Proposed Faculty of Architecture for Lead City University, Ibadan
(Integration of Passive Design Strategies in Designing Faculty Building)

David Oladayo EMMANUEL
LCU/PG/0005101

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Certification

This is to certify that David Oladayo Emmanuel with matriculation number LCU/PG/005101, carried out this research work titled; "Integration of Passive Design Strategies In Designing Faculty Of Architecture Lead City University, Ibadan, Oyo State", for the award of Master Degree (MSc) in Architecture and has not been previously submitted.

Arc.AseyanBabajide
Member, Supervisory Committee

Date

Dr.OludareObaleye,
Head of Department

Date

Dedication

This report is dedicated to God Almighty.

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Abstract

Hot-dry climates present environmental challenges, including high temperatures and a heavy reliance on energy systems for indoor comfort. In Nigeria, where power supply is often unreliable, educational buildings depend on energy-consuming systems to maintain comfortable environments. Globally, buildings account for over 40% of non-renewable energy consumption, highlighting the need for sustainable solutions. This research explores integrating passive design strategies, architectural principles, and renewable energy in educational buildings, particularly faculty structures, to enhance energy efficiency. Using a case study approach, three examples were analyzed and compared with secondary data. Findings reveal that passive strategies, such as proper building orientation, natural ventilation, evaporative cooling, and renewable energy sources, can significantly reduce the need for active cooling systems. This approach supports climate-responsive architecture, lowers energy demands, and promotes comfortable learning environments. Dormitories, often requiring excessive energy, can benefit from passive design to improve study conditions and minimize energy use. The study emphasizes the role of architects in adopting environmentally friendly, cost-effective solutions. Recommendations include encouraging architectural bodies to promote energy-efficient design practices. Passive design is vital for enhancing thermal comfort, reducing energy use, and creating sustainable, comfortable built environments in the face of climate change.

Key words: Energy Efficiency, Faculty Buildings, Passive Design, Sustainability, Thermal Comfort

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Chapter One

1.0 Introduction

Indoor Environment Quality is increasingly being focused on as one of the key elements of health and well-being ((Ackley et al., 2024).

The provision of good indoor environmental quality can be achieved effectively through the good building, analysis for design, integration of passive means of designs, selection of low-pollution building materials, both energy-saving and efficient and low-cost strategies, by avoiding or reducing sources of indoor air pollution. There is very little attention to the demanding analysis of the actual environmental impacts of design on buildings by designers. Since we spend most of our lives indoors, it is clear that the most important thing in our health-related environment is the indoor environment.

If society recognizes the importance of addressing indoor air quality issues in buildings, there will be a push to develop strategies, construction technologies, and architectural approaches that allow for the design, construction, and maintenance of sustainable, long-lasting, and affordable buildings. Recent studies have shown that indoor air can often be more polluted than outdoor air, even in large, industrialized cities. The main causes of these indoor air problems are poor building design and pollution sources that release harmful gases or particles into the air.

1.1 background of study

One of the key purposes of buildings is to protect occupants from heat and harsh weather conditions. The main objective of building design is to create a comfortable and energy-efficient indoor environment. Globally, buildings are recognized as one of the fundamental needs for human survival (Agboola, 2004). In an environmental study, (Akinola,2015) observed that many buildings rely heavily on active energy systems for both thermal and visual comfort, indicating that they are not truly passive. (Akinpade,2012) highlights that the environment plays a crucial role in everyone's life, whether they are students, teachers, employers, or employees.

The success of an institutional building project is directly tied to how satisfied its users are, as they expect indoor environments that can support both computer-based and paper-based activities. A dormitory’s primary role is to serve as a home away from home for students, offering a comfortable and conducive environment for studying.

These guidelines aim to create a welcoming, secure, and peaceful living atmosphere in dormitories. In most universities, dormitories and other public buildings consume large amounts of energy for heating and cooling (Adamson & Aberg, 1993). Passive design refers to an age-old concept of designing buildings that utilize natural elements like sunlight and weather to maximize indoor comfort without relying on excessive energy use. This approach optimizes heating and cooling through natural climate benefits (Stewart, 2009).

Passive design encompasses various strategies that leverage the natural environment to create energy-efficient buildings, reducing energy consumption per unit of output and promoting energy conservation. This approach focuses on architectural design techniques that minimize energy use by incorporating energy-saving features such as ample windows, a well-insulated building envelope, thermal mass, and enhanced natural lighting (Sanford and Stamas, 2008).

Currently, heating and cooling systems in university dormitories, malls, offices, hotels, and other public buildings are significant contributors to high energy consumption (Adamson & Aberg, 1993). Life cycle analyses have shown that most energy in a building is consumed during its operational phase, or post-occupancy period (Australian Association of Cement and Concrete, 1994).

One of the biggest challenges of the 21st century is the global energy crisis (Goyle & Simmons, (2014), with buildings accounting for a significant portion of the world's energy consumption and carbon emissions Li et al., 2013). The use of air-conditioning systems for cooling has surged, especially in hot climates, over recent decades (Izadpanahi et al., 2021). Buildings contribute 30-40% of total energy consumption due to heating and cooling needs, and people spend about 90% of their time indoors (Hook & Tang, 2013).

A key issue is the lack of studies that evaluate the efficiency of passive design strategies in buildings, particularly in hot, arid regions under future climate conditions. This highlights the importance of identifying and integrating passive design measures to enhance thermal comfort. Passive design strategies utilize renewable resources like sunlight and wind for cooling, ventilation, and lighting. As a result, these strategies can help regulate energy use in buildings and reduce reliance on non-renewable energy sources. They offer a cost-effective solution by lowering energy consumption without depending heavily on mechanical systems, balancing outdoor and indoor temperatures, improving indoor air quality, and creating healthier, more comfortable living environments.

Over the past decade, the importance of sustainable development and eco-friendly building practices has grown, largely due to the environmental impact of many construction projects.

Embracing sustainable principles is essential for creating healthier and more environmentally friendly built spaces. Buildings are primarily designed to adapt to local weather conditions, providing comfort for their occupants. However, with the ongoing challenges posed by climate change and global warming, achieving indoor comfort has become more difficult yet increasingly important (Akande, 2010).

Educational facilities, in particular, demonstrate a clear link between building performance, energy use, and thermal comfort. Since students spend a significant amount of time in classrooms, maintaining a comfortable indoor environment is essential for their optimal performance. However, these buildings tend to consume a lot of energy, mainly due to the heating and cooling required to sustain thermal comfort (Khaled et al., 2012).

In tropical regions, where high temperatures and intense solar radiation are common, educational buildings often struggle with maintaining thermal comfort. Air-conditioning is the usual solution, but where mechanical cooling is costly or unavailable, occupants endure uncomfortable conditions that can hinder productivity, particularly in schools and workplaces (Ojebode & Gidado, 2010). In Nigeria, frequent power shortages have led to the widespread use of backup generators for cooling and lighting, further increasing reliance on fossil fuels (Adegbie, 2016). This dependence contributes significantly to global energy consumption, with buildings accounting for around 40% of total energy use and over 30% of carbon emissions (Saliu & Achimugu, 2016).

To address the issue of thermal discomfort, passive architectural strategies have been explored (Ochedi et al., 2016). Passive design focuses on creating climate-responsive buildings that maintain indoor comfort naturally, without relying on mechanical systems. As Naresh (2014) notes, these approaches reduce dependence on non-renewable energy sources by incorporating features like proper orientation, natural ventilation, and effective shading. By using passive architecture, educational buildings can achieve better energy efficiency and provide a more comfortable environment for their occupants, without increasing energy consumption and carbon emissions.

1.2 Statement of Problem

In Nigerian colleges, the Faculty of Architecture is still not well-known, and excessive energy and mechanical device spending is a big issue for educational facilities. This is mostly because buildings without passive design principles have inadequate heat control. Because so many educational buildings are inadequately planned for the local conditions, many of them are not well suited for the people who occupy them in this environment. Furthermore, the comfort and welfare of building inhabitants are highly dependent on the design and construction of the building, since the majority of institutions cannot afford to run mechanical air conditioning for prolonged periods of time. The purpose of this study is to investigate how energy-saving passive design techniques might enhance thermal comfort in educational settings.

1.3 Aim and Objectives

1.3.1 Aim

The primary goal of this thesis is to improve learning by creating an academic setting that is passively cooled. There are goals that need to be pursued in order to accomplish this. The goal of this research is to better understand how passive architecture concepts can be incorporated into the design of educational facilities in order to create self-sufficient structures that promote learning and reduce discomfort while using the least amount of energy possible.

1.3.2 Objectives:

i. To draw attention to the key ideas behind passive design strategies.

ii. To incorporate into my suggested design the appropriate passive design techniques for faculty buildings in hot, arid regions.

iii. To apply these guiding principles in designing the proposed Faculty of Architecture at Lead City University (LCU), Oyo State.

iv. To investigate the ideas and tenets of passive architecture in relation to educational structures.

v. To examine how passive design strategies are applied in existing educational buildings located in hot, dry climates.

1.4 Research Questions

Building on the previous submission, this study aims to answer the following questions: how passive design strategies can be integrated into the design of faculty buildings, the use of passive design techniques in the design of a Faculty of Architecture, and the key design considerations when creating institutional buildings. It also seeks to explore how passive design in architecture can be applied to faculty buildings.

i. How much have the concepts of passive design been used in hot, dry climates in educational buildings?

ii. What is energy saving crucial for Nigerian educational buildings?

iii. How may energy efficiency and thermal comfort in educational buildings be enhanced by the use of passive architectural principles?

1.5 Significance of Study

In Nigeria There's need for more Faculty of Architecture, the approval, was organized by ARCON in 2018 through the recent conference called Architects' Colloquium (2018), since the Faculty have been approved, it has not become very relevant in the Nigeria universities, the study of this project will share more light on the Faculty of Architecture Nigeria, most especially in the Lead City University Oyo State Nigeria, the proposed faculty of Architecture will foster more resilience in Architecture in Nigeria,

Furthermore, the Faculty will serves as the source of psychological, Social and Economical values to the Lead City University, also to the Ibadan metropolis, the State and to the Country at Large.

1.6 Scope

This study will focus on integrating passive design strategies into the Faculty building, particularly targeting design principles and techniques that can improve indoor air quality and thermal comfort within the Faculty of Architecture at Lead City University, Ibadan, Oyo State. Passive design involves various elements such as thermal mass, insulation, landscaping, ventilation, and building orientation. The research aims to identify and implement effective passive design solutions that are well-adapted to the environmental conditions of institutional buildings, fostering a comfortable and conducive setting. The study's scope will cover the

Faculty of Architecture and related facilities, including the library, workshops, lecture halls, and recreational spaces.

1.7 Definition of Terms

Passive Design involves creating buildings that align with the local climate to keep indoor temperatures comfortable. An effective passive design can minimize or eliminate the need for extra heating or cooling, depending on the specific location, and typically requires the occupants to engage with the design for optimal performance.

Passive Design Strategies utilize natural energy sources instead of relying on purchased energy like electricity or natural gas. These strategies can include techniques such as day lighting, natural ventilation, and harnessing solar energy.

Passive Techniques often involve modifying building elements, such as walls, to enhance heat transfer and improve efficiency in processes like evaporation and condensation, while also increasing critical heat flux levels.

In architecture, passive design aligns with the local climate to ensure a comfortable indoor environment. This design approach employs strategies related to layout, building materials, and overall form to reduce or eliminate the need for mechanical heating, cooling, ventilation, and lighting.

Passive lighting strategies utilize natural sunlight from dawn, distributing it effectively throughout a building. To achieve this, architects design features like windows, skylights, light tubes, mirrors, and light shelves, which help capture and direct light to key areas.

Unlike active design strategies, which rely on mechanical and electrical systems, passive design takes advantage of natural resources for heating, cooling, ventilation, and lighting. By prioritizing passive techniques, buildings can be made more energy-efficient before introducing more complex systems. This approach significantly lowers energy use, reduces utility costs, and minimizes the building's carbon footprint.

For the Faculty Building, passive design strategies aim to create spaces that seamlessly adapt to the local climate. This reduces the need for mechanical heating or cooling, ensuring a comfortable and sustainable environment.

Chapter Two

Literature Review

2.1 **Conceptual Review**

The conception and development of a new feature or product involve assessing different ideas to determine which ones should be prioritized for funding and development. A concept review helps in evaluating these varied, sometimes conflicting, ideas to decide which projects a company should move forward with.

2.1.1Introduction

This chapter lays the theoretical groundwork for the study, examining key theories, concepts, and current discussions relevant to the topic. It also reviews previous publications, offering insights from other researchers to establish a comprehensive understanding of the subject.

2.1.2 Passive Design

Passive design plays a crucial role in sustainable building practices, as it adapts to local climate and site conditions to improve occupant comfort and well-being while reducing energy consumption. By implementing passive design, buildings can maintain more stable temperatures, enhance indoor air quality, and create a drier, more comfortable indoor environment (Oikos, 2008).

This strategy utilizes natural, renewable energy sources like sunlight and wind for heating, cooling, ventilation, and lighting, which can reduce or even eliminate the need for mechanical systems (Oikos, 2008). It also contributes to lower energy usage and minimizes environmental impacts, including greenhouse gas emissions.

Recently, there has been a growing interest in passive design, reflecting a shift toward creating buildings that are both comfortable and energy-efficient. Passive solar design, for instance, supports cooling and ventilation during summer by using natural air currents that arise when warm air rises (Oikos, 2008).

2.1.3 Elements of Passive Design: The successful design of a building hinges on several interrelated factors, including its site location and orientation, layout, window design, insulation (including that of the windows), thermal mass, shading, and ventilation. Each of these elements contributes to achieving comfortable indoor temperatures and maintaining good air quality (Stamas, 2008).

A primary objective is to ensure adequate solar access, providing warmth during colder months while preventing overheating in the summer. This balance can be achieved by thoughtfully considering the building's placement, orientation, room configuration, window design, and shading techniques. Insulation and thermal mass work together to keep temperatures stable, while ventilation enhances passive cooling and indoor air quality. It is essential to view these components as part of an integrated design strategy. For example, large windows that let in plenty of natural light can also result in excessive heat gain, especially when they direct sunlight onto areas with thermal mass. Similarly, opening windows for ventilation may introduce unwanted noise. Additionally, architects should consider factors such as views, local regulations, and the preferences of the building owners when implementing passive design features (Stamas, 2008).

2.1.4 Principle of Passive Design: Passive design refers to a construction methodology that fosters a comfortable indoor environment with minimal energy consumption, primarily by reducing reliance on active heating and cooling systems (Abubakar Ibrahim Dutse, 2015). This approach is grounded in several key principles, including Solar Gain, Solar and Heat Protection, Heat Modulation, Heat Dissipation, Thermal Mass, Super Insulation, Airtightness, and Mechanical Ventilation with Heat Recovery (MVHR). In hot-dry climates, principles such as Solar and Heat Protection, Heat Modulation, Heat Dissipation, Thermal Mass, and Super Insulation are especially pertinent. (Refer to Figure 2.1 for a comparison of Active Design and Passive Design, as highlighted by Abubakar Ibrahim Dutse, 2015).

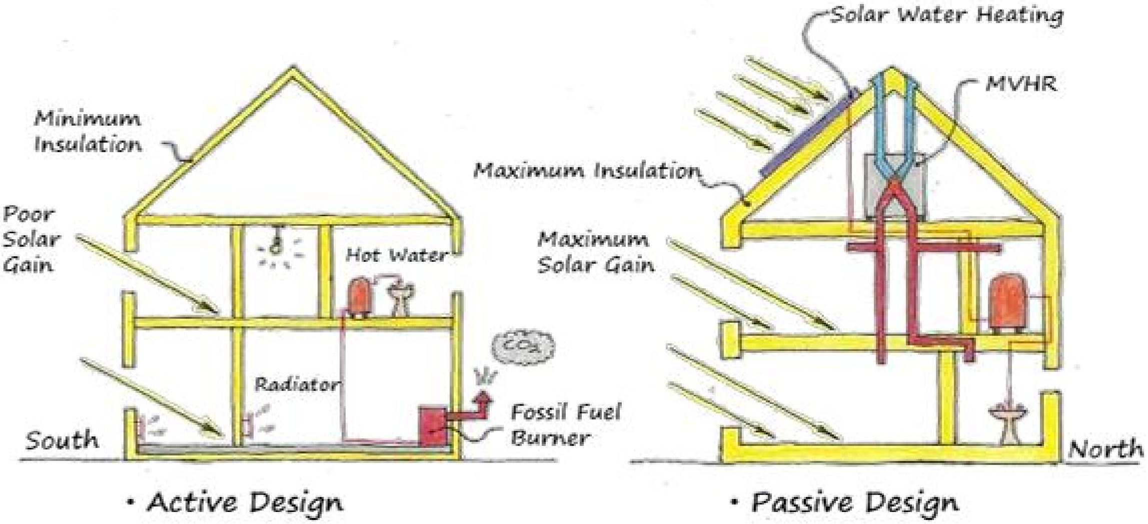


Figure 2.1 Principle of passive design **Source:** Passive design toolkit, (2005)

2.1.5 Impact of Passive Design: Passive design is a construction strategy aimed at creating a comfortable indoor environment while minimizing energy consumption, primarily by reducing reliance on active heating and cooling systems (Abubakar Ibrahim Dutse, 2015). This approach is founded on several essential principles, including Solar Gain, Solar and Heat Protection, Heat Modulation, Heat Dissipation, Thermal Mass, Super Insulation, Airtightness, and Mechanical

Ventilation with Heat Recovery (MVHR). In hot-dry climates, the most relevant principles are Solar and Heat Protection, Heat Modulation, Heat Dissipation, Thermal Mass, and Super Insulation. (For a visual comparison of Active Design and Passive Design, see Figure 2.1, as referenced by Abubakar Ibrahim Dutse, 2015).The following are passive deign dependent variables:

i Planning aspect
ii Building envelope

I. Planning aspects Analysis of the building site should be made to determine the following:

i. Site Analysis: Before constructing a building, it's essential to analyze the site to ensure it's suitable. This involves evaluating factors like topography to see if the land is appropriate for the intended building type, accessibility to check how easily people can reach the site via roads or waterways, and overall usability to determine if the site is buildable.

ii. Building Form: According to Gut and Ackerknecht (2021), building forms with larger surface areas are more effective than compact designs because they promote better ventilation and heat release at night. Therefore, buildings should have an open design that is oriented outward and constructed with slits. Givoni (1998) adds that the form of a building is influenced by whether it will use air conditioning or rely on natural ventilation.

iii. Building Orientation: Properly orienting buildings can maximize the benefits of solar energy and prevailing winds. Gut and Ackerknecht (2021) recommend that the longer side of the building be aligned east-west to minimize solar heat gain on the building's exterior. It's advisable to limit openings on the eastern side; if unavoidable, they should be shaded effectively with features like verandas and tall trees.

iv. Landscaping: Raeissi and Taheri (1999) emphasize the positive effects of trees in landscaping. Planting trees can lead to energy savings, reduced noise and pollution, and adjustments in temperature and humidity, along with psychological benefits for people. Trees can complement window overhangs by effectively blocking the low morning and afternoon sun, while overhangs are more effective against high noon sunlight. According to Simpson and Macpherson (1996), the shade provided by trees can cut annual cooling energy costs by 10% to 50%.

II Building Envelope

i. External Wall: In tropical building design, the primary aim is to minimize direct heat gain from sunlight and reduce internal wall temperatures. This can be achieved by using protected openings and walls (Gut and Ackerknecht, 1993). One effective method is to design the roof to extend significantly beyond the walls, creating broad overhanging eaves. Gut and Ackerknecht (1993) also suggest that the outer surface of external walls should be light-colored and reflective. A study by Wong and Li (2007) found that using thicker materials for the east and west walls can decrease solar heat gain and reduce cooling loads by 7% to 10% if the wall thickness is increased from 114 mm to 229 mm.

ii. Thermal Insulation: Bolatturk (2008) states that thermal insulation is one of the best ways to save energy for heating and cooling buildings because it limits heat transfer. However, this viewpoint is challenged by Gut and Ackerknecht (1993) and Yang and Hwang (1993), who point out that in warm, humid climates, condensation can occur, compromising the thermal performance of the building and potentially causing mold issues. Gut and Ackerknecht (1993) further explain that thermal insulation has a dual effect: while it keeps excess daytime heat out, it can prevent the building from cooling down at night, making it unsuitable for structures relying on natural climate control.

iii. Building Materials: Gut and Ackerknecht (1993) recommend several materials for use in tropical climates:

- Burnt clay bricks: These offer good thermal resistance and humidity regulation.
- Timber: It also provides good thermal resistance and humidity control, but its use has declined due to the high cost of seasoning.
- Natural materials: Bamboo, grass, and leaves allow for ventilation and are not airtight, making them suitable in some cases, but they are often only used in temporary structures and are not common in urban settings.

iv. Roof: The roof is crucial for energy conservation since it receives the most solar radiation, and shading it can be challenging. Vijaykumar et al. (2007) and Alvarado and Martinez (2008) note that heat entering through the roof is a significant discomfort factor in non-air-conditioned buildings, and it contributes heavily to the cooling load in air-conditioned spaces. Gut and Ackerknecht (1993) state that this mainly applies to single-story buildings and the top floors of multi-story buildings. Therefore, the height of the roof design is a key aspect of passive design strategies.

v. Windows: Openings like windows are essential for allowing natural light, airflow, cross-ventilation, and views. According to Liping et al. (2007), increasing the window-to-wall ratio

(WWR) can improve ventilation and indoor air quality, but it may also lead to higher solar heat gain.

vi. Size: The size of openings is crucial for controlling the movement of light, heat, cold, and airflow into the building.

Vii Shading Devices: According to Watson and Labs (1983), shading devices can be divided into three categories: the solar transmittance of glazing materials, interior shading options, and exterior window shades. Solar transmittance refers to the ability of glazing materials to either allow or block heat. They, along with Gut and Ackerknecht (1993), caution against using heat-absorbing, heat-reflecting, or tinted glazing. Watson and Labs (1983) note that while heat-absorbing clear and tinted glass can decrease solar transmission, they may create discomfort as the heat absorbed by the glass radiates into the interior through conduction and thermal radiation.

viii. Natural Ventilation: Ventilation refers to the movement of air within a building. According to Watson & Labs (1983), ventilation serves three important purposes in construction:

i. It provides fresh air for occupants.

ii. It enhances the body's ability to lose heat through evaporation and sensible heat loss.

iii. It helps cool the building by replacing warmer indoor air with cooler outdoor air.

2.1.6.PRIORITISATION OF PASSIVE DESIGN STRATEGIESAs mentioned earlier, implementing passive design strategies is essential for creating sustainable solutions to design challenges. To effectively address the design brief, it is important to understand how these strategies should be applied to achieve optimal thermal comfort. The prioritization of these strategies largely depends on choosing those that are most appropriate for the specific design.

According to Ahmed et al. (2014), "the choice of a suitable passive strategy for a building depends significantly on the local climate of the area." To ensure the occupants' comfort, factors like temperature and humidity must be taken into account. Therefore, understanding the climatic conditions is crucial for selecting the right passive design strategies.

2.2 Theoretical Review

2.2.1 Passive Architecture

Passive Architecture (PA) focuses on designing buildings that respond effectively to local climate conditions, aiming to provide comfortable indoor environments with minimal reliance on mechanical systems (Adegbie, 2016). The term "passive" refers to a design approach that shields occupants from the elements, while "architecture" emphasizes the architect's role in creating these carefully planned structures (Zaki et al., 2012).

In hot and humid climates like Nigeria, PA strategies aim to limit heat gain from sunlight, enhance natural cross-ventilation using prevailing winds, and maximize daylight within buildings. Over the past decade, there has been a growing interest in PA, reflecting a shift toward creating buildings that are both comfortable and resource-efficient (Naresh, 2014). Torwong (2007) describes PA as designing structures that make the most of local climate and natural energy sources—like sunlight and wind—to maintain comfort while minimizing dependence on artificial energy and mechanical systems.

As concerns about global warming and climate change grow, there is increasing pressure on the building industry to reduce energy consumption. Adopting passive design techniques instead of relying on mechanical systems is a sustainable way to achieve this. For example, a building that utilizes natural cooling and ventilation effectively can consume only a third of the energy used by air-conditioned spaces while maintaining the same comfort level. This is because passive design allows buildings to adapt to specific climates, making better use of natural energy sources such as wind and solar power. Additionally, buildings that are naturally ventilated tend to provide healthier and more pleasant environments compared to those using mechanical ventilation, which can lead to issues like sick building syndrome (Torwong, 2007).

