.
- Data room for storage of maps, drawings, etc.
- Other offices for junior and senior administrative staffs.

D. BURSARY

- Office of the bursar. secretary and waiting.
- Secretary to the vice bursar, waiting room and computer/typing room.
- A committee room with conference facilities as an extension of the bursar's office.
- Two executive offices for directors and head of units.
- Adequate storage space.
- Two offices for accounts department including cashier's cage with sufficient waiting space.
- Four offices for Audit department.

TABLE 6.1 SCHEDULE OF ACCOMODATION

A. OFFICE THE VICE CHANCELLOR

S/No	FUNCTIONAL SPACE	NO. REQ.	(A) m^2
1	**Vice Chancellor's office**	**1**	**56**
2	**Secretary to the Vice Chancellor**	**1**	**18**
3	**P/Asst. to the Vice Chancellor**	**1**	**28**
4	**Senate Chamber**		**120**

B ADMINISTRATIVE UNIT:

S/No	FUNCTIONAL SPACE	NO. REQ.	(A) m^2
1	**Vice- Chancellor's Admin Office**	**1**	**42**
2	**Secretary to the Vice Chancellor's Admin**	**1**	**18**

3	Meeting room	1	24
4	Registrar's office	1	36
5	Secretary to the registrar	1	12
6	Director's office	2	24
7	Office of the head of units	2	24
8	Data room	1	24
9	Offices for junior administrative staffs		16
10	Offices for senior administrative staffs		24

C BURSARY UNIT

S/No.	FUNCTIONAL SPACE	NO. REQ.	(A) m^2
1	Office of Bursar	1	36
2	Secretary to the Bursar	1	16
3	Meeting room	1	42
4	Deputy Bursar office	1	36
5	Secretary to the Deputy Bursar	1	16
6	Director's office	2	24
7	Office of the head of units	2	24
8	Store room	1	18
9	Office for accounts department	2	24

D ACADEMIC UNIT

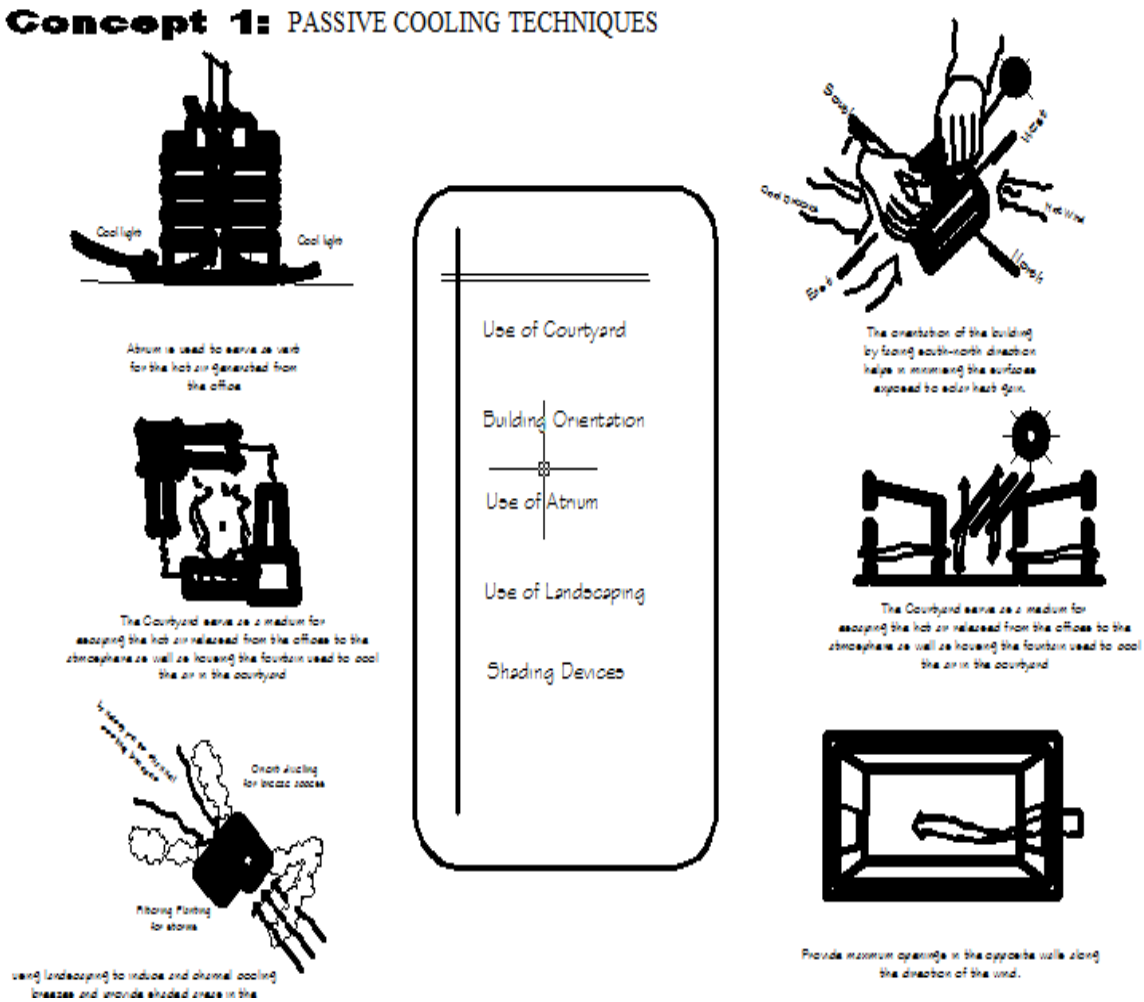
S/No.	FUNCTIONAL SPACE	NO. REQ.	(A) m^2
1	Office of the DVC academic	1	36
2	Secretary to the vice-president academic	1	12
3	Committee room	1	24
4	Office of the Director academic planning	1	24
5	Secretary to the Director	1	10

	academic planning		
6	Office Director research and statistics	1	24
7	Secretary to the director research and statistics		10
8	Offices for heads of unit	2	24
9	Offices for junior staffs	8	16
10	Offices for senior staffs	8	24

Table 6.1.: Schedule of accommodation
(**Source:** Author's field work)

6.3 CONCEPT DEVELOPMENT

The design concept in this project is purely functional, the concept was derived from proper use of passive cooling techniques in the design and also from selecting appropriate footprint suitable for passive cooling approach.



Various shapes were analyzed based on the climatic responsiveness and site condition.

