INTEGRATION OF PASSIVE COOLING DESIGN CONSIDERATION FOR FACULTY OF BASIC MEDICAL SCIENCES, FEDERAL UNIVERSITY, BIRNIN KEBBI, KEBBI STATE

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APRIL, 2023

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ABSTRACT

A reoccurring discourse currently in the built environment of architectural practice and education is Passive Design as it has progressively become difficult to ignore the concerns by professionals in the built environment. This passive design approach is geared towards reducing potential negative impact of developments on the well-being of the environment and human health, through the use of an "eco-friendly" construction materials and principles. The Faculty of basic medical science building with integrated "eco-friendly" passive cooling design features will enhance the indoor air quality by eliminating heat gain within the building and replenishing the indoor environment with the most efficient and most comfortable temperatures for human activities. The aim of this study is to integrate passive cooling design considerations with the view to achieving good indoor air quality and environmental sustainability. The method of sampling employed for this research is the convenient purposive sampling. A purposeful survey was conducted on four (4) faculties of basic medical science buildings in tertiary institutions in Nigeria. A direct observation of passive cooling variables which include orientation, building envelope, thermal mass, shading and overhangs, openings, ventilation, and landscaping. The instruments used in collecting information for this research are questionnaires and observation schedule. The research findings revealed that passive design features for energy efficiency are green roof, soft landscape, roof vent, evaporative effect, and atrium for cooling the building. The research recommended that green building design should be made a criterion to be met by design proposals before approval for construction is given to ensure that new buildings are sustainable.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

A reoccurring discourse currently in the built environment of architectural practice and education is “Passive Design” as it has progressively become difficult to ignore the concerns by professionals in the built environment. The Intergovernmental Panel on Climate (IPCC) (2014), declared that: the 21st century will continue to witness an upswing in temperatures and emissions of greenhouse gases due to massive urbanisation, industrialization and advancement in technology, which in turn raises a lot of questions for the professionals whether to continue with the old ways of designing which can affect the environment negatively or upgrade to a more advance principle which can solve the growing need of sustainability. Green architecture or green design has been discussed by various scholars as an approach in advancement of sustainable architecture (Bulus *et al.*, 2017).

This passive design approach is geared towards reducing potential negative impact of developments on the well-being of the environment and human health, through the use of an “eco-friendly” construction materials and principles (Ishaq *et al.*, 2019). The objective of environmental building design is the creation of a comfortable and also energy efficient internal environment. The successful design of buildings relies on an appropriate understanding of the climatic nature of the environment. Factors such as the urban surroundings or site characteristics, orientation and architectural design of the building, choice of building materials, etc. are not given enough importance. Consequently buildings often have a poor indoor climate, which affects comfort, health and efficiency (Emmanuel and Baker, 2012).

Green architecture is defined by Aynsley, (2014), as "philosophy of architecture that advocates sustainable energy sources, the conservation of energy, the reuse and safety of building materials, and the siting of a building with consideration of its impact on the environment". However, Manna and Chakraborty (2017), defined green architecture as the practice of increasing the efficiency with which buildings and their sites use energy, water, and materials, and reducing building impacts of human health and the environment, through better siting, design, construction, operation, maintenance, and removal throughout the complete life cycle."

Some of the notable designs and architecture are said to be Millan's Galleria Vittorio Emanuele II and London's Crystal Palace which employed a design methodology that minimise the effect of the "structure on the environment" by introducing vents in the roof and air cooling chambers underground which regulates "indoor air" quality (Markus *et al.*, 2017). The ideology of green architecture and design is woven around the philosophy of sustainable development and this philosophy has led to various architectural offering of various concepts and approach to design that will serve the function and aesthetic need of the present without jeopardising future hedonic.

Ishaq *et al*. (2019), has observed that although "green buildings" may not include all of the identified green building design types but could include one or more of the following features;

1. Ventilation systems designed for efficient heating and cooling
2. Energy-efficient lighting and appliances (e.g., ENERGY STAR® products)
3. Water-saving plumbing fixtures
4. Landscaping with native vegetation and planned to maximize passive solar energy
5. Minimal harm to the natural habitat
6. Alternative renewable energy power sources such as solar power or wind power

7. Non-synthetic, non-toxic materials used inside and out
8. Locally-obtained woods and stone, eliminating long-haul transportation
9. Responsibly-harvested woods
10. Adaptive reuse of older buildings
11. Use of recycled architectural salvage
12. Efficient use of space
13. Optimal location on the land, maximizing sunlight, winds, and natural sheltering
14. Rainwater harvesting and grey-water reuse

Passive Cooling refers to those processes of heat dissipation that will occur naturally, that is without the mediation of mechanical components or energy inputs. The definition encompasses situations where the designing of spaces and building elements to lose heat to ambient heat sinks by means of natural modes of heat transfer leads to an appreciable cooling effect indoors. The term "passive" implies that energy-consuming mechanical components like pumps and fans are not used. Passive cooling is based on the interaction of the building and its surroundings. Passive cooling strategies are adopted according to the local climate called natural cooling, a passive solar energy technique that allows or augments the natural movement of cooler air from exterior, shaded areas of a building through or around a building. In general, passive design balances all aspects of the energy use in a building: lighting, cooling, heating, and ventilation. It achieves this by combining, in a single concept, the use of natural sources of energy and conventional, energy-efficient strategies (Emmanuel and Baker, 2012).

Passive design means that nature (and the architect) does the work. Passive strategies adjust to environmental conditions primarily through architecture and should be considered before active.

This means that the architect must be strategic. It means using the resources on site rather than importing energy from a remote source. Passive cooling is achieved by using ventilation, coupled with the configuration and thermal properties of the building. In addition to cooling, ventilation is necessary to provide for respiration of the occupants, and also to control the level of pollutants inside a building. Natural ventilation is clearly a valuable tool for sustainable development as it relies only on natural air movement, and can save significant amounts of fossil fuel based energy by reducing the need for mechanical ventilation and air conditioning. Reducing electrical energy used for cooling contributes to the reduction of greenhouse gas emissions from the electrical generating plant providing the energy (Hyde, 2017).

The need to reduce our consumption of energy and to give users more control over their immediate environments, are good reasons for designers now to re-evaluate the role of natural ventilation in buildings and to become familiar with the basic principles involved (Hyde, 2017). Natural ventilation relies on moving air through a building under the natural forces caused by outside wind pressure and the buoyancy effects of temperature differences. Air paths need to be simple and generous as wind and buoyancy pressures are low. Energy efficiency in simple term refers to using less energy to perform the same tasks and functions. For academic building, this could mean reducing the amount of energy needed for heating by improving insulation of the building, by introducing lighting control or also regulate space heating and cooling, and other methods.

1.2 Problem Statement

Global warming is a phenomenon that has set experts of various fields to work on possible causes and the required palliative measures to reduce human contributions to this phenomenon by establishing findings on the effective and efficient management of the environmental resources. Consequently buildings often have a poor indoor climate, which affects comfort, health and efficiency. The problem is found in dwellings as well as workplaces and public buildings.

The location of Birnin Kebbi, which is in the arid region of the country with hot dry climate, which is usually at its peak during the dry season, could render a poorly designed faculty building unliveable and generally unsustainable as the excruciating weather condition could bring great discomfort to the users and the managing personnel. The common practice will be to introduce artificial cooling system in the form of air condition, whose function depends on high energy consumption. Likewise, the use of air conditioner as a major source of cooling system has been found to be a major contributor to global warming (Ali and Ehsan 2017).

1.3 Aim of the Study

The aim of this study is to integrate passive cooling design considerations in faculty of basic medical sciences, Federal University, Birnin Kebbi, with the view to achieving good indoor air quality and environmental sustainability.

1.4 Objectives of the Study

The objectives of this study are to:

i. Identify passive cooling design features that can be adopted to ensure users comfort.
ii. Investigate existing faculty of basic medical science buildings in Northern Nigeria, to determine the extent to which passive cooling design elements have been employed in their designs.

iii. Propose a design of faculty of basic medical sciences for Federal University, Birnin Kebbi that incorporates passive cooling design features with the view to ensuring users comfort and environmental sustainability.

1.5 Scope of the Research

There are various Passive Design considerations used to address issues of high temperatures in hot, humid and dry climate as experienced in the North Western region of Nigeria where Birnin Kebbi is located. This study will focus on passive cooling consideration to reduce energy needed to effectively run faculty of basic medical sciences building in Federal University Birnin Kebbi. The application of passive cooling design techniques depends largely on the environment and can be applied in regions with hot climatic conditions. Some of the foremost procedure embraced includes; Building orientation which helps with spatial organisation of the building based on function, external environment and weather factors and the other is the use of shading devices integrated from the onset of the design of the building to its construction or in its direct location (Abdulsalam and Alibaba 2019).

1.6 Research Justification

Climate change is a global phenomenon which is said to be eating up the earth and putting environmental and human health in grievous danger. The phenomenon has been said to be anthropogenic in most cases and developing countries have been identified as major contributors.

Development practices in developing countries such as Nigeria are mostly not “eco-friendly”. Clearance of large acre of land for physical developments displaces the eco-system of the land area where fauna and flora use their natural habitat. In addition, developing countries still rely heavily on hydroelectricity and fuel generators with little or no effort made to take advantage of the passive cooling design strategies to attain energy efficiency. This research work seeks to propose a design that considers passive cooling design elements to achieve passive energy efficiency. The benefits of applying passive cooling design elements include; cost of savings as the need to use hydroelectricity power generators are reduced to the minimum, and reduction in environmental degradation. Faculty of basic medical science building with integrated "eco-friendly" passive cooling design features will enhance the indoor air quality by eliminating heat gain within the building and replenishing the indoor environment with the most efficient and most comfortable temperatures for human activities.

As an important element of national security, public health not only functions to provide adequate and timely medical care but also track, monitor, and control disease outbreak. The Nigerian health care had suffered several setbacks as a result of understaffing in medical institutions caused by the insufficient number of higher institutions running medical courses in Nigeria (Welcome,2011).

Welcome (2011), also concluded that to achieve success in health care in this modern era, a system well-grounded in routine surveillance and training of professionals in the health sector is necessary, besides adequate management couple with strong leadership principles.

Proposing energy efficient Faculty of Basic Medical Science Building at the university will encourage students, lecturers and researchers alike, to explore the full potentials of its advantage all year round and reducing artificial cooling systems. Also, it will encourage more research works in a much more conducive environment where harsh weather of global warming has been a problem to human.

1.7 Study Area

The study area in this research is passive cooling design strategies in faculty of basic medical science building in the Federal University Birnin Kebbi. Federal University Birnin Kebbi is a new university based in Birnin Kebbi, Kebbi State of Nigeria as seen in Figure 1.1 and 1.2. Established on 18th February, 2013 with other Federal universities by the Federal Government of Nigeria, it is in line with the policy of the Federal Government to establish a Federal University every state of the federation. Academic activities began in November 2014 for the 2014/2015 academic session, the university maintains two sites; the start-up and permanent site. The permanent site maintains the major campus capacity buildings at Unguwar Jeji (a village 4 kilometres away from the take-off site.). The town sits on longitude (4° 0′ 0″ E) and latitude (11° 30′ 0″ N) (Federal Ministry of Land and Survey (FMLS), 2019)

Figure 1.1: Nigeria Map showing the location of Kebbi State.
Source: (Magaji *et al.*, 2019)

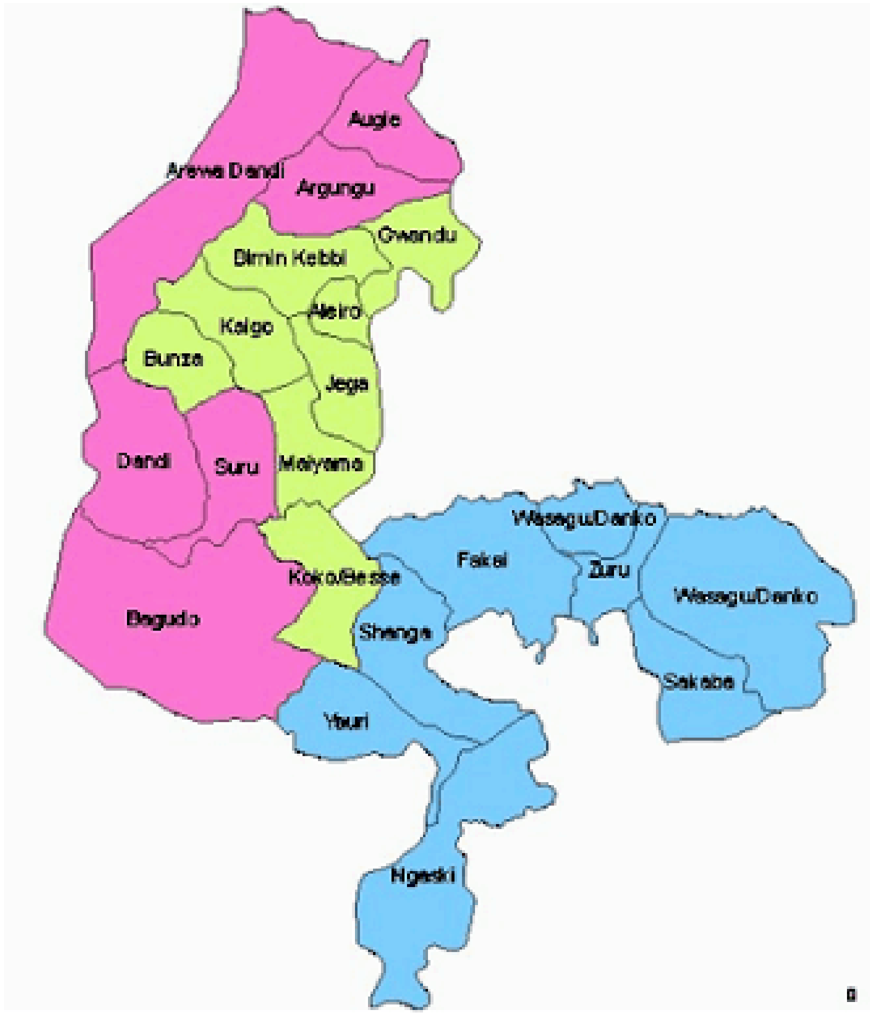


Figure 1.2: Map of Kebbi State
Source: (Magaji *et al.*, 2019)

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction to Energy Efficiency in Building

The buildings sector accounts for about 76% of electricity use and 40% of all U. S. primary energy use and associated greenhouse gas (GHG) emissions, making it essential to reduce energy consumption in buildings in order to meet national energy and environmental challenges and to reduce costs to building owners and tenants. Opportunities for improved efficiency are enormous (Randolph and DOE 2013).

The *International Energy Agency* (IEA) (2015), states that By 2030, building energy use could be cut more than 20% using technologies known to be cost effective today and by more than 35% if research goals are met. Much higher savings are technically possible. Building efficiency must be considered as improving the performance of a complex system designed to provide occupants with a comfortable, safe, and attractive living and work environment.

This requires superior architecture and engineering designs, quality construction practices, and intelligent operation of the structures. Increasingly, operations will include integration with sophisticated electric utility grids. The major areas of energy consumption in buildings are heating, ventilation, and air conditioning—35% of total building energy; lighting—11%; major appliances (water heating, refrigerators and freezers, dryers)—18% with the remaining 36% in miscellaneous areas including electronics (Randolph and DOE 2013). In each case there are opportunities both for improving the performance of system components (e.g., improving the efficiency of lighting devices) and improving the way they are controlled as a part of integrated building systems (e.g., sensors that adjust light levels to occupancy and daylight).

2.1.1 Energy application in buildings

Electrical energy appeared first in the late 19th century produced chiefly by progressively efficient engines and primarily used for lighting. However, until the commercialization of fluorescent lighting, lamps remained inefficient. The improvement of practical electric motors largely expanded applications for mechanical power. The invention of innumerable small machines and labour saving devices made energy a universal commodity by the beginning of the 20th century. Energy consumption accelerated by the beginning of the 20th century while the energy consuming population of the earth also grew rapidly. When it comes to the consumption of energy in tropical buildings, cooling using air conditioning consumes a higher proportion of energy compared with heating. However some tropical countries which incidentally fall within the developing countries, consume very little energy when compared to the developed countries.

2.2 Passive Design

Passive design is a term used to encompass a wide range of strategies and options resulting in energy-efficient building design and increased occupant comfort. The concept emphasizes architectural design approaches that minimize building energy consumption by integrating conventional energy-efficient methods, such as building siting, an efficient envelope, appropriate amounts of fenestration, increased day-lighting design, and thermal mass (Cook, 2008). Passive design involves collection, storage, distribution and control of energy flow by natural processes of cooling and ventilation. Passive becomes very effective with the use of natural energy to conserve conventional energy for achieving thermal comfort. The primary objective of passive design strategies is to reduce or even eliminate the need for active mechanical systems while maintaining or even improving occupant comfort (Oikos, 2008).

2.3 Passive Design Strategies

Certain passive building elements have inherent synergies and can be combined to produce different and potentially greater improvements in comfort and building energy performance. However, combining elements incorrectly or using certain elements in isolation can negatively impact thermal comfort and building energy efficiency. For example, large south and west facing windows beneficial for passive solar heating must be implemented in combination with high performance windows and external shading to protect the interior from excessive solar heat gains during summer in order to achieve the desired overall building efficiency gains (Fergus, 2008).

2.3.1 Building insulation

Buildings need to be well-insulated in order retain heat in winter and keep the cool during summer. Insulated materials are poor conductors of heat, form a barrier between interior and exterior spaces, and serve to maintain warmth in cold season between interior and exterior and maintain cold between interior and exterior in hot season. According to Santamouris (2007), Insulation is important in both warm and cold climates, minimal energy is expended in cooling the building in hot season and to heat the building in cold season and this results in maintaining a good indoor temperature all year round.

2.3.2 Shading and overhangs in buildings

Overhangs and shadings help in reducing overheating in hot seasons (Tin – Tai, 2017). They should be properly sized on the surface of the building that receives the most sunlight to ensure adequate shading. This will reduce overheating in summer months. Careful design of shading devices must be made considering the size and slope to let in sunlight during winter and provide shade in summer seasons as seen in Figure 2.1. The geometry of the building, angle of incidence of sun and visual appearance of the device are to be taken into consideration at the initial design stage to meet technical and aesthetic aspect in the whole architecture.