2.2.2 Design Approach

Kabiru (2011) emphasizes that climate-conscious design involves careful planning and phased implementation. Haruna (2006) suggests a methodical, step-by-step approach, divided into stages, to analyze and apply climate-responsive design strategies, ensuring buildings serve their intended purposes effectively.

2.2.2.1 Stage 1: Examination and Evaluation

At this stage, research is conducted to yield specific results based on local variables. The architect should use the findings to guide design decisions.

2.2.2.2 Analysis and Considerations

i. **Sun and Temperature**: Understanding local sun and temperature conditions helps architects determine the building's form and orientation to minimize heat exposure (Kabiru, 2011).
ii. **Sun Movement**: Knowing how the sun moves across the site allows for strategic placement of building openings to limit solar heat gain (Kabiru, 2011).
iii. **Wind and Precipitation**: By considering wind direction, strength, and precipitation, architects can identify exposed areas and enhance site planning for improved airflow and protection (Kabiru, 2011).
iv. **Terrain and Vegetation**: The site's terrain and existing vegetation can be used to provide shade and protect against direct sunlight and strong winds (Kabiru, 2011).
v. **Comfort Levels**: Assessing local comfort levels based on bio-climatic charts allows for the creation of spaces that cater to the occupants' physical, mental, and emotional well-being (Kabiru, 2011).
vi. **Occupancy**: Understanding the number of expected users helps in effective space allocation (Kabiru, 2011).
vii. **Internal Heat Gain**: Without proper cross-ventilation, internal heat can accumulate, affecting comfort. Heat generation depends on materials and items within the building (Kabiru, 2011).

2.2.2.3 Planning

i. **Building Placement**: Proper siting reduces exposure to harsh climatic conditions (Kabiru, 2011).

ii. **Positioning of Structures**: Effective placement ensures natural lighting and ventilation across buildings (Kabiru, 2011).

iii. **Topography and Vegetation**: Considering terrain and vegetation helps determine which elements to retain or remove during site design (Kabiru, 2011).

iv. **Building Design and Layout**: Climate-appropriate design is crucial for energy efficiency, such as achieving net-zero energy (Kabiru, 2011).

v. **Organization of Activities**: Efficient planning of activities on-site is essential for functionality (Kabiru, 2011).

vi. **Building Components**: Identifying microclimates allows for strategic positioning of shading devices and openings (Kabiru, 2011).

vii. **Building Volumes**: Ceiling height impacts air circulation and should be decided during the design phase (Kabiru, 2011).

2.2.2.4 Specifications: Eco-friendly Materials

i. **Low Emission Materials**: These help reduce environmental impact and combat climate change (Kabiru, 2011).

ii. **Recyclable Materials**: Using recyclable materials promotes sustainability (Kabiru, 2011).

iii. **Non-toxic Materials**: Prioritizing non-toxic or low-toxicity materials ensures safety for occupants and minimal environmental impact (Kabiru, 2011).

2.2.3 Stage Two: Synthetic Application

This involves applying solutions to the issues identified during Stage One, such as passive cooling, strategic building orientation, shading, insulation, thermal mass, passive solar heating, and the use of renewable energy sources (Kabiru, 2011).

2.2.4 Vernacular Architecture

Vernacular architecture naturally integrates buildings with their surroundings, establishing a balance between climate, architecture, and the local community (Tong Yang & Derek J. Clements-Croome, 2012). This approach leverages local environmental features, including temperature, humidity, wind, and sunlight patterns (Tong Yang & Derek J. Clements-Croome, 2012).

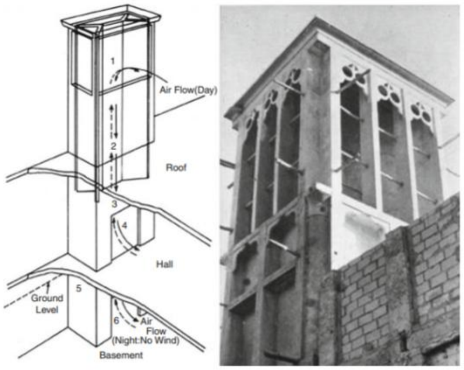
For instance, in areas with a wide daily temperature range, traditional designs can maintain more stable indoor temperatures through methods like time-lag and night cooling. In humid climates, these structures promote comfort by encouraging air to flow over the body's thermo-receptors, aiding in cooling (Tong Yang & Derek J. Clements-Croome, 2012).

Good air quality is also achieved through natural ventilation, with strategic placement of potential pollutant sources. Traditional solutions such as wind towers, courtyards, and igloos utilize natural airflow to adapt to local climates (Tong Yang & Derek J. Clements-Croome, 2012).

2.2.5 Wind Towers

Wind towers, or bagdirs, are a long-standing feature of Islamic architecture, known for enhancing natural ventilation. Used across the Middle East, Pakistan, and Afghanistan, these structures have even influenced modern Western designs. Wind towers capitalize on wind movement around buildings, generating positive pressure on the windward side and negative pressure on the leeward side, allowing air to flow through the building.

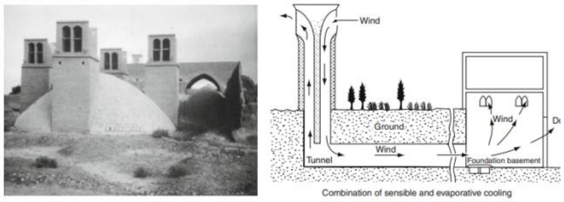
The effectiveness of wind towers relies on the height and design of openings, encouraging airflow through pressure gradients. During the day, the sun heats the structure, causing warm air to rise and escape through the tower, promoting natural ventilation.



Natural Ventilation in Built Environment. Figure 1
Bagdir in Dubai, in United Arab Emirates [2]

Fig 2.2: wind Towe; Source Fathy H (1986)

At night, the cooler air lowers the temperature of the building and its interior. This cooler, denser air then flows downward, helping to cool the indoor spaces after the warmth accumulated during the day. Figure 2



Natural Ventilation in Built Environment. Figure 2
Wind towers in Yazd, Iran to ventilate houses, are also constructed to cool underground cisterns (water reservoir) [3]

Fig. 2.3 : wind Towe; Source Miller JD (2007)

This demonstrates how underground water cisterns might benefit from wind towers' natural cooling capabilities.

2.2.6Courtyards: Courtyards have been a fundamental design element in homes for thousands of years, with distinctive forms appearing across various regions, including Latin America, China, the Middle East, the Mediterranean, and Europe. While the core concept of the courtyard remains consistent, each region has adapted it to suit their local climate and cultural practices. In China, the Courtyard House, or Siheyuan, is particularly prevalent in the northern part of the country. This architectural style provides a sense of space, comfort, tranquility, and privacy.

A Siheyuan is typically a rectangular layout where houses border each side of a central courtyard, usually oriented towards the south. The gate is often positioned on the southeast side, and the surrounding walls shield the home from the cold winter winds and spring dust storms originating from the Gobi Desert. The design of these homes incorporates deep eaves that allow winter sunlight to warm the rooms, while also providing shade and protection from summer rains.

Reflecting traditional Chinese values, the architecture adheres to the principles of Feng Shui and Confucian ideals of order and hierarchy. Each room faces the courtyard, with doors and large windows opening onto it, while smaller, higher windows at the back of the house face the street. The ridged roofs help in maintaining warmth during winter and offering shade in summer.

Verandas within the Siheyuan connect different areas of the courtyard, creating a flexible space for people to gather, regardless of the weather. Serving as an open-air living room and garden, the courtyard becomes a communal area where family members can chat and enjoy the natural surroundings, including plants, rocks, and flowers. In the cold northern regions, courtyards are designed to be broad and open, maximizing exposure to sunlight and allowing fresh air, rainwater, and natural light to support the plants and garden. Conversely, in the warmer southern regions, courtyard houses are often multi-story structures that encourage cross-ventilation for natural cooling. The orientation of these southern homes is less rigid, adapting to the local landscape and proximity to water sources.

Natural Ventilation in Built Environment. Figure 3
A typical courtyard house in southern China

Fig. 2.4: Typical Courtyard; Source Miller JD (2007)

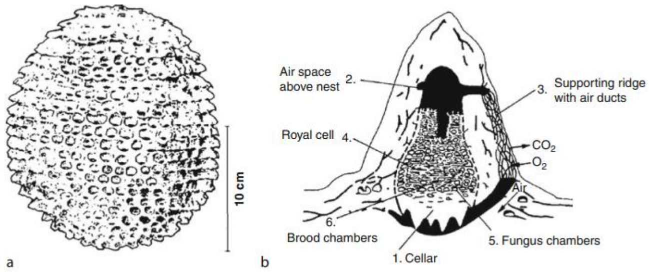
They are constructed with several stories to promote natural cooling effects through cross ventilation. Instead than strictly following a north-south orientation, buildings are oriented to take use of the nearby hills and convenient access to water supplies.

2.2.7LESSONS FROM NATURE:

Termites are remarkable examples of natural architects, demonstrating exceptional skill in building complex structures. With over 2,000 species mainly found in tropical and subtropical areas, termites showcase a variety of dwelling styles that emphasize natural ventilation. Their nests are ingeniously designed to regulate internal temperatures, manage gas exchange, and control moisture levels, all without relying on a fixed temperature. Instead, the temperature inside the nest changes gradually with the seasons, adapting to external environmental conditions.

In Australia, compass termites are known for constructing large, flat, chisel-shaped mounds oriented along a north-south axis. This specific alignment minimizes exposure to the intense midday sun while capturing the warmth of the early morning and late afternoon rays, which is especially beneficial during colder seasons. The north-south orientation can lower peak temperatures by about 7°C, helping to maintain an optimal range of 30–32°C.

There are two main types of termite mounds. The first type, open ventilation mounds, features chimneys or holes that allow air to flow in and out, facilitating ventilation. The second type consists of fully enclosed mounds where gases are exchanged through porous, thin-walled tunnels. One example of these intricate nests is the *Apicotermes gurgulifex* species, which demonstrates the termites' mastery of natural climate control.



Natural Ventilation in Built Environment. Figure 4
Ventilation of termite molds (**a**) Nest of a termite species *Apicotermes gurgulifex* [4]; (**b**) Longitudinal section through the nest of *Macrotermes bellicosus* from Ivory Coast showing the air being circulated by buoyancy [4]

(1)

Fig 2.5. : The nest of a termite species; Source Von Frisch K (1975)

The termite nest is built underground but covered by a layer of air, providing effective insulation. It is made from the termites' own excrement, making it well-protected against external conditions. The outer wall features a series of raised, ring-shaped patterns that enclose carefully spaced ventilation slits. These slits allow airflow between the inside and outside of the nest.

In the case of the Macrotermes bellicosus, a species known for cultivating fungus, their nests can reach impressive heights of 3 to 4 meters and house over two million termites. The fungus chambers inside these nests are designed as complex, sponge-like structures with multiple support systems, optimizing space for the cultivation process.

2.2.8PASSIVE COOLING CONCEPTPassive cooling is a design approach that utilizes natural methods to manage heat and maintain a comfortable indoor environment with minimal energy use. The main idea behind passive cooling is either to block heat from entering the building or to dissipate the heat that has accumulated inside. This helps to enhance indoor comfort. The comfort level within buildings is influenced by four key factors: air temperature, mean radiant temperature, humidity, and air circulation.

2.2.8.1 Natural ventilation involves the movement of air between the inside and outside of a building through openings like inlets and outlets. It is an effective way to lower energy usage by bringing in fresh air and expelling stale air without relying on mechanical systems. Cooling methods such as cross ventilation and the stack effect make use of natural ventilation principles to improve indoor air quality and comfort.

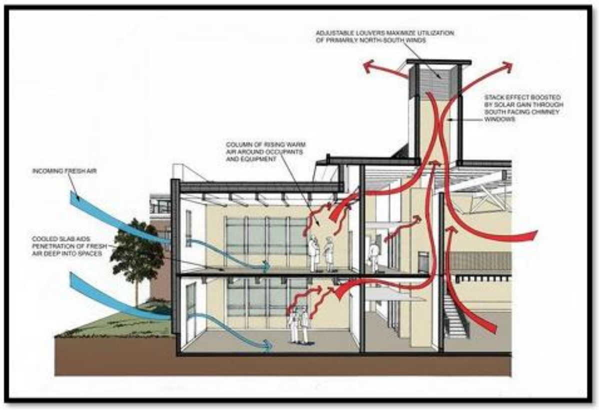


Figure 2.6. Air flow in a building Source: Hay, 2010

2.2.8.2 Stack ventilation, also known as the "chimney effect," relies on the natural movement of air driven by thermal buoyancy. This process occurs when there is a temperature difference or height variation between the inside and outside of a building, creating a difference in air density. Warm air inside the building rises, creating positive pressure at the upper levels, while cooler air sinks, leading to negative pressure at the lower levels. This pressure difference causes air to flow through openings such as inlets and shafts, facilitating natural ventilation. At a specific height between the positive and negative pressure zones, a neutral plane forms where the pressures balance each other.

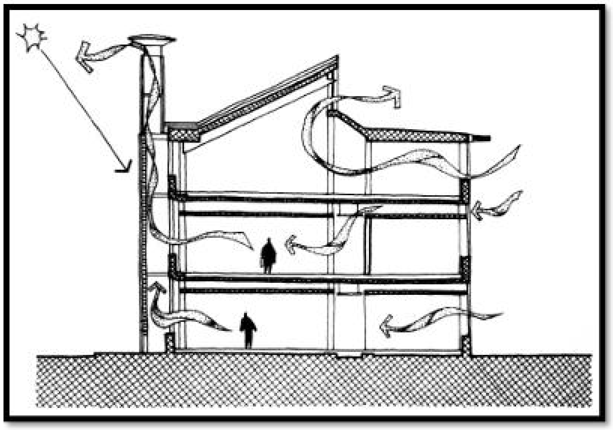


Figure2.7The stack effect: heated air rises because of its buoyancy, drawing in outside air through its low pressure. Source: Mark & DeKay, 2014

2.2.8.3Solar radiation has a significant impact on the visual and thermal comfort of people inside buildings. Solar shading systems help regulates the amount of light that enters through windows or transparent facades, while also enhancing views of the outdoors. These systems reduce solar heat gain and help manage heat transfer through glass surfaces. There are various ways to achieve solar shading, including installing cooling roofs, using trees and vegetation for shade, implementing solar devices, and applying surface shading. By controlling the amount of daylight that enters a building, shading devices can help prevent discomforting issues like glare. (Bellia et al., 2013).

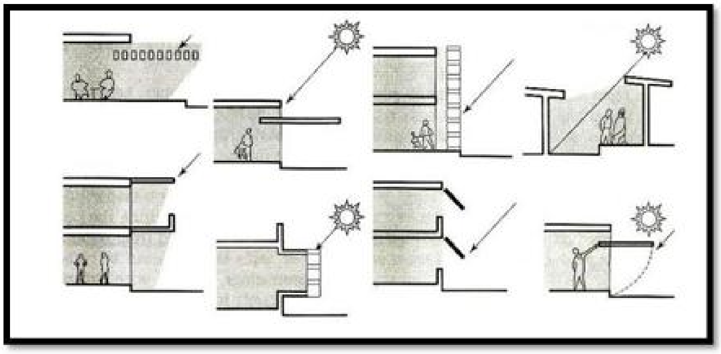


Figure 2.8 Different types of sun shading devices Source: Kamal, 2012

2.2.8.4Insulation is a passive design technique used to minimize heat loss or heat gain across a building's exterior due to temperature differences between the inside and outside. In hot climates, insulation is applied to the outer surface of walls or roofs. This setup ensures that the thermal mass of the walls has minimal interaction with the outside heat while maintaining a strong connection with the interior space, (Kamal, 2012). .

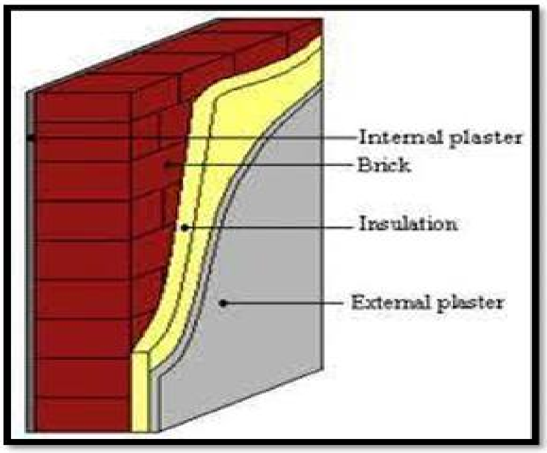


Figure 2.9Insulation applied to the wall's outside surface Source: Abdelgadir et al., 2019

2.2.8.5 Cooling via evaporation: The process of evaporating water to lower temperature is known as evaporating cooling. By turning the latent heat of water evaporation into sensible heat loss from the air, an evaporative cooling system lowers the air's temperature to that of a wet bulb.

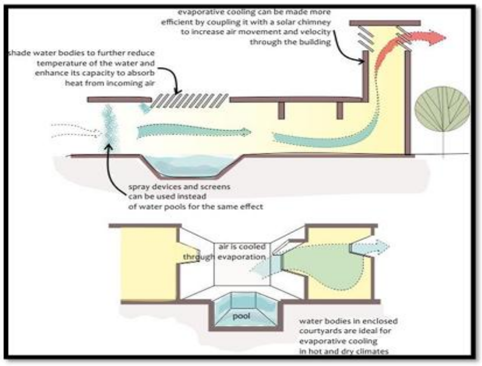


Figure2.10 Working principle of evaporative cooling Source: Net Zero Energy Buildings (NZEB)

2.2.9Passive cooling is a design approach that allows a building's structure to enhance ventilation and maintain cooler temperatures within its components. As defined by the NKBA (2009) and explained by Abubakar Ibrahim Dutse (2015), this method leverages predictable summer breezes and provides shade to windows to reduce the building's cooling load. The term "passive" indicates that this system does not rely on energy-consuming mechanical devices like pumps or fans. Instead, passive cooling serves as an alternative to mechanical cooling systems, which often require complex refrigeration setups. By integrating passive cooling techniques into modern buildings, it is possible to eliminate the need for mechanical cooling altogether or reduce the size and cost of cooling equipment. This approach depends on the interaction between the building and its environment, with strategies tailored to the local climate. Sometimes referred to as natural cooling, passive cooling harnesses solar energy to facilitate the movement of cooler air from shaded exterior areas into or around the building.

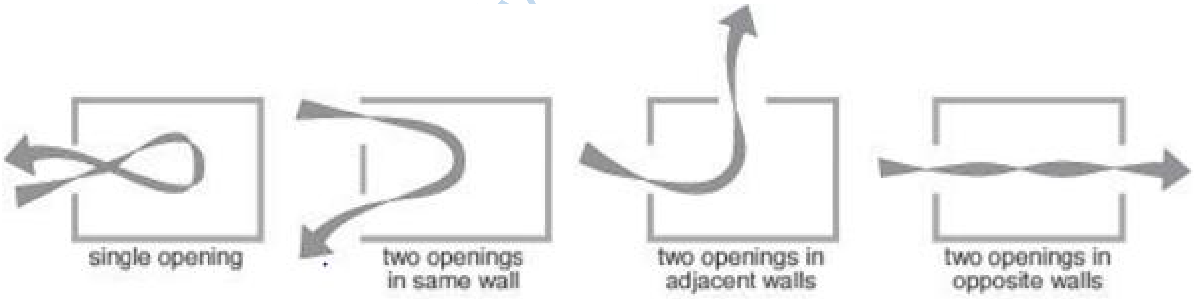


Figure 2.11 passive cooling strategies,Source passive toolkit,(2005)

2.2.10 Principles of Passive Cooling Techniques

Passive cooling techniques are highly effective in reducing a building's cooling needs, providing thermal comfort and improving indoor air quality, all while using minimal energy. Research by Reinhart et al. (2001) highlights that efficient passive systems have been developed and tested, proving their ability to maintain comfort with low energy usage. When internal and solar heat gains in a building are managed effectively, a more efficient cooling system, termed a "lean" climate control system, can be established. This concept of "lean" refers to the use of energy-efficient systems that require only minimal electricity to operate fans and pumps, maintaining comfortable temperatures throughout the year.

2.2.11 Classification of Passive Cooling Techniques

According to Santamouris and Assimakopoulos (2002), passive cooling methods can be categorized into three main groups:

1. **Solar and Heat Protection Techniques:** These methods focus on shielding the building from excessive solar heat, using strategies such as strategic landscaping, creating outdoor and semi-outdoor spaces, choosing appropriate building layouts and external finishes, installing solar control features, adding shading devices, applying thermal insulation, and managing internal heat sources.
2. **Heat Modulation Techniques:** This approach leverages the thermal storage capacity of the building's structure to regulate heat. By storing heat during peak times and releasing it later, the building can reduce fluctuations in internal temperature. Effective heat modulation relies on a cycle of heat storage and discharge, often paired with methods like night ventilation to prevent overheating.
3. **Heat Dissipation Techniques:** These strategies focus on disposing of excess heat by connecting the building to a cooler environmental "sink," such as the ground, air, water, or the sky. Successful heat dissipation depends on the availability of an appropriate heat sink, efficient thermal connection to the sink, and adequate temperature differences to

allow for heat transfer. Techniques include ground cooling, convective and evaporative cooling, and radiative cooling using the sky as a heat sink. In cases where mechanical devices aid the process, it is referred to as hybrid cooling.

2.2.12 Types of Passive Cooling Techniques

Considering the hot, dry climate of the proposed project location, several passive cooling methods can be evaluated for their suitability. The key techniques include:

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

2.2.12.1 Natural Ventilation

Natural ventilation relies on air movement to cool the occupants. Effective cross-ventilation is achieved by placing windows on opposite sides of a building, allowing breezes to flow through. To enhance this effect, designers may include tall spaces called stacks, with openings at the top to let warm air escape and cooler air to enter from lower openings.

Ventilation works best when the building is open during the day to allow air circulation. Convective cooling through ventilation can significantly improve comfort, indoor air quality, and temperature reduction. Higher air speeds can enhance comfort, provided they do not exceed certain limits. While natural ventilation is often limited to nighttime use, it can be effective during the day when outdoor temperatures are cooler than indoor temperatures.

Natural ventilation relies on wind forces, temperature differences, or a combination of both. However, in dense urban areas, the cooling potential is often reduced due to lower wind speeds (Geros et al., 2001). The placement and sizing of windows and other openings are crucial in ensuring effective ventilation. Airflow is vital for passive cooling, as it increases the rate of evaporation, which cools the space. Generally, cross ventilation is most effective for cooling the building, while fans enhance air movement to cool people directly.

Air movement can provide cooling benefits in most climates, though it may be less effective in tropical regions with high humidity. Fortunately, Jigawa, where the proposed project is located, has lower humidity compared to coastal areas. The prevailing wind direction in the area is from the northwest, and placing windows on this side of the building will help enhance natural air movement. According to Reardon (2008), a breeze moving at 0.5 meters per second can produce a cooling effect equivalent to a one-degree drop in temperature at 50% relative humidity.

In more humid conditions, higher air speeds are needed to achieve the same cooling effect, demonstrating the importance of effective air movement for maintaining comfort.

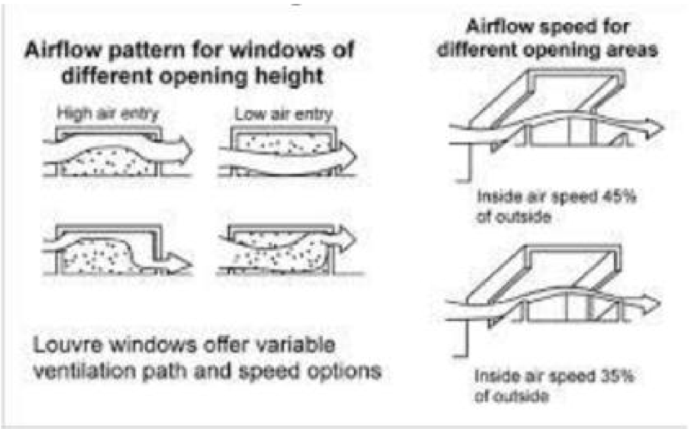


Figure 2.12 ventilation (air movement) Reardon, (2008)

2.2.12.2 Thermal Mass

Thermal mass refers to a material's ability to absorb, store, and gradually release heat energy. High-density materials like concrete, bricks, and tiles have a high thermal mass because they require significant energy to change their temperature. In contrast, lightweight materials such as timber have lower thermal mass. When used effectively in buildings, thermal mass can enhance comfort and lower cooling costs (Reardon et al., 2008). Commonly, thermal mass materials are integrated into walls, floors, ceilings, and partitions to maximize heat storage.