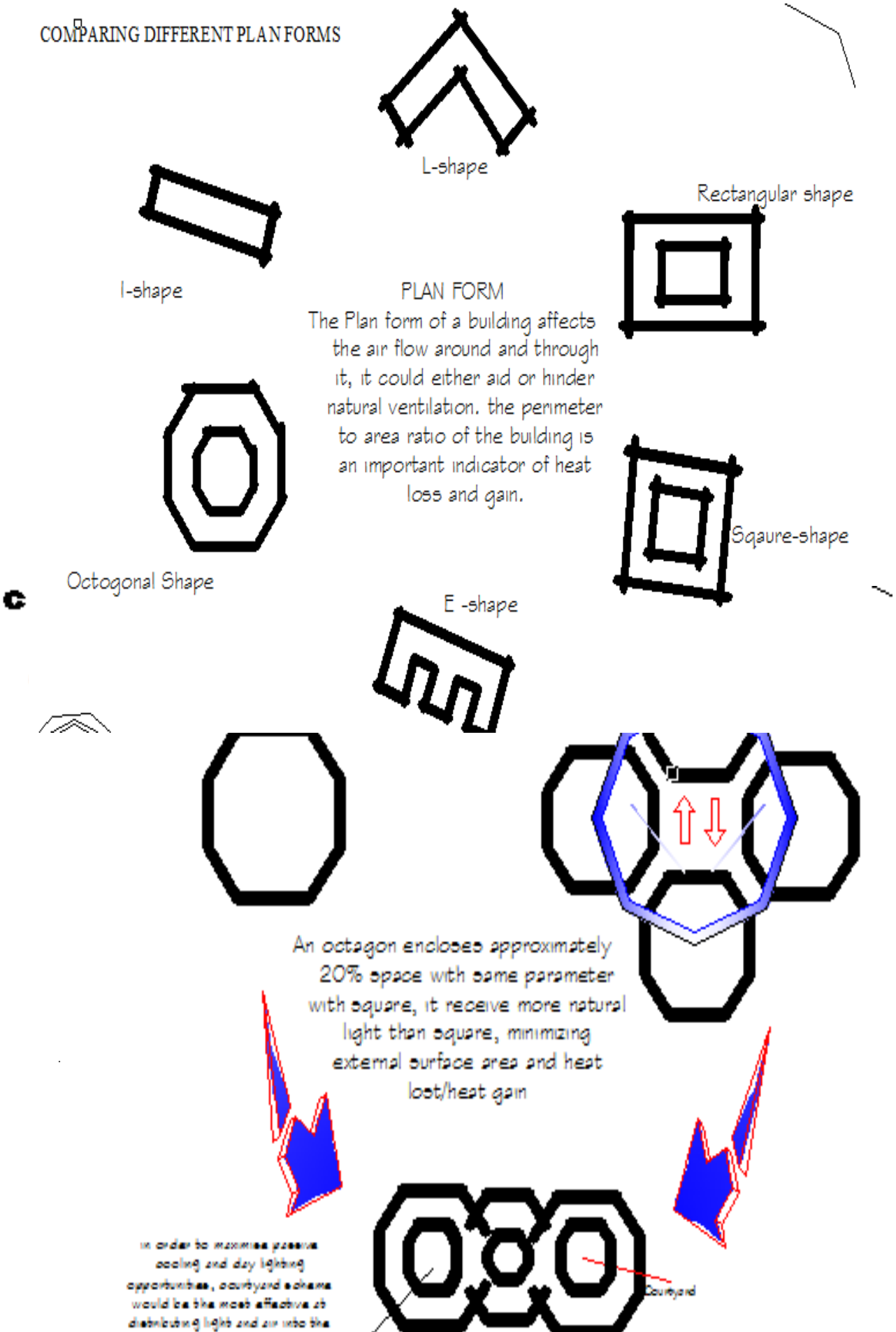


Figure 6.3.: Design Concept 3: Plan from
(**Source:** Author's Design)

in order to maximize passive cooling and day lighting opportunities, courtyard scheme would be the most effective at distributing light and air into the building

6.5 GENERAL SITE PLANNING

The whole facility is design to rotate around a central core. This makes accessibility easy and quick. The longer side of the buildings is in the east west axis to limit exposure to solar. The parking lots are arranged on two wings as you approach the building from the main entrance. This arrangement reduces excessive traffic around the buildings, there are two different vehicular routes to the site apart from the main entrance, one for key staff officers leading to the V.I.P parking at the back of the building and the other for services. there are pedestrian walkways linking to the site from other facilities around.

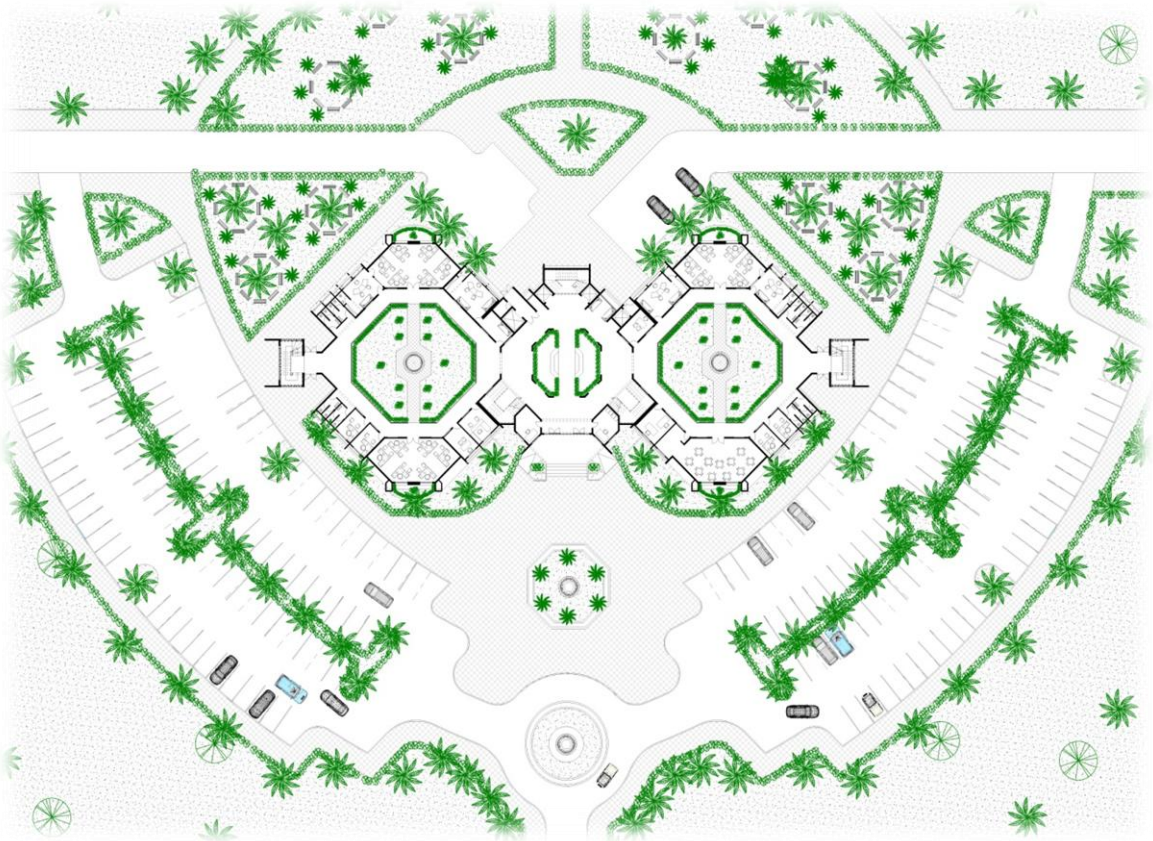


Figure 6.4.: Site plan of Proposed Senate Building
(**Source:** Author's Design)

6.6 MAIN BUILDING DESIGN

The senate building is design to house six (6) floors with a courtyard so as to achieve efficient cross ventilation and adequate day lighting looking at the fact that the building is made in a single banking system. Apart from the fact that the courtyard made easy adequate day light and cross ventilation it also contain well design green area as well as a fountain to provide evaporative cooling

At the ground floor, the facilities are zone according to the activities taken place. From the reception hall, it leads to offices by going either right or left, the offices at this floor are mainly for junior officers as well as student affairs unit in other to minimize students crowd in the building. On the upper floors which is the first and second floors, for both the two wings, there are offices for academic records as well as M.I.S unit, so also to cater with student activities at this lower floors. As the design is consist of podium and tower where the podium terminates at the third floor in which only the senate chamber is located at this floor. while the senior staff offices are on the fourth and fifth floor, and the V.C, the chancellor are on the sixth floor.