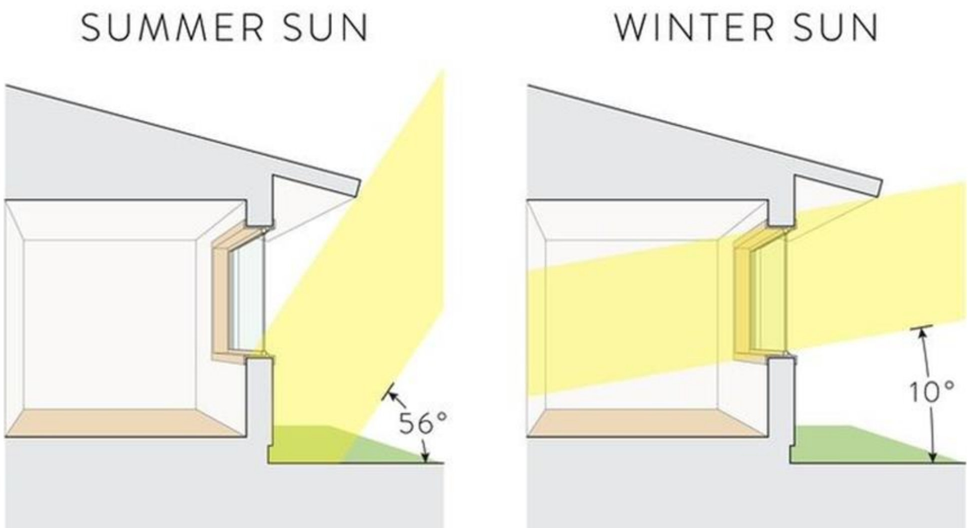


Figure 2.1: Overhangs shading the building from high summer sun

Source: (Tin – Tai, 2017)

Shading of the building is a permanent or temporary surface cover or an object used to prevent the direct impact of solar radiation on a habitable place as the building, cover for the building envelop or out layer. Shading can be seen in different ways, size, types, and placement depend on the geometric between the sun and the building. Shadow are place in proportional to the angle of the sun ray to the building. shading increase the cool of an environment as it reduce heat load on the building cool the airflow temperature.it should be situated in the direction of sun rise and sun set, this window at such position should be shade to prevent solar load as direct, diffuse and reflect radiation.

The form and shape of building can as well create shaded areas to the building. Designers and builders should make use of shading device as horizontal, vertical louvers, overhang and egg-crate shading device, these are shown in Figure 2.2

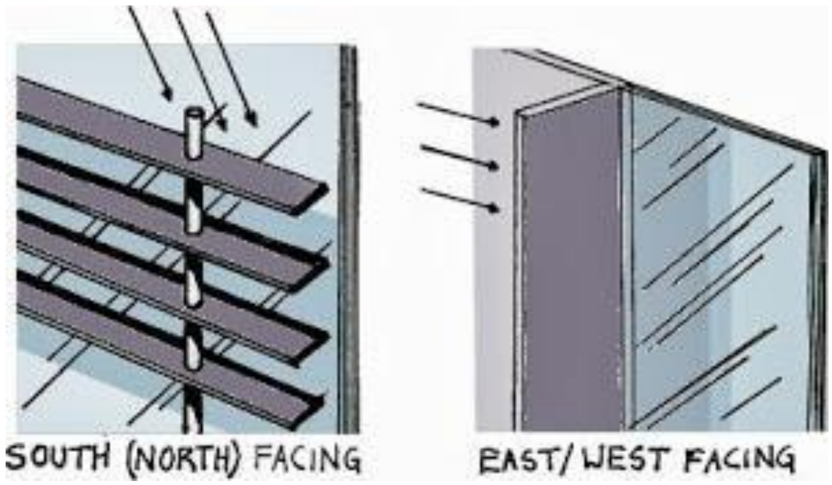


Figure 2.2: Best shading solutions for various sides of a building

Source: (Tin – Tai, 2017)

2.3.3 Building orientation

Orientation refers to the way a building is placed on site to take advantage of climatic features such as sun and cooling breezes (McGee, 2013). East and west facing walls receive the highest amounts of radiation, especially during hot periods. Therefore, the best orientation in the tropics is rectangular with long axis running east-west in order to minimize solar heat gain through the long façade (Abimaje and Akingbohungbe 2013).

The amount of sun received by the building is dependent on these factors:

i. The geographic latitude of the site, which determines the height of the sun in the sky.

ii. The positioning of the building on the site, such as position of rooms in the building.

iii. The season in the year, this also affects the height of the sun in the sky.

iv. The local cloud conditions, which can block solar radiation.

v. The angles between the sun and the building surfaces, because maximum gain occurs when surfaces are at right angles to the rays of the sun.

vi. The type of windows and glazing used in the building as regards its absorption or reflection of radiation.

2.3.4 Window sizes, glazing and location

Energy consumption can be greatly reduced through the use of windows with low emissivity and air tightness. Most importantly, a significant reduction of air leakage can reduce infiltration load with simple weather stripping techniques and incorporation of photovoltaic panels can produce electricity while absorbing solar radiation and minimizing heat gain through the building envelope (Crisp *et al.*, 2008). This will improve thermal energy performance of the building envelope. A cross-section of such windows is shown in Figure 2.3.

Glazed windows and doors have very important functions in letting in natural light and fresh air. However, in the tropics, they are the main sources of undesirable heat gain reaching up to 87% (McGee, 2013). The ideal design would have only south and north windows and no east or west windows. When that is not possible, the number of east and west windows should be minimized and the number of north and south windows maximized. Making windows on the east and west facades smaller than those on the north and south facades is another free strategy to save energy for cooling (Lechner, 2014).

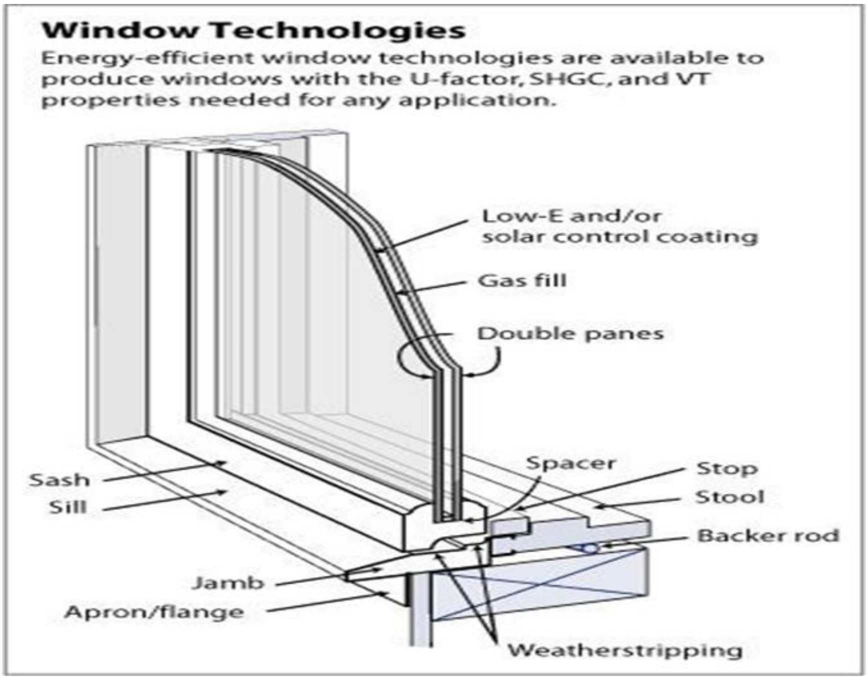


Figure 2.3: A cross section of a double-paned glass with solar control coating
Source: (McGee, 2013)

2.3.5 Day-lighting

Day-lighting is the efficient use of natural light in order to minimize the need for artificial light in buildings (Cuttle, 2013). Day-lighting is achieved via the use of control strategies and adapted components which are characterized thus:

i. Conduction components - spaces used to guide or distribute light towards the interior of a building
ii. Transparent components (e.g. windows) - these allow light to pass from one room or section of a building to another
iii. Control elements - specially designed to control the manner light enters through a transparent component.

iv. Day-lighting combines energy conservation and passive solar design with the aim of making the most benefit from sunlight. It uses the following alternative techniques such as:

v. Roof lights and skylights

vi. Large windows to allow light penetrate inside rooms

vii. Positioning of task lighting directly over the workplace, instead of lighting the whole interior of the building

viii. The use of shallow plan design, allowing daylight to penetrate rooms and corridors

ix. Light walls in the centre of the building.

Spaces are lit primarily from side windows, which are shaded from direct solar heat gain by deep reveals, overhanging eaves or adjacent parts of the building, this is represented in Figure 2.4. Small windows are also used to distribute day-lighting without unnecessarily causing high heat transfer. North lights and roof lights are used extensively to meet the combined needs of stack ventilation and day-lighting, while the full height concourse admits daylight into the core of the main building.

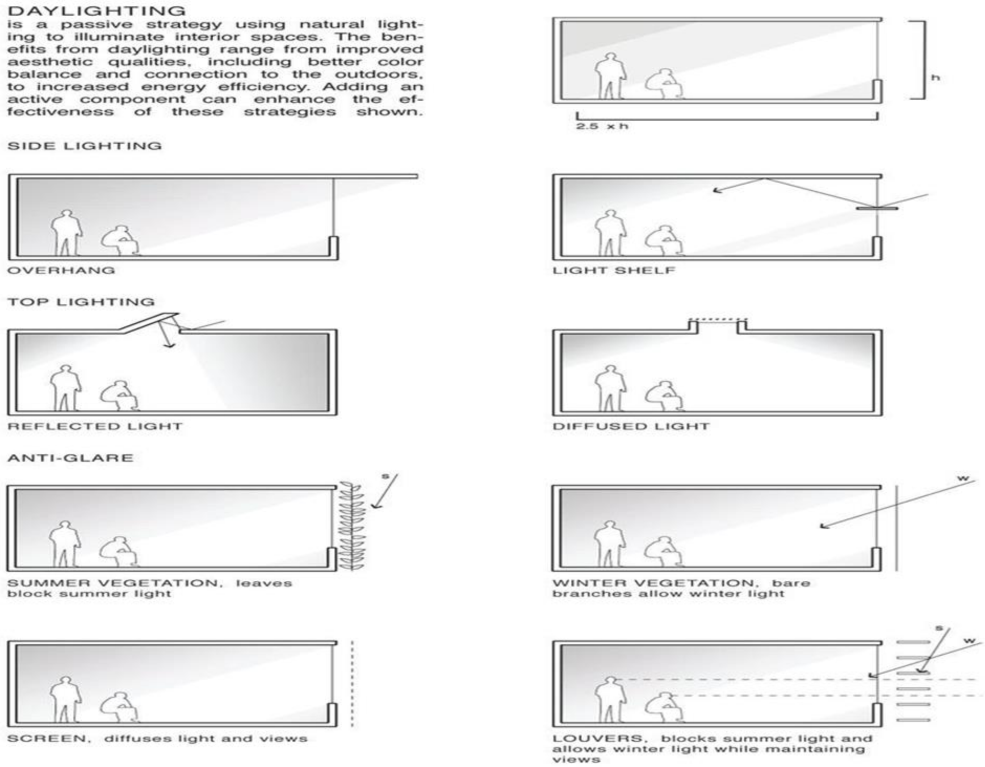


Figure 2.4: Day-lighting in the interior of the building.
Source: (Cuttle, 2013)

2.4 Passive Cooling Techniques

Passive cooling is considered an alternative to mechanical cooling that requires complicated refrigeration systems. By employing passive cooling techniques into academic building, mechanical cooling will be eliminated or reduced to the barest minimum. Passive cooling design involves the use of natural processes for cooling to achieve balanced interior conditions. The flow of energy in passive design is by natural means: radiation, conduction, or convection without using any electrical device (Choudhary *et al.*, 2014).

Passive cooling is based on the interaction of the building and its surroundings. Before adopting a passive cooling strategy, matching of local climate must be ensured. It is evident that the total energy consumption of buildings for cooling purposes varies as a function of the quality of design and climatic conditions (Oikos, 2008). Passive cooling strategies prevent the building from overheating by blocking solar gains and removing internal heat gains (e.g. using cooler outdoor air for ventilation, storing excess heat in thermal mass). Passive cooling strategies are often coupled with passive ventilation strategies, and the cooling function is achieved by increased passive ventilation air flow rates during periods when the outdoor air temperature is low enough to flush heat from the building (Fergus, 2008).

Passive cooling is the passive design method that is required in hot dry climates as prevalent in Kebbi which makes them the system to be considered for the purpose of this thesis. Heat enters and leaves a home through the roof, walls, windows and floor. Internal walls, doors and room arrangements affect heat distribution within a home. These elements are collectively referred to as the building envelope. Passive cooling maximizes the efficiency of the building envelope by minimizing heat gain from the external environment and facilitating heat loss to natural sources of cooling: A useful design strategy for the hot dry climate is to first control the amount of heat from solar radiation and heated air reaching the building, then to minimize the effect of unwanted solar heat within the building skin or at openings. Next to reduce internal or casual heat gains from appliances and occupants and finally, where necessary, to use environmental heat sinks to absorb any remaining unwanted heat.

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

Passive cooling measures are sub-divided into three group as heat reduction and preventive, thermal insulation, and heat dissipation method. Heat reduction and prevention method is achieved by minimizing heat gain from solar radiation into the indoor space by proper integrating building to it local climatic factors and micro environmental element as landscape, nature ventilation, proper orientation, and calculated shading.

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

The passive cooling techniques which will aid the cooling of the buildings towards energy efficiency are discussed below

2.4.1 Evaporative cooling

Evaporative cooling decreases the indoor air temperature by evaporating water, this is shown in Figure 2.5. In dry climates, this is commonly done directly in the space. But indirect methods, such as roof ponds, allow evaporative cooling to be used in more temperate climates too. Ventilation and evaporative cooling are often supplemented with mechanical means, such as fans. They use considerably less energy to maintain comfort compared to refrigeration systems (Brown *et al.*, 2011). It is also possible to use these strategies in completely passive systems that require no additional machinery or energy to operate.

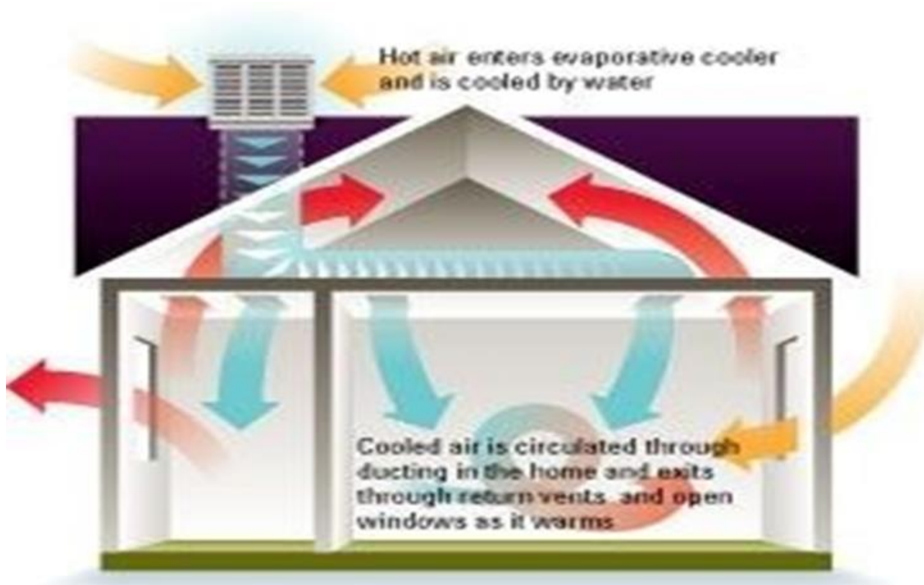


Figure 2.5: Evaporative cooling technique
Source: (Brown *et al.*, 2011)

Evaporative cooling is cooling that deals with water. Heat from hot air is absorbed by water body, leaving cool air in the atmosphere. The amount of Heat absorbed from the air depends largely on the amount of moisture content in the air. Evaporative cooling can be achieved in the presence of water bodies such as fountains, courtyard pools, and water falls. The presence of these water bodies in an environment cause absorption of heat and flow of cool air. Evaporative cooling can also be achieved through vegetation (plant, shrub and tress) as evapotranspiration as seen in Figure 2.6.

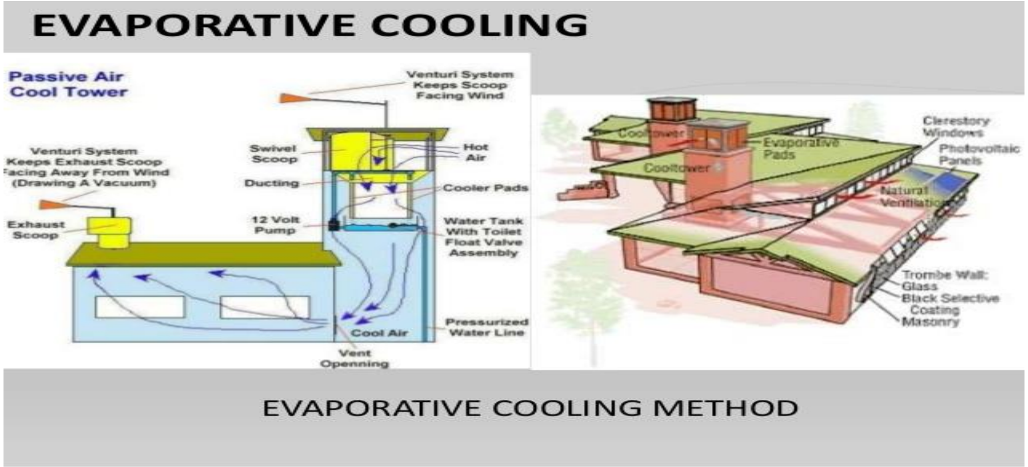


Figure 2.6: Evaporation cooling method
Source: (Brown *et al.*, 2011)

2.4.2 Convective air movement

Convective air movement relies on hot air rising and exiting at the highest point, drawing in cool air from shaded external areas over ponds or cool earth, this is represented in Figure 2.7. Convection produces air movement capable of cooling a building but has insufficient air speed to cool the occupants. Clerestory windows spin away roof ventilators, and vented ridges, eaves and ceilings will allow heat to exit the building in nil breeze situations through convection (Chris, 2008).