The effectiveness of thermal mass depends on several factors, including the properties of the materials, building orientation, insulation, ventilation, climate, auxiliary cooling systems, and the building’s use. For optimal heat storage, materials should have a high capacity for heat and be able to conduct it effectively, allowing them to absorb warmth during heating periods and release it during cooler times (Reardon et al., 2008).

The placement and distribution of thermal mass are influenced by surface orientation and the desired time lag, which refers to how long it takes for heat to move through the material. Natural ventilation during cooler nights, known as "night ventilation," can cool the building's structure, allowing it to store more heat the next day. This method can reduce cooling needs in air-conditioned buildings by up to 60% and minimize overheating in non-cooled structures by up to 75% (Abubakar, 2015).

For thermal mass to function efficiently, it must be exposed to interior spaces. Materials such as phase-change plaster can improve heat storage, helping to keep indoor temperatures lower. Proper use of thermal mass moderates internal temperatures by balancing the extremes of day and night, leading to greater comfort and reduced energy costs. However, incorrect usage may lead to overheating, especially during hot summer months. To maximize benefits, thermal mass should be integrated with well-planned passive design strategies, such as appropriate glazing, shading, insulation, and orientation.

How Thermal Mass Works

Thermal mass functions like a thermal battery. During hot weather, it absorbs heat throughout the day, keeping the building’s interior cool. During colder seasons, it can store warmth from sunlight or heating systems and release it at night, maintaining a comfortable indoor environment. Unlike insulation, which blocks heat transfer, thermal mass stores and gradually radiates heat. Buildings with high thermal mass require more energy input or loss to change their internal temperature, whereas lightweight buildings quickly respond to temperature changes (Reardon, 2008).

Using Thermal Mass

Thermal mass is most effective in climates with a significant difference between day and night temperatures, known as the diurnal range. Generally, if the diurnal range is less than 6°C, thermal mass may not be very effective, while ranges between 7°C and 10°C can offer some benefits depending on the climate. In regions where the diurnal range exceeds 10°C, high-mass construction is particularly advantageous. Exceptions to this general rule may occur under more extreme conditions.

(Figure 2.12) illustrates how thermal mass is used. Utilizing a thermal mass source (Figure 2.13). Mike Cleaver, Clever Design, (2013)

i. In tropical climates with a diurnal temperature range of 7-8°C, the use of high thermal mass construction can lead to discomfort unless the design is well-considered, with proper shading and insulation. Effective passive design strategies should always accompany thermal mass to ensure comfort. Given that Jigawa has a low diurnal temperature range, it is preferable to use materials with lower thermal mass. For materials with high thermal mass, like concrete, shading is essential to reduce heat absorption from the sun.

ii. Thermal Mass Properties:

iii. High Density: Denser materials can store more heat because they have less air trapped within. For example, concrete has a high thermal mass, while materials like autoclaved aerated concrete (AAC) have a lower thermal mass, and insulation has almost no thermal mass.

iv. Good Thermal Conductivity: Efficient heat conduction is key for a material to absorb and release heat. For instance, rubber conducts heat poorly, while brick is more effective, and reinforced concrete is even better. However, materials that conduct heat too quickly (like steel) may not create the lag effect needed for balancing temperature changes between day and night.

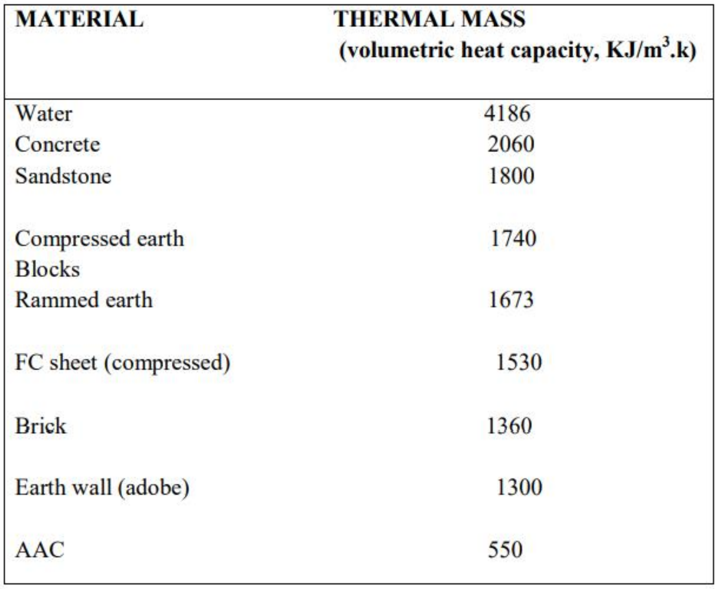
v. Low Reflectivity: Dark, matte, or textured surfaces absorb and re-radiate more heat than lighter, smooth, and reflective ones. If walls have high thermal mass, pairing them with more reflective flooring can help redirect heat towards the walls.

Table 2.1 lists the thermal mass properties of various common materials, highlighting their volumetric heat capacity (in $kJ/m^3 \bullet K$), which indicates how well they can store heat energy.

- Water has the highest thermal mass at 4186 $kJ/m^3 \cdot K$, making it extremely efficient at storing heat.
- Concrete follows with a thermal mass of 2060 $kJ/m^3 \cdot K$, showing it is also a good heat-storing material.

- Sandstone and compressed earth have thermal masses of 1800 kJ/m³·K and 1740 kJ/m³·K, respectively.
- Rammed earth blocks come in at 1673 kJ/m³·K, while fiber cement (FC) sheets are slightly lower at 1530 kJ/m³·K.
- Brick has a thermal mass of 1360 kJ/m³·K, and adobe earth walls (traditional, unfired earth walls) have a thermal mass of 1300 kJ/m³·K.
- Autoclaved Aerated Concrete (AAC) has the lowest thermal mass among these materials at 550 kJ/m³·K, reflecting its lightweight nature and lower heat capacity.

These values help in selecting suitable building materials based on their ability to absorb and retain heat, aiding in effective passive design.



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

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

Comparison of Thermal Mass in Common Materials

The table highlights the thermal mass properties of various building materials, showing their ability to store heat energy. Measured as volumetric heat capacity (kJ/m³·K), these values indicate how much heat each material can hold:

- Water has the highest capacity at 4186 kJ/m³·K.
- Concrete follows with 2060 kJ/m³·K, while sandstone and compressed earth have values of 1800 kJ/m³·K and 1740 kJ/m³·K, respectively.
- Rammed earth blocks are at 1673 kJ/m³·K, and fiber cement (FC) sheets come in slightly lower at 1530 kJ/m³·K.
- Brick has a thermal mass of 1360 kJ/m³·K, while adobe earth walls sit at 1300 kJ/m³·K.
- Autoclaved Aerated Concrete (AAC) has the lowest thermal mass at 550 kJ/m³·K.

Practical Application of Thermal Mass

The volume and thickness of materials play a key role in their thermal mass. For instance, while compressed fiber cement (FC) sheet flooring has a higher thermal mass than brick or earth walls, its typical thickness of only 20mm restricts how much heat it can store. In contrast, brick walls usually range from 110mm to 230mm thick, and earth walls are generally at least 300mm thick, enabling them to retain more heat.

To assess the effective thermal mass, one must consider the material's heat capacity and the volume exposed to absorb heat. Floor coverings, such as carpets, can reduce this exposed surface, limiting heat absorption. Although materials like concrete and brick have high thermal mass, using them extensively can lead to significant embodied energy.

2.2.12.3Thermal Insulation The role of insulation is to control the flow of heat across the building envelope, either retaining or blocking heat from entering the building. It also helps isolate thermal mass, preventing unwanted heat effects in occupied areas. Every building material provides some insulation, but floor coverings like timber and carpets can insulate concrete slabs and diminish their effectiveness as heat sinks. Insulation is essential in design, especially to prevent heat transfer, expressed by R-Value (resistance to heat flow) and U-Value (rate of heat transfer). Building standards, like ASHRAE 90.1, set guidelines for these values to ensure energy efficiency. Insulation also maintains comfortable interior surface temperatures to prevent issues like condensation and discomfort. Achieving consistent insulation requires detailing with thermal breaks—non-conductive materials separating conductive ones, avoiding thermal bridging.

Flexible wood fiber insulation, a medium-density insulation made from wood chips, is ideal for hot, humid climates. It has various beneficial properties:

1. Strong thermal performance in all seasons.
2. Excellent soundproofing.
3. High vapor permeability and moisture control.
4. Resistance to pests and mold.
5. Non-toxic and flame-resistant properties. (Vladimir, 2008).

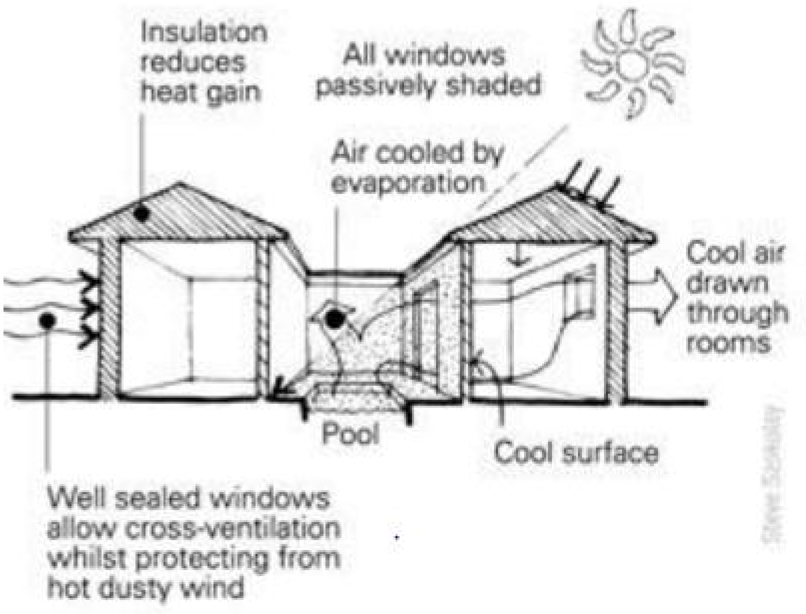
2.2.12.4Buffer Spaces Buffer spaces, like double facades and sunspaces, improve energy performance by providing extra insulation that slows down heat loss. They are especially useful in winter, creating a layer between the indoor and outdoor environments. In summer, they can be converted to exterior spaces to help cool and ventilate adjoining areas. Properly positioned, these buffer zones enhance passive solar designs, particularly when facing south or west. They act as passive solar collectors, trapping and distributing heat through the structure's thermal mass. Sunspaces can also be integrated with mechanical systems for efficient heat distribution. Benefits include energy savings, reduced drafts, and increased natural ventilation, (Abubakar Ibrahim Dutse 2015).

2.2.12.5Evaporative Cooling Evaporative cooling uses the cooling effect of water evaporation to reduce indoor temperatures. When water evaporates, it absorbs heat from the air, leading to a cooling effect. There are two types:

1. Direct evaporative cooling: Water evaporates directly in the space, adding moisture to the air.
2. Indirect evaporative cooling: Evaporation occurs within a heat exchanger, cooling the air without increasing humidity, (Abubakar Ibrahim Dutse 2015).

This technique is most effective in dry climates where the air can hold more moisture. It can be implemented passively using water features like fountains and ponds or integrated with mechanical systems. The effectiveness of evaporative cooling increases with air movement and the exposed surface area of water. Well-placed water elements can help cool incoming air and generate breezes, enhancing natural ventilation, (Chris, 2002).

Figure 2.14A courtyard layout featuring an evaporative cooling pool Source: Design guidelines for passive solar energy, 2008



2.2.12.6Shading Devices: To effectively manage sun exposure within buildings, it's crucial to incorporate exterior shading into the architectural design. These devices can be either added to the structure or integrated by designing the building floors to create natural overhangs. Exterior shading is preferable to interior shading because it prevents solar radiation and heat from entering the building in the first place.

Generally, the north-facing side of a building doesn't need much shading since, apart from summer mornings and evenings, there is minimal sun exposure. It's advisable to limit windows on the north side to avoid unnecessary heat loss, and if windows are essential for natural light, it's important to use highly efficient glazing to minimize energy transfer.

In contrast, the south-facing side is easier to manage regarding solar energy control. Shading devices on this side are often designed as horizontal projections above windows. The length of these projections is based on the height of the window and the sun's angle at solar noon. Properly designed shading can block direct sunlight during the summer while allowing full sun exposure during winter, promoting passive heating. Various shading methods, such as overhangs, louvers, and adjustable screens, can be used to achieve these effects.

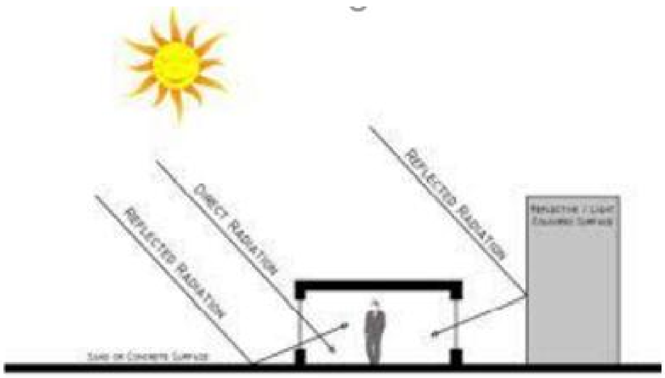


Figure 2.15: Fundamental techniques for shading. (Carbon Neutral Design, 2011).

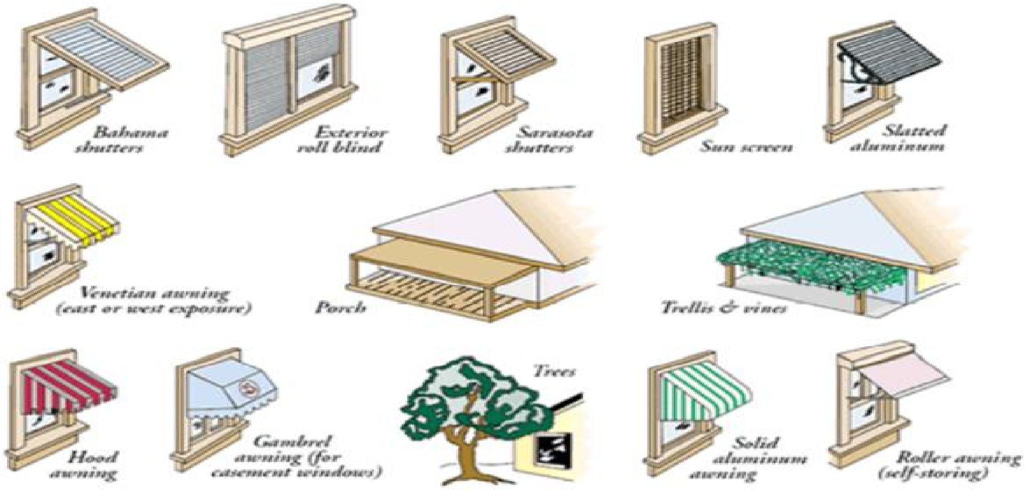


Figure 2.16: Fundamental techniques for shading Window orientation shading (2011).

The east and west sides of a building present more challenges for shading because the sun's low angle in the morning and afternoon makes it difficult to block sunlight using standard overhangs. While morning sunlight is typically cooler and less intense, the afternoon sun can produce more heat and glare.

To manage shading on these sides, landscaping and vegetation are effective solutions. Deciduous trees are particularly useful as they provide shade during the summer when it's needed most, and then shed their leaves in winter to allow sunlight to pass through. While fences can block sunlight and maintain privacy throughout the year, they are not as adaptable to changing seasonal conditions.

Vines growing on semi-transparent structures, such as trellises, offer a more flexible solution. They provide shade during summer by bearing leaves and then shed them later in the fall when sunlight is welcome again. This approach can also be used on south-facing trellises to vary the opacity of shading depending on the season, making it an effective passive design strategy.

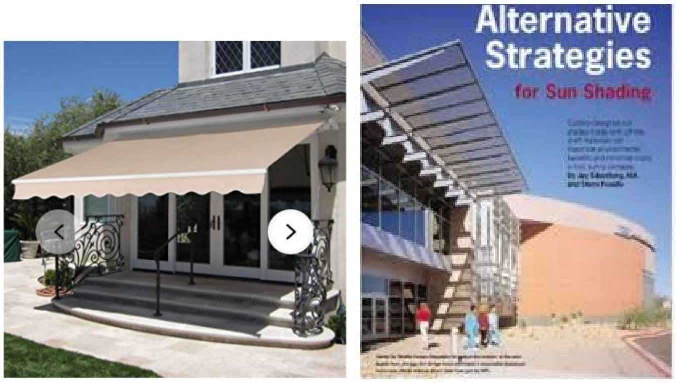


Figure 2.17: Fundamental techniques for shading Alternative shading techniques, (2011)

Types of Exterior Shading Devices: Exterior shading devices are generally classified into three main types: horizontal, vertical, and egg crate structures, as illustrated in Figure 2.16. When designing these devices to minimize heat gain, it is important to also consider the amount of sunlight needed during cooler months. In climates where cooling demands are significantly higher than heating needs (such as hot climates), shading should be prioritized for most of the year. In some cases, this may lead to a design approach that reduces the use of south-facing windows in favor of north-facing windows, which can provide natural daylight without increasing indoor temperatures,(Abubakar Ibrahim Dutse 2015).

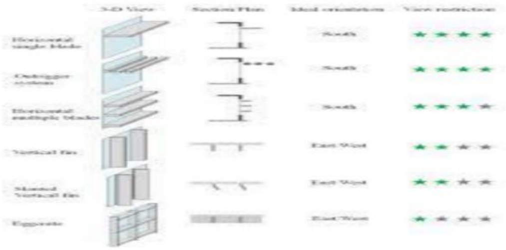


Figure 2.7: Basic shading devices
Source: Carbon neutral design, (2011)

Figure 2.16: Basic shading devices Source: Carbon neutral design, (2011)

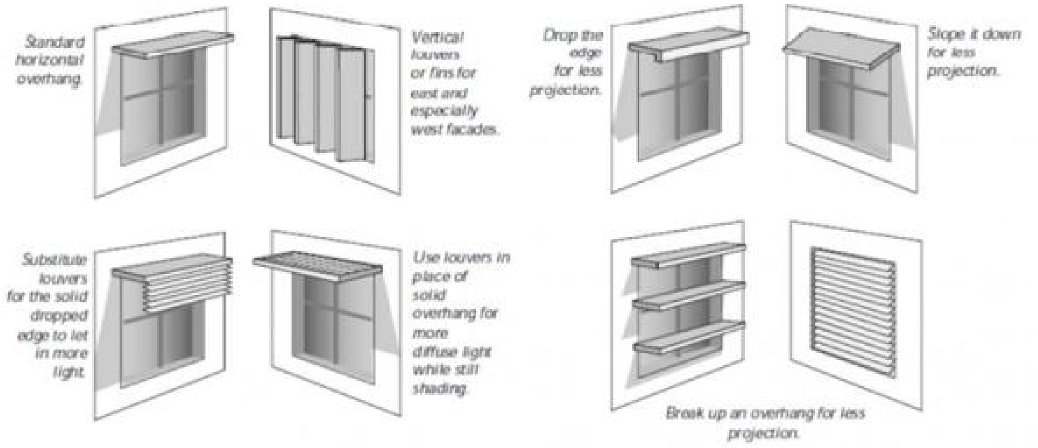


Figure 2.18.1: Basic shading strategies, Source: carbon neutral design, (2011)

i. Horizontal Shading Devices

Horizontal shading devices are ideal for south-facing windows, effectively blocking direct sunlight. Roof overhangs can also be used to shade south-facing areas, particularly on low-rise buildings. This approach is not only cost-effective but can also enhance the visual appeal of residential buildings.

ii. Vertical and Egg-Crate Shading Devices

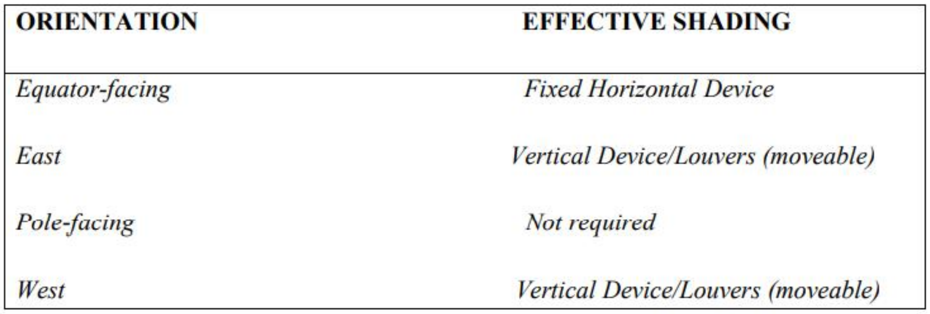
For facades that receive sunlight from south-east or south-west angles, vertical shading devices work well to block the sun. Egg-crate devices, which combine horizontal and vertical elements, are often effective for facades that are not directly south-facing, providing versatile shading for various orientations.

2.2.12.7Orientation Considerations: In hot climates, the key goal of building orientation is to minimize the impact of the sun during summer. Solar radiation patterns indicate a clear preference for north-south orientation for the main facades, particularly for window placement. This orientation allows for simple and cost-effective shading of southern windows during the hotter months. The heating effects of sunlight on walls can be reduced by selecting reflective colors for the exterior. According to Reardon (2008), proper building orientation reduces the need for cooling, leading to lower energy costs and a decrease in greenhouse gas emissions. Buildings should utilize the site's characteristics to achieve the best possible orientation, especially for areas of study.

In hot, humid climates, the objective is to keep sunlight out throughout the year while maximizing exposure to cooling breezes. Even when ideal orientation isn't feasible, as often seen in dense urban areas, passive cooling can still be achieved with thoughtful design. The effectiveness of shading devices, especially horizontal shades, depends on the sun's specific path across the sky, which means shading strategies need to be customized for each window's orientation. While some orientations are easy to shade, others can be challenging due to direct sunlight exposure at certain times of the day.

Guidelines provided in Table 2.2 outline suitable types of shading devices for different building orientations, offering a basis for design, though there remains significant potential for innovation in the details of shading solutions.

table 2.2: Simple shading strategies for different orientation.



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

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

According to Reardon (2008), building orientation should prioritize exposure to cooling breezes. It's advisable to limit windows on the east and west sides, as these areas receive more direct sunlight and heat. In contrast, north-facing windows are less problematic; they can easily be shaded with a simple overhang, allowing for good views. On the other hand, east and west windows often require more extensive shading solutions, which can obstruct outside views for much of the year.

To optimize energy efficiency, buildings should ideally be elongated along the east-west axis to increase the number of south-facing windows, which are more beneficial. However, buildings with large glass areas are at risk of overheating. Reardon (2008) stresses the importance of minimizing east- and west-facing windows and ensuring that shading devices are appropriately sized. Orientation should be carefully considered during the site planning phase, aiming to reduce east and west glazing as much as possible. Poor design choices regarding orientation, insulation, and glazing often lead to significant energy waste, regardless of the building type. Additionally, the orientation of a building needs to account for latitude, with tropical regions favoring a direction that is about 50 degrees north of east (Reardon, 2008).

2.2.12.8Form:The shape and massing of a building play a crucial role in reducing its energy consumption, but this can be affected by various factors, including planning requirements, building type, and initial feasibility. Some building shapes, like tall and narrow towers, tend to have a higher surface area relative to their volume, which can lead to poorer energy efficiency, especially in buildings that rely on heating. In contrast, buildings with a smaller exterior surface area for the same square footage can perform better in terms of energy efficiency. A compact building design lowers energy intensity and decreases the reliance on active mechanical systems. Optimizing massing can enhance passive energy performance without necessarily increasing construction costs. Therefore, when designing a building, it’s important to consider massing early on, taking into account its orientation and the specific conditions of the site.