6.7 DESIGN CONSIDERATIONS

A) ASSESSEMENT OF THE PASSIVE COOLING VARIABLES IN THE SENATE BUILDING DESIGN

When applying the principles of passive cooling the following variables has to be incorporated in the design. And these are:

1. Windows and vents
2. Atriums

3. Courtyards
4. Orientation
5. Shading devices
6. Insulation
7. Roof garden

B) WINDOWS AND VENTS

When designing bearing in mind cooling the building passively the provision of windows as an inlet of cool air and vent as the outlet of the warm air thereby maintaining the office cool through principle of stack effect.

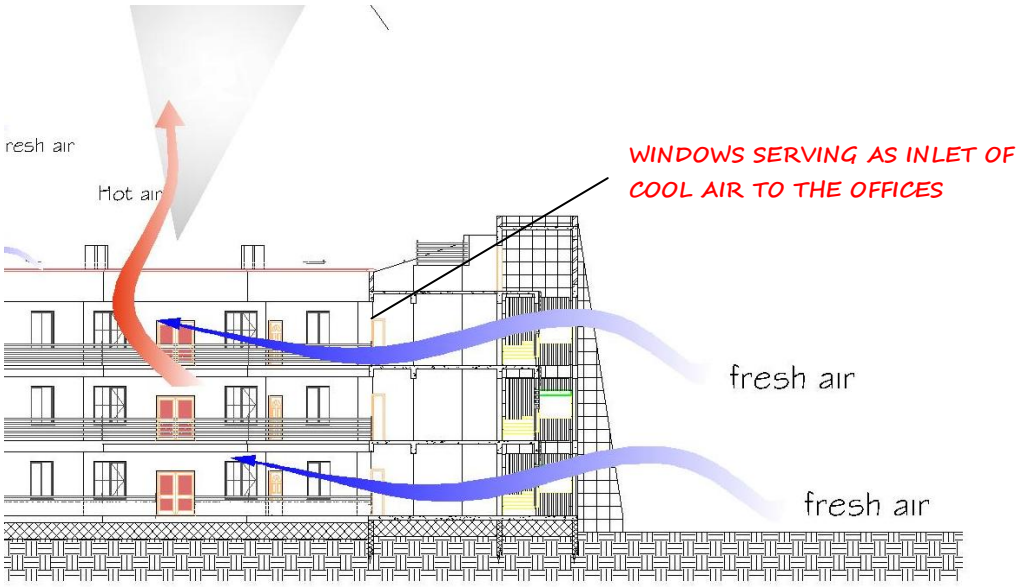
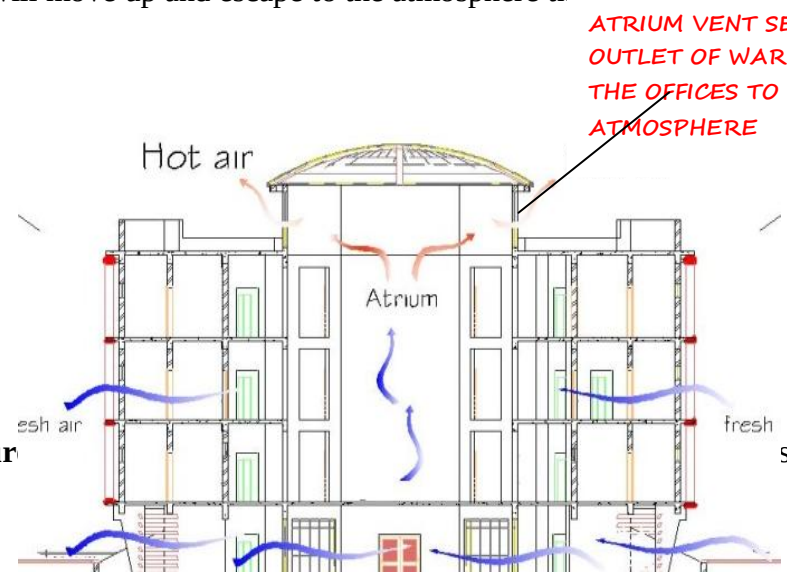


Figure 6.5.: Segment of the section of Proposed Senate Building showing airflow through the windows.
(**Source:** Author's Design)

C) ATRIUM

The atrium is provided to serve as the collector of the warm air from the offices 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 in the atrium



Figur showing

E) COURTYARD SYSTEM

The courtyard system is serving as medium for bringing in fresh air to the rooms and releasing the warm air to the atmosphere. It serve as a medium to locate the fountain to serve as cooling system when the fountain is releasing water.

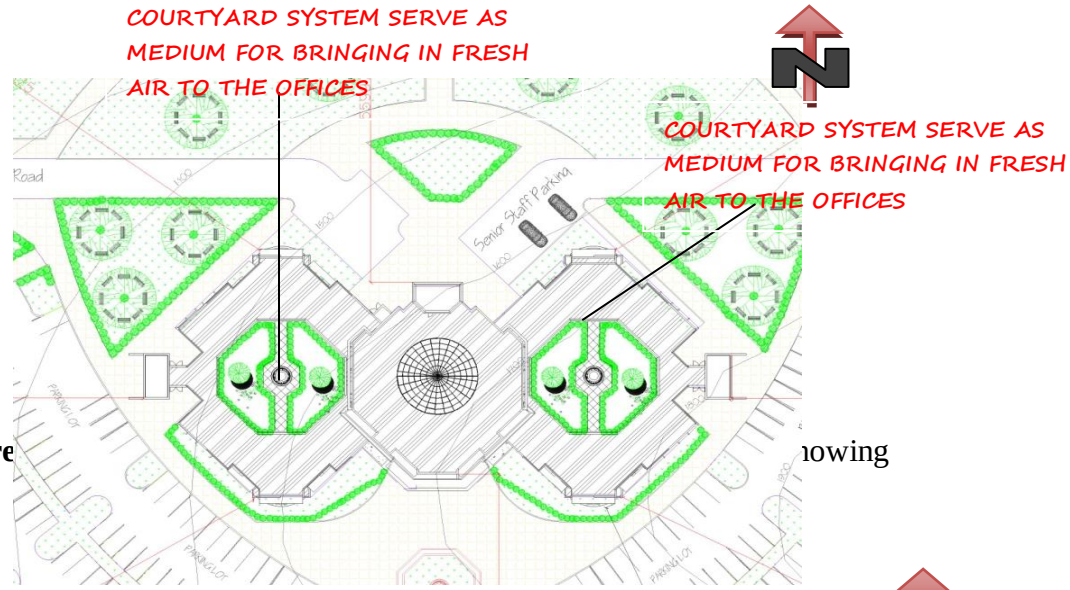
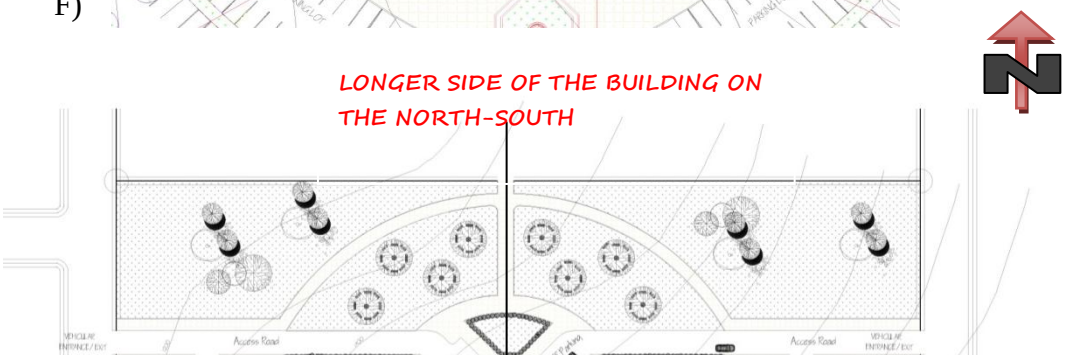


Figure howing

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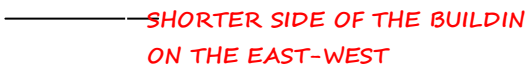


Figure 6.8.: Floor Plan on Site of Proposed Senate Building showing the Orientation
(**Source:** Author's Design)

The orientation of the building is another variable considered when designing with passive cooling 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. The proposed senate building has its longer sides on north-south direction while the shorter sides on east-west direction.