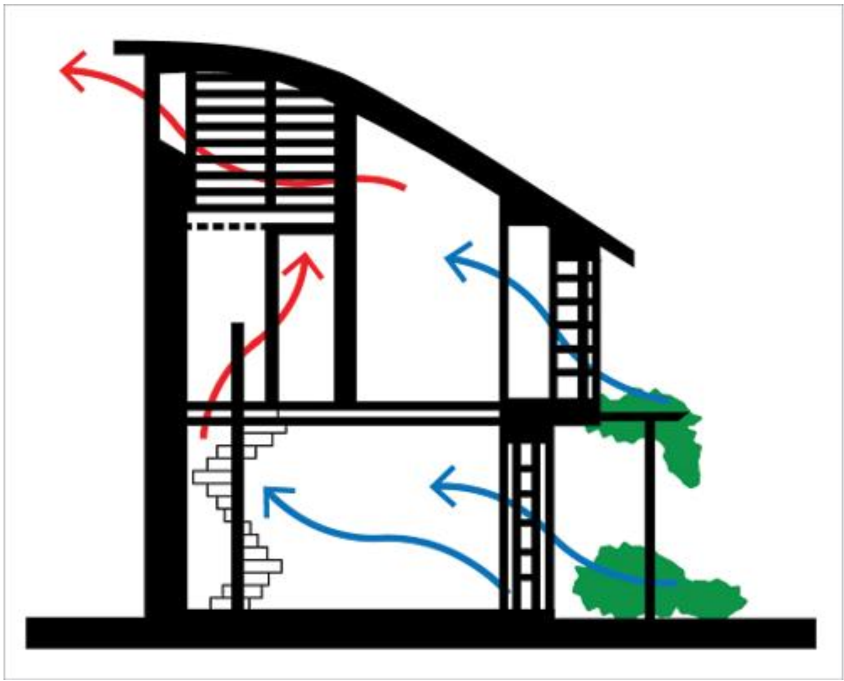


Figure 2.7: Convective air movement in a building
Source: (Chris, 2008)

2.4.3 Natural ventilation

This method of cooling uses mainly air movement to ventilate occupants' space (Chen, 2019). Windows are positioned on opposite sides of the building to enhance the process of cross ventilation. Designers decide on enhancing natural ventilation with the use of tall spaces within buildings in the form of stacks or chimneys since there is no absolute control of the occurrence of natural breeze, this is represented in Figure 2.8. The openings are positioned near the top of the stack to allow warm air to escape, while cooler air moves into the building from openings at the lower level. For buildings to be well ventilated, they are to be open during the day for air flow (Freire, 2013).

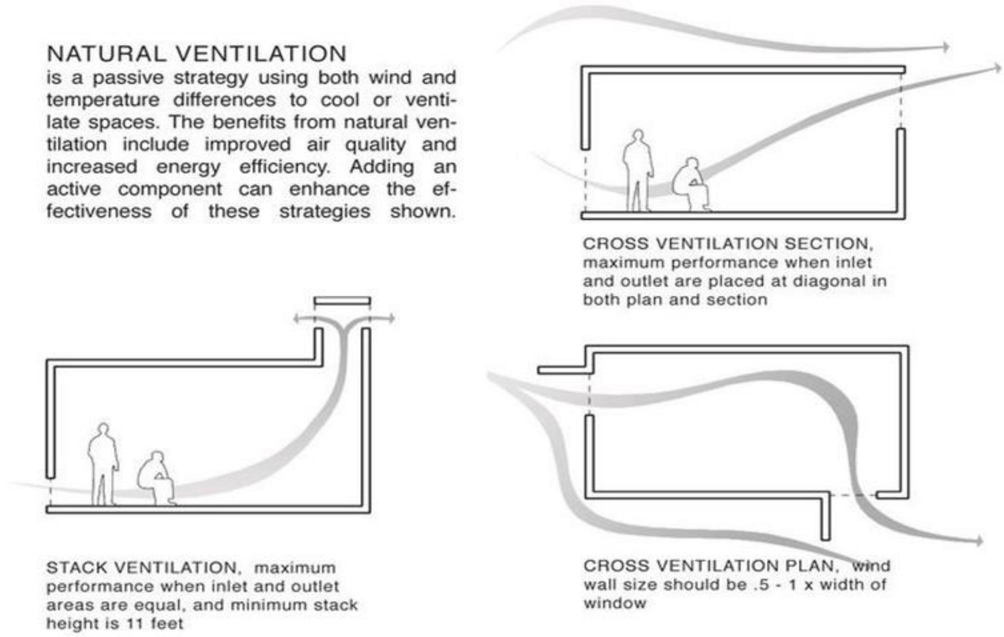


Figure 2.8: Natural ventilation with the assistance of air blown into an indoor area

Source: (Freire, 2013)

Also, natural ventilation can greatly contribute in improving thermal comfort, decrease the needs for air conditioning, and improve indoor air quality in the developed world. As previously explained, a serious limitation of natural and night ventilation application in dense urban environments has to do with the severe reduction of wind speed in urban canyons. Outdoor pollution is also a grave limitation for natural ventilation in urban areas (Matheos, 2005).

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

A proper natural ventilation is one of the most important passive cool strategy in a hot humid climate. It is an element which allow the flow of air to increate evaporation and reduce heat from the fabric of the building (Szokolay, 2004). When natural ventilation is under a shade environment, it is mostly effectively cooling as the flow air changes in evaporation and relative humidity as seen in Figure 2.9.

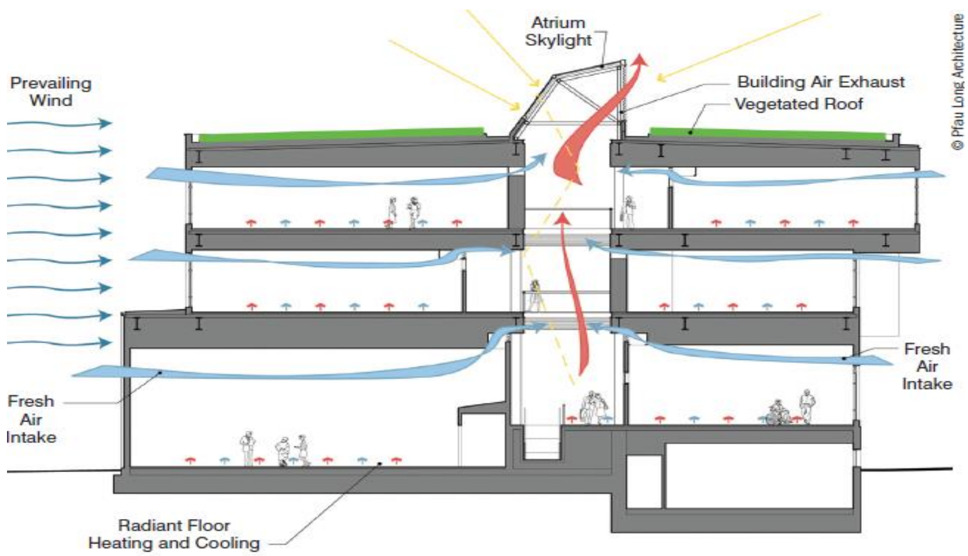


Figure 2.9: Effect of proper cross ventilation to change air flow and its temperature

Source: (Matheos, 2005).

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

2.4.3.1 Thermal buoyancy

Thermal buoyancy driven ventilation occurs when there is a density difference between the internal and external air, which again is caused by temperature differences between the inside and outside

(Lechner, 2014). Thermal buoyancy is sometimes referred to as the stack effect or the chimney effect. The difference in density creates pressure differences that pull air in and out of a building through suitably placed openings in the building envelope. When the indoor air temperature exceeds the outdoor temperature, an over-pressure is built up in the upper part of the building and an under-pressure is formed in the lower part. At a certain height, the indoor and outdoor pressure equals each other, and this level is referred to as the neutral plane. An over-pressure above the neutral plane drives air out through openings in the building envelope, and an under-pressure under the neutral plane pulls air in through openings in the building envelope (Klieven, 2003).

2.4.3.2 Wind

Wind driven ventilation occurs as a result of various pressures created on the building envelope by wind. These pressure differences drive air into the building through openings in the building envelope‘s windward side, and drive air out of the building through openings in the building envelope‘s leeward side (Chiras, 2012).

There are several types of ventilation opening but the common ones are single-sided ventilation, cross ventilation, and stack ventilation and are represented in Figure 2.10 and 2.11.

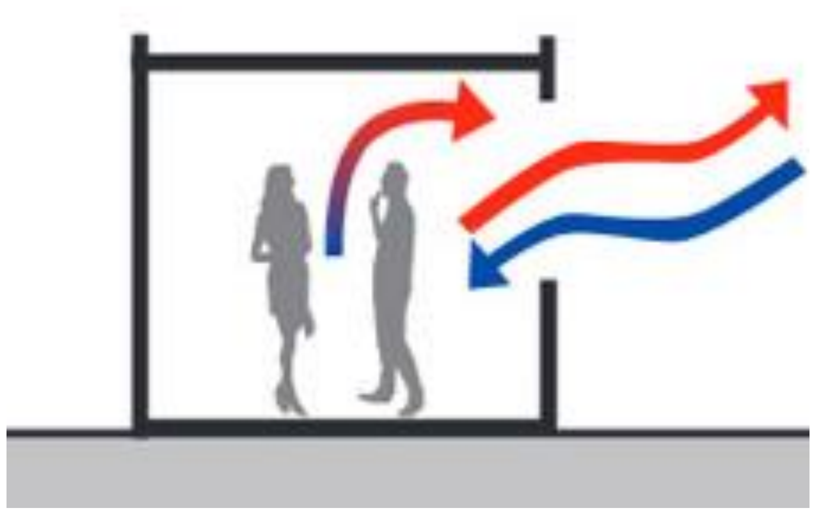


Figure 2.10: Single-Sided Ventilation
Source: (Klieven, 2003).

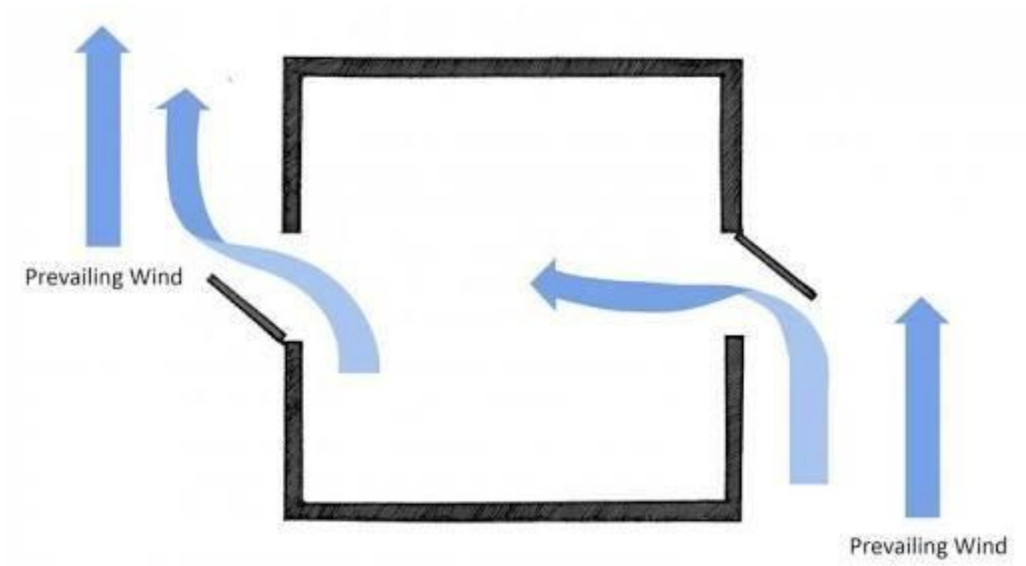


Figure 2.11: Cross ventilation
Source: (Klieven, 2003).

2.4.4 Thermal mass of buildings

Thermal mass generally means materials capable of absorbing, holding, and gradually releasing heat (thermal energy), this can be seen in Figure 2.12. Thermal mass is the ability of a material to absorb heat energy. A lot of heat energy is required to change the temperature of high density materials like concrete, bricks and tiles. They are therefore said to have high thermal mass. Lightweight materials such as timber have low thermal mass. Appropriate use of thermal mass throughout a building can make a big difference to comfort and cooling (Chris, 2008). High thermal mass depends on the ability of materials in the building to absorb heat during the day. Each night the mass releases heat, making it ready to absorb heat again the next day. To be effective, thermal mass must be exposed to the usable spaces. A slab floor would be an easy way to accomplish this in a design.

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

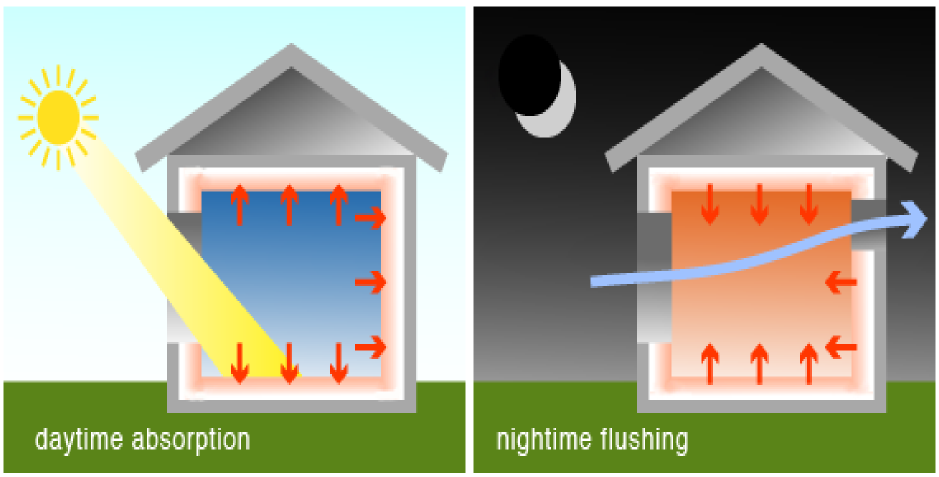


Figure 2.12: Effect of thermal mass

Source: (Vladimir, 2008)

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

2.4.5 Thermal insulation

Thermally insulating materials are poor thermal conductors that slow the rate of heat losses and gains to and from the outside. Effective thermal insulation is one of the most critical design parameters of building envelope (Santamouris, 2007). This reduction of heat transfer is expressed in terms of R Value and U-Value. Minimum R-Values and maximum U-values for key building envelope components are prescribed by current ASHRAE 90.1 building energy standards. Any building material has an insulating effect. This is most apparent with floor coverings on concrete slabs. Timber or carpet will effectively insulate the slab and reduce (or eliminate) its effectiveness as a heat sink. Internal strapping and lining to walls will have the same effect, as will acoustic ceiling tiles (Santamouris, 2007).

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

This insulation function as a passive system which reduces the amount of heat gain in hot humid climatic building, and also moderate the rate at which heat is gain or lose for in the building at some period in the day. Thermal insulation can be seen in three type as; capacity, resistive and reflective thermal insulation.

Capacity thermal insulation elongate the time for heat transfer or sink into the indoor space. It mass content slow the movement of heat through it, this might take up to eight to twelve hours (8-12hours). This long hour of heat transfer reduces the effect of the heat gain and later become lower to be ventilated by night ventilation. Thermal massing should be used in places which are exposed to direct solar radiation as under the roofing and the interior of an exposed wall as shown in Figure 2.13.

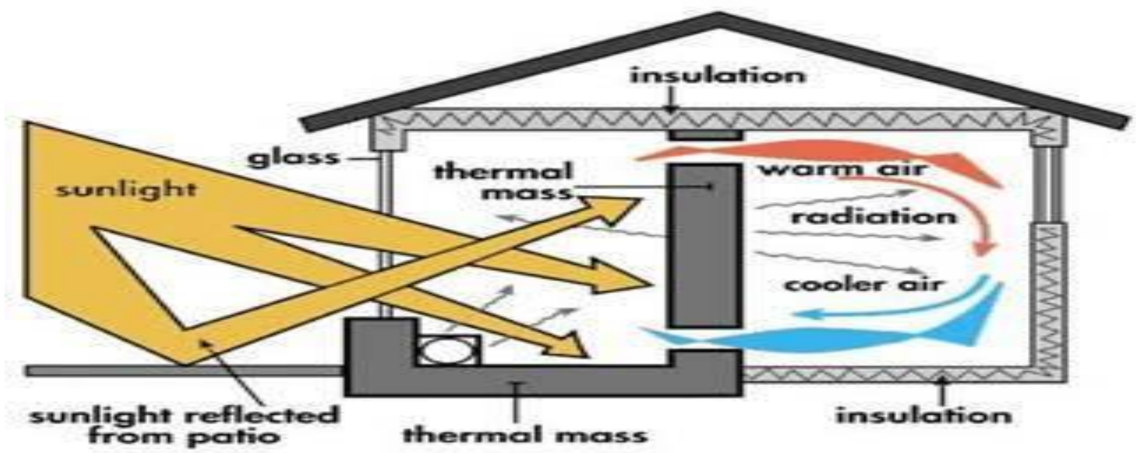


Figure 2.13: Effect of thermal insulation in heat absorption

Source: (Vladimir, 2008).

2.4.6 Building orientation

Properly oriented buildings take advantage of solar radiation and prevailing wind. According to Li *et al*, (2007), the longer axis of the building should lie along east-west direction for minimum solar heat gain by the building envelope. This is because the orientation of a building controls the heat gain on the exterior walls of the building as it affect the cool capacity in the space as shown in Figure 2.14. In the case of conflict between the building orientation against solar radiation to building and the wind flow, the application of overhangs, wall shades are used and for the wind flow vegetation is advice.