2.2.12.9Landscaping:Landscaping can significantly improve a passive cooling system. Using plants to shade a house is an effective cooling method. When strategically placed, plants provide cool shade and enhance the building's aesthetic appeal. Additionally, plants help cool the air because they absorb heat. Their dark, coarse leaves reflect little light, making them excellent at controlling solar radiation. During photosynthesis, plants undergo a process called evapotranspiration, where they release large amounts of water vapor through their leaves. This vapor cools the surrounding air, helping to lower the temperature around the building (Givoni, 2001).

By strategically planting trees, shrubs, and vines around a building, as illustrated in (Figure 2.17), and on structures like pergolas and overhangs, the microclimate can be improved. When done correctly, this can significantly reduce the need for internal and external shading devices. Carefully chosen plants can shade windows, entire facades, and roofs, cutting down on both conductive and radiative heat gains. Givoni (2001) notes that deciduous trees and vines provide shade during the warmer months when it's most needed, while evergreens offer year-round shading. Vegetation can also help lower ground reflection and, through evapotranspiration, cool the surrounding air temperature.

Evergreen shrubs and ground cover can minimize reflection from roads, pavements, and buildings, and they can act as wind barriers. Deciduous plants are particularly effective in temperate climates.

Figure 2.19: Landscape design, (Wikipedia org. 2011)

Figure 2.19.1: Landscape design, Source Wikipedia org. (2011)

The shading effects of vegetation depend on factors such as plant type (tree, shrub, or vine), species, and age, which influence leaf characteristics and vegetation density. For deciduous plants, this density varies seasonally. Vegetation can affect a building's internal temperature and cooling load in several ways:

1. Tall trees and pergolas placed near walls and windows provide shade while still allowing ventilation.
2. Vines on walls and tall shrubs near buildings can offer shade and reduce wind speed around the structure.
3. The air temperature around the exterior of the building is cooled, leading to less heat being absorbed through conduction and infiltration.

4. Ground cover plants help minimize reflected solar radiation and the emission of long-wave radiation from the surrounding area, reducing overall heat gains.
5. Planting vegetation on the eastern and western sides of a building can effectively shield it from the sun.

On hot days, walls shaded by trees or a combination of trees and shrubs can be up to 60°C cooler, while climbing vines can reduce wall temperatures by up to 45°C. However, vegetation can sometimes reduce the cooling effect of shading. For instance, in the Mediterranean, a white wall can be up to 15°C cooler than the air. When vegetation shades a wall, it may limit the wall's ability to release heat, making the shading less effective. Therefore, the wall color and the distance between vegetation and the wall should be carefully considered.

2.3Empirical Review

2.3.1 Historical Background

Natural cooling techniques have been used as the traditional method of thermal cooling in architecture long before mechanical systems like refrigeration and HVAC (Heating, Ventilation, and Air Conditioning) became commonplace. Many preserved historical buildings illustrate the sophisticated natural cooling methods that were employed to keep interior spaces comfortable without modern technology. Here are some examples:

Golestan Palace, often referred to as the Rose Garden Palace, is a former royal complex located in Tehran, Iran, that belonged to the Qajar dynasty. As noted in Wikipedia, the palace comprises a series of royal structures that were once surrounded by a mud-brick fortress within Tehran's citadel. It features beautiful gardens, royal buildings, and a collection of Iranian crafts alongside European gifts from the 18th and 19th centuries.

The buildings in Golestan Palace utilized wind catchers, or wind towers, to capture and channel the wind for cooling purposes. These traditional architectural elements serve both passive cooling and natural ventilation needs. Wind catchers are chimney-like structures placed on the rooftops, designed with upper openings that contain multiple small ducts. Additionally, there is an underground water reservoir that functions as a heat sink, enhancing the cooling effect withinthe palace.

Figure 2.20 Golestan Palace Tehran, Iran

2.3.2 TAJ MAHAL: The Taj Mahal is widely regarded as one of the most iconic structures in both Islamic architecture and global history. This stunning ivory-white marble mausoleum, located in Agra, India, was built in the 17th century by Emperor Shah Jahan in memory of his beloved wife, Mumtaz Mahal. As a major tourist attraction, the Taj Mahal is also celebrated for its seamless integration with the natural environment.

A remarkable example of natural cooling techniques, the Taj Mahal incorporates strategically placed windows that create a funnel effect, allowing outside air to flow into the interior. This clever design features larger openings on the exterior and smaller ones on the inner wall, enhancing airflow throughout the space. Additionally, the water channels and fountains surrounding the mausoleum, along with the nearby Yamuna River, help cool the air as it enters the building. The structure's double-wall construction further contributes to thermal comfort inside, ensuring a pleasant atmosphere,(Misra, 2014).

Figure 2.21: Taj Mahal Agra, India Source: The Guardian Nigeria

2.3.3 THE PANTHEON: The Pantheon is an ancient Roman temple that was commissioned by Marcus Agrippa during Augustus's reign and has been a Roman Catholic Church since 609 AD. Located in Italy, the Pantheon features a remarkable passive ventilation system, primarily due to the open oculus at the top of its rotunda.

This design allows air to flow in two ways: through convection and the Venturi effect. As warm air rises through the oculus, it creates a vacuum that pulls air in from the portico entrance, which acts as an inlet for cooler air at the bottom of the building. This interaction produces a continuous upward airflow, enhancing ventilation throughout the space, (Chu, 2011).

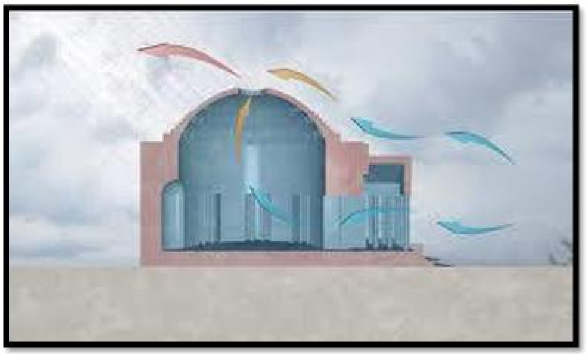


Figure 2.22: 3D model of the Pantheon Rome, Italy

The airflow over the oculus generates the Venturi effect, where the dome shape causes the air to speed up as it passes over the opening. This increase in speed leads to a drop in pressure. Meanwhile, the air near the portico moves more slowly, which raises the pressure in that area. The difference in air pressure causes air to flow from the higher pressure near the portico to the lower pressure at the oculus, creating a continuous movement of air, (Chu,2011).

2.3.4THERMAL COMFORT: Understanding the factors that contribute to thermal comfort is essential for effective building and system design, particularly in passive design, where the goal is to maintain comfort without relying on mechanical systems for as much of the year as possible. As noted by Vladimir (2008), thermal comfort is specifically about how we perceive temperature in our environment. This topic is complex and highly subjective. Passive design influences four key indoor environmental factors that affect thermal comfort:

1. Air temperature
2. Air humidity
3. Air velocity
4. Surface temperatures

Each of these factors impacts thermal comfort in different ways. While conventional design often focuses on air temperature and humidity—affecting only 6% and 18% of our comfort perception, respectively—it's crucial to also consider surface temperatures and air velocity. These two factors play a more significant role, accounting for 50% and 26% of our thermal comfort perception, respectively. The success of passive strategies largely depends on the acceptable thermal comfort parameters established for the project, (Vladimir, 2008).

2.3.5 Thermal Comfort Models

Understanding human thermal comfort is complex and subjective, making it challenging to define precise comfort parameters. Nevertheless, several models have been developed to quantitatively assess how comfortable occupants feel, with the Fanger and Adaptive Models being the most notable.

a. The Fanger Model

The Fanger Model is mainly applied in conventional buildings that rely entirely on mechanical systems for climate control. It assesses comfort based on air temperature and humidity, as these are easy to measure and regulate. The model sets a narrow, fixed range of comfort levels that do not change with daily or seasonal variations in outdoor conditions (Vladimir, 2008). For passive cooling strategies, which depend on fluctuations in temperature and humidity throughout the day, their effectiveness can be evaluated using a bioclimatic chart, as shown in (Figure 2.21).

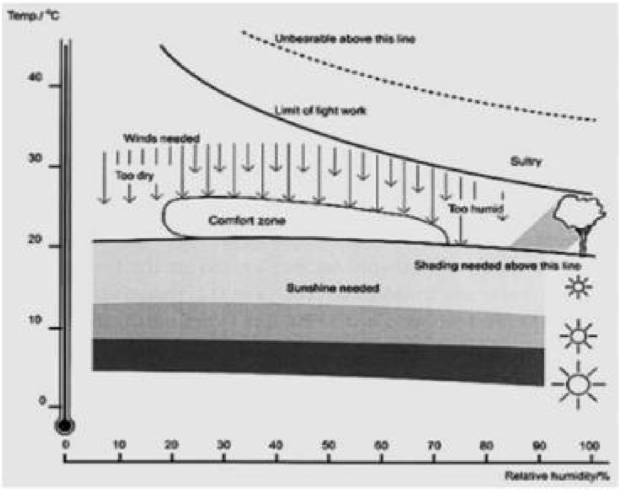


Figure 2.23: Bioclimate charts, (Climate responsive building, 2014)

The bioclimatic chart presents four passive cooling strategies based on temperature and relative humidity, which helps determine the most appropriate methods for a specific building site's climate. To use this chart effectively, it's essential to collect local weather data for each month of the year, including:

i. Average maximum temperature

ii. Average minimum temperature

iii. Average maximum relative humidity

iv. Average minimum relative humidity

In the chart, passive cooling strategies are represented as overlapping zones. When the lines intersect different zones, it indicates that a particular strategy may be effective for the given climate conditions. Some months might be suitable for several strategies, so it's advisable to select one or two that complement each other and fit well with the building's design to keep costs down (Vladimir, 2008).

These passive cooling concepts focus on eliminating excess heat that accumulates in buildings. Effective passive cooling relies on minimizing heat gains through high insulation, heat-reflective windows, optimal solar orientation, and adequate shading from building features and landscaping. This passive strategy is a part of the broader Bioclimatic approach, which itself is a component of Ecological (Green) design that addresses larger environmental issues (Fairey, 1994).

2.3.6 Thermal Balance:

The body can maintain its temperature through different mechanisms. This thermal balance is influenced by two main factors: the "internal heat load" and the energy flow (or thermal exchange) between the body and its surroundings. There are four primary ways this thermal exchange occurs: conduction, convection, radiation, and evaporation. (Abubakar 2015).

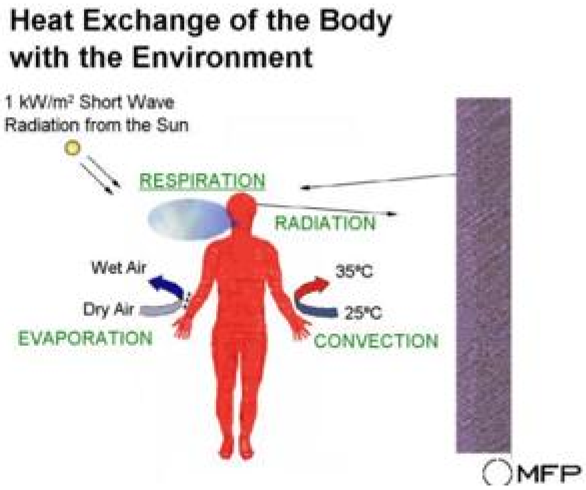


Figure 2.24: How the human body exchanges heat, (Climate responsive building, 2014)

Conduction

Heat exchange through conduction is influenced by the thermal conductivity of materials that come into direct contact with the skin. Generally, conduction plays a minor role in overall heat transfer, mainly providing localized cooling to body parts that touch materials with high conductivity. This consideration is particularly important when choosing flooring materials, especially in areas where people frequently sit (Abubaka, 2015).

Convection

Convection involves heat transfer driven by the temperature difference between the skin and the surrounding air, along with air movement. This type of heat exchange can be somewhat regulated through appropriate clothing. The insulating effect of clothing is measured using a "clo" value, where 1 clo equals 0.155m2·°C/W0.155 m^2 \cdot °C/W0.155m2·°C/W. For reference, wearing no clothing is rated at 0 clo, while clothing designed for Arctic conditions is around 4 clo (Abubaka, 2015).

Figure 2.25: Clothes insulation diagram (I clo = 0.155m2 K/W), from Webdelson.com (2014)

iii. Radiation

Radiation involves heat exchange between the human body and nearby surfaces, such as walls, windows, and even the sky and sun when outdoors. Unlike conduction or convection, factors like temperature, humidity, and air movement have minimal influence on the amount of heat transferred through radiation. Instead, the process is mainly determined by the temperature difference between the skin and surrounding surfaces. Depending on whether the environment is cooler or warmer than the body, heat can either be absorbed or released. When the temperature of the surrounding air and surfaces rises above 25°C, a person in clothing may struggle to release enough heat through conduction, convection, or radiation (Abubaka, 2015).

2.3.7PASSIVE DESIGN PRINCIPLES OF BUILDINGS:In passive design, energy flows naturally through processes like radiation, conduction, or convection without relying on electrical devices. According to Taleb (2014), creating a comfortable indoor environment in hot climates hinges on minimizing heat gains and facilitating the removal of excess heat. The core principle of passive cooling is to prevent heat from entering the building or to eliminate it once it has. This relies on two key conditions: having a heat sink that is cooler than the indoor air and promoting heat transfer to this sink. As outlined in Table (2014), the main environmental heat sinks include:

1. Outdoor air: Heat is transferred mainly by convection through openings.
2. Water: Heat is removed by evaporation inside or outside the building envelope.
3. The night sky: Heat is released through long-wave radiation from the roof or other adjacent surfaces.
4. Ground: Heat is transferred through conduction via the building envelope.

The principles of passive design are elaborated on in the sections that follow.

2.3.8SOLAR SHADING:Effective sun control and shading devices, whether integrated into a building or positioned separately from its facade, can significantly reduce peak heat gain and cooling needs while enhancing the quality of natural light inside. According to Kumar (2005), solar shading can lead to an indoor temperature reduction of approximately 2.5°C to 4.5°C. Their research highlights that solar shading plays a crucial role in passive architecture, helping to keep indoor air temperatures lower than those in conventional buildings without shading.

The study also evaluated various solar passive cooling techniques, including solar shading, insulation of building components, and the rate of air exchange. It was found that solar shading alone can lower indoor temperatures by about 2.5°C to 4.5°C. When combined with insulation and controlled air exchange, the temperature reduction increased to between 4.4°C and 6.8°C. This suggests that solar shading is an effective strategy for passive cooling, maintaining indoor temperatures lower than those of buildings lacking shading (Abubaka, 2015).

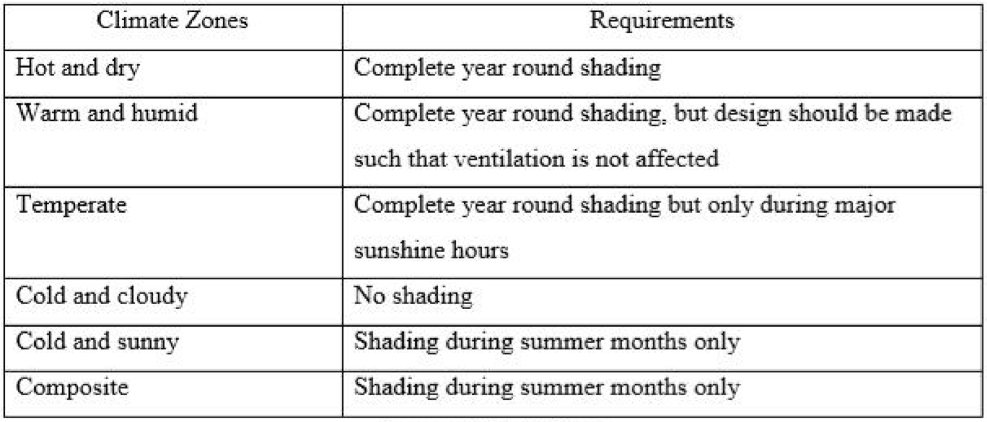
While shading the entire building is beneficial, focusing on window shading is particularly important. The total solar load includes three elements: direct, diffuse, and reflected radiation. To avoid unwanted passive solar heating, it’s essential to explore various shading methods that contribute to natural cooling and energy conservation. Windows should always be shaded from direct solar radiation and often from diffuse and reflected radiation as well. The timing and placement of shading devices can significantly influence the comfort level within a space. Here are some effective shading methods:

- Recesses in the building's external envelope can provide shade.

- Static or movable external blinds or louvres can offer shading.
- Building orientation can create transient shading on its external walls.
- Surrounding buildings, screens, or vegetation can provide permanent or transient shading.
- Roofs can be shaded using reflective materials, earthen pots, or vegetation.

Additionally, the research outlines different shading criteria tailored to various climatic zones as indicated by Bansal.

Table 2.3 outlines various shading techniques suitable for different climatic zones



Climate Zones	Requirements
Hot and dry	Complete year round shading
Warm and humid	Complete year round shading, but design should be made such that ventilation is not affected
Temperate	Complete year round shading but only during major sunshine hours
Cold and cloudy	No shading
Cold and sunny	Shading during summer months only
Composite	Shading during summer months only

Source: Maleki, 2011

, as highlighted by Kamal (2012). These methods include:

1. Using overhangs, louvers, and awnings to provide shade.
2. Roof designs that offer natural shading.
3. Incorporating trees and vegetation to create shaded areas.

These strategies help manage solar exposure effectively across various environments.

2.3.8.1According to Kamal's (2012) study, "Shading by Overhangs, Louvres, and Awnings," sun shading devices ought to be installed in accordance with the sun's path. The optimal shading device design will rely on the building facade's solar orientation. In tropical nations, the best sun shading device type and location are projected canopies at the top of east and west windows and protruding fins at the north and south windows' sides. However, during summer's peak heat gain periods, the same horizontal

Well-thought-out sun control and shading elements, integrated into the structure or positioned apart from its facade, can significantly lower the peak heat gain and cooling requirements of a building while also enhancing the interior natural lighting conditions. The solar direction of a given building facade will determine how shading devices are designed to be effective. For instance, in the summer, when sun angles are strong, simple permanent overhangs work incredibly well to shade windows facing south. Nevertheless, during summer's peak heat gain periods, the same horizontal device is useless at preventing the late afternoon light from entering west-facing windows. Shading devices can be categorized as follows:

1. Movable Opaque Devices: Examples include roller blinds and awnings. These reduce heat from the sun but may limit airflow and obstruct the view.
2. Louvres: These can be either adjustable or fixed. They offer shade from sunlight while allowing some air movement.
3. Fixed Shading: Structures like overhangs (or Chajjas) provide consistent protection to walls and windows against both sun and rain.

Figure 2.24 shows the different types of shading devices.

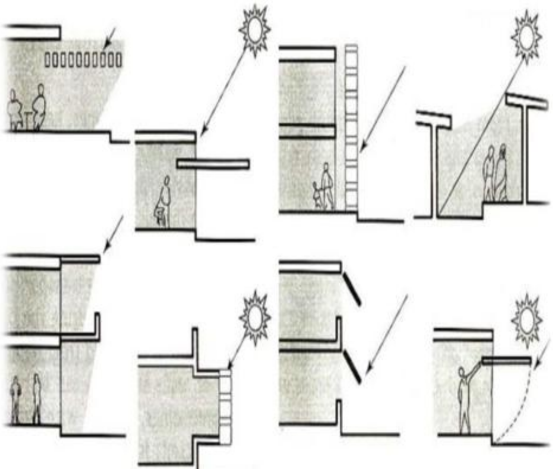


Figure 2.26 Different types of shading devices. Source: Kamal (2012)

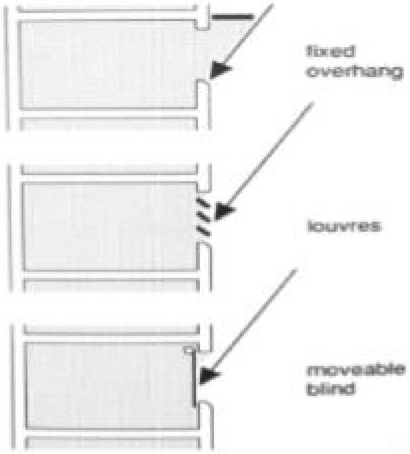


Figure 2.27. Different types of shading devices Source: Maleki, 2011

Solar control devices serve two main purposes:

1. They minimize the amount of sunlight entering a room by reflecting and absorbing the radiation.

2. They enhance the way light is distributed within the space, creating a more balanced and comfortable indoor environment.

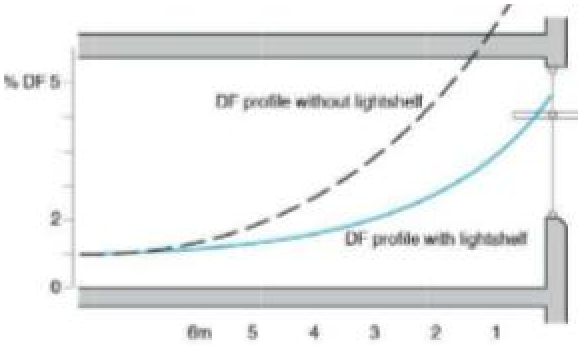


Figure 2.28. A light shelf obscures sunlight to the front of the room whilst reflecting light to the back of the room, (Maleki, 2011).

A light shelf helps control sunlight by blocking it from reaching the front of the room while reflecting it towards the back, thereby reducing solar gain by at least half without sacrificing daylight levels. Light shelves can be placed externally, internally, or mid-pane, each offering distinct advantages and disadvantages.

The term "greenhouse effect," originally unrelated to global warming, describes how short-wavelength solar radiation passes through transparent glass into a room. The room's surfaces absorb this radiation, heat up, and emit long-wavelength radiation that the glass does not allow to escape, trapping the energy inside.

External shading devices are the most thermally efficient because they block solar energy before it enters the room, preventing it from being trapped behind the glass. However, they must be weather-resistant and can be harder to manage from indoors.

Internal shading is usually less expensive to install and easier for occupants to control but is not as effective in blocking heat.

Mid-pane shading devices have become more popular as technical challenges have been resolved. They can now be integrated into sealed, gas-filled double glazing units, with louvres controlled via magnetic linkages. These devices combine the benefits of both external and internal shading and are particularly effective in double-skin buildings. In such setups, they are well-protected, and the large cavity allows for independent ventilation, removing any absorbed solar heat.

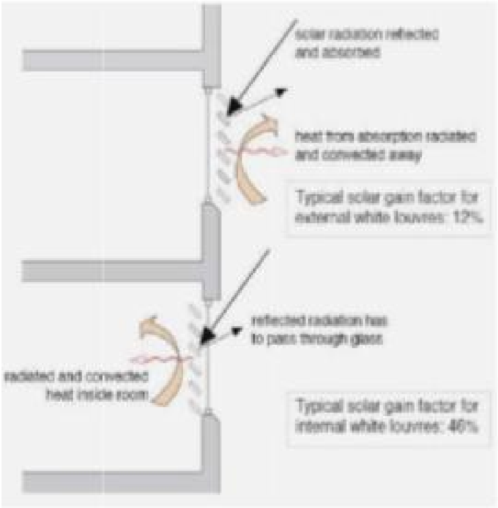


figure 2.29. An analysis of internal and external shading (Maleki, 2011)

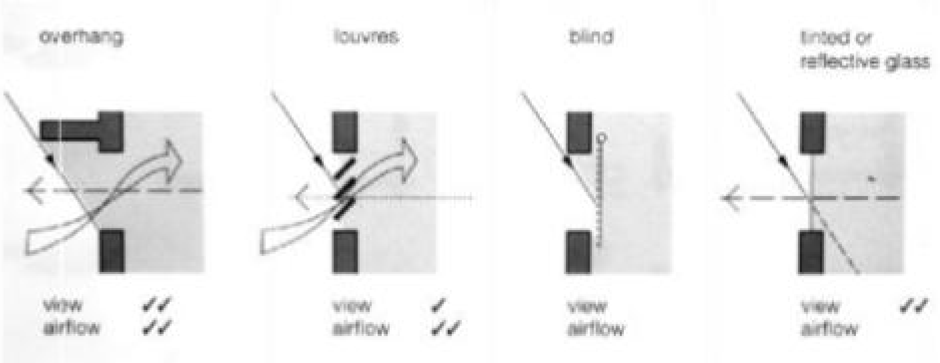


Figure 2.30. The effects of different forms of shading on ventilation and vision Meneki (2011) as the source

2.3.9.2 Roof shading is an essential technique for minimizing heat gain. Various methods can be used, such as covering the roof with materials like concrete, plants, canvas, or even traditional earthen pots. However, it's important that these shading solutions do not hinder the cooling of the building during the night (Kamal, 2012).