G) SHADING DEVICES

The shading devices are used in passive cooling design to shade the building from solar radiation heat gain through the openings. There are two types of shading devices which include vertical and horizontal (combination of the two). In the cause of this design, horizontal shading device is used on the longer sides to shade the sides from the solar radiation intensity. While the combination of the two shading devices is used on the shorter sides to create

barrier and also to shade the courtyard from direct solar radiation intensity which leads to solar heat gain.

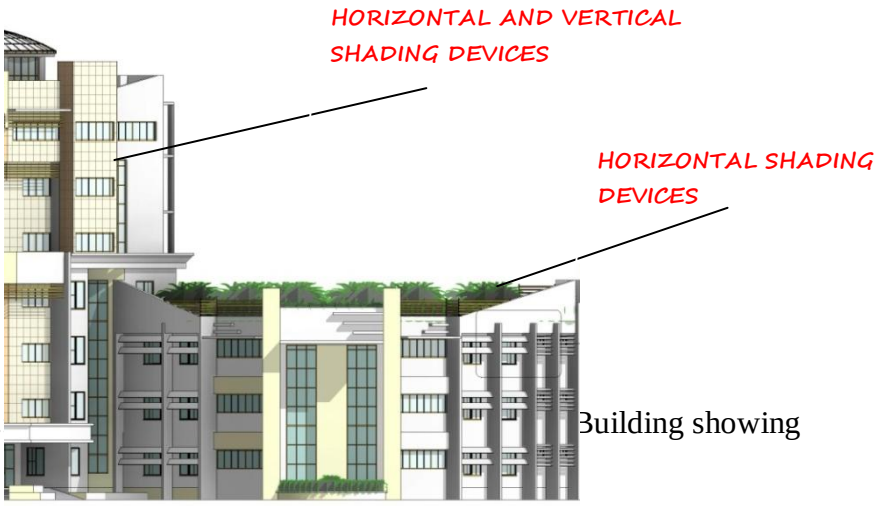


Figure 6.9. Building showing

H) INSULATION

When designing with passive cooling principles, the solar heat gain has to be discouraged through the insulation of the building. Insulation of the building from solar heat gain to keep the interior cool. In this design ventilated exterior wall is used on the external walls. This wall has a vacuum with a layer of heat resistant material to contain the radiant heat from the solar intensity; the hot air in the vacuum will be dissipated back to the exterior thereby keeping the interior cool. In every floor there is a ceiling void provided to serve as an insulation of solar radiation from the roof. Landscaping is also incorporated to absorb the incident rays of solar radiation to prevent the reflectance of the radiant heat to the interior of the hotel

I) ROOF GARDEN

The roof garden is incorporated in the design to serve as an absorbent of the radiant heat from the solar on the roof of the building. The roofing sheets refract some amount of heat to the interior of the building and reflect some to the surrounding environment thereby increasing the temperature of the

ROOF GARDEN

environment. The plants absorb the rays as part of their photosynthesis process and release fresh air to the surrounding environment.



Fig ıowing

J) FOUNTAIN

The use of fountain contributes to evaporative cooling through the spraying of the water which when in contact with the hot air will cool the air by inducing moisture into the air. Fountain serves two purposes in this design, for evaporative cooling and for aesthetic purpose.

K) FENESTRATION CONFIGURATION

Effect of window position on lighting and ventilation: High windows act as ventilation points and also allow for the best distribution of light from overcast skies. Low windows do not allow much ventilation but allow an even distribution of ground reflected light. Middle windows allow for even ventilation but do not distribute the light as well. Light shelves allow for this.

An ideal case fenestration positioning: Openings (windows) are placed on two external walls with the door on one internal wall. If air is incident on any of the external windows, then the fenestration configuration not only ensures a good distribution of air but also has a larger outlet area than inlet area. If the air is incident on any of the other

walls then the door could act as the inlet into the room. Once again the outlet would be larger than the inlet and the configuration would allow good air distribution.

L) LANDSCAPING

The proposed senate building is surrounded by landscaping ranging from the planted trees to shrubs. This landscape is also serving two purposes in this design. The first purpose is that, it serves as solar radiation rays absorber where the rays are absorbed thereby reducing the radiant heat gain to the immediate surroundings. The second purpose is that, it serves as garden for leisure as well as aesthetic value.

6.8 MATERIALS AND CONSTRUCTION

The proposed senate building can be constructed and serve the task of cooling itself passively and ventilating itself through the adoption of the following materials and construction method.

A) FOUNDATION

The type of foundation footing is subject to structural engineer who in conjunction with geo-technician will recommend the appropriate foundation footing to be used based on the nature of soil of the proposed site.

B) WALLS

The wall is what encloses a space to make it serve as shelter for the human being. It is also the building component which interacts with the environment, therefore, the walls should be responsible for the control of the interior climate.

The external wall should be constructed using ventilated exterior wall system which has a vacuum between the wall core and the finishing cladding. The

internal partition is made up of block work with a plaster on top. The walls are finished with a decorative light coloured paint which will aid in keeping the interior cool.

C) WINDOWS

The type of windows to be used in this proposed project is purpose made decorative swinging casement windows. The reason for swinging casement window is that, it is the type of window that gives almost 100% of ventilation. The sizes vary with the location and position of the window.

D) DOORS

The door type recommended for this proposed design is purpose made doors with high thermal resistance to prevent heat gain through the doors.

E) ROOF

The roof is the building component that covers the highest level of the building preventing the interior of the building from the weather. In this design proposal there are two types of roofs adopted based on the roofing materials, namely roofing with roofing sheet and the roof with roof garden. The type of roof with roofing sheet has steel trusses to support the roofing sheet with a void serving as vacuum to contain the radiant heat. The roof garden has a concrete deck with plants on top to absorb the solar radiation intensity to minimize the solar heat gain from the roof.

F) CEILING

The ceiling type suitable for this project is suspended ceiling for it having a void which will serve two purposes, the service duct and vacuum for radiant heat from the roof.

G) LANDSCAPING

The proposed senate building is surrounded by landscaping ranging from the planted trees to shrubs. This landscape is also serving two purposes in this design. The first purpose is that, it serves as solar radiation rays absorber where the rays are absorbed thereby reducing the radiant heat gain to the immediate surroundings. The second purpose is that, it serves as garden for leisure as well as aesthetic value

H) SERVICES

The services provided in this senate building can be grouped into two i.e Mechanical and Electrical Engineering Services. The mechanical services provided in this building are:

(i) WATER SUPPLY

This office complex is linked with the mains of water supply of the Katsina state water board for supply of water for such needs as, domestic fire-fighting, coo1ing and softening plant. Bore hole will also be drilled to serve as an alternative source of water supply.

(ii) WATER STORAGE, DISTRIBUTION AND PRESSURE

Sufficient water equal to at least 100% of the daily requirement is stored in tanks located in the basement to ensure continuity of supply and a suitable constant pressure. .All pumping equipment is duplicated with provision for isolation, drainage and repairs.

the following pipe networks are provided for in this design;

- Supplies to water closet flushing values
- Hot and cold water distribution to toilets
- Supplies to sprinklers located in gardens hedges and lawns and the fountain.