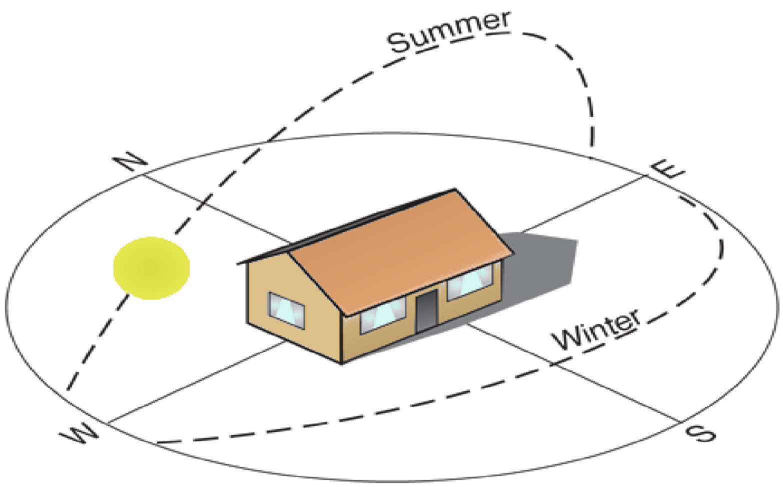


Figure 2.14: Building orientation with reference to the sun direction
Source: (Li *et al*,. 2007)

2.4.7 Soft landscaping elements in building

Studies highlight the importance of trees and shrub in a built environment, these save energy, reduce and moderate air temperature and reduces air pollution. It increase relative humidity and improve human health. Proper tree planting reduces the heat load on the building to about 40%. Tall tree with large foliage that are positioned well are most preferable for passive system, there canopy prevent solar radiation from the building and easy flow of wind under them as seen in Figure 2.12. They also note that trees can act complementary to window overhangs, as they are better for blocking low morning and afternoon sun, while overhangs are better barriers for high noon sunshine.

The study by Nowak *et al.* (1996), ascertain that tall tree shades can reduce annual energy for heat gain by 10% -50%, this is represented in Figure 2.15. The style and pattern of plant-covered wall sections affect the cooling behaviour of the building dynamics during the dry season. discovery for research study, point the that thermal benefit for tree planting depend mainly on its canopy coverage level and planting density in the built environment, and a little on other species characteristics (Emmanuel and Baker 2012).

Figure 2.15: Effect of landscape element
Source: (Emmanuel and Baker 2012)

Table 2.1 shows the various passive cooling measures and their relative Architectural elements that can be adopted in building design.

Table 2.1: Passive cooling measures

S/N	**Passive cooling measures**	**Architecture elements (Variables)**
1	Building orientation control	Longer side on northeast – southwest trades wind axis
2	Soft landscaping elements in building	Shrubs, trees climbers, green roof, ground cover grass, indoor planting
3	Shading devices use in building	Vertical, horizontal and Egg-crate shading devices

4	Fenestration in building	Openings in building for fresh air in, windows and openings
5	Thermal insulation in building	Hollow block walls and concrete floors
6	Natural Ventilation	Fresh air around the building
7	Evaporative cooling system in buildings	Water pool, fountains and atrium
8	Radiative cooling in building	Reflective materials, reduction of hardcover around the building
9	Ground cooling system	Suspended floors for good air movement
10	Courtyard pool in building	Courtyard and openings

Source: (Ahsan, 2009)

2.7 Benefits of Passive Cooling Strategies

Energy consumption is an essential element of development. While increased energy use clearly has many benefits, we are also becoming increasingly aware of the negative impacts of energy use (Yamba, 2016). We experience these negative impacts globally and locally in the form of climate change and degradation of local environments in terms of poor air quality, degradation of soils, resource depletion, and noise pollution.

However, more efficient use of energy at all stages of the supply/demand chain could reduce the negative impacts of energy consumption, while still allowing the same economic development. Some of the benefits are discussed below.

2.7.1 Minimized life-cycle costs

Life cycle costs of a building depend on the insulation performance of walls, shape of the building, area of floor and ceiling; ventilation and air conditioning systems, heating and cooling requirements (Pitts, 2017). Minimizing the amount of energy used for the building's operation will improve its energy efficiency and reduce costs significantly.

2.7.2 Reduced resource consumption

In addition to overall environmental benefits that arise from a more energy efficient building, there are also economic benefits. Reduced heating and electrical bills are one major benefit to upgrading a home or building a more energy efficient home. As well, installing these energy-efficient technologies effectively works to "future-proof" the building by making investments that will be selling points well into the future (IEA, 2015). Overall, even though there is an initial amount of money that must be put in to improve energy efficiency, home owners will often recover these costs in a short period of time due to the reduced energy expenses. This payback time can be short, taking only a few years (Kumar *et al.*, 2015). Methods of integration are being studied in different countries as many buildings were not designed from inception with a comprehensive operational approach. However, to minimize energy demand in current development trends, building owners and occupants are reconsidering the incorporation of different systems in their buildings; for instance, buildings are now integrated with water management and alternative power generation with Green roofs and Living walls to bring down costs (Francis and Lorimer, 2011).

2.7.3 Reduced environmental impact

The need to use fossil fuels to power generating sets to provide energy for operation is reduced when the building is energy efficient and as a result, greenhouse gas emission is reduced. As well, the reliance on non-renewable fuels is not sustainable, and it involves using more and more destructive processing means to obtain these fuels. Homes and other buildings account for nearly 40% of total US energy use (Cheng and Ma, 2015), Canada is lower with just under 29% (Leuko *et al.*, 2015), and thus increasing their efficiency will improve the reliance on non-renewable fuels for the future. This environmental benefit of reducing the number of greenhouse gases is both local and global. There are local benefits due to the fact that a buildings energy demand requires a local supply of energy, which causes local pollution and negative health side-effects. This allows communities to focus on investing funds in other places instead of in building power plants (IEA, 2015).

2.7.4 Healthier indoor environment

An energy efficient building will promote a healthy indoor environment for its occupants. There are significant considerations in creating comfort conditions during the design phase. For example, size of openings to allow sufficient ventilation and natural light will minimize the use artificial lighting to brighten up work and living spaces. However, introduction of vegetation in the form of Living walls and Green roofs can reduce airborne pollutants like dust and pollen. Plants also filter noxious gases given off of the furniture and fitting placed inside the building. It has been estimated that 1m2 of grassed roof top removes 0.2kg of airborne particulates from the air each year (Shi *et al.,* 2015).

2.7.5 Emissions and health benefits

Fossil fuel-based electricity generation is a source of air pollution that poses risks to human health, including respiratory illness from fine-particle pollution and ground-level ozone (Hu *et al.,* 2016). The burning of fossil fuels for electricity is also the largest source of greenhouse gas (GHG) emissions from human activities in the United States, contributing to global climate change (Ncube *et al.,* 2017). Improving energy efficiency and increasing the use of renewable energy can reduce fossil fuel-based generation and its associated adverse health and environmental consequences.

2.7.6 Improvement in designing of building envelope

Location and surrounding features influence the temperature of a building. For instance, trees, landscaping, and topography provide shade and serve as wind brakes.

Solar passive heating is achieved in cooler climates by positioning windows southwards to increase the amount for sunlight into the building. Improvement of thermal insulation, low emissivity glazing, reduction of air leakage and photovoltaic panels are the major options to improve the performance of the building envelope. The addition of thermal insulation for building surfaces can be a cost-effective measure of improving energy efficiency (Lam *et al.,* 2011).

2.8 History of Medical Educations in Nigeria

Pre-colonial Medical care was essentially provided by traditional practitioners who had their training through apprenticeship usually under relatives, conversant with the art of healing. It is still the mainstay of medical care for some in Nigeria. Though sources differ regarding the first Nigerian to be trained as a medical doctor in the western type of medicine, most sources believe Africanus Horton and William Davies were the first to qualify in London in 1858 (Scram, 1971). The first to be employed in the public service was Dr. OguntolaSapara in 1896 (Brown, 1961). The first formal attempts at offering Medical Education in Nigeria was in 1927 when the government decided to set up an institution for training medical manpower to diploma level (Scram, 1971). They were trained to practice only in Nigeria. Though they had the standard five-year training as in British Medical Schools, their facilities and teachers were inadequate to train them to standards acceptable outside this country. They came to be seen as second-class doctors, and they resented the differential in conditions of service they were subjected to compare to foreign- trained doctors. It was therefore of no regrets when the program was abolished.

The background to the establishment of the first medical school was the outcome of the Asquith and Elliot Commissions on higher education in the colonies (Brown, 1961). The latter was specifically focused on West Africa. Its outcome was the decision to establish the University College, Ibadan, with a Faculty of Medicine as one of the initial faculties. This was realized in 1948. The plan was to train the premedical students at Ibadan, the preclinical students in Lagos and the clinical years at Ibadan. The graduates were to be trained to the same level as those in Britain and to be awarded the degree of the University of London. However it became apparent that the general hospital that was to be used as a teaching hospital was inadequate to meet the standards required by the University of London. A decision was then taken to establish an appropriate teaching hospital, the UCH Ibadan.

2.8.1 Growth of medical schools in Nigeria

In 1960 the Ashby Commission on Higher Education in Nigeria recommended the establishment of more training institutions, including medicine (Brown, 1961). It was therefore decided to expand the facilities at Ibadan for increased intake, to establish a new medical school in Lagos and another in Northern Nigeria. Thus the College of Medicine of the University of Lagos was established. The regional governments, decided to establish their universities and with them medical faculties at Zaria, Enugu and Ile-Ife. The Mid-West region, which came later, followed with its university and Medical School at Benin. These latter four were all taken over by the Federal Government and, together, can be said to be the first generation (Ibadan) and second generation (the other four) medical schools. (Some would prefer to include Benin in the group of eight that were later established by the Federal Government (Tishkoff *et al.*, 2009)

The military government later established more universities in 1975- 76, and with them more medical schools, these being the third generation schools. The first private medical school was established in 1990 and more State and Religious-sponsored institutions have been established since then so that as of now we have over 28 fully or partially accredited medical schools in existence in the country (Jinadu *et al.,* 2012). The fourth generation medical schools would comprise these ones that have been established subsequently. Many are still struggling to find their feet. There are also others that are yet to receive even partial accreditation and so are not included in this list.

2.8.2 Regulation of medical education in Nigeria

Regulation of undergraduate medical education has continued to be under the dual oversight of the National Universities Commission (NUC) and the Medical and Dental Council of Nigeria (MDCN) (Malu, 2010). While the former establishes academic standards and all that go with it, the latter is more concerned with the quality of the graduates that come from the training institutions. that they are being adhered to by training minimum allowed academic standards and does periodic monitoring to see that they are being adhered to monitoring to see that they are being adhered to by training institutions while the MDCN usually makes sure all facilities and staff are adequate for accreditation at inception, but after the final accreditation for the first final examination in the school it appears not to carry out any more inspection on a regular basis.

This research will incorporate all findings in this study to design a well nature ventilated faculty of basic medical sciences in the location mentioned in this study with design of three main departments in the faculty.

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

For the purpose of achieving the objectives as stated in the introductory part of this research work, a descriptive survey method of quantitative research design was adopted. Descriptive survey method involves a direct observation of a sample of a population. A purposeful survey was conducted on four (4) faculties of basic medical buildings in tertiary institutions spread across Nigeria. The survey was conducted by direct observation of passive cooling variables which include orientation, building envelope, thermal mass, shading and overhangs, openings, ventilation, and landscaping. An extensive investigation was carried out to determine the extent to which passive cooling design techniques have been adopted in university faculties of basic medical science building design. For the purpose of this research, survey research method was adopted and result gotten was statistically analysed.

3.1 Population of Study

The population of study refers to the number of elements or individuals under investigation. These elements include the study of some functional faculties of basic medical science buildings in Nigerian tertiary institutions. The Ahmadu Bello University Faculty of Basic Medical, Zaria, Kaduna State, the Usman Danfodio University Sokoto Faculty of Basic Medical Science, Sokoto, Sokoto State, the Kaduna State University Faculty of Basic Medical Sciences, Kaduna, Kaduna State and Faculty of Basic Medical Sciences, Bayero University Kano. These university were all with purposive sampling.

3.2 Data Types and Sources

The types of data used in this research are the primary data and secondary data. Primary data is seen as the data collected directly by the researcher or the investigator conducting the research from the field. Secondary data source include the data collected by someone else for some other purposes but being utilized by the researcher for his research purpose.

3.2.1 Primary Data

For this research, primary data was obtained through survey. Direct observations were carried out on the sampled office buildings. Structured questionnaires and observation schedules were the instruments used in obtaining information. The observation schedule presented checklist derived from the techniques and strategies obtained from literature.

3.2.2 Secondary Data

Secondary data was obtained from extensively reviewed literature on the passive cooling design principles and concepts used in passively enhancing the energy efficiency of office buildings. Books, conference papers, journals, presentations and the internet sum up the other sources of secondary data.

3.3 Data Collection Instruments

The instruments used in collecting information for this research are questionnaires and observation schedule. Review of literature also provided principles and checklists used in developing the observation schedule.

3.3.2 Observation schedule

The observation schedule was divided into two sections namely section A, and B. Section A provides information about the Faculty of Medical Science buildings, the information provided in this section include the names, location and ownership of the buildings, the facilities provided in the building. Section B provided information concerning the passive cooling design strategies used in the buildings, the building forms, orientation, construction materials and landscape design were outlined in checklist form.

3.4 Sampling Technique

The method of sampling employed for this research is the convenient purposive sampling. Convenient sampling is a type of nonprobability sampling in which populations are sampled simply because they are convenient sources of data for the researcher. Conveniently, faculties of basic medical science buildings in Northern Nigeria and from around the world were purposively selected. As such, four (4) faculties of basic medical science buildings were selected across Nigeria. Table 3.1 shows the faculties of medicine buildings studied.

Table 3.1 Faculties of medicine buildings observed

S/N	Name of Building.	Location
1	UDUS medical faculty	Sokoto state, Nigeria.

2	ABU Zaria Faculty of Basic Medical Science	Kaduna state, Nigeria.
3	Kaduna State Uni. Faculty of Basic Medical Science	Kaduna State, Nigeria.
4	BUK Faculty of Basic Medical Science	Kano State, Nigeria

Source: (Author's fieldwork 2019)

3.5 Method of Data Analysis

Data were obtained from the field by means of physical observation with an observation schedule as a guide. The data obtained from the field survey was analysed with measures of central tendency such as mode and percentages, otherwise known as descriptive statistical tools. Results are derived using Microsoft Office Excel, and represented in tables and charts for easy understanding.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Data Analysis

This chapter is a discussion on how data collected from the field was analysed, and the tools employed. These discussions are arranged in the order in which the objectives discussed in Chapter One were stated.

4.2 Passive Cooling Design Features that can be adopted to Ensure Users Comfort

From the discussion in Chapter 2.0, the research focused it study deeply into the passive cooling design features that can be adopted in cooling system of the building. The passive cooling measures for faculty of basic medical sciences that was adopted in this research as the passive means of ensuring energy efficiency in the design of the faculty in Nigeria is principal ten in number. Nigeria as a nation does not suffer harsh winter conditions, therefore the passive design features assessed were those necessary for the control of heat gain and heat loss in the building. These design features are integrated within the building's envelope from the roof to the walls and the surrounding environment. These passive design features were the features adopted from the passive cooling measures. They are classified generally as passive cooling measures for energy efficiency as summarised in Table 2.1.

4.3 Extent to Which Passive Cooling Measures Were Applied in Medical Buildings in Northern Nigeria

Before assessing the relevant design features, it was a necessary to get some background information on the medical buildings studied. This information is represented in Table 4.1.

Table 4.1: Basic Information on the medical buildings studied

Name of school	Location (State)	Type of buildings
ABU	Kaduna	Storey
BUK	Kano	Storey
KASU	Kaduna	Bungalow
UDUS	Sokoto	Storey

Source: (Author's fieldwork, 2019)

The analysis of feedback of the questionnaire distributed is shown in Table 4.2 and the result from the valid data collected were analyzed below using SPSS software which were represented using descriptive charts and tables .

Table 4.2: Information on the data collected

Total no. of distributed questionnaires	Total no. of returned questionnaires	Total no. of invalid questionnaires	Total no. of valid questionnaires
600	520	40	480

Source: (Author's fieldwork 2019)

The respondents of this instrument were mainly lecturers and students who use the buildings for over a year, this shows reliability of the data collected. The respondents to the information gathered were more of male than the female identified that both genders make use of the buildings. Majority of the users of the faculty were lecturers and students.

The educational qualification of the majority of the users in the buildings were degree holders which is 46% from the result in Figure 4.1 followed by the 23% of O'level holders. This reveals that the data collected were mainly from educated individuals which emphasis the credibility and also the reliability of the research.

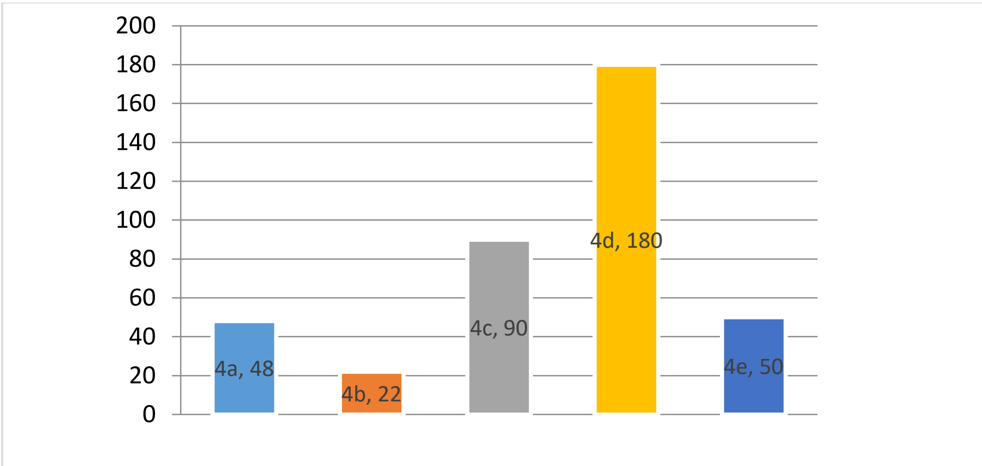


Figure 4.1: Educational qualification of the respondents
Source: (Authors fieldwork 2019)

The staff working experience were evaluated and it revealed that the majority of staff that data were collected from have being working in the for 3-4 years as was shown in the Figure 4.2 below that 32% were from 3-4 years working experience.