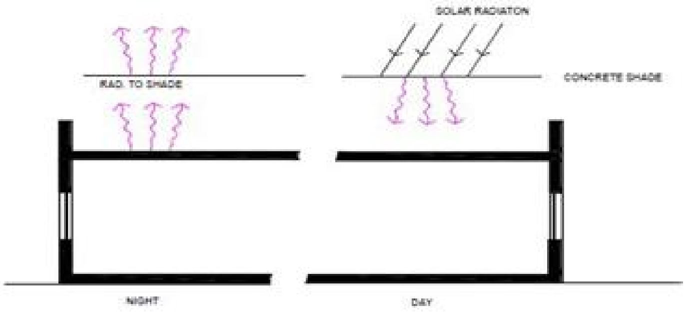


Figure 2.31: Roof shading by solid cover. Source: Kamal (2012)

One common approach is using concrete or galvanized iron sheets to shield the roof from direct sunlight. While effective during the day, this method can trap heat at night, preventing it from dissipating. Naresh (2014) suggests that using deciduous plants or creepers is a more efficient alternative. The evaporation from their leaves cools the roof, keeping its temperature lower than the surrounding air during the day, and even cooler than the night sky after sunset.

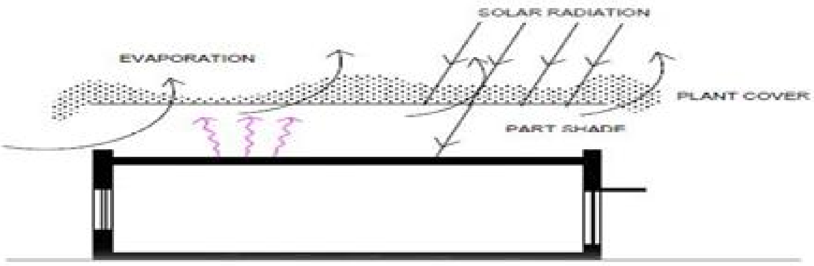


Figure 2.32: Roof shading by plant covers, (Kamal (2012)

Another traditional method involves placing closely packed inverted earthen pots across the roof. This increases the surface area, enhancing radiative cooling. Insulating covers can also block heat from entering the building, but they make the roof space less functional and harder to maintain.

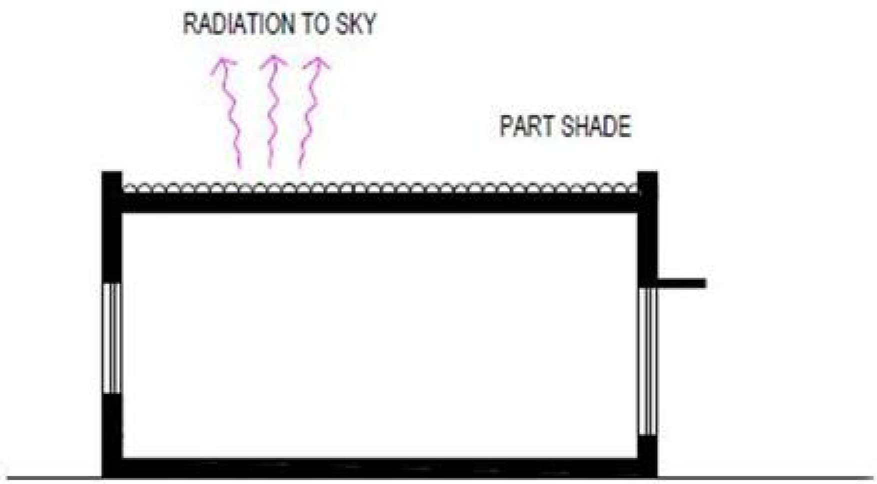


Figure 2.33: Roof shading by earthen pots. Source: Kamal (2012).

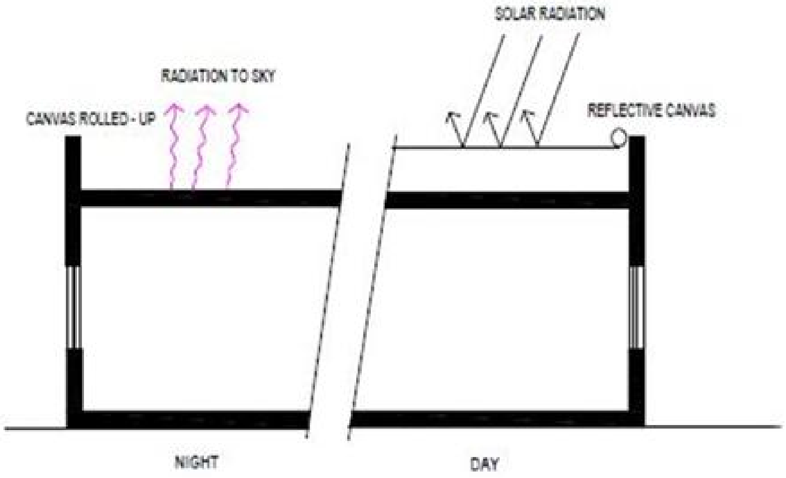


Figure 2.34: Removable roof shades. Source: Kamal (2012)

Alternatively, reflective surfaces like broken china mosaic or ceramic tiles can be added to the roof to deflect sunlight. A more affordable and versatile option is using a removable canvas cover. During the day, it blocks heat, and at night, removing it allows the roof to cool. Painting the canvas white further reduces heat absorption by minimizing both radiative and conductive heat gain (Kamal, 2012; Kumar et al., 2005).

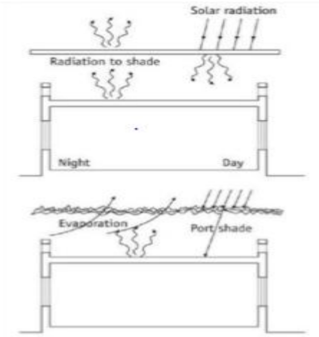


Figure 2.35. Some methods of shading the roof

Source: Maleki, 2011

2.3.9.3 Effective landscaping plays a vital role in energy conservation for buildings. Trees and other vegetation can greatly reduce heat gain by providing natural shade. Strategically planting trees can offer shade to roofs, walls, and windows, effectively lowering indoor temperatures. The cooling effect from vapor-transpiration, where plants release water vapor, can decrease the surrounding air temperature by up to 5°C. By selecting different types of plants—such as trees, shrubs, and vines—based on their growth characteristics (tall, low, dense, or light-permeable), it's possible to achieve the desired level of shading for different window orientations and building conditions.

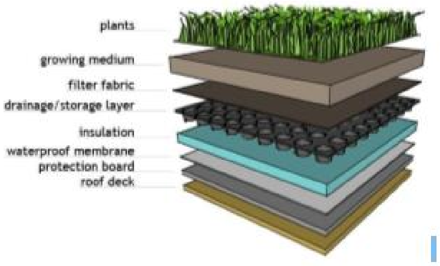


Figure 2.36. Some methods of shading the roof Source: Maleki, 2011

Kamal (2012) suggests the following considerations for effective summer shading:

1. Deciduous Trees and Shrubs: These provide shade during summer while allowing sunlight to penetrate during winter when they shed their leaves. The ideal placement for deciduous trees is on the south and southwest sides of a building, enabling winter sunlight to warm the interior.
2. Dense Foliage Trees: Trees with thick canopies effectively block sunlight and create a cool, dense shade. High-branching trees can be used to shade roofs, walls, and windows.
3. Evergreen Trees: Planting evergreens on the south and west sides offers protection from the intense summer sun and shields against cold winter winds.
4. Vertical Shading: For east and west-facing walls and windows, vertical shading is effective against the low-angle sun in summer. This can be achieved using dense shrubs, trees, or deciduous vines on frames, as well as a combination of shrubs and trees.
5. Wall Shading and Insulation: Climbing plants, like English ivy, can adhere to walls, or be supported nearby, like jasmine, to provide both shading and insulation.
6. Horizontal Shading: This is most effective for south-facing windows. Deciduous vines, such as ornamental grape or wisteria, can be grown over structures like pergolas to provide summer shade while allowing sunlight through during the winter.

2.3.10The choice of building materials for the envelope plays a crucial role in achieving thermal comfort. Heat gain, heat loss, and airflow within a building are greatly influenced by the components of the building envelope, which include walls, roofs, windows, and surface finishes.

Buildings with high thermal mass can absorb, store, and gradually release heat, which helps to maintain a steady internal temperature. The goal of using materials with high thermal mass is to lower peak daytime temperatures and raise nighttime temperatures, creating a more comfortable environment. In warm climates, massive construction is beneficial as it moderates indoor temperatures. However, to prevent discomfort from heat retained in thermal mass at night, additional ventilation can be integrated into the design.

High thermal mass construction is most effective in areas with significant temperature variations between day and night (high diurnal ranges). In regions with low diurnal ranges, it is less beneficial. In hot climates, insulation is applied to the outer surface of walls or roofs, which decouples the wall's thermal mass from external heat while linking it to the interior, thereby improving indoor comfort. For instance, using 40 mm thick expanded polystyrene insulation on walls and vermiculite concrete insulation on roofs reduced energy consumption for space conditioning by about 15% in a retreat building in Gurgaon (Majumdar, 2001).

Additionally, air cavities within walls or in the roof-ceiling combination can minimize solar heat gain, reducing the demand for cooling. This effect is enhanced when the voids are ventilated, as heat is transferred through these cavities by convection and radiation.

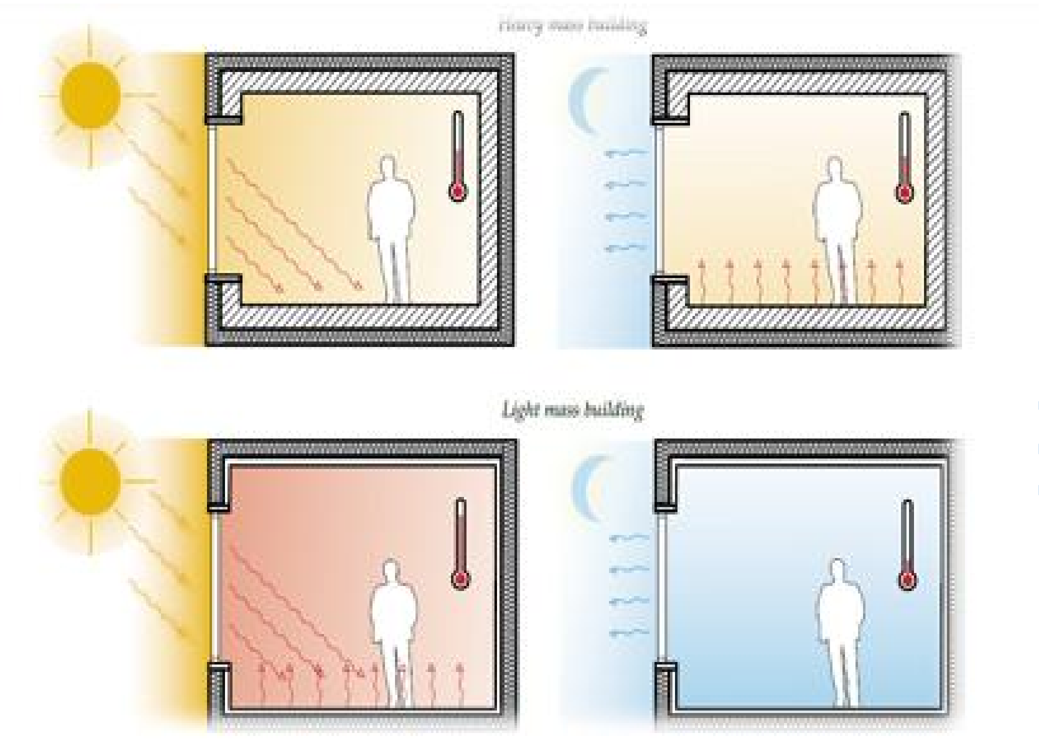


Figure 2.37: Effects of thermal mass Source: Mikler et al. (2008)

2.3.10.1.1Buffer spaces, like double facades and sunspaces, are positioned along the building's perimeter and can be designed as either occupied or unoccupied, and as semi-conditioned or unconditioned areas. These spaces enhance a building's energy efficiency by expanding the range of outdoor temperatures in which indoor comfort can be achieved with minimal mechanical energy use. Buffer spaces are particularly useful in winter, as they add an extra layer of insulation, reducing heat loss between the outside and the interior. Ideally, they can be converted to open, exterior spaces in the summer to facilitate ventilation and cooling of adjacent indoor areas. See Figures 2.31 and 2.32.

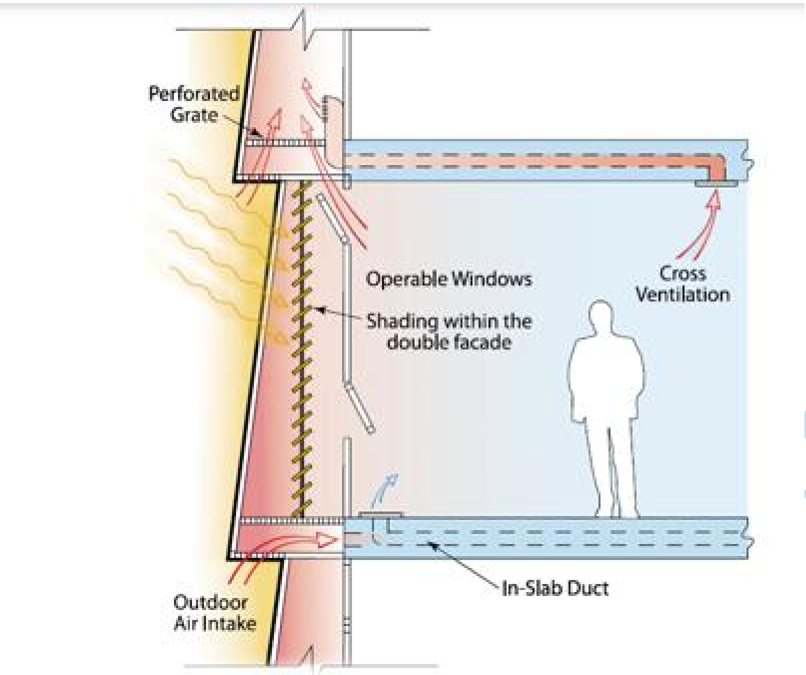


Figure 2.38: Double facade as buffer space (summer performance) Source: Mikler el al. (2008)

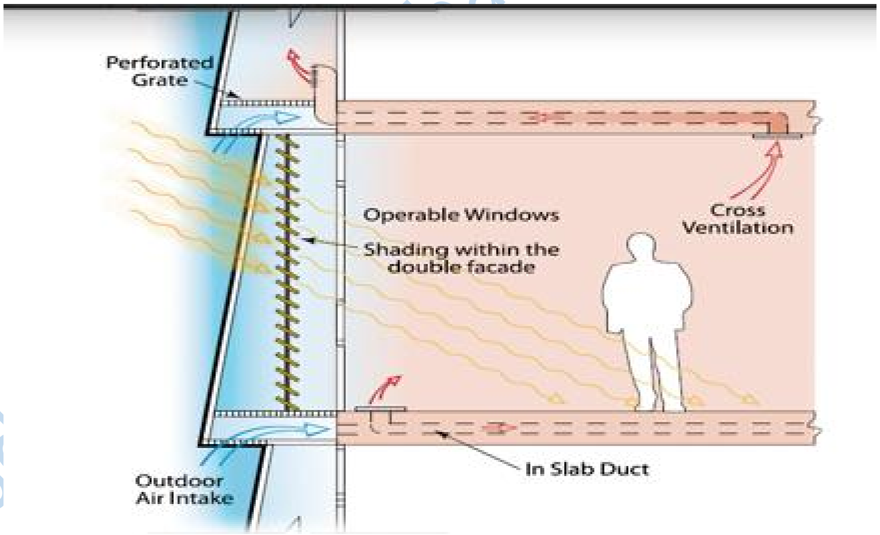


Figure 2.39: Double facade as buffer space (winter performance) Source: Mikler el al. (2008)

2.3.11Induced Ventilation Techniques: One of the main methods for cooling buildings in hot climates without relying on mechanical systems (known as passive cooling) is to utilize natural ventilation. This process involves replacing the air in a space to improve indoor air quality, which helps control temperature, replenish oxygen, and remove moisture, odors, dust, and carbon dioxide. Several techniques are used to create induced ventilation in buildings, including:

1. Solar Chimneys: Structures that harness solar energy to promote airflow.
2. Air Vents: Openings that allow air to circulate in and out of a building.
3. Wind Towers: Architectural features designed to capture and direct wind into the building.

2.3.11.1 A solar chimney is a modern system designed to enhance natural ventilation by using the thermal buoyancy effect. During the day, the chimney absorbs solar energy, heating the air inside it, which causes the warm air to rise. This rising air creates a vacuum that draws cooler air from the building into the chimney through an opening at its base. As the hot air is expelled from the house, it is replaced by ambient air from outside (Figure 2.33).

However, in hot climates, the outside air is often warmer than the indoor air during the day. If the solar chimney continues to operate in such conditions, it may inadvertently heat the building that was cooled overnight (Barbera et al., 1984).

Despite this, solar chimneys effectively expel hot air quickly, enhancing the cooling potential of incoming air through other openings in the building. With relatively low construction costs, solar chimneys can move air without relying on traditional energy sources, contributing to nighttime cooling and overall comfort. They can also improve daytime comfort when combined with evaporative cooling devices (Taleb, 2014).

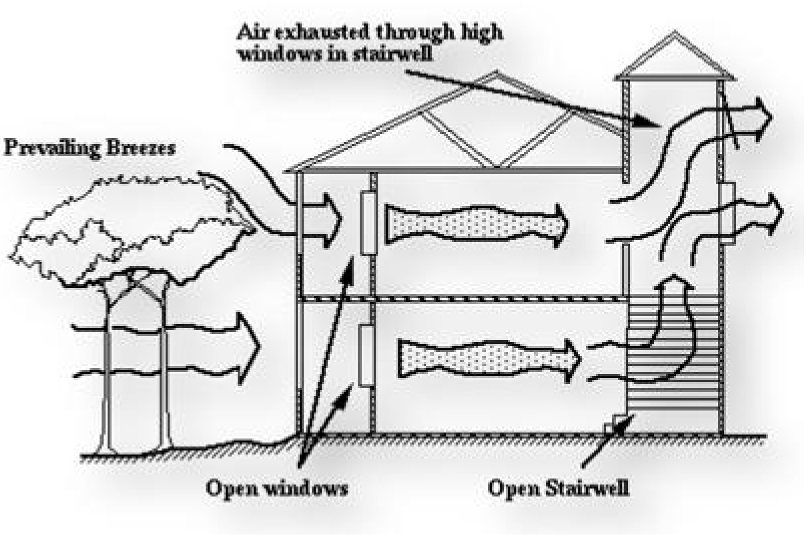


Figure 2.40: Thermal chimney effect built into a building Source: Taleb (2014)

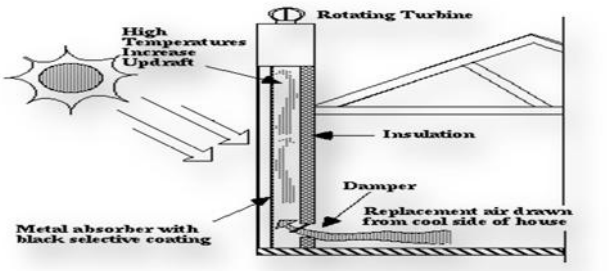


Figure 2.41: Solar Chimney Source: Taleb (2014)

2.3.11.2 Air vents, particularly when combined with curved roofs, are an effective method for passive cooling in hot and dry climates, where dusty winds can make wind towers less effective. This system is ideal for individual units and works well in both hot, dry, and warm, humid climates.

The design features a hole at the peak of a domed or cylindrical roof, covered with a protective cap that directs wind over the vent (Figure 2.35). This opening allows for ventilation and provides a way for hot air to escape from the top of the structure. Additionally, arrangements can be made to draw in cooler air from the lowest parts of the building to maintain continuous airflow and cool the living areas. The system operates based on the principle of induced ventilation, relying on pressure differences to facilitate air movement.

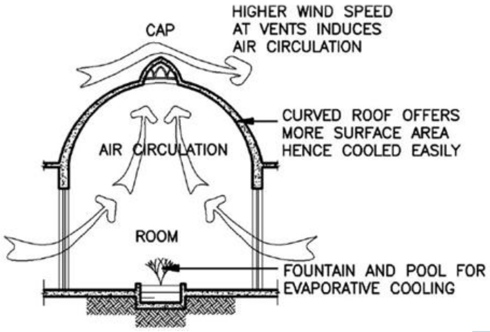


Figure 2.42: Induced ventilation through curved roof and air vents Source: Taleb (2014)

2.3.11.3 A wind tower functions by allowing hot ambient air to enter through openings in the structure, where it gets cooled and becomes denser, causing it to sink. This movement of air helps induce cool airflow into the rooms. When there is an inlet in the rooms paired with an outlet on the opposite side, a draft of cool air is created. The design is similar to a chimney, with one end reaching the basement or lower floor and the other extending to the roof.

The upper section of the tower is divided into several vertical air channels that open to the sides of the tower (Figure 2.12). When wind is present, it enhances the cooling effect and accelerates the airflow down the tower and into the living spaces. This system is particularly effective in hot and dry climates, where there are significant temperature fluctuations between day and night.

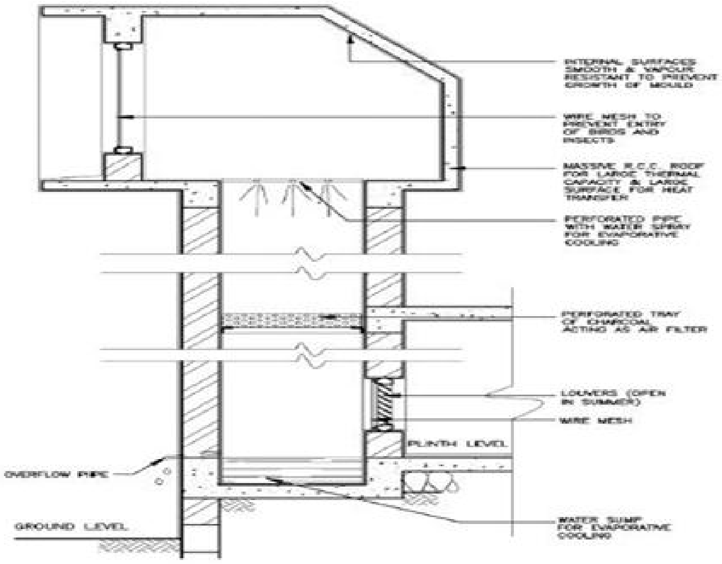


Figure 2.43 : Section and detail of a wind tower. Source: Taleb (2014)

2.3.12Evaporative Cooling: According to Ford (2001), evaporative cooling is a passive architectural method that involves cooling outdoor air through the evaporation of water before it enters a building. The principle behind this process is that the heat from the air is used to evaporate water, which cools the air and, in turn, cools the living spaces within the building.Passive evaporative cooling can also occur indirectly. For example, a roof can be cooled using a pond, wet pads, or sprays. This approach allows the ceiling to act as a cooling element, lowering the temperature of the space below through convection and radiation without increasing indoor humidity.

2.3.12.1 Passive Downdraft Evaporative Cooling: Passive downdraft evaporative cooling systems feature a tower that contains wetted cellulose pads at the top. Water is distributed over these pads, where it collects at the bottom and is then recirculated by a pump. Some designs eliminate the need for a recirculation pump by utilizing the pressure from the water supply line to periodically surge water over the pads, which means they don't require any electrical energy.

In certain models, water is sprayed through micronizers or nozzles instead of using pads, while in others, it simply drips down. These towers are designed to create cool air that flows down by gravity.

Often referred to as reverse chimneys (Figure 2.37), these towers work oppositely to traditional chimneys. Instead of warm air rising, cool air descends. The airflow rate is influenced by several factors, including the efficiency of the evaporative cooling device, the height and cross-section of the tower, and any resistance to airflow within the cooling system, tower, or the building itself (Thompson et al., 2006).

An example of this technology's successful application is at the Torrent Research Centre in Ahmedabad. According to an evaluation by Leena and George (2007), the indoor temperatures were recorded between 29 and 30 °C while the outside temperatures reached 43 to 44 °C. The system achieved six to nine air changes per hour across different floors. See Plate I.