(iii) WATER SUPPLIES FOR FIRE FIGHTING

Two independent sources of water at specified pressure for fire-fighting are provided. There exists on the one hand, water hydrants linked with the mains supply and on the other hand, an underground storage tank.

This underground storage tank is connected via a network of piping to

- Sprinklers with automatic opening at a set temperature at intervals of 4.Au in corridors, public rooms and lobbies.
- Hose reels and stand pipes placed on escape routes (adjacent to staircase enclosures) 20m apart.

CHAPTER SEVEN

SUMMARY: CONCLUSION AND RECOMMENDATION

7.0 CONCLUSION

This thesis demonstrated the current problems and solutions facing energy efficient design in senate buildings in a hot dry climate by incorporating different types of passive cooling techniques to achieve energy efficiency. It has been established in this thesis that adoption of some passive cooling techniques like use of courtyard, optimum orientation, materials specification, roof garden, insulation, shading devices, landscaping etc.

The inferences drawn from these findings are the application of some of the mentioned passive cooling techniques in senate building designs in hot dry climate, it is possible that the senate buildings will become more viable since it will enhance the comfortable and conducive working place while not compromising the quality of the environment. It is also important that buildings are designed with the thought of reducing energy consumption by optimized building siting, orientation and proper material selection to reduce total energy consumption and the need for air

conditioning. The external colour and the texture of the building and the building envelope provide more effective considerable thermal comfort to the inner volumes.

The objective of this study is to explore the principles passive cooling in the design of senate building as a means of minimising the energy consumption which is threat to the environment for the fact that, The objective of environmental building design is the creation of a comfortable yet energy efficient internal environment, it also emits carbon that is responsible for global warming.

7.1 ARCHITECTURAL CONTRIBUTION

The architectural contributions of this study are:

A. The study has demonstrated that the application of elements of passive cooling and natural ventilation will reduce the energy consumption as well as carbon emission thereby reducing the effect of global warming.

B. The study has also highlighted the use of roof gardens contributes a lot in absorbing the radiant rays acting on the roofs, the study has found out the use of ventilated exterior wall will reduce the solar heat gain to the indoor spaces from the exterior walls.

7.2 RECOMMENDATION

Well-designed energy efficient buildings maintain the best environment for human habitation

while minimizing the cost of energy. the objectives of energy efficient buildings are to improve the comfort levels of the occupants and reduce energy for heating, cooling and lighting.

The public, along with designers and clients, now realize the tremendous impact our buildings have on the natural and built environment. However, architects have to continually work towards providing friendly environment for the occupants of these buildings, 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 buildings.

It is also recommended that, further research should be carried out to explore the sufficiency of the passive means of cooling and ventilating senate buildings.

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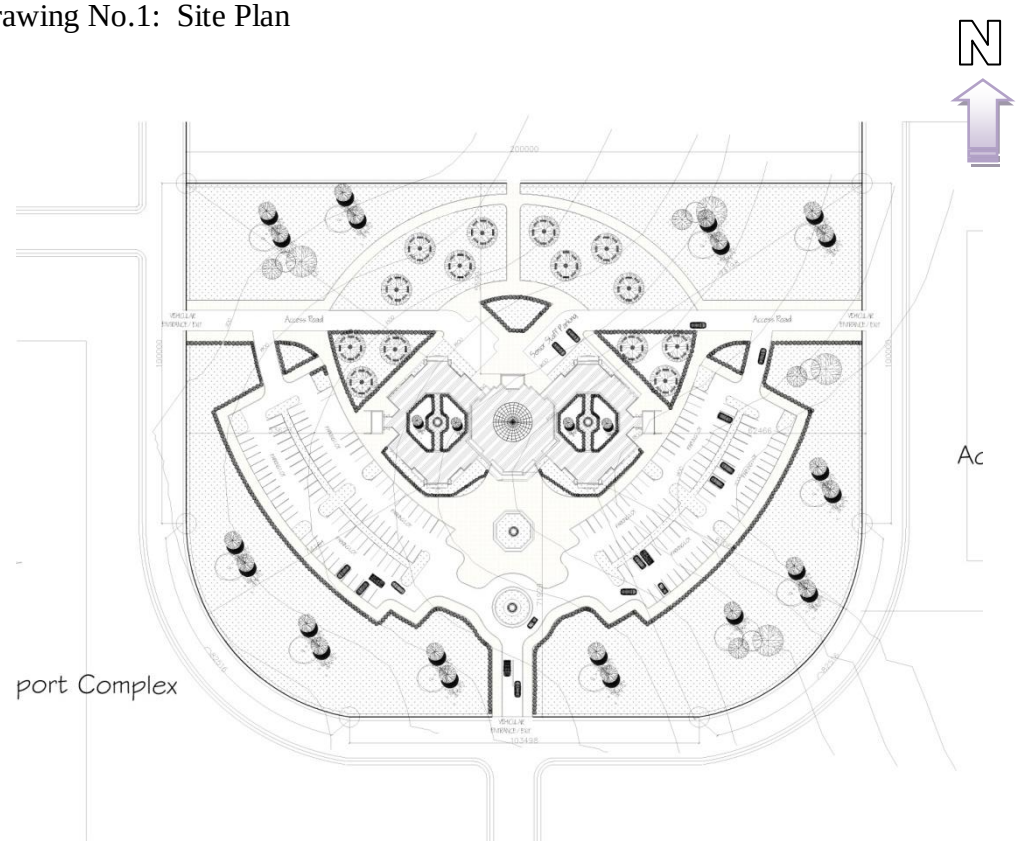
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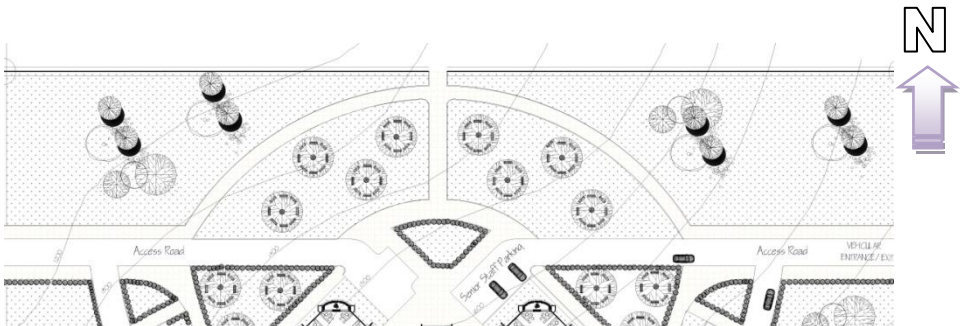
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APPENDIX