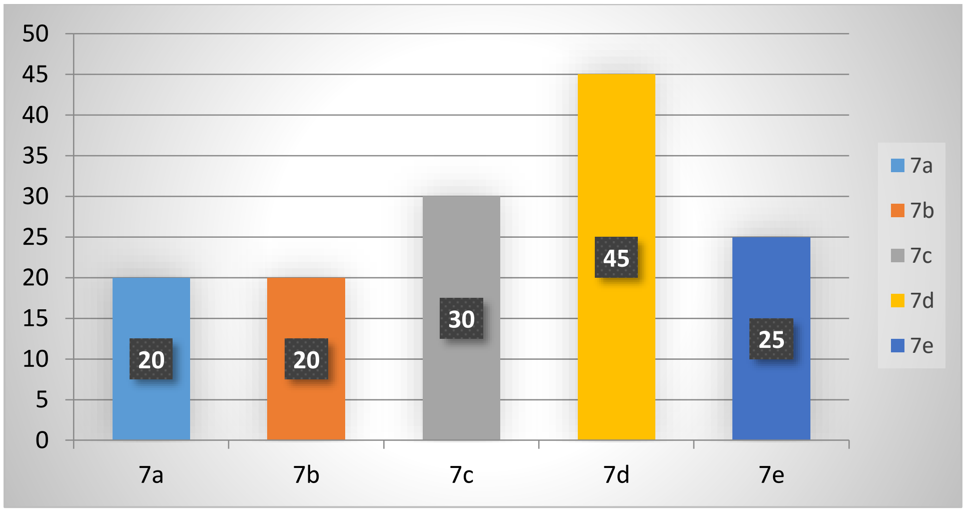


Figure 4.2: Length of working experience of the respondents in the building
Source: (Authors fieldwork, 2019)

From Figure 4.3 it indicated that the operational hours of the buildings were mainly from 8am-6pm which has the percentage of 36% from the result. This result revealed the operation hour of the buildings during the day time.

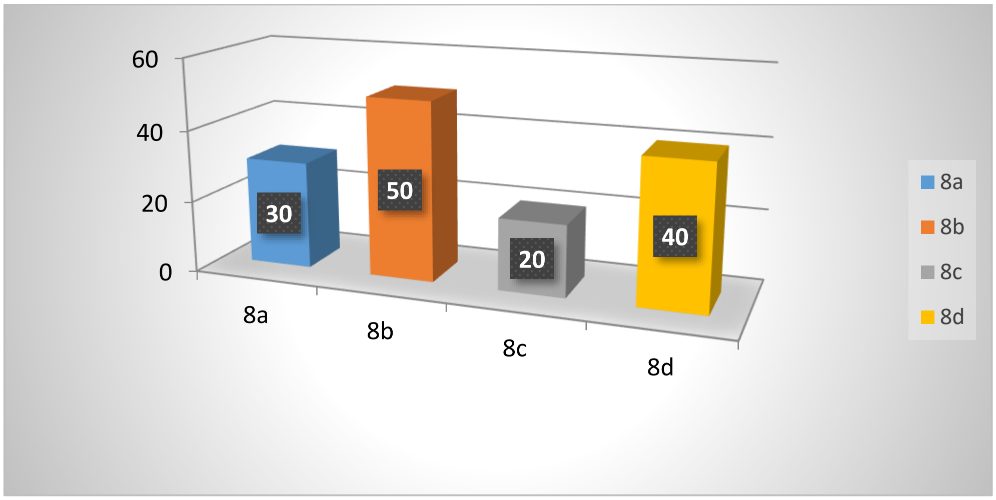


Figure 4.3: Working hours of the respondents in the buildings
Source: (Authors fieldwork, 2019)

39% of the result from Figure 4.4 showed that AC/ Fan were usually switch on between 12pm-7pm to cool the building. This implied that the building became warmer within this period.

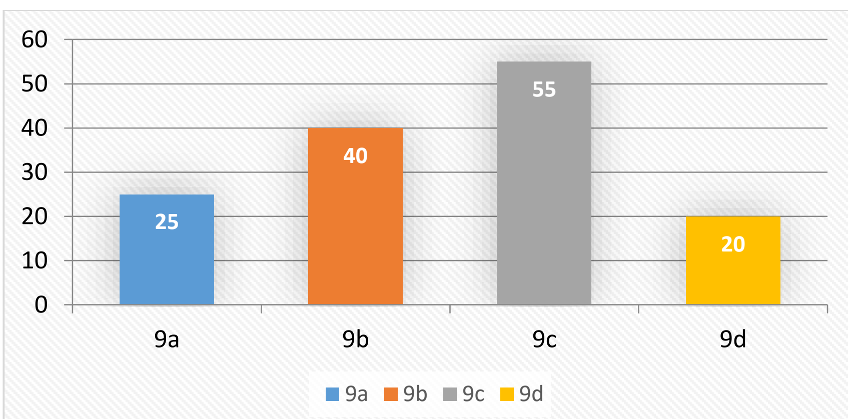


Figure 4.4: Period for putting on the AC/Fan
Source: (Authors fieldwork, 2019)

The result indicated that the users have good knowledge on cooling system as it depicted in Figure 4.5 about 40% of the result showed that. This indicates how well the users have ideas about the research area of this work.

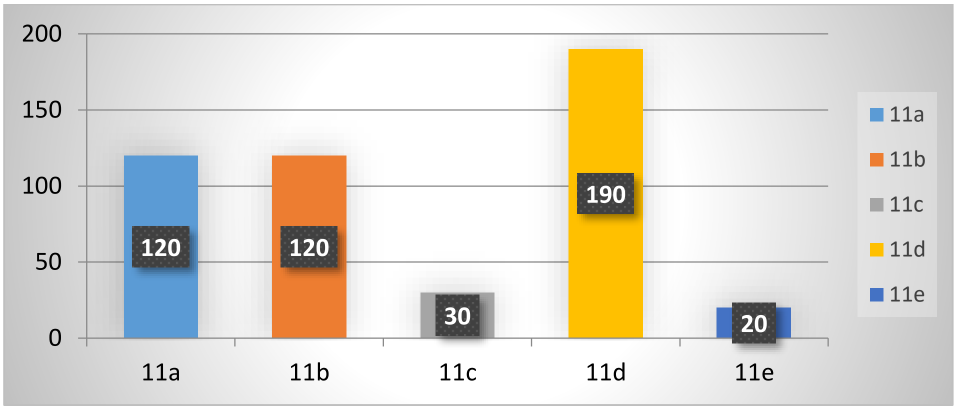


Figure 4.5: Respondents' knowledge on cooling system
Source: (Authors fieldwork, 2019)

44% of the result showed that the majority are a little concerned about the energy conservation in the buildings from Figure 4.6. This implied that the users are not really concerned about energy conservation in the buildings.

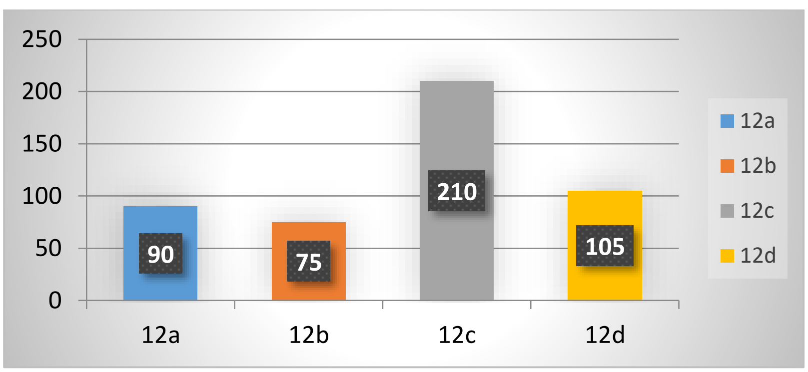


Figure 4.6: Respondents' perception on energy conservation in the building
Source: (Authors fieldwork, 2019)

In the course of this research, it was discovered that the passive design measures for energy efficiency in faculty buildings could be addressed through energy conservation and passive cooling features adopted in the buildings. Therefore, this objective was divided into two parts, thus:

i. Design features for energy conservation in faculty of basic medical sciences.

ii. passive cooling features adopted in the buildings.

Which are represented respectively in Table 4.3 and 4.4.

Table 4.3: Design features for energy conservation

S/N	Design features	Variables
1.	Windows	Types of Windows
		Sizes of windows
3.	Glazing	Type of Glazing
		Use of double-skin façade
4.	Shading Devices	Type of shading device
		Orientation of shading device
5.	Roof	Type of Roof
		Size of Roof overhang
6.	Landscaping	Type of planting used
		Orientation of trees

Source: (Author's fieldwork, 2019)

Table 4.4: Adopted passive cooling measures in buildings

S/N	Passive Design features	Variables
1.	Roof	- Green roof
		- Roof vent
		- Roof material (Breathing skin)
2.	Building Envelope	- Breathing Wall material
		- Floor vent
		- Basement floor
		- Photovoltaic cell/glass/curtain walls
3.	Evaporative Cooling	- Atrium
	System	- Fountains for evaporative cooling

Source: (Author's fieldwork, 2019)

4.3.1 Design features for energy conservation in medical faculty buildings

For the purpose of this research the following Key will be used.

X=YES

Table 4.5 shows the types of windows found in the faculties sampled. From the Table, it is observed that none of the buildings used automated louvers; these would have helped reduce heat gain by automatically opening up to aid natural ventilation when the indoor temperature is high and vice versa. 80% of the selected medical faculty have sliding windows installed. This implies that these buildings have their openings for air inlet and outlet reduced by 50%, 60% of the faculty buildings have casement windows which admits more air compared to sliding windows of the same size. Finally, 40% of the buildings have a combination of sliding and casement window, this is represented in Plate I and Plate II.

Table 4.5: Types of windows found in the selected medical faculty

S/N	Name of Sample	Sliding Windows	Casement Windows	Projected Windows	Louvers
1	ABU	X			
2	BUK	X	X	X	
3	KASU	X	X		
4	UDUS	X		X	
		4	3	2	0

Source: (Author's fieldwork, 2019)

Plate I: Sliding windows at ABU
Source: (Author's fieldwork, 2019)

Plate II: Projected Windows at UDUS
Source: (Author's fieldwork, 2019)

Table 4.6 reports the shading devices in the faculty buildings studied. From this Table, it can be derived that 40% of the buildings studied were made up of horizontal shading devices on east facing wall, combination of both on southwest wall and combination of both on southeast wall that shading devices were not considered in majority of the faculty buildings studied, as only some of the buildings studied is seen to possess short balconies and veranda walls as shading devices. This is also represented in Plate III and Plate IV.

Table 4.6: Type and orientation of shading devices in selected medical faculty

S/N	Name of sample	Horizontal shading devices on east facing wall	Horizontal shading devices on west facing wall	Vertical shading devices on south facing wall	Combination of both on southwest wall	Combination of both on southeast wall
1	ABU	X				X
2	BUK				X	
3	KASU				X	X
4	UDUS	X				
		2	0	0	2	2

Source: (Author's fieldwork, 2019)

Plate III: Shading devices at UDUS
Source: (Author's fieldwork, 2019)

Plate IV: Shading devices at ABU
Source: (Author's fieldwork, 2019)

Table 4.7 shows that none of the buildings studied incorporated green roof into its design. This implies that the building envelope is not protected from solar radiation and direct sunlight. 80% of the faculty buildings were found to use roof overhang with eave projection of 600mm, this size of eave projection is largely insufficient to provide shading for the building envelope and 20% of the buildings studied use roof overhang above 600mm. A deep roof overhang of above 1200mm would have been sufficient to provide shading for the building envelope. This is shown in Plate VI

Table 4.7: Roof in selected faculty building

Percentage of the buildings with Green Roof	Percentage with Roof Overhang 0-600mm	Percentage with Roof Overhang above 600mm	Percentage without Roof Overhang
0%	80%	20%	0

Source: (Author's fieldwork, 2019)

Plate V: Roof Overhang at UDUS
Source: (Author's fieldwork, 2019)

Table 4.8 is a report on how landscaping has been used as a tool for reducing heat gain in the studied buildings. The surroundings of the buildings were found to be covered mostly by hard landscaping as a result of the need for parking spaces. This significantly reduces the rate of evaporative cooling as hot air is met mostly by hard surfaces than the leaves of plants. Some of these can be seen in Plate VII.

Table 4.8: Landscaping for energy conservation

S/N	Name of sample	Shrubs around building	Tall shading trees on south face of buildings	Shading trees on east face of buildings	Shading trees on west face of buildings
1	ABU	X	X	X	X
2	BUK	X	X		
3	KASU	X		X	
4	UDUS	X	X		
		4	3	2	1

Source: (Author's fieldwork, 2019)

Plate VI: Shrubs at BUK
Source: (Author's fieldwork, 2019)

4.3.2 Adopted passive cooling measures in medical faculty buildings

In assessing passive design features for cooling system in medical faculty buildings, the necessary design features were checked to ascertain how well they were applied for energy efficiency.

Table 4.9 reveals that 40% of the faculty have roof vent for hot air outlet from the building however, they did not take advantage of their roof material or green roof as passive cooling features in the buildings. This implies that solar heat, which is abundant in the studied location, is being absorbed by the roof surface through radiation effect into the building and thereby increasing and generating much heat gain within the building. This raised the amount of energy consumption in the faculty studied in cooling the building for the occupant's comfort.

Table 4.9: Integration of roof passive design features for cooling in the buildings studied

S/N	Name of sample	Green roof	Roof vent	Breathing roof material
1	UDUS faculty of Basic Medical Science			
2	ABU Zaria faculty of Basic Medical Science			
3	Kaduna State Uni. Faculty of Basic Medical Science		X	
4	BUK faculty of Basic Medical Science		X	
		0	2	0

Source: (Author's fieldwork, 2019)

Table 4.9 shows that floor vents have not been incorporated into the faculty buildings studied in any way. In table 4.10 the result shows that 40% of breathing wall material (perforated bricks wall) and 40% of curtain walls were also incorporated in the building. This implied that most of the buildings studied did not apply passive design features in the building envelope for energy efficiency.

Table 4.10: Integration of building envelope (passive design features) for cooling in the buildings studied

S/N	Name of sample	Breathing Wall material	Floor vent	Basement floor	Photovoltaic cell/curtain walls
1	UDUS medical faculty	X			
2	ABU Zaria faculty of basic medical science				X
3	Kaduna State Uni. faculty of basic medical science	X			X
4	BUK faculty of basic medical science				
		2	0	0	2

Source: (Author's fieldwork, 2019)

Table 4.10 shows that evaporative cooling design features were rarely applied in the studied facility buildings, 20% of atrium and fountains were applied in the buildings studied as demonstrated in table 4.11 below. This implied that evaporative cooling features were not adopted in the facility buildings studied thereby increasing the cooling cost of the building and increases the energy efficiency of the building.

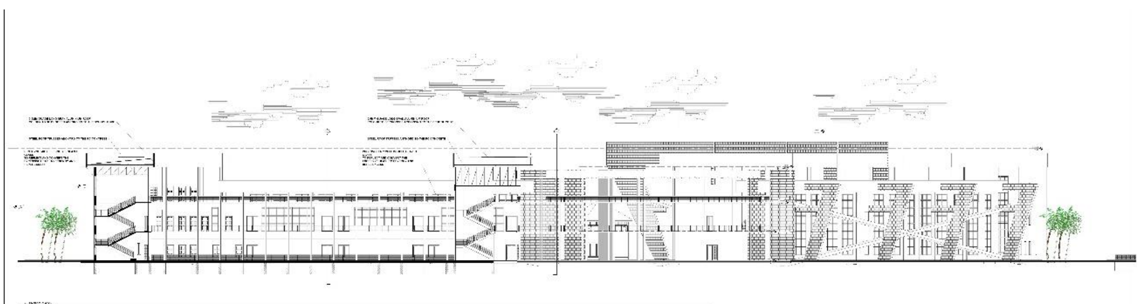
Table 4.11: Integration of evaporative cooling design features in the buildings

S/N	Name of sample	Atrium	Fountains for evaporative cooling
1	UDUS medical faculty		
2	ABU Zaria faculty of basic medical science	X	
3	Kaduna State Uni. faculty of basic medical science		
4	BUK faculty of basic medical science		X
		1	1

Source: (Author's fieldwork, 2019)

4.4 The Proposed Medical Faculty Design

The faculty building proposed is 2 suspended floors. It is designed with every floor having a different floor area and gentle ramp running from the ground floor to the second floor of the proposed basic medical faculty. In order to encourage passive cooling within the building's interiors, it has been designed with a central courtyard, which has openings at different levels of the building. These openings provide inlet and outlet to aid air circulation in the building. These openings are provided on the ground floor (floor vent), the roof vent, breathing roof materials and the breathing wall materials which enhance more fenestration and air movement by the presence of openings in all floors in the building as illustrated in Figure 4.7.



SECTION XX

Figure 4.7: 2-Dimensional Section of the proposed basic medical sciences showing the Courtyard and Air Inlets
Source: (Author's fieldwork 2019)

Fountains as shown in Figure 4.8 were integrated in the proposed building design at each courtyard. It cools the hot air from the building as it comes in contact with the cool water vapour from the fountains in the courtyard; that brings about the evaporative cooling of the hot air and building in general thereby cooling the structure and increases the energy efficiency, as demonstrated in Figure 4.9.

Figure 4.8: 3-Dimensional Section of the proposed basic medical sciences showing the Fountains
Source: (Author's fieldwork 2019)

Figure 4.9: 3-Dimensional Section of the proposed basic medical sciences showing the water body for Evaporative Cooling
Source: (Author's fieldwork 2019)

From Figure 4.10, it shows relaxation area within the second floor and in figure 4.17 demonstrated the flowing and possibilities of air movement into the building courtyard, thereby increasing the outlet of air and inlet of air. This openings on all floors allows the free movement around and within the building and increases the cooling rate of the proposed faculty of basic medical science building. This reduces the use accumulated heat within the building and increases the air fenestration. This take site advantages like the trade-winds and the land - sea breeze.