Plate I: Torrent Research Centre in Ahmedabad. Source: Thompson et al. (2006)

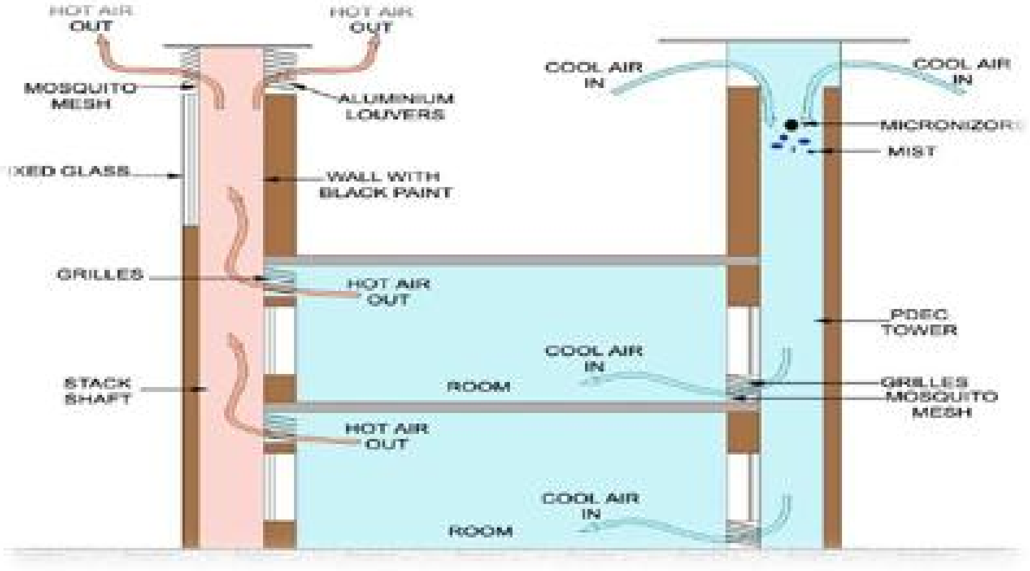


Figure 2.44: Passive downdraft evaporative cooling tower. Source: Thompson et al. (2006)

2.3.12.2 Roof Surface Evaporative Cooling: In tropical countries, roofs absorb a significant amount of solar radiation during the summer, which can lead to excessive heat buildup in the rooms below. One effective and cost-efficient way to cool roof surfaces is by spraying water over water-retentive materials, like gunny bags, placed on the roof. This wet roof surface allows evaporation to occur as the unsaturated air absorbs moisture. As the water evaporates, it extracts the necessary latent heat from the roof surface, lowering its temperature and reducing heat gain in the building.

However, one major challenge with this method is the high water demand it requires, making it less feasible in arid regions where water is scarce. (Kumar 2005).

2.3.14Building Orientation: Bhatia (2008) points out that since the sun is positioned lower in the sky during winter compared to summer, we can design buildings to capture heat from the sun in winter while keeping it out in summer. The building's orientation is crucial; for hot and dry climates, the ideal approach is to align the long axis of the building along the East-West direction, as illustrated in Figure 2.14. This orientation helps to minimize heat gain.

In contrast, buildings with a north/south orientation experience higher peak cooling loads, necessitating larger cooling systems and resulting in increased energy costs. Various site factors can influence passive design, including urban planning elements, the building's orientation on the site, shading from surrounding structures, wind patterns, proximity to industrial areas, noise levels, and the character of the neighborhood. All these considerations are essential for optimizing passive design strategies, and some may lead to design conflicts.

Therefore, the significance of building orientation should be a primary consideration during the initial planning stages, as it plays a vital role in maximizing occupant comfort within the interior spaces.

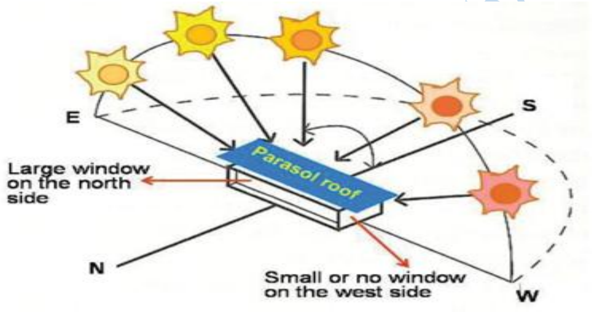


Figure 2.45: Perfect orientation of building Source: Koch- Nelson (2002)

2.3.15 Building Form: The shape of a building can significantly impact its energy efficiency, but various factors, including planning considerations, building type and purpose, feasibility, and initial costs, often influence design decisions. Certain building shapes, such as tall, slender towers, can lead to a higher envelope area-to-volume ratio, which may reduce energy performance in buildings that primarily require heating. In contrast, buildings with a more compact form tend to have a smaller exterior surface area, resulting in better energy efficiency for the same floor space.

A compact shape effectively lowers the building's energy intensity and reduces the reliance on mechanical systems (Mikler et al., 2008). Holtz (n.d.) noted that elongated building designs are particularly advantageous for passive solar structures, especially those that utilize daylight. An elongated building can reduce energy consumption by 15-25% compared to a compact design of the same size, thanks to its improved daylight access. Additionally, Rosenlund (2000) emphasized that the shape of the roof is crucial in passive design. Cylindrical and dome roofs have a higher heat transfer coefficient and a larger surface area than flat roofs with the same base. While the area absorbing solar energy is similar, the curved roofs offer a greater convection heat transfer area.

Chapter Three:

Methodology (Case Study)

3.1. Research Design: The research design outlines the overall strategy for integrating different components of the study in a clear and logical manner, ensuring effective resolution of the research problem. It serves as a blueprint for collecting, measuring, and analyzing data. In this study, I utilized an exploratory research approach.

3.2. case study method

Data for the research was collected from both primary and secondary sources. Primary sources included a comparative case study analysis of buildings featuring passive design strategies, both within Nigeria and internationally. Key information was derived from the master plan of Lead City University and relevant guidelines from the National Universities Commission.

A thorough investigation was conducted using the internet, academic books, past unpublished theses, architectural journals, photographs, papers, and case studies to understand the contributions of similar facilities worldwide. Extensive field research was also performed, which involved site visits to study existing conditions and conducting relevant surveys. Photographs and personal observations were documented, along with an analysis of climatic data to determine how to effectively incorporate passive design techniques into the existing environment.

3.2.1Sources Of Data

A. Primary Sources

The primary data sources for this research include:

1. Architectural drawings and specifications.
2. Direct observations of how different elements function in relation to users.
3. Identification of elements that may not be apparent from floor plans.

B. Secondary Sources

The secondary data sources for this research comprise:

1. Books
2. Journals

3.2.1. Case Study Selection Criteria

The case studies were intentionally chosen based on their status as Faculties of Architecture that integrate passive design strategies in their building designs. These strategies were evaluated to determine their suitability for the proposed design. The strategies examined include:

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

3.3. Case Studies Analysis

Analyzing case studies involves investigating a problem, exploring different solutions, and proposing the most effective option supported by evidence. Studying existing works in the relevant research area is crucial for success. This thesis conducts an in-depth examination of academic buildings both locally and internationally, focusing on the use of passive design strategies. This analysis aims to identify areas for improvement where current designs may fall short.

3.3.0. Case Study 1: University of Kigali, Rwanda

- Project: Faculty of Architecture and Environmental Design
- Client: University of Kigali, Rwanda
- Architects: Patrick Schweitzer & Associates
- Date: 2017
- Location: The Faculty of Architecture and Environmental Design is situated on the main campus of the University of Kigali in Rwanda.

3.3.1. Description of the Building

The design of this building stems from a comprehensive site analysis. Its architecture draws inspiration from the local landscape, incorporating colors and shapes found in nature. The four natural elements are symbolically represented in the building's conception: fire is depicted through the use of orange colors, water is represented by an inner garden, air is embodied in the circulation spaces, and earth is reflected through the use of lava rock and rammed earth materials.

The design features prisms inspired by the Rwandan landscape and topography, which have been segmented to create fault lines and canyons. A prominent central fault line forms an outdoor living space, connecting the project to the KIST entrance, the surrounding valley, and the city beyond.

3.3.1.1. SITE PLANNING AND LANDSCAPING

Plate 3.3.1 Case Study 1: Site plan and landscape of the university of kigali, rwandaSource: ArchDaily (2024)

3.3.1.2. Building Envelope and Material Types

The building envelope is primarily constructed from stone and various forms of concrete. The window frames and doors are made from materials like aluminum and composite materials. Additionally, specialty coatings, tints, and gases are often used on the glass in both windows and doors to enhance their performance.

Plate 3.3.2 Case Study 1: Interior of the university of kigali, rwandaSource: ArchDaily (2024)

Plate 3.3.3 Case Study 1: Exterior southwest side of the university of kigali, rwandaSource: ArchDaily (2024)

3.3.1.3. Building and Forms

In architectural design, "form" refers to the geometric shapes that make up a building, encompassing both its internal spaces and its exterior, as well as the outdoor living areas. The fundamental shapes include circles, triangles, and squares, along with their variations. Additionally, three-dimensional shapes and overall appearances are also considered forms, with the primary shape of this building being square.

Plate 3.3.4 Case Study 1: Site landscape of the university of kigali, rwanda,(ArchDaily 2024)

3.3.2. Appraisal of The Building

An appraisal assesses a building's value to ensure that its price accurately reflects its condition, age, location, and features, such as the number of bathrooms. This process also helps banks and lenders prevent lending more money than the property is actually worth.

3.3.2.1university Of Kigali,Rwanda Observation Guide

Table 3.1: Summary Of Findings In Relation To Passive Design

PASSIVE DESIGN STRATEGIES	ADEQUATE	NOT ADEQUATE	AVAILABLE	NOT AVAILABLE
Orientation	✓			

Form		✓		
Thermal Mass			✓	
Natural Ventilation	✓			
Atrium		✓		
Stack Ventilation		✓		
Shading Device				✓
courtyard			✓	
Thermal insulation		✓		
Evaporative cooling		✓		
Buffer space			✓	
Landscape		✓		

At the University of Kigali in Rwanda, Table 3.1 indicates that passive design strategies have been implemented; however, there is a noticeable absence of shading devices in the design. This suggests that the potential benefits of incorporating shading devices into passive design strategies have not been fully realized.

3.3.2.2 Advantages and Disadvantages

Advantages:

- The well-developed road network enhances accessibility.
- The building benefits from ample natural lighting.
- There is effective natural ventilation.

Disadvantages:

- The landscaping is not well executed.

3.3.3. Case Study 2

University of Istanbul, Turkey

- Project: Faculty of Architecture
- Client: University of Istanbul
- Architects: ARK-itecture, BG Architects
- Date: 2020
- Location: The Faculty of Architecture is situated on the main campus of the University of Istanbul in Turkey.

3.3.3.0 Description Of The Building

The Faculty of Architecture and Design Building at Özyeğin University represents the culmination of ten years of planning and design work by ARK, a design studio founded by architect Roger L. Klein, AIA. He collaborated with local firm BG Architects on this project. Designing a building specifically for the study of architecture and design is a unique opportunity for any architect. The challenge of creating a building with high aspirations on a limited budget made this project both ambitious and a significant achievement.

3.3.3.1.SITE PLANNING AND LANDSCAPING

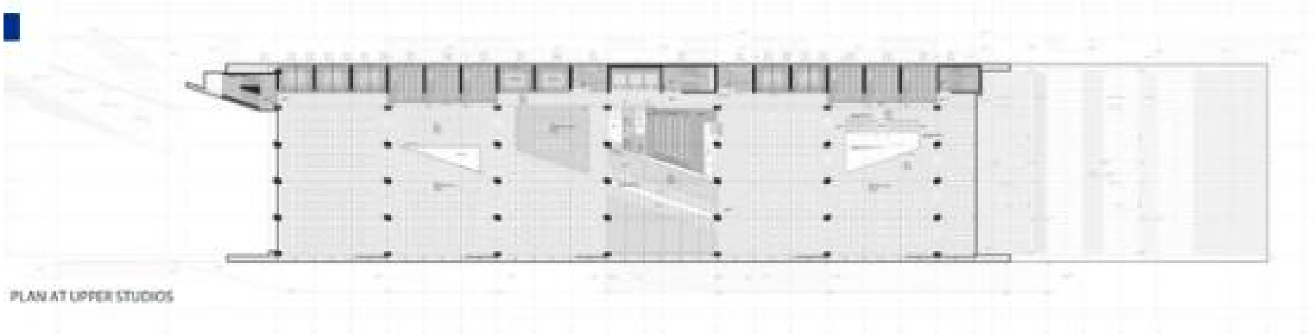


Plate 3.3.5 Site plan and landscape of the university of Mendoza, (ArchDaily 2024)

3.3.3.2. Building Envelop And Material Types

The foundation of the building envelope is primarily made of stone, brick, or concrete. The window frames and doors are typically constructed from a variety of materials, including aluminum, composite materials, fiberglass, vinyl, and wood. Additionally, specialty coatings, tints, and gas fills are often applied to the glass used in the windows and doors to enhance their performance

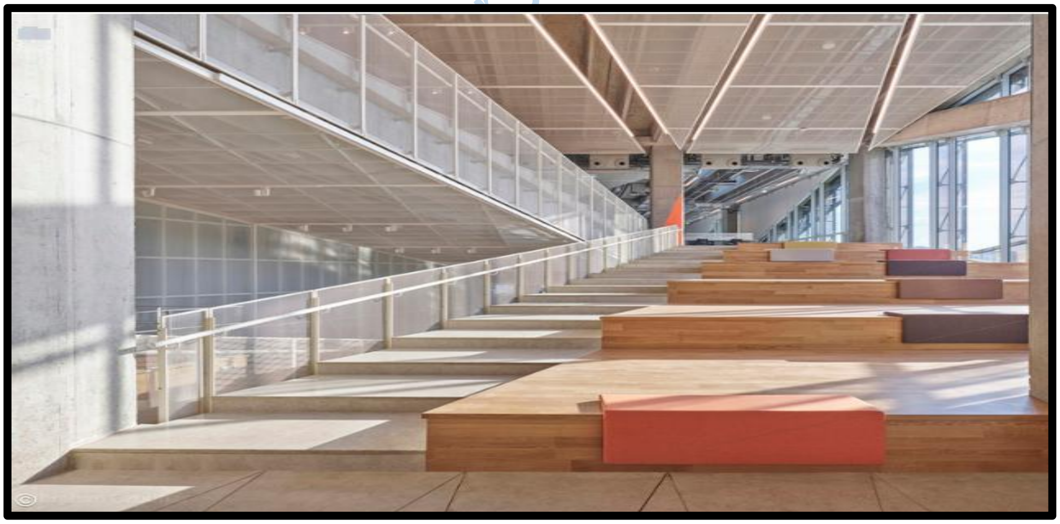


Plate 3.3.6 Case Study 2: Corridor of the university of istanbulSource: ArchDaily (2024)

Plate 3.3.7 Case Study 2: Exterior envelopes of the university of istanbulSource: ArchDaily (2024)

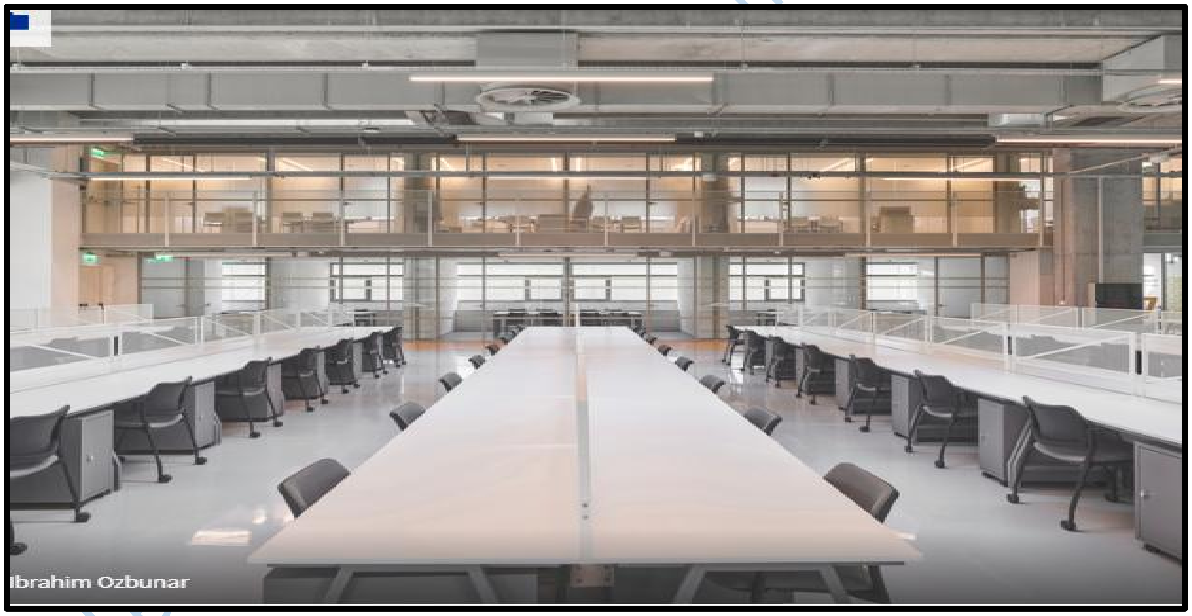


Plate 3.3.8 Case Study 2: Interior of the university of istanbulSource: ArchDaily (2024)

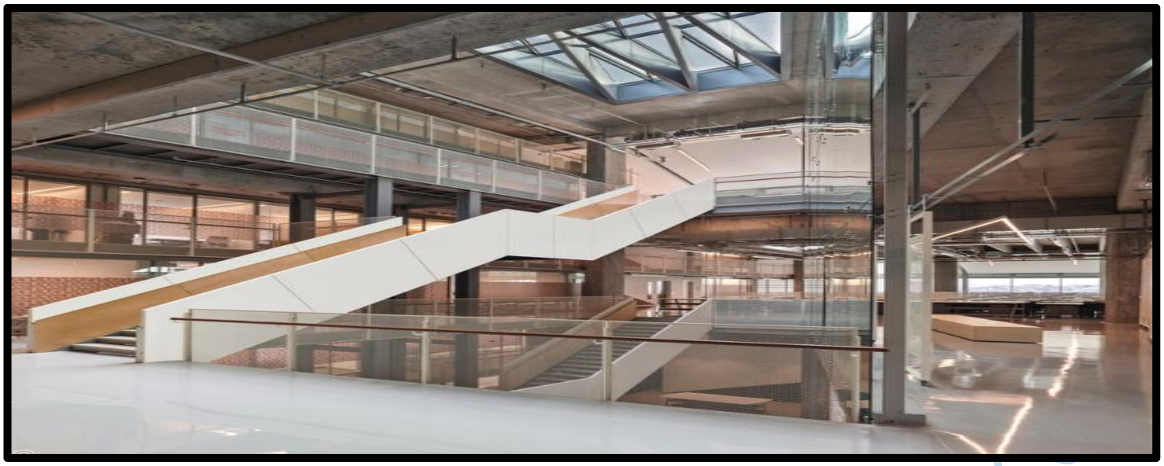


Plate 3.3.9 Case Study 2: Interior of the university of istanbulSource: ArchDaily (2024)

3.3.3.3. Building Forms

In architectural design, "form" refers to the geometric shapes that make up a building. This encompasses both the interior spaces and the exterior, including outdoor living areas. The basic shapes are circles, triangles, and squares, along with variations of these shapes. Additionally, three-dimensional shapes and appearances are also considered forms; in this case, the form being discussed is rectangular.

3.3.4. Appraisal Of The Building

An appraisal assesses the value of a property to ensure that its price accurately reflects its condition, age, location, and features, such as the number of bathrooms. This process also helps banks and lenders avoid lending more money than the property is worth.

3.3.4.1 Assessment Based On The Parameters Identified From Literature

University Of Istanbul, Turkey Observation Guide

Table 3.2: Summary Of Findings In Relation To Passive Design

PASSIVE DESIGN STRATEGIES	ADEQUATE	NOT ADEQUATE	AVAILABLE	NOT AVAILABLE
Orientation	✓			
Form		✓		
Thermal Mass			✓	
Natural Ventilation	✓			
Atrium		✓		
Stack Ventilation		✓		
Shading Device				✓
courtyard			✓	
Thermal insulation		✓		
Evaporative cooling		✓		
Buffer space			✓	
Landscape		✓		

At the University of Kigali in Rwanda, Table 3.2 indicates that while passive design strategies were integrated into the building's design, it notably lacks any shading devices. This absence suggests that the potential benefits of these passive design strategies are not being fully utilized.

3.3.4.2. Merits And Demerits

Merits:

- The building benefits from natural lighting.

- There is effective natural ventilation.
- The structure is both architecturally and structurally enhanced.
- The use of prefabricated materials for the building envelope increases structural integrity and provides some shading.

Demerits:

- The design lacks sufficient energy efficiency.

3.3.5. CASE STUDY 3: University of Mendoza

- Project: School of Architecture
- Client: University of Mendoza
- Architect: Enrico Tedeschi
- Date: 1960
- Location: The School of Architecture is situated on the main campus of the University of Mendoza in Mendoza, Argentina.

3.3.5.0. DESCRIPTION OF THE BUILDING

The facade of the Faculty of Architecture at the University of Mendoza is often described as resembling the organic shape of a tree, while others interpret it as depicting human figures. This building is considered a significant example of 1960s architecture in Argentina, holding substantial importance in the national and international architectural landscape. In 2015, it was selected for the exhibition "Latin America in Construction: Architecture 1955 to 1980" at the Museum of Modern Art (MoMA) in New York City.

3.3.5.1.SITE PLANNING AND LANDSCAPING

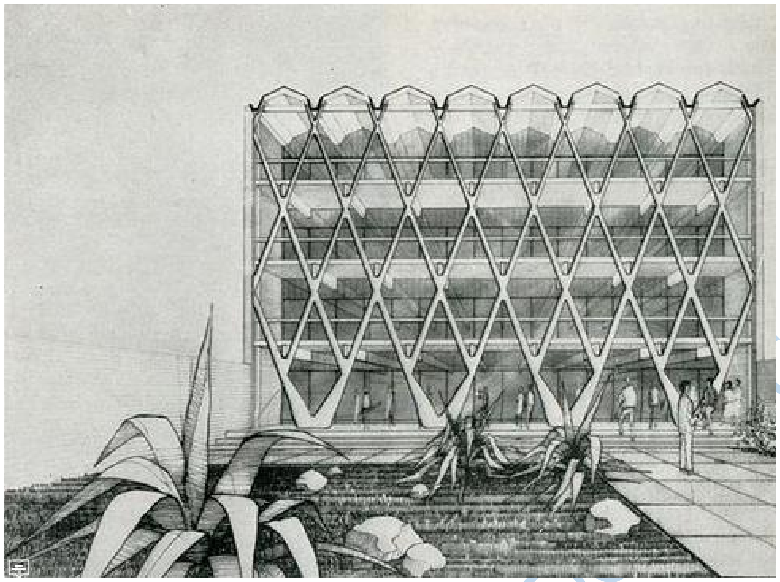


Plate 3.3.10 Site plan and landscape of the university of Mendoza(ArchDaily 2024)

3.3.5.2. BUILDING ENVELOP AND MATERIAL TYPES

The building's envelope is primarily made of stone, brick, or various types of concrete, along with prefabricated components. For the windows and doors, typical materials include aluminum, composite, vinyl, and wood. Additionally, specialty coatings and tints, along with gas fillings, are often used on the glass in both windows and doors.

Plate 3.3.11: Exterior envelopes of the university of MendozaSource: (ArchDaily 2024)

Plate 3.3.12 Case Study 3: corridor of the university of MendozaSource: ArchDaily (2024)

3.3.5.3 BUILDING FORMS

In architectural design, "form" refers to the geometric shapes that make up a building. This encompasses the internal spaces, the exterior design, and any outdoor areas. The basic shapes include circles, triangles, and squares, along with their variations. Additionally, the three-dimensional aspects and overall appearance also contribute to the building's form, which in this case is square.

Plate 3.3.13 Case Study 3: corridor of the university of MendozaSource: ArchDaily (2024)

3.3.6. Building Appraisal

An appraisal is an assessment that determines a property's value, ensuring that the price accurately reflects the building's condition, age, location, and features, such as the number of bathrooms. This valuation process is crucial for banks and lenders, as it helps prevent them from lending more money than the property is actually worth.