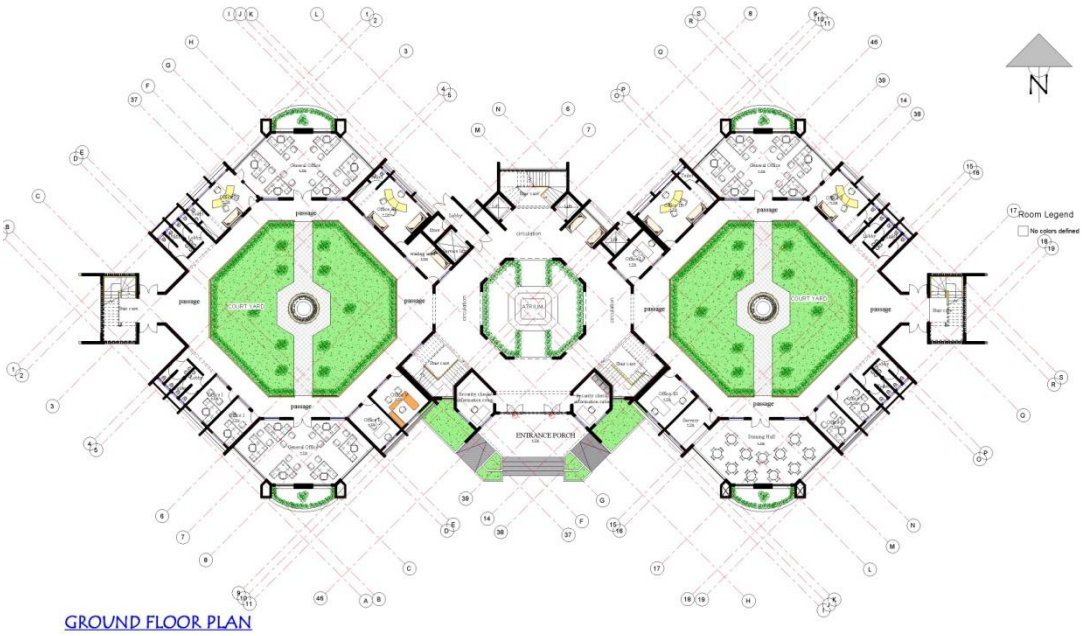
Drawing No.1: Site Plan



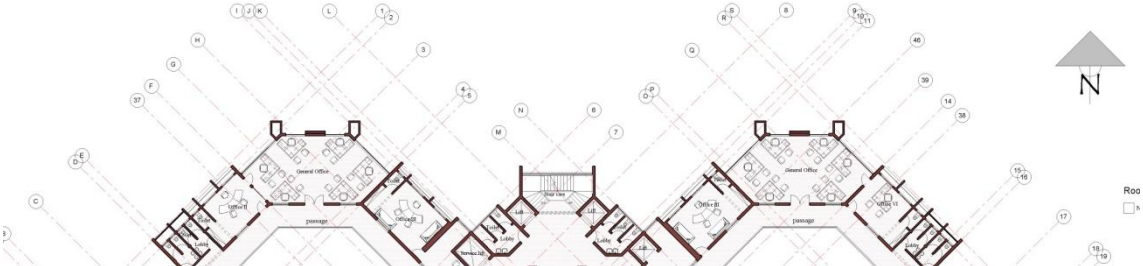
Drawing No.2: Plan on Site



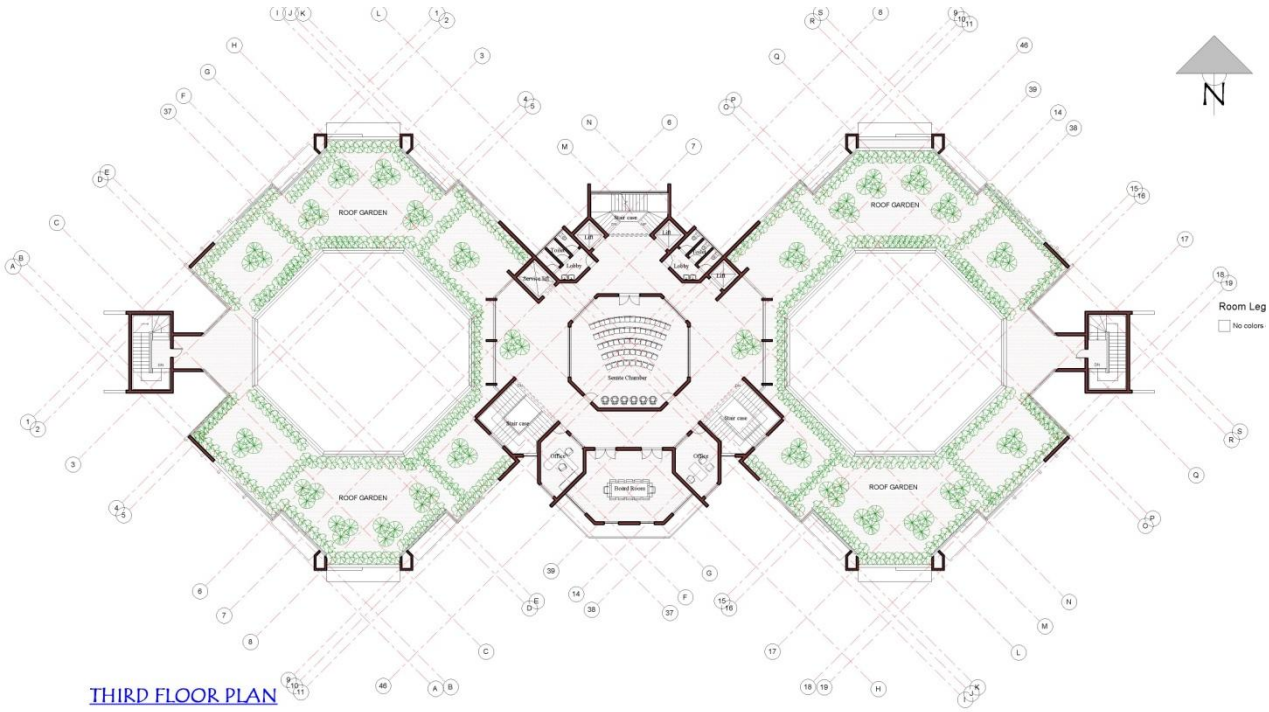
Drawing No.3: Ground Floor Plan



Drawing No.4: Typical First and Second Floor Plan



Drawing No.5: Third Floor Plan

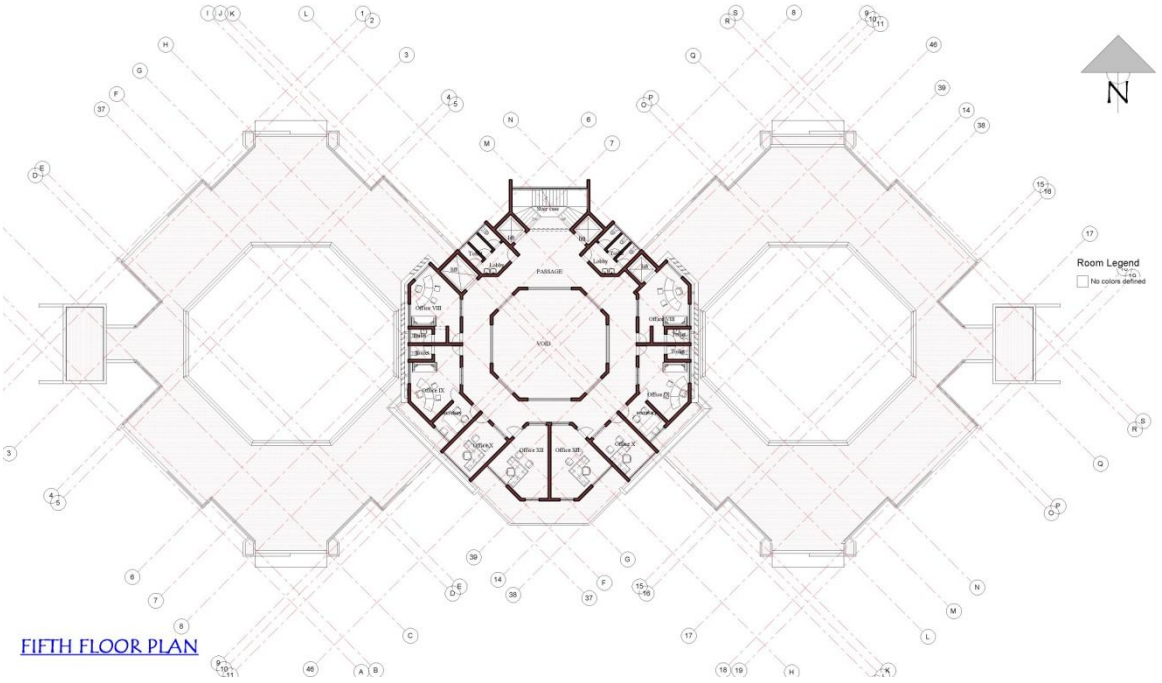


Drawing No.6: Fourth Floor Plan

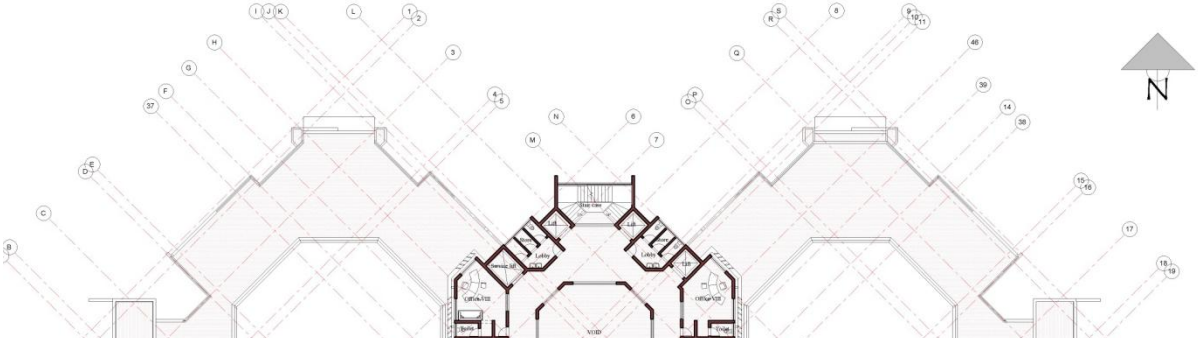


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Drawing No.7: Fifth Floor Plan