Figure 4.10: 3-Dimensional Section of the proposed basic medical sciences showing the second-floor students relaxation area
Source: (Author's fieldwork 2019)

Figure 4.11 shows the application of louvers and breathing walls in the proposed faculty of basic medical science building design. It increases the cooling ability of the building and also allows the free flow of inlet and outlet of air. The louvers are adjustable and can be control to suit the demand air flows. The breathing wall materials applied is ETFE materials which have pores on it surface and have the capability of fenestration of air in and out thereby increasing the cooling level of the proposed building as there will not be any much or little hot air within the building thus increases the energy efficiency.

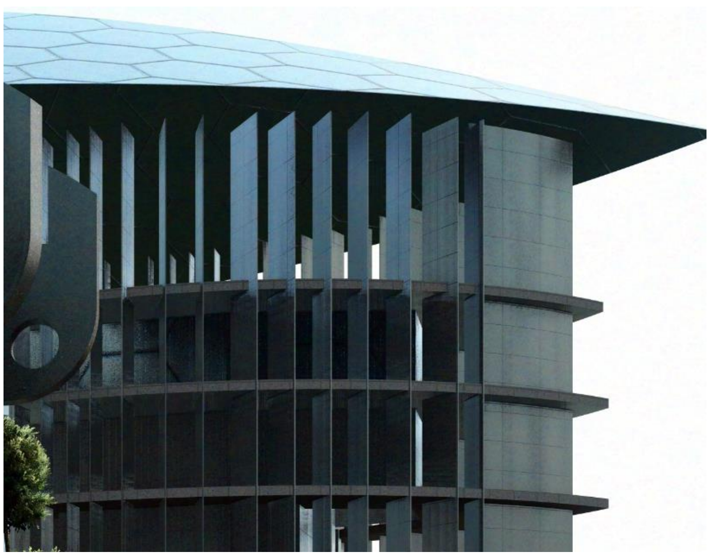


Figure 4.11: 3-Dimensional Section of the proposed basic medical sciences showing the breathing walls and louvers
Source: (Author's fieldwork 2019)

Figure 4.12 shows the application of floor vent in the proposed faculty of basic medical science building design, the floor vent applied aid the air flow in the auditorium and also in the other spaces where it was applied in this design. It allows the flow of air inlet and outlet from the spaces and thereby brings about cooling in the space. The floor vent cools the space within the building as it increases the ventilation of the spaces therefore increases cooling efficiency in the faculty of basic medical science building.

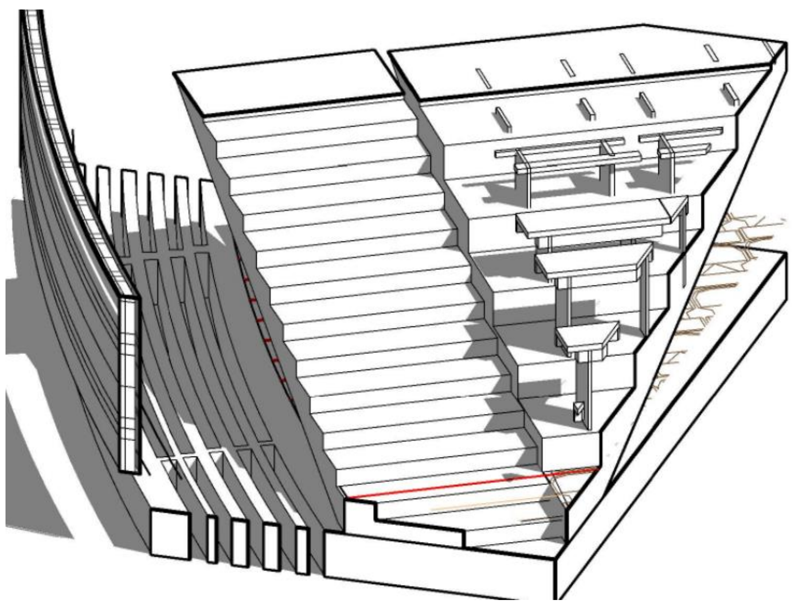


Figure 4.12: 3-Dimensional Section of the proposed basic medical sciences showing the Application of Floor Vent
Source: (Author's fieldwork 2019)

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Passive cooling design features are essential elements for energy efficiency. However, faculty of basic medical science buildings cannot run without adequate passive design features and energy conservation, thereby putting energy at the core of sustainable development. This research showed that although some of the passive design features necessary for the integration of energy efficiency features are not present in the buildings reviewed, however, it should be made a requirement that all designers and developers alike of faculty buildings, especially in hot, dry climate, should resolve to adopt passive cooling design strategies right from the conceptual stage down to the design and final construction, to reduce the over reliance on mechanical means of cooling thereby ridding the environment of harmful gases and providing a sustainable conducive academic environment.

5.2 Recommendations

1. *Members of the built industry should be educated on the benefits of passive design as it affects the environment and the overall health status of the beneficiaries of the built environment and how to achieve it practically.*
2. *Organizations and governing bodies should enact laws governing the construction of buildings to ensure strict adherence to sustainable principles right from the conceptual design stage down to the final construction of the building, thereby reducing the over dependence on the use of mechanical cooling devices and ridding the environment of harmful gases.*

5.3 Contribution to Knowledge

The 21st century has continued to witness an upswing in temperature and emissions of greenhouse gases due to massive urbanization, industrialization and advancement in technology which in turn rises a lot of questions for the professionals of which an upgrade to a more advance principle can solve the growing need of sustainability. This research identified the existing prevailing climatic issues negatively affecting human comfort in built up environment and provided solutions to addressing them. In assessing passive cooling design features for cooling system in basic medical faculty buildings, the necessary design features were checked to ascertain how well they were applied for energy efficiency and sustainability. 80% of windows of buildings observed were sliding, thereby reducing 50% natural air inlet to the habitable spaces. 80% of faculty buildings have roof overhangs 600mm and less thereby giving less protection to the building envelope. Only 40% have roof vents to allow heated air escape from the buildings and did not take advantage of green roof materials. 20% of faculty buildings have atrium, scattered soft landscape and none has fountain, which implied that evaporative cooling features were not adopted thus increasing the cost of cooling the buildings and increase the energy efficiency of the buildings. The knowledge of passive cooling design considerations if fully integrated in faculty of basic medical science buildings will be a positive step to achieving a comfortable and sustainable learning environment in hot dry climatic regions.

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APPENDICES

Appendix A

Federal University of Technology Minna,
School Environment Technology
Department of Architecture

INTEGRATION OF PASSIVE COOLING DESIGN CONSIDERATION FOR FACULTY OF BASIC MEDICAL SCIENCES, FEDERAL UNIVERSITY, BIRNIN KEBBI, KEBBI STATE

Dear respondent,

I am a student in the above named institution currently conducting a research on the topic integration of passive cooling design consideration for faculty of Basic Medical Sciences, Federal University, Birnin Kebbi State. This research is being earned out among different selected buildings within the university in Birnin Kebbi.

Your assistance in completing this questionnaire will be valuable for the study and all information you provide will be completely anonymous and confidential. This survey will provide a valuable insight on the proposed project because it’s strictly for academic purpose.

Thank you.

Salihu, Madalla Usman

QUESTIONNAIRE

Information based on Social Group Factors

i. Age range

10 – 20 years [ ], 21 – 30 years [ ], 31-40 years, [ ]

41 – 50 years [ ], 51 years and Above [ ]

ii. Place of residence. Within school [ ] outside school

iii. Gender: Male [ ] Female [ ]

iv. Status: Staff [ ] Student [ ]

Educational qualification of the respondents

i. Primary school certificate [ ] ii. Secondary school certificate [ ]

iii. First degree [ ] iv. Master's degree [ ]

v. PHD [ ]

Working experience

i. 1-4 years [ ] ii. 5-9 years [ ]

iii. 10-14 years [ ] iv. 15-19 years [ ]

v. 20 years and Above [ ]

Working hours of the respondents in the buildings

i. 1-3 hours [ ] ii. 4-5 hours [ ]

iii. 6 – 7 hours [ ] iv. 8 - 9 hours [ ]

v. 10 hours and Above [ ]

Period for putting on the AC/Fan (use of mechanical cooling devices)

i. 6am – 9am [ ] ii. 9am – 12 noon [ ]

iii. 12noon – 3 pm [ ] iv. 3pm – 6pm [ ]

v. After 6pm [ ]

Respondent's knowledge on cooling system

i. No knowledge [ ]

ii. Knowledgeable [ ]

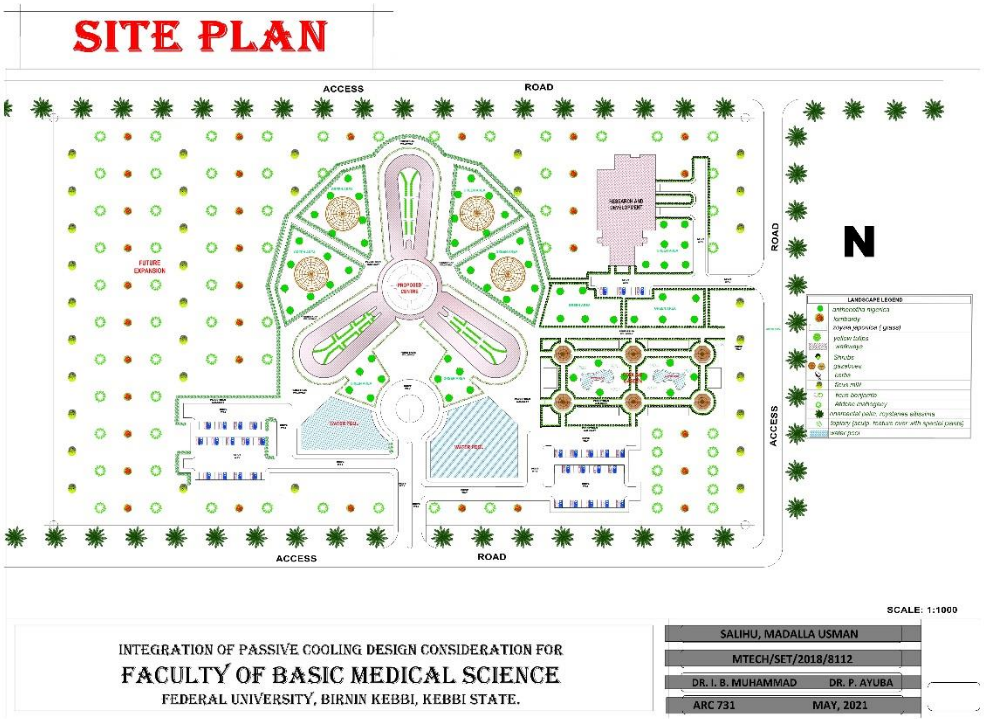
Respondents' perception on energy conservation in the building

i. Not Concerned [ ] ii. Little Concern [ ]

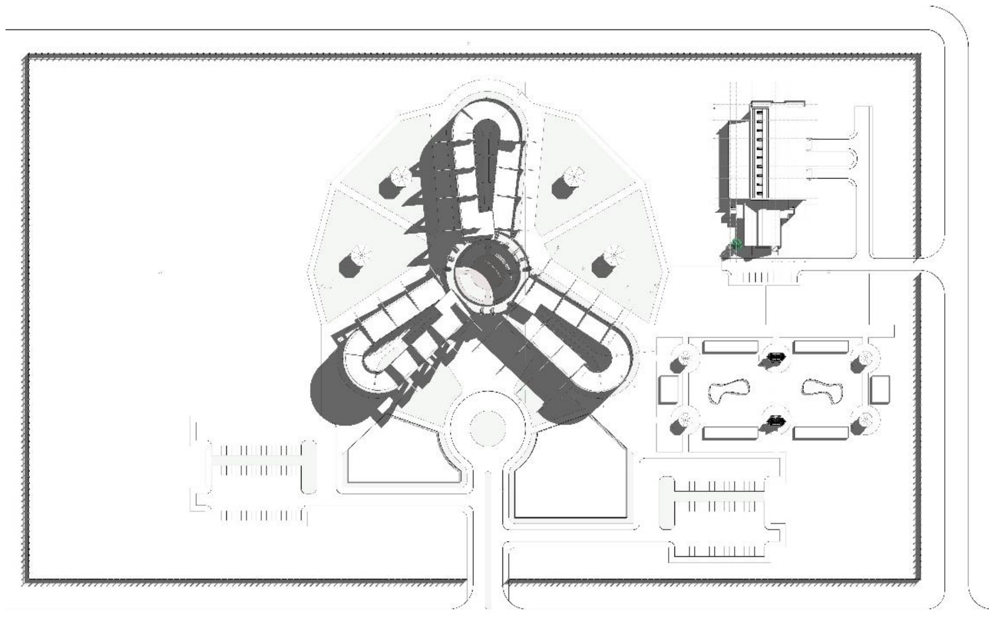
ii. Averagely Concerned [ ] iv. Concerned [ ]

v. Very Concerned [ ]