3.3.6.1Assessment Based On The Parameters Identified From Literature

University Of Mendoza Observation Guide

Table 3.3: Summary Of Findings In Relation To Passive Design

PASSIVE DESIGN STRATEGIES	ADEQUATE	NOT ADEQUATE	AVAILABLE	NOT AVAILABLE

Orientation	✓			
Form		✓		
Thermal Mass			✓	
Natural Ventilation	✓			
Atrium			✓	
Stack Ventilation		✓		
Shading Device	✓			
courtyard			✓	
Thermal insulation	✓			
Evaporative cooling			✓	
Buffer space	✓			
Landscape		✓		

Case Study Analysis: University of Kigali, Rwanda

According to Table 3.3, the University of Kigali has successfully integrated passive design strategies into its architecture. This demonstrates that the implementation of these strategies is effective and well-executed.

3.3.6.2 Merits and Demerits

Merits:

- The building benefits from natural lighting.
- There is effective natural ventilation.
- The structure has been improved both structurally and architecturally.

Demerits:

- The design lacks sufficient energy efficiency.
- The introduction of daylight is inadequate and does not fully align with passive design strategies.

3.3.7 Case Study 4: Federal University of Technology Akure

- Project: Departments of Architecture
- Client: University of Akure
- Architect: Adewale Afolami
- Date: 1997
- Location: The Department of Architecture is situated on the main campus of the Federal University of Technology Akure in Akure.

3.3.7.0 Description of the Building

The program at this department focuses on developing students who are not only skilled and creative but also ethical and socially responsible. It aims to produce well-rounded individuals who are intellectually mature, environmentally aware, and prepared to tackle a wide range of challenges related to the design and construction of various spaces.

3.3.7.1. Site Planning and Landscaping

Plate 3.3.14: Site plan and landscape of the Federal university of Technology, (ArchDaily 2024)

3.3.7.2. BUILDING ENVELOP AND MATERIAL TYPES

All that's needed for the building foundation is stone, brick or concrete. components Gases and window tints are frequently applied to any glass on windows and doors.

Plate 3.3.15: Exterior of federal university of Technology Akure, (Fieldwork2024)

Plate 3.3.16Exterior of Federal university of Technology Akure, (Field work 2024)

Plate 3.3.16 Exterior of Federal university of Technology Akure, (Field work 2024).

3.3.7.3. BUILDING FORMS: In architectural design, "form" refers to the geometric shapes that make up a building, encompassing both its internal spaces and external structure, including outdoor areas. The fundamental shapes include circles, triangles, and squares, along with their variations. Additionally, three-dimensional shapes and their overall appearance are also considered forms; in this case, the predominant shape is square.

Plate 3.3.13Exterior of the Federal university of Technology Akure, (ArchDaily, 2024)

3.3.8. BUILDING APPRAISAL

An appraisal determines the home's value to ensure that the price reflects the home's condition, age, location, and features such as the number of bathrooms. Also, valuations help banks and lenders avoid loaning more money to the borrower than the house is worth.

3.3.8.1assessment Based on The Parameters Identified From Literature

Federal University of Technology, Akure Observation Guide

Table 3.4: Summary of Findings In Relation To Passive Design

PASSIVE DESIGN STRATEGIES	ADEQUATE	NOT ADEQUATE	AVAILABLE	NOT AVAILABLE
Orientation	✓			
Form		✓		
Thermal Mass			✓	
Natural Ventilation	✓			
Atrium				
Stack Ventilation		✓		
Shading Device		✓		
courtyard			✓	
Thermal insulation		✓		
Evaporative cooling			✓	
Buffer space				✓
Landscape		✓		

At the University of Kigali in Rwanda, Table 3.4 indicates that passive design strategies were implemented; however, the design lacks adequate buffer space, which is a significant oversight. This suggests that the passive design strategies that incorporate buffer spaces are not being fully utilized.

3.3.8.2 Merits and Demerits

Merits:

- All the departments are interconnected, allowing for a smooth flow of space.
- The use of a courtyard enhances energy efficiency in the faculty building.
- The faculty is perceived as a cohesive unit.

Demerits:

- One of the courtyards is not large enough.
- The lobby area surrounding the faculty is narrow.
- Natural lighting in the building is insufficient.

Table 3.5: CASESTUDY SUMMARY SHEET

VARIABLES	CASE STUDY ONE UNIVERSITY OF KIGALI ,REWANDA	CASE STUDY TWO UNIVERSITY OF ISTANBUL	CASE STUDY THREE UNIVERSITY OF MENDOZA	CASE STUDY THREE FEDERAL UNIVERSITY OF TECHNOLOGY AKURE
Windows Ventilation/Air movement	Good	Excellent	Good	Good
Courtyard	Satisfactory	Satisfactory	Excellent	Excellent
Atrium	Satisfactory	Excellent	Satisfactory	Satisfactory

Orientation	Satisfactory	Good	Good	Good
Buffer space	Satisfactory	Satisfactory	Excellent	-
Landscape	Satisfactory	Satisfactory	Excellent	Good
Thermal mass	Satisfactory	Satisfactory	Excellent	Satisfactory
Evaporative cooling	Satisfactory	Satisfactory	Satisfactory	Satisfactory
Shading device	-	-	Good	Satisfactory

3.4 Case Study Synthesis

The synthesis of case studies differs from conducting meta-analyses of formal experiments with quantitative data. It requires considering the flexible nature of the case studies, the qualitative nature of the data, and the variety of cases examined in each primary study.

3.4.1 Common Spaces and Facilities

The Faculty of Architecture includes the following departments:

- Architecture
- Landscape
- Interior Design
- Furniture Design
- Architectural Technology
- Architectural Education
- Lecture Theatre
- Library

- Studio
- Offices
- Administrative Building
- Workshops
- Outdoor Spaces
- Computer Room
- Model Room
- Student Hall
- Conference Room

3.4.2 Special Spaces and Facilities

- Naval Architecture
- Swimming Pool

3.4.3 Deductions from Case Study

1. Incorporation of courtyards, buffer spaces, varied opening sizes, and landscaping.
2. Selection of materials that support passive design strategies.
3. Enhancement of energy efficiency through natural lighting and ventilation.
4. Development of economically viable low-energy buildings.

Chapter Four

Site Analysis and Design Synthesis

4.1 Study Area

Study areas are defined geographic boundaries used in research to outline the scope of your analysis. These boundaries are typically established at the beginning of a project to ensure that your data is focused on a specific region. In this case, the study area relates to the "integration of passive design strategies in the design of faculty buildings."

4.1.1 Site Location

The proposed site is situated on the main campus of Lead City University in Ibadan. The university's address is 8VGG+PJ8 Toll-Gate Area, off Oba Otudeko Avenue, Ibadan 200255, Oyo State. Lead City University is located near neighboring states, including Ogun State and Lagos State.

4.1.2 Site Selection Criteria

Selecting a site is a critical step in developing a supportive housing project, as it significantly influences the project's success. Generally, permanent financing and community backing can only be pursued after identifying and securing control over the site. Before starting the search for a site, it's essential to define the project's concept, including the site's specific requirements and layout for the proposed supportive housing project. Key site selection criteria include:

- Scale
- Housing type and construction
- Location
- Acquisition or lease costs
- Zoning considerations
- Community acceptance

I chose Lead City University in Ibadan for my project because it is already an established academic community.

4.2 Project Analysis and Design Synthesis

While analytical writing focuses on dissecting elements to examine them individually, synthesis involves integrating ideas and information to identify overarching patterns and relationships.

4.2.1 Brief Analysis

In light of the National Universities Commission's (NUC) approval of the Faculty of Architecture in Nigerian universities, I've researched the status of architecture programs in the country. It appears that faculties of architecture are relatively rare in Nigerian universities, particularly in the southwestern region. As a result, I have been commissioned to design a Faculty of Architecture for Lead City University in Ibadan.

4.2.2 Brief Development

The architectural brief is often developed in collaboration with the architect and outlines opportunities, identified constraints, and areas needing further investigation. Key components of the brief include:

1. Patio
2. Open seating area
3. Recreation space
4. Lecture theatre (1)
5. PhD seminar room
6. Reception area
7. Faculty library
8. Head of Department (HOD) office
9. Faculty manager office
10. General meeting room
11. Mini meeting room
12. Lecture rooms (6)
13. Exhibition space
14. Models room
15. Computer room
16. Studios (6)

17. Student association area

18. Senior lecturer offices

19. Lecturer I office

20. Lecturer II office

21. General office for junior and assistant lecturers

22. Workshops (1)

23. Dean's office & secretary

24. Professors' offices

4.2.3 Design Criteria

Design criteria provide specific guidelines to address the key questions at the core of the problem that requires a solution. They also serve as a benchmark for evaluating potential solutions. Examples of design criteria include:

- Accessibility
- Sustainability
- Landscape design
- Enhancement of form, function, and aesthetics
- Appropriate use of proportion and scale
- Connection between various spaces in the design
- Flexibility
- Efficiency and economy
- Architectural and structural design
- Planning and circulation

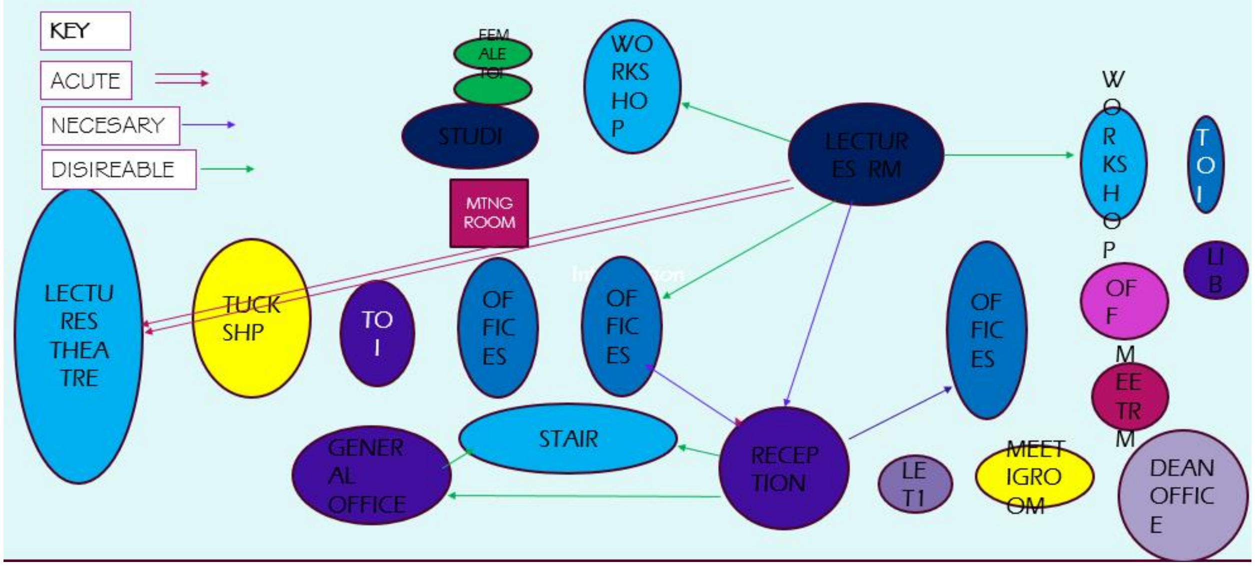
- Water supply and sewage systems
- Road network

4.2.4 Conceptual Development

Concept development is crucial in architectural design, helping architects generate and refine ideas throughout the design process. It provides a framework for making decisions and solving problems.

4.2.5 Functional Relationship

Functional architecture is an architectural model that identifies the functions of various systems and their interactions.



4.2.6 Space Allocation / Schedule of Accommodation

A schedule of accommodation outlines the specific facilities and spaces required by the future occupants of a building project. This list is typically created by the consulting team during the concept design phase.

Outdoor Spaces

1. Patio
2. Open seating area
3. Recreation space

Administrative Areas

1. Reception
2. Head of Department (HOD) office
3. Faculty manager office
4. General meeting room
5. Mini meeting room

Academic Spaces

1. Lecture rooms (6)
2. Studios (6)
3. Lecture theatre (1)
4. PhD seminar room

Offices

1. Professors' offices
2. Senior lecturers' office
3. Lecturer I office
4. Lecturer II office
5. General office for junior and assistant lecturers
6. Dean's office & secretary

Information Areas

1. Faculty library
2. E-library

Workshops

1. Workshops (1)

Student Hall

1. Reception
2. Student association area

4.2.7 Construction Methods

Construction methods refer to the techniques and practices professionals use to build houses, offices, and other structures. The choice of construction method often depends on factors such as costs, available materials, the expertise of the construction team, and the building's location.

Modern Methods of Construction Include:

- 3D volumetric construction
- Flat slabs
- Frame construction
- Precast panels
- Concrete walls and floors
- Precast foundations
- Twin wall technology
- Thin joint masonry

For this project, the chosen construction methods will be precast foundations and frame construction.

Construction Materials

Commonly used building materials include:

- Steel: An alloy of iron and carbon, often enhanced with other elements to improve strength and resistance to fractures.
- Concrete
- Wood
- Stone
- Brick/Masonry

For this project, the selected construction materials will be stone, wood, concrete, and brick/masonry.

4.2.8 Building Services

Building services encompass the electrical, plumbing, and mechanical systems within a structure. Often referred to as MEP services (mechanical, electrical, and plumbing), these systems will utilize imported pipes that will be integrated throughout the building.

Chapter Five

Conclusion

5.1 Project Appraisal

Project appraisal is a structured process for evaluating the feasibility and justification for moving forward with a project or proposal. This process typically involves comparing different options using economic analysis or other decision-making techniques. The appraisal indicates that Lead City University in Ibadan is capable of supporting this project, making it feasible to construct.

5.2 Conclusion

Based on the research conducted, it is concluded that the most crucial passive design strategy is solar protection, followed closely by heat dissipation strategies. Since the sun is the primary source of heat, allowing it to enter the building can undermine other passive design strategies. Therefore, preventing solar gain should be the top priority before addressing other design strategies.

5.1 Recommendations

Educational buildings play a crucial role in personal development, serving as important settings for key moments in our lives. They are the places where we transition from home to the broader community, and where we grow from adolescence into adulthood during our college years. Therefore, the design of educational facilities is particularly significant for everyone involved.

Before commencing any design work, it is essential to gather climate data for the site, as this information will guide the design process. For low-rise buildings, it is advisable to optimize orientation for both solar protection and wind access. However, for high-rise structures, the focus should solely be on solar protection. Although radiation intensity is generally lower in hot-dry climates, it still contributes significantly to heat, so preventing its entry into buildings is critical. In hot-dry conditions, radiation is typically directional, allowing for accurate shadow angle calculations. Thus, shading devices should cover a large portion of the sky, not just the area directly above the sun.

Additionally, openings in these buildings should be larger than in typical hot-dry environments, which further emphasizes the need for extensive shading. The strategic placement of shade-providing vegetation, such as trees, around the building is vital for enhancing the indoor climate. Another effective approach is to incorporate green roofs and walls, which act as an additional layer of protection.

Airflow can be influenced by the building's orientation, topographical features, and the positioning of nearby structures. Intentional obstructions can be used to direct wind in a preferred manner. According to Anthienitis and Santamouris (2002), designers should promote natural ventilation by incorporating tall spaces within the building, known as stacks. This allows warm air to escape through openings at the top while cooler air enters through lower openings. Effective ventilation requires that the building remains open during the day to facilitate airflow.

It is important to encourage architectural solutions that align with natural principles, providing reliable alternatives to artificial or mechanical cooling and ventilation methods. Additionally, further research is needed to assess the effectiveness of passive cooling strategies in the Faculty of Architecture

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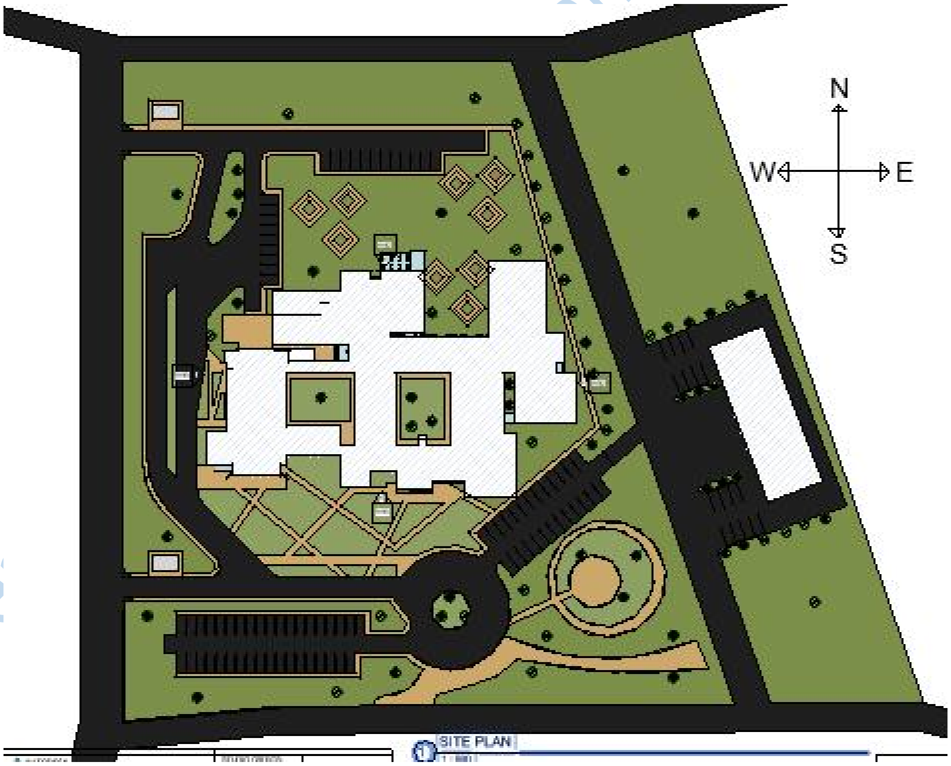
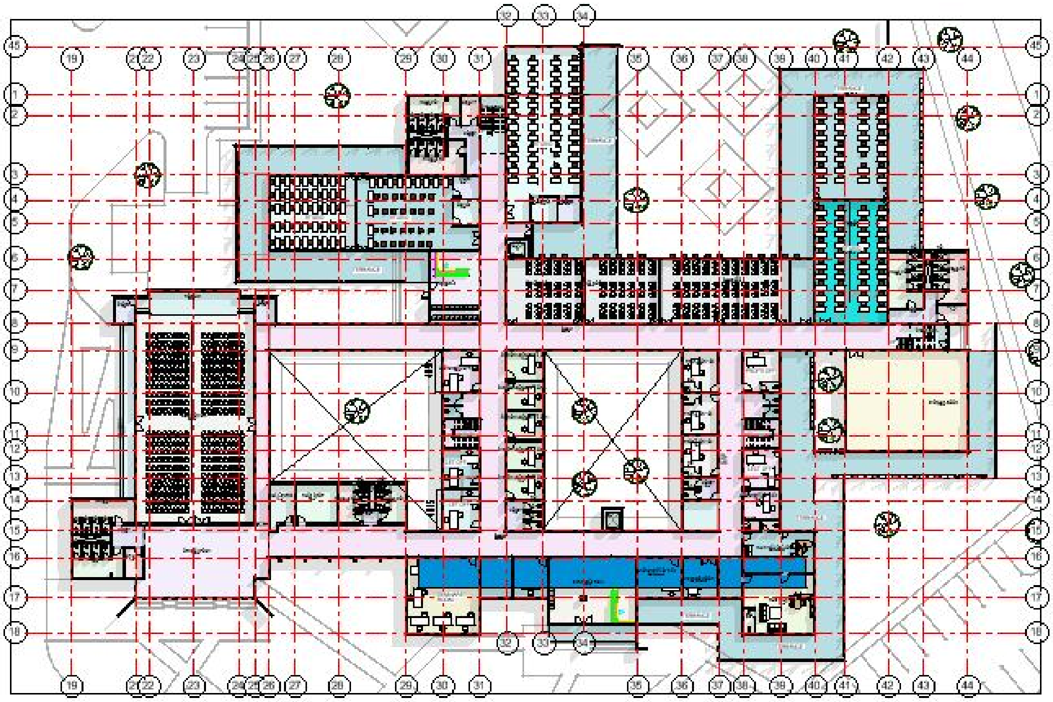
- APPENDIXES (ALL DRAWINGS)

- APPENDIX 1: PRESENTATION DRAWING

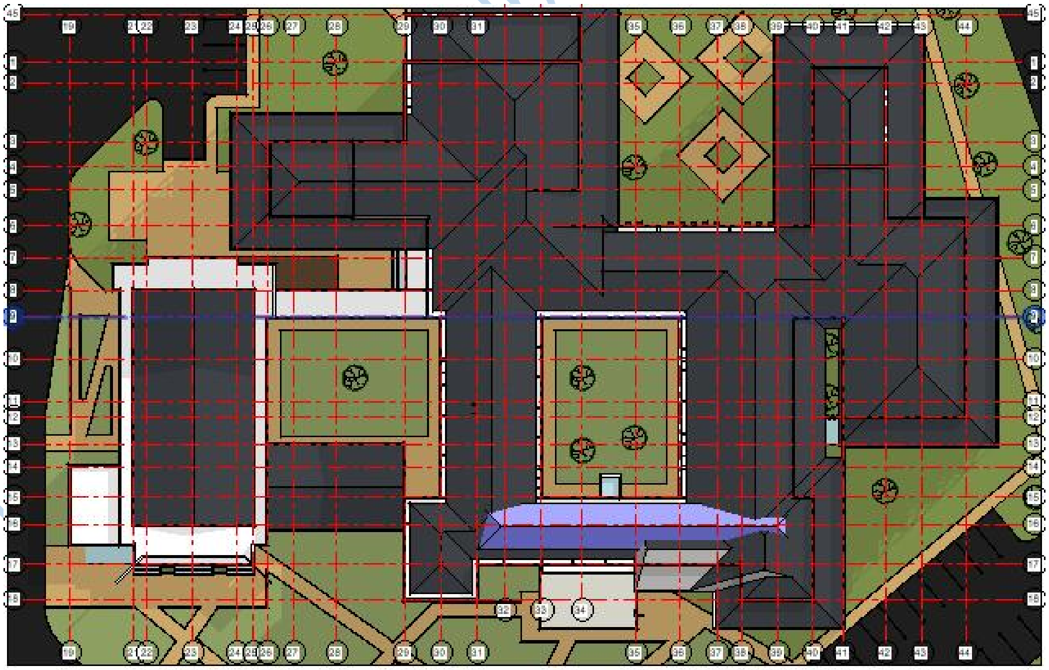
Appendix 1.1: Master plan of Lead City University,Ibadan.