Drawing No.8: Sixth Floor Plan



Drawing No.9: South Elevation

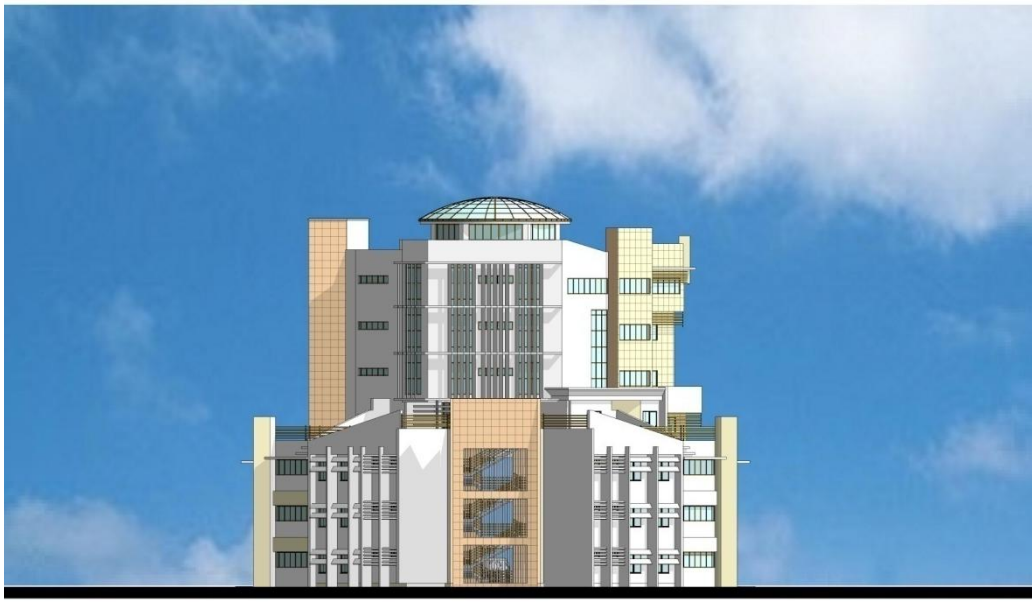


APPROACH ELEVATION

Drawing No.10: North view



Drawing No.11: East View

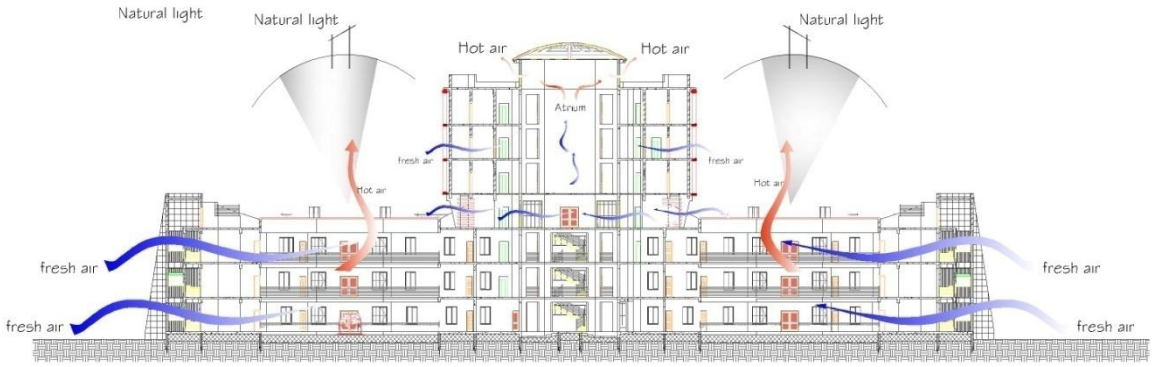


LEFT SIDE ELEVATION

Drawing No.12: West View



Drawing No.13: Section Showing air movement through the building



Drawing No.15: 3D View Approach



Drawing No.16: Right Side 3D view