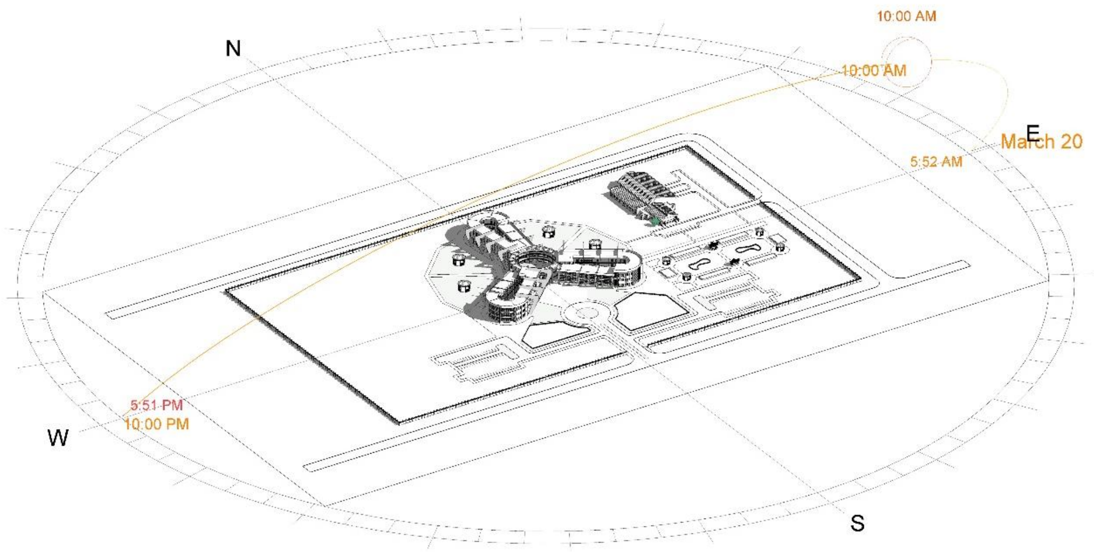
Appendix II



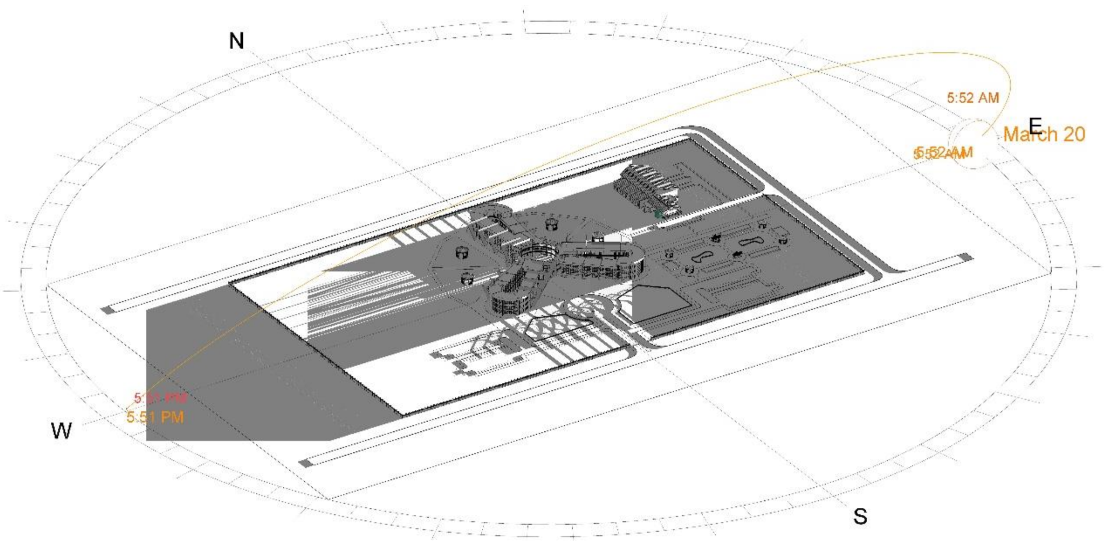
Appendix A: Propose Site Plan



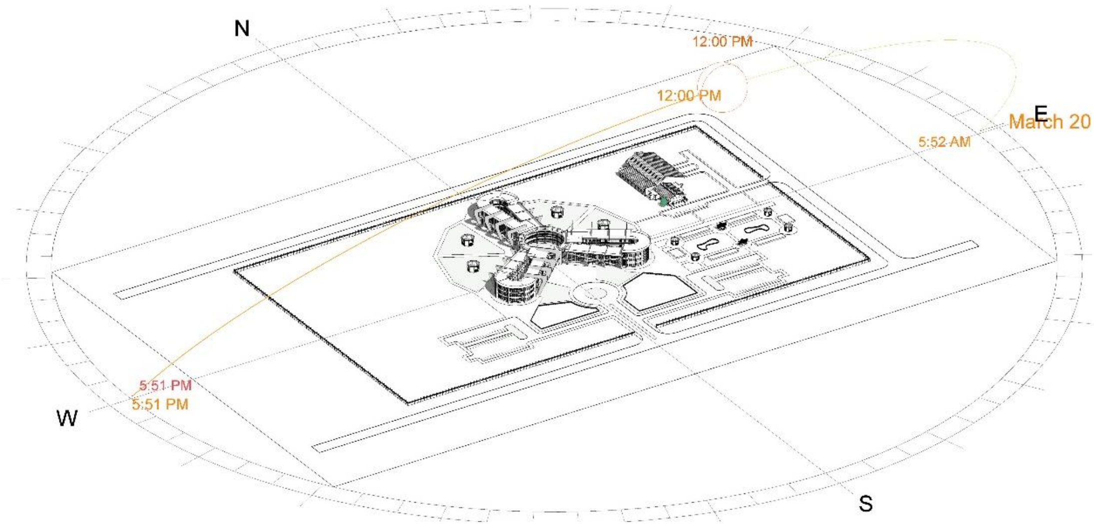
Appendix B: Site Layout



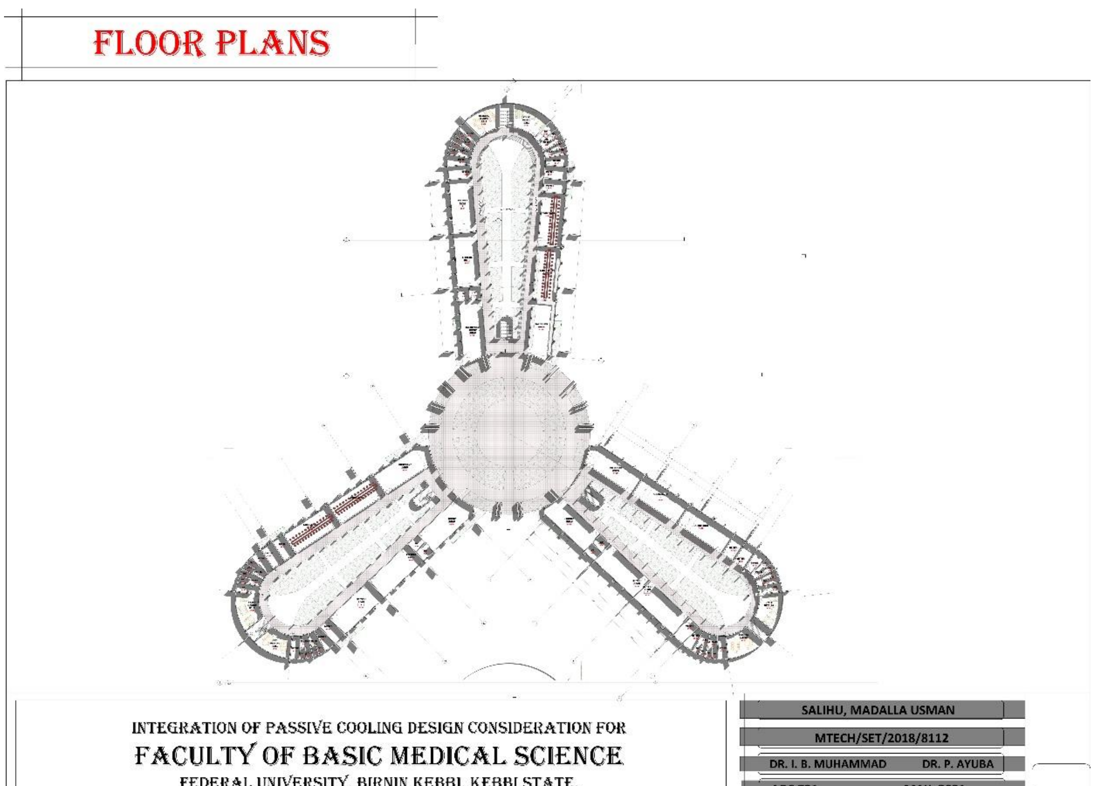
Appendix C: Solar Study



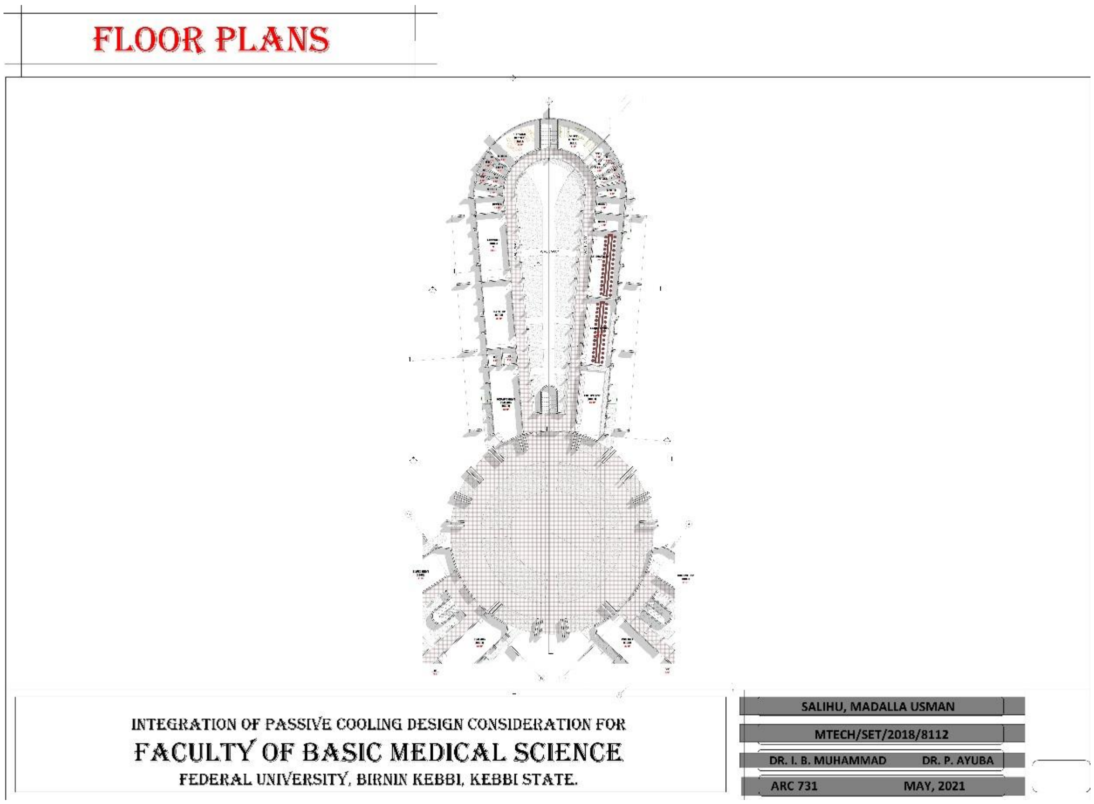
Appendix D: Sunrise



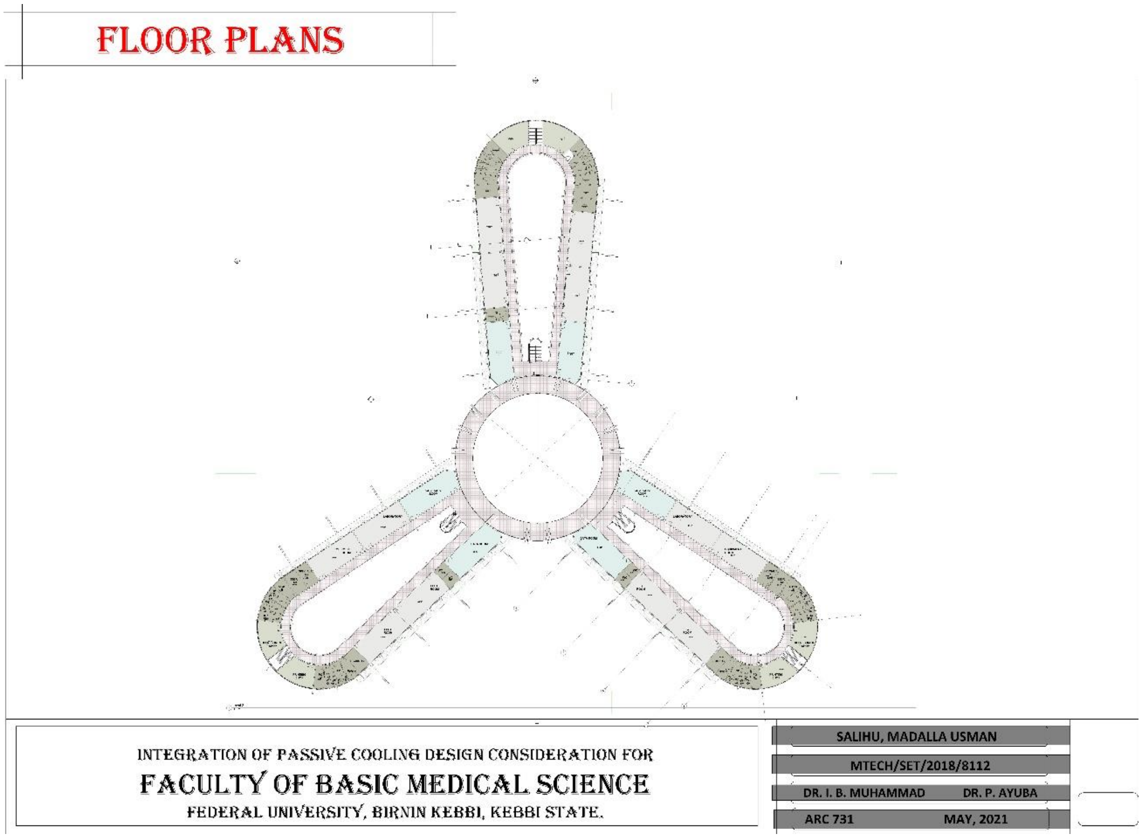
Appendix E: Noon



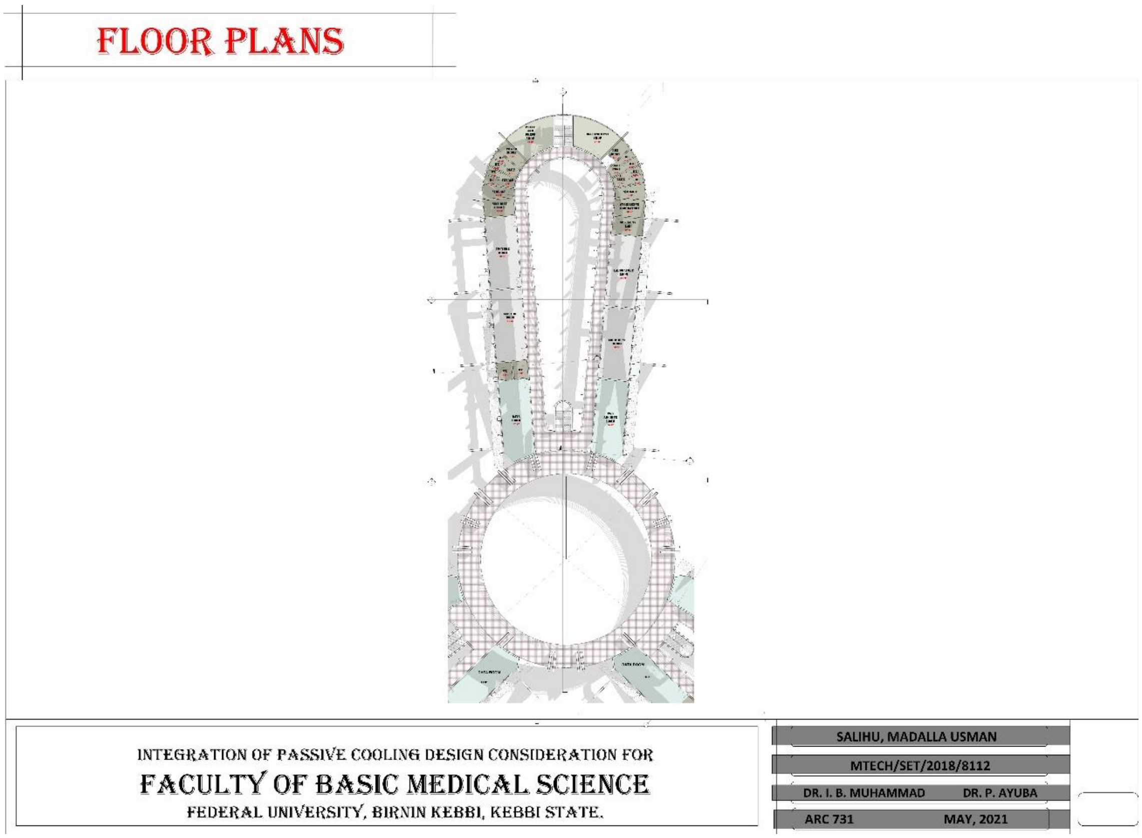
Appendix F: Ground Floor Plan



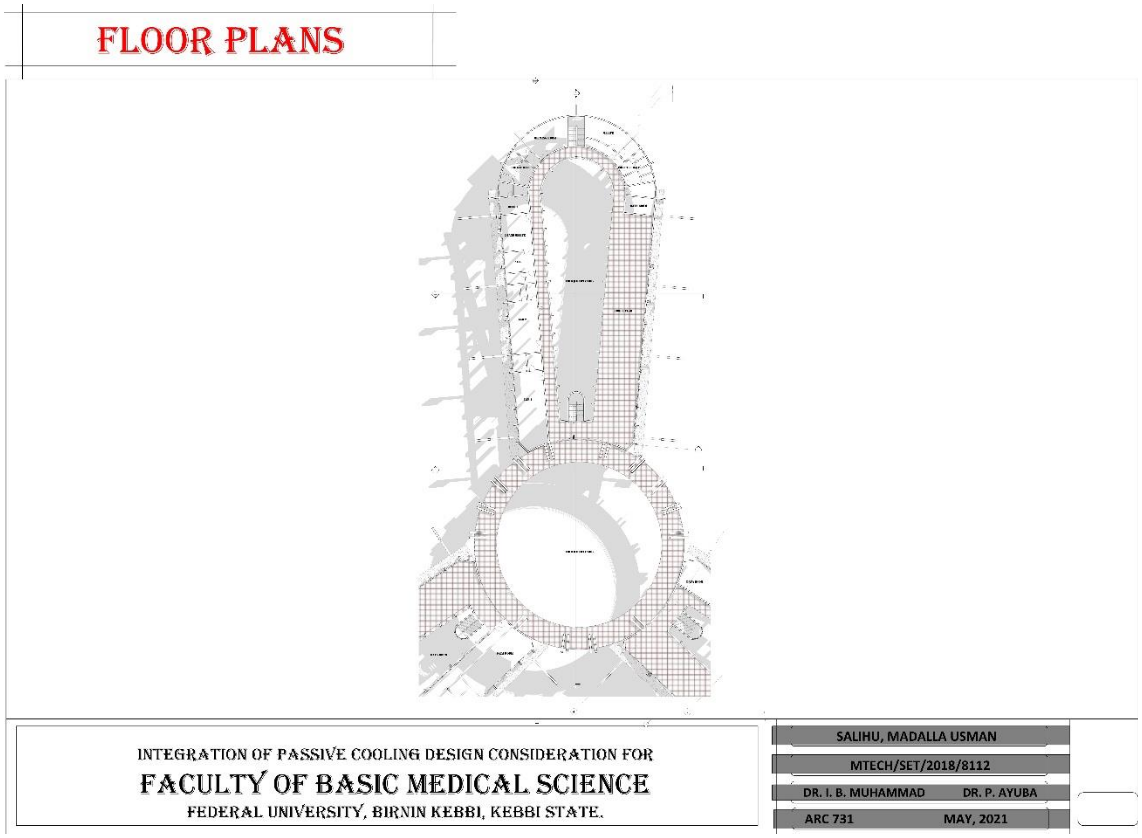
Appendix G: Ground Floor Plan (Blown)