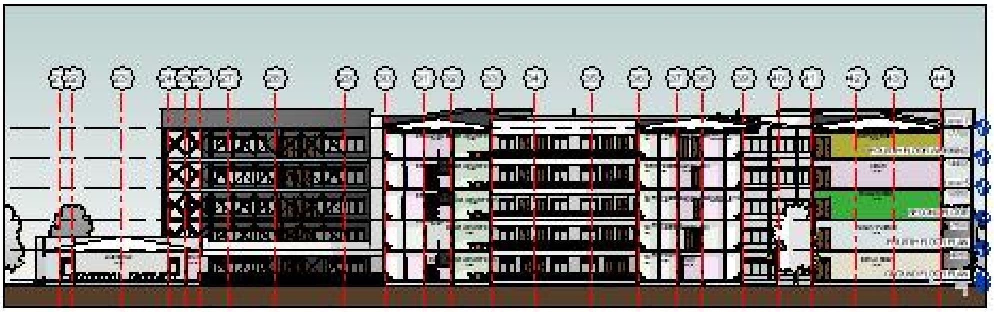
Appendix 1.2: Site plan



Appendix 1.3: Floorplan



Appendix 1.4: Roof plan



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2 Section 2

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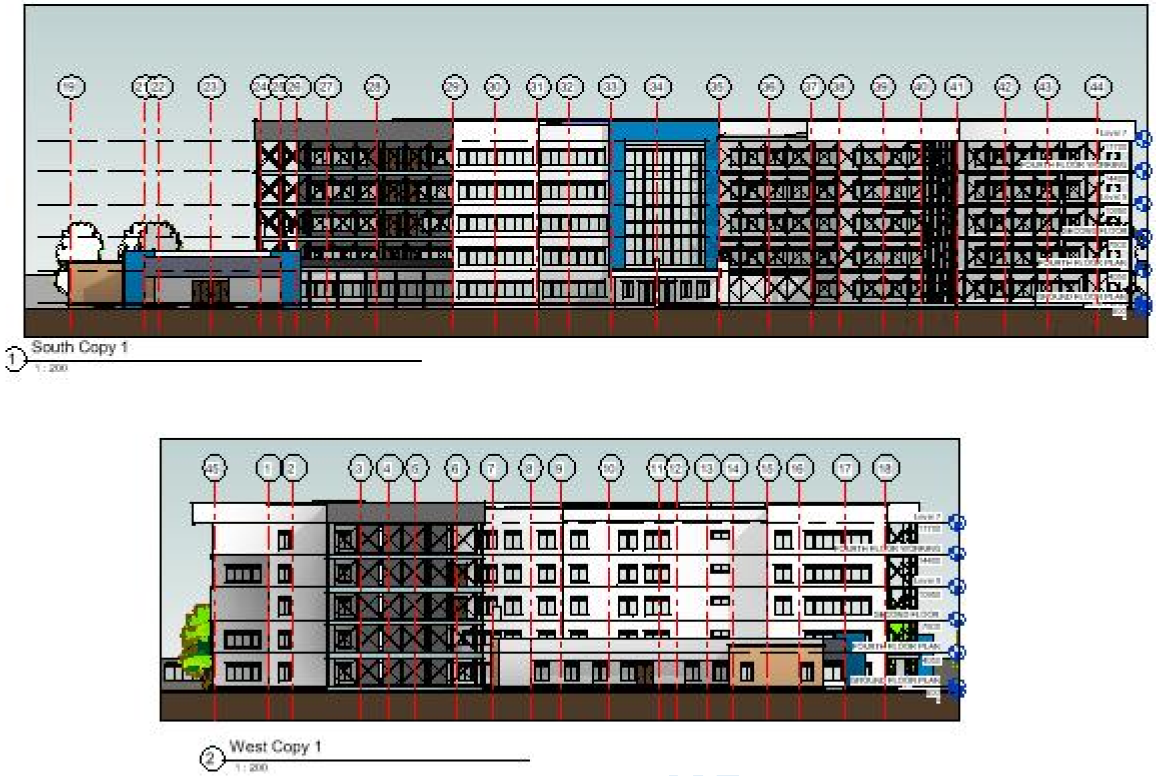
Appendix 1.5: Section



Appendix 1.6: Elevation

Appendix 1.7: 3D

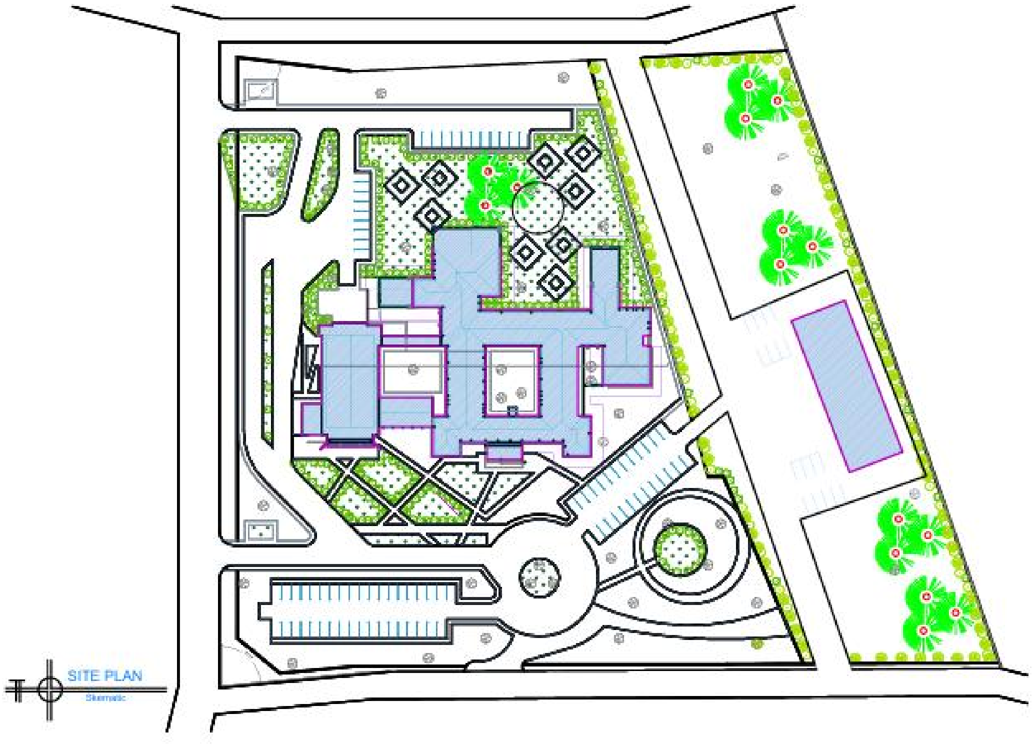
Appendix 1.8: 3D

Appendix 1.9: 3D

Appendix 1.10: 3D

Appendix 1.11: 3D

- APPENDIX 2: WORKING DRAWINGS



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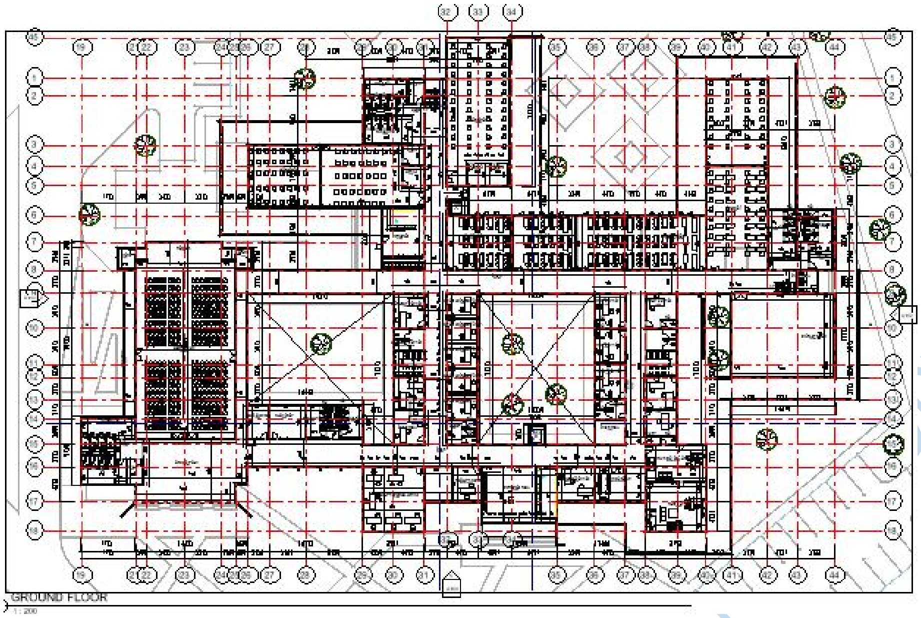
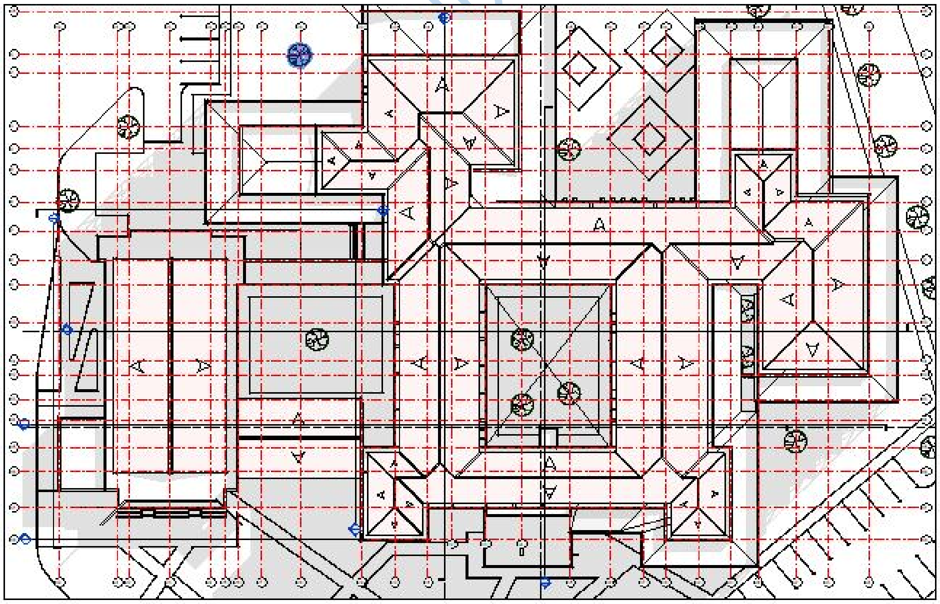
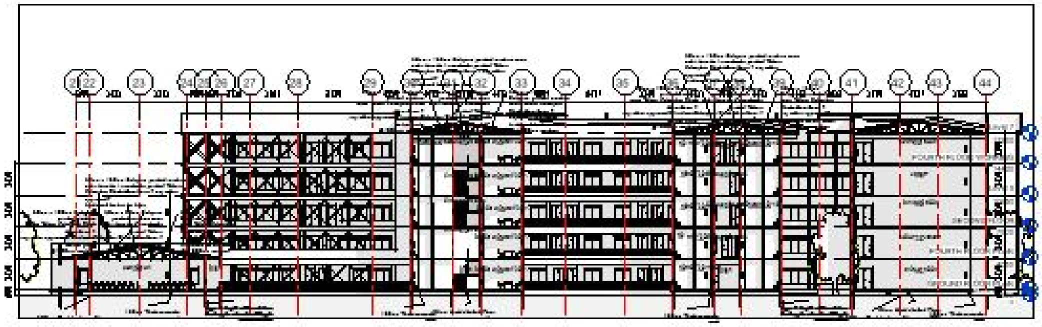


Appendix 2.2: Floor plan



Appendix 2.3: Roof plan



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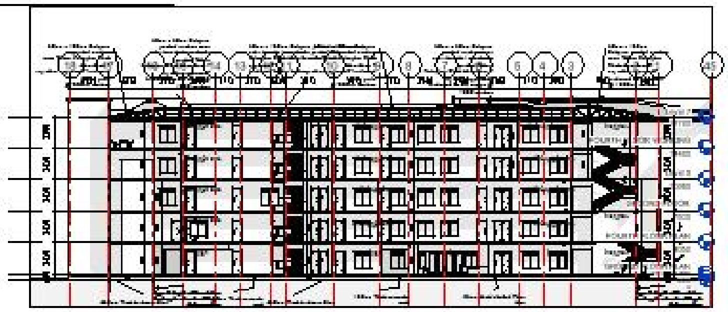

② Section 2 WORKING
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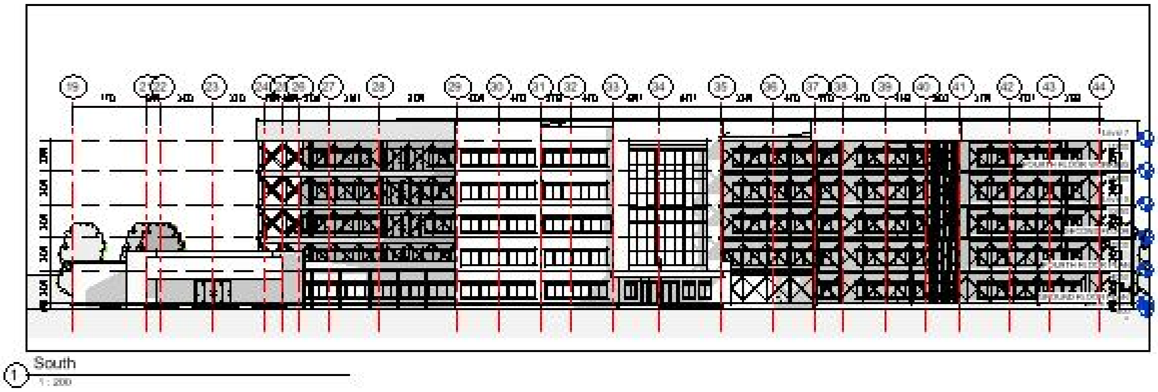
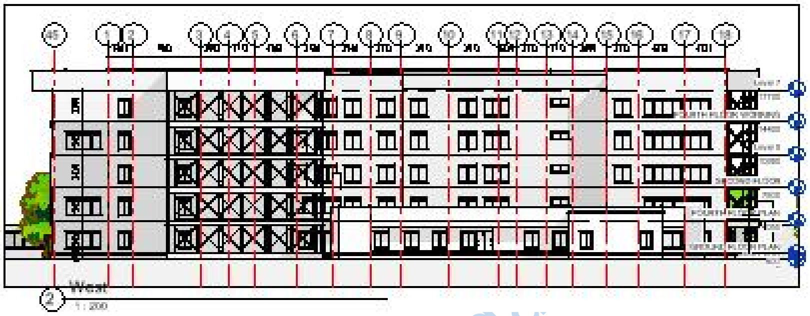
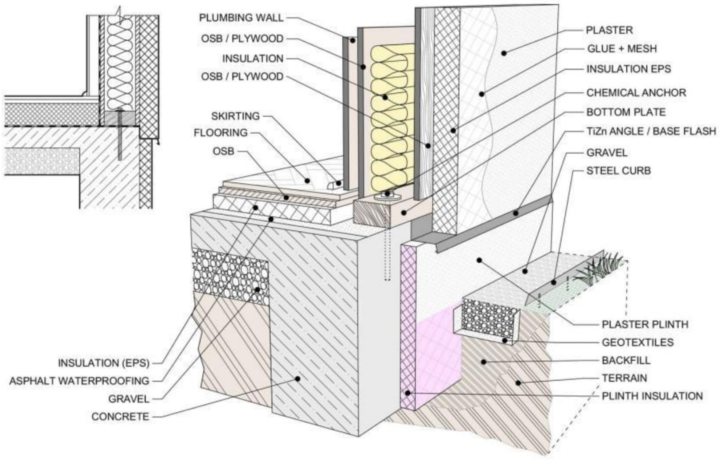
Appendix 2.4: Sections



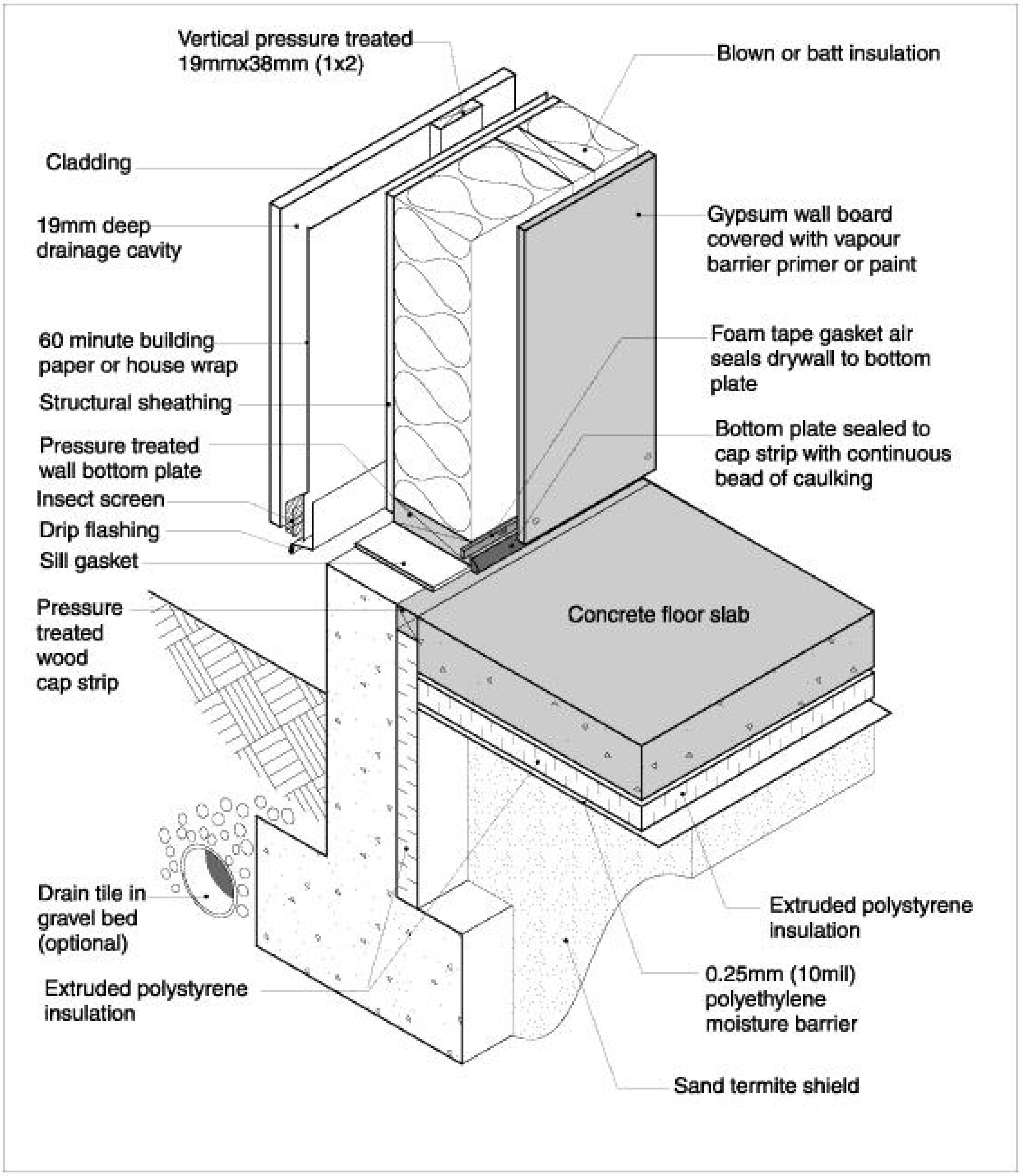


Appendix 2.5: Elevations

- APPENDIX 3: DETAILS

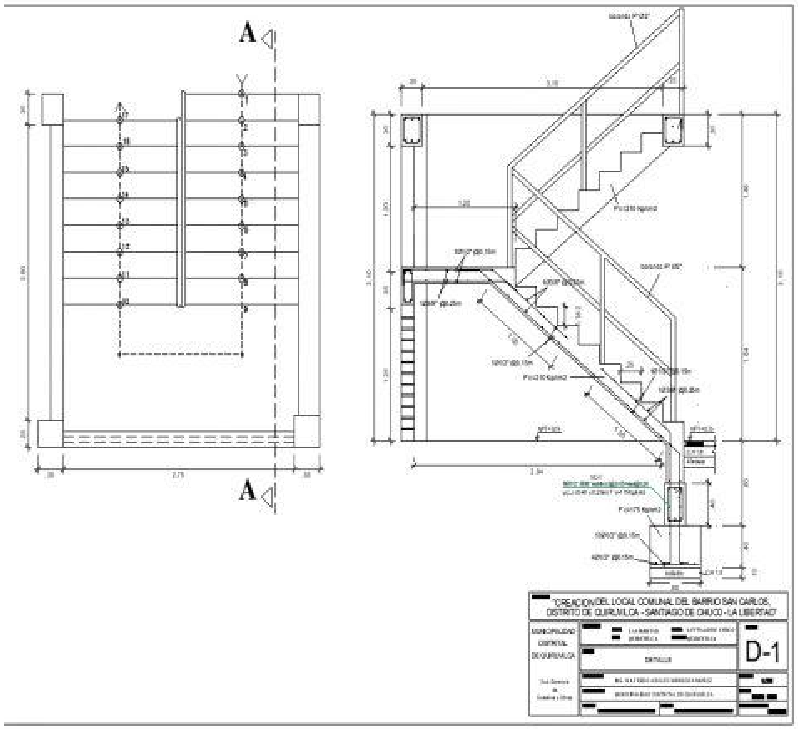


Appendix 3.1: Foundation Details

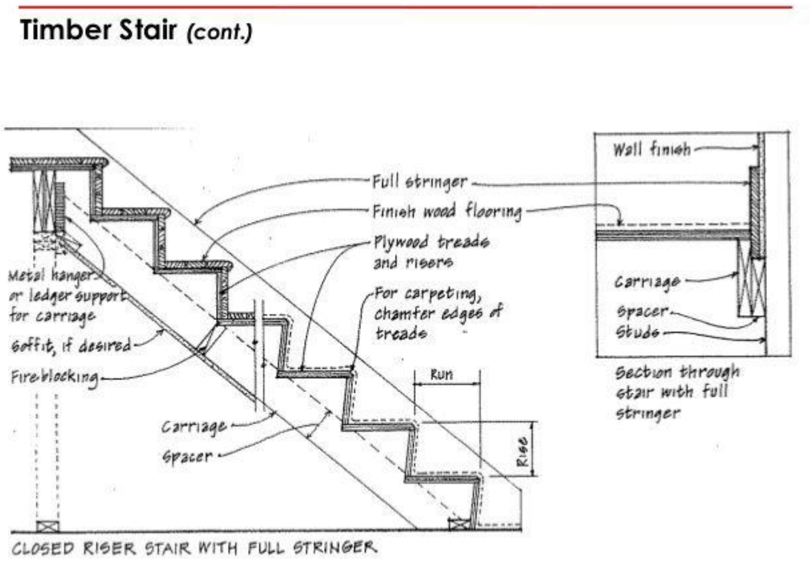


SLAB ON GRADE FOUNDATION DETAIL
AIRTIGHT DRYWALL AIR BARRIER

Appendix 3.2: Foundation Details



Appendix 3.3: Stairs Details



Appendix 3.4: Stairs Details

Biodata

A. Personal data:

1. Name: David Oladayo Emmanuel

Permanent Home Adress: B8 zone4 Ore-Ofe Avenue, Ogungbade, Ibadan,Oyo State, Nigeria.

Contact Address: Lead City University, Ibadan, Nigeria.

Email Address: david.oladayo@lcu.edu.ng

Phone Number: 07032168030

2. Date of Birth: 13th Feburary, 1986

Place of Birth: Olokoto, Oyo State

3. Nationality: Nigerian

4. Next of Kin

Name: Oluwafunmilola David Serah

Address: B8 zone4 Ore-Ofe Avenue, Ogungbade, Ibadan,Oyo State, Nigeria.

B. Education background with date

i. Institutions attended with dates

Lead City University, Ibadan, Oyo State. 2022-2024

Lead City University, Ibadan, Oyo State. 2020-2022

The Federal Polytechnic, Offa, Kwara State
HND Architecture 2012 – 2014
The Federal Polytechnic, Offa, Kwara State
ND Architecture 2006 – 2009

UMCA Secondary Grammar School Igbeti Oyo State 2002 – 2004
Senior Secondary School Certificate **(SSCE)**

Ogunbode Memorial Grammar School Igbeti Oyo State 1999 – 2002
Junior Secondary Certificate (**JSSC**)

U M S Primary School Olokoto Oyo state. 1992 – 1998
First School Leaving Certificate **(FSLC)**

ii Qualifications with dates

B.Sc. Architecture (LCU): 2022

HND Arcitecture (FPO): 2014

WASSCE: 2004

C. Working experience with date

Blooming Architectural Design & Construction *tilldate*
2017-2019 Department: Design & Monitoring Team

Imperial Consultant 77, Iwo Road tilldate Department:

Design & Monitoring Team

D. **Professional affiliation**

Graduate member, Nigerian Institute of Architects, Oyo State Chapter

E. Referees

Arc. (Dr.) Tosin Babalola
Department of Architecture
Faculty of Environmental Design and Management
Lead City University, Ibadan, Nigeria
Babalola.oluwatosin@lcu.edu.ng +234 703 822 0942

Arc. Olami Marthin Olaniyan
Department of Architecture
Faculty of Environmental Design and Management
Lead City University, Ibadan, Nigeria
Mobile: +2348052711977 arclaniyan@gmail.com

Arc. (Dr.) Funmilayo Adedire
Department of Architecture
Faculty of Environmental Design and Management
Lead City University, Ibadan, Nigeria
Funmidire@gmail.com +234 816 926 3162

Signature -- Date --

University Compliance Form

This is to certify that this thesis by David Oladayo Emmanuel with matriculation number LCU/PG/005101 in the Department of Architecture, Faculty of Environmental Design and Management, Lead City University, Ibadan is in full compliance with the approval of the University´s format and style.

Signature --- Date ---