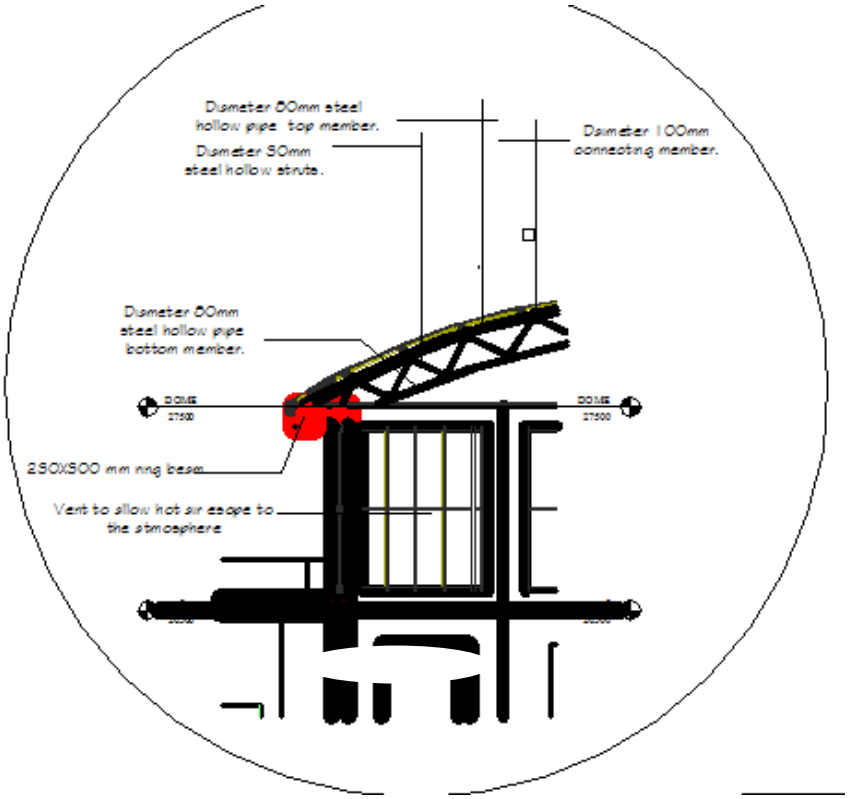
Drawing No.17: Rear 3D View



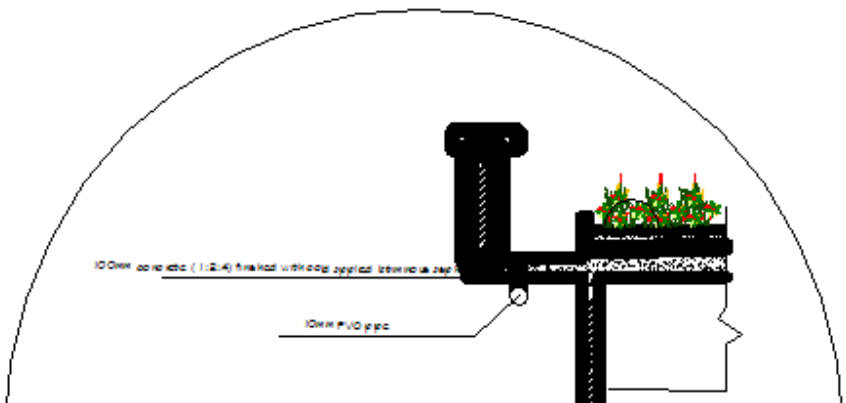
Drawing No.18: Axial 3D View



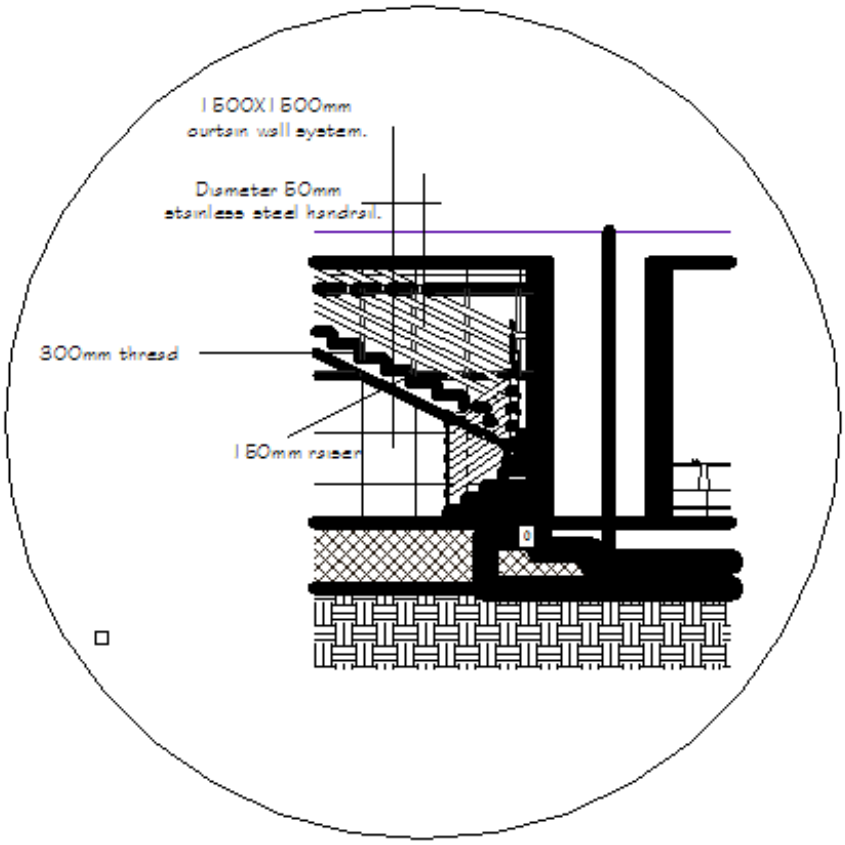
Drawing No.19: Detail–A



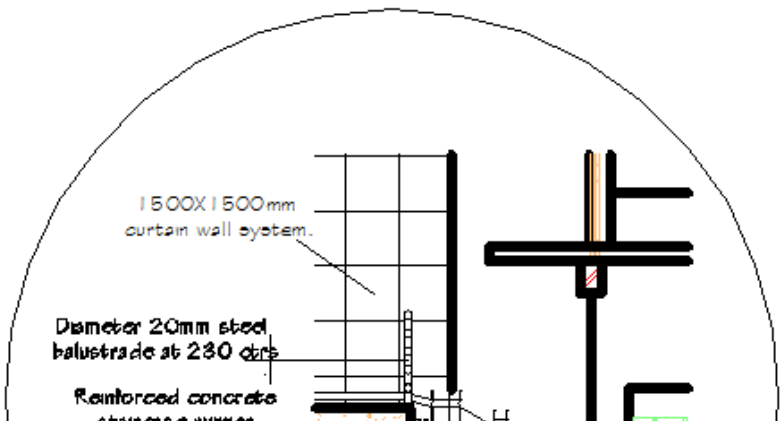
Drawing No.20: Detail-B



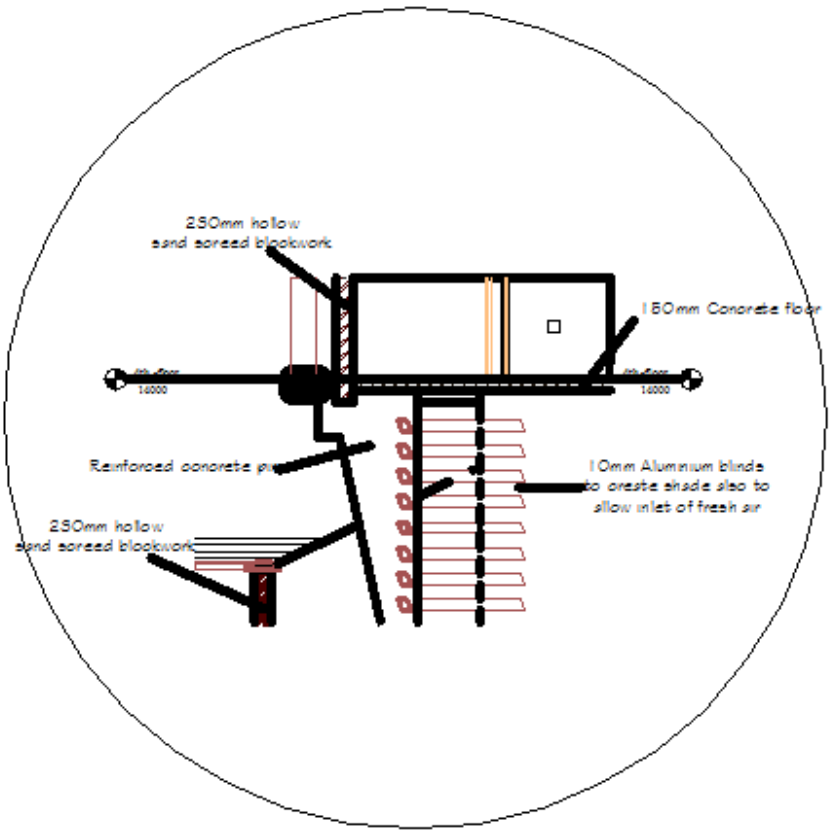
Drawing No.21: Detail–C



Drawing No.22: Detail–D



Drawing No.23: Detail–E



Drawing No.23: Detail–F