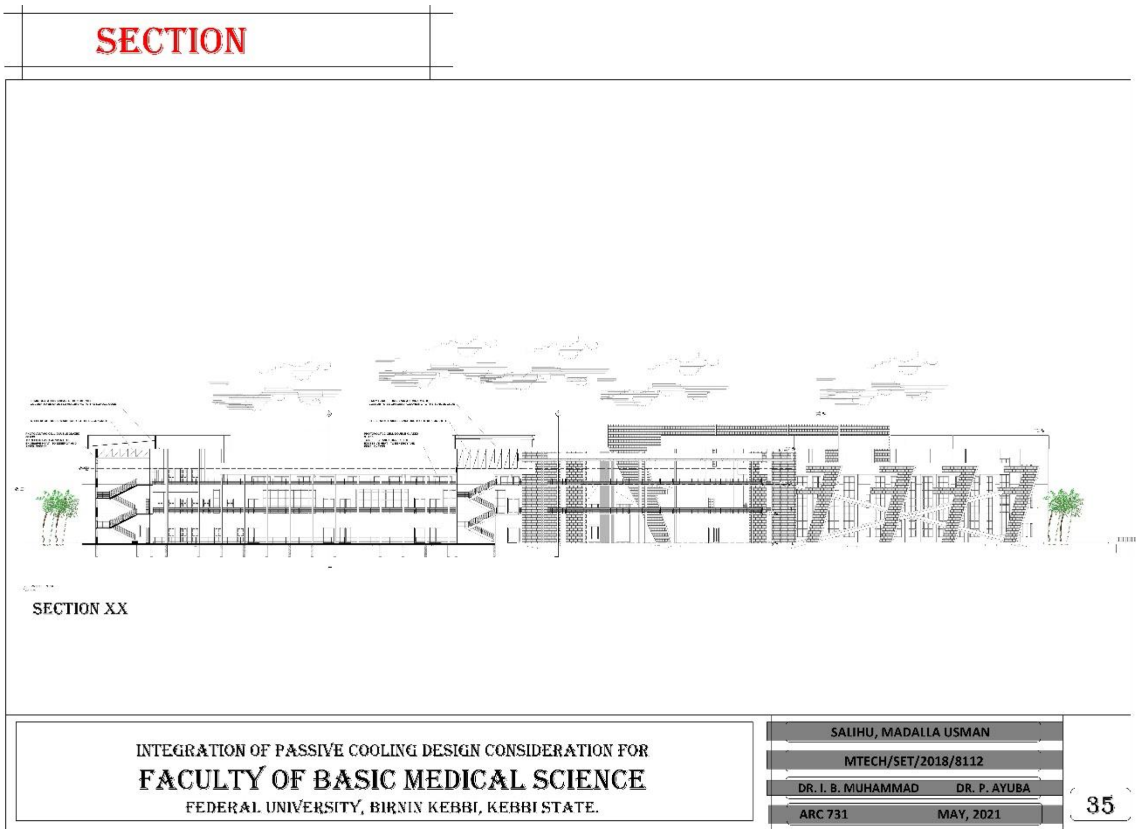
Appendix H: First Floor Plan



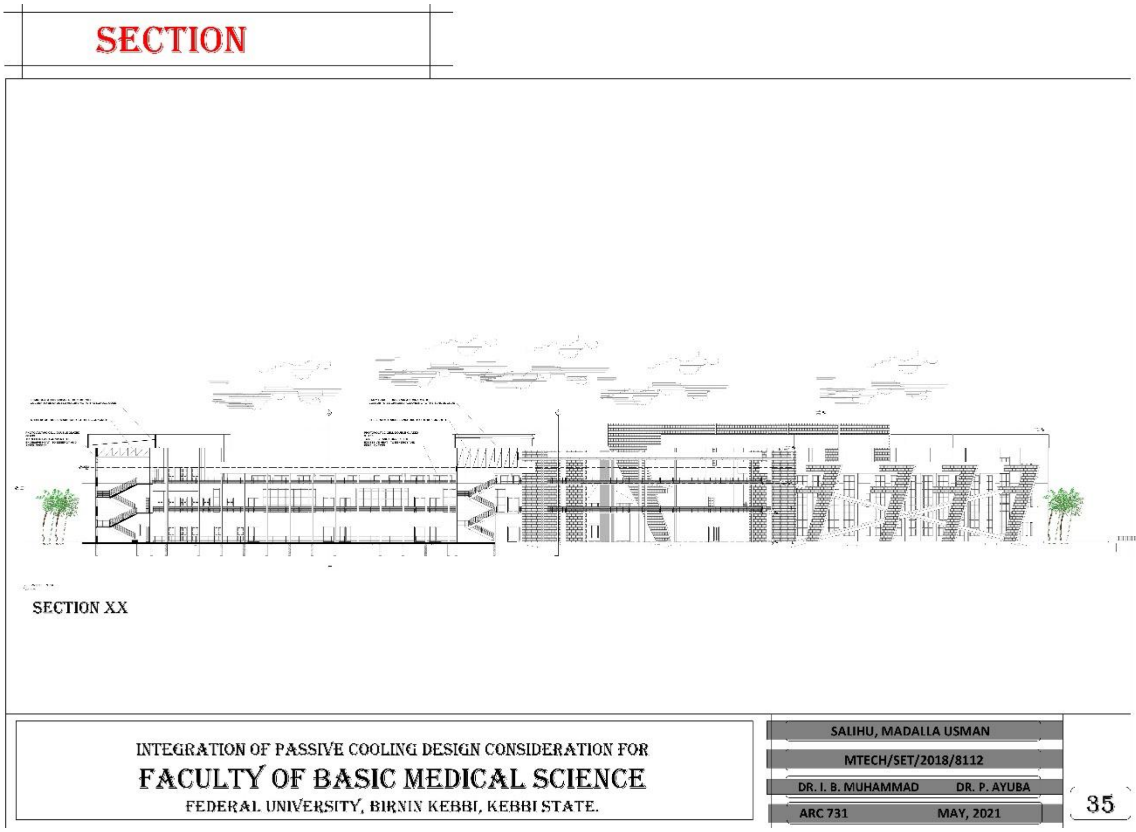
Appendix I: First Floor Plan (Blown)



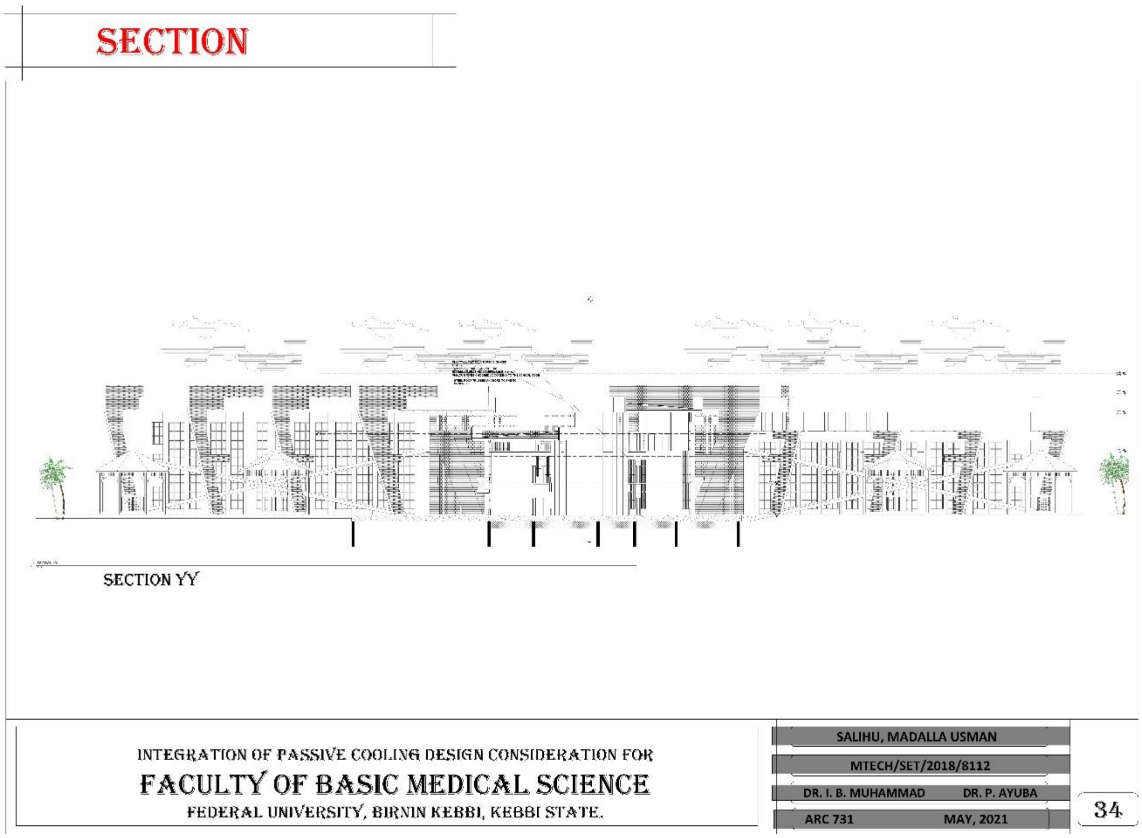
Appendix J: Second Floor Plan



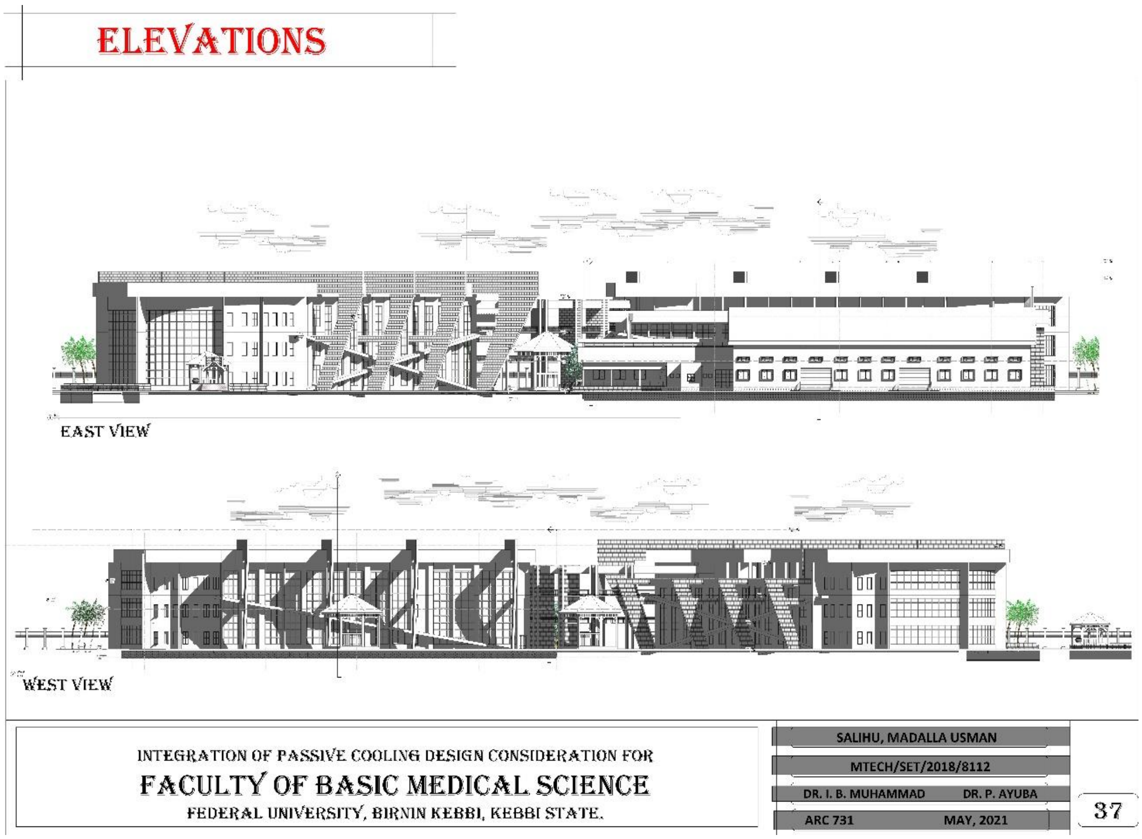
Appendix K: Roof Plan



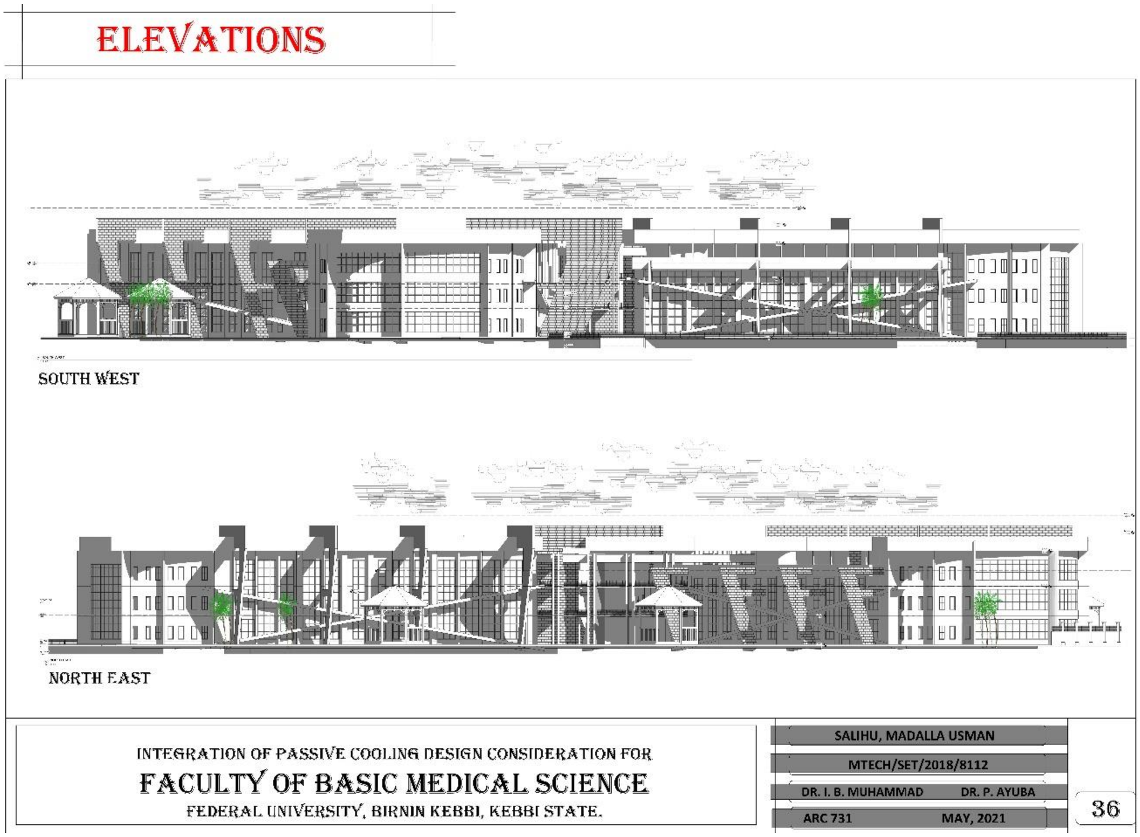
Appendix L: Section X-X



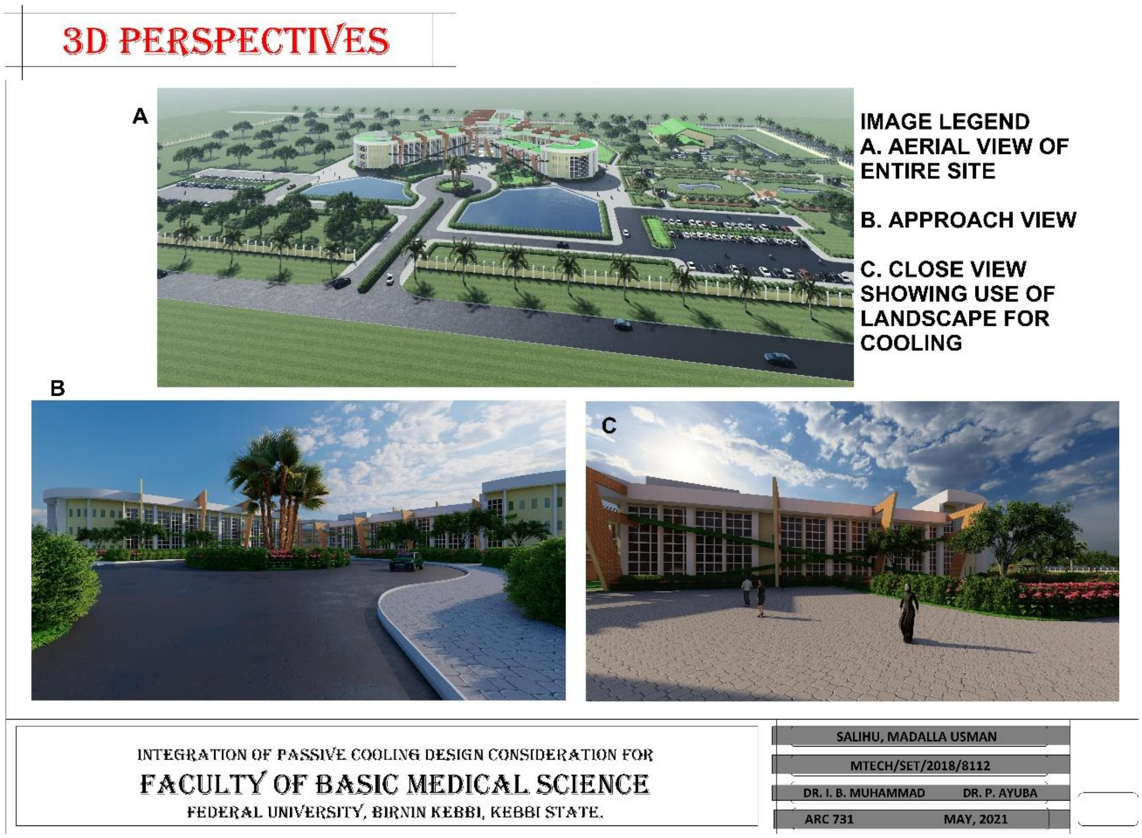
Appendix M: Section Y-Y



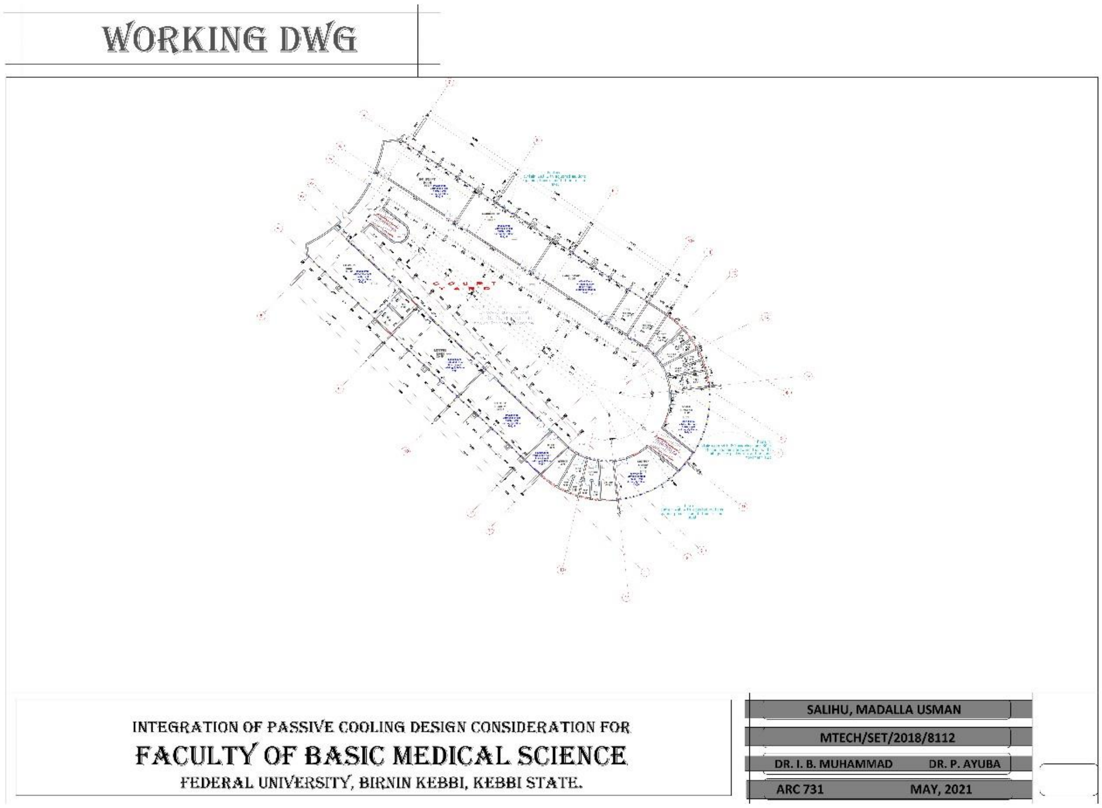
Appendix N: Elevations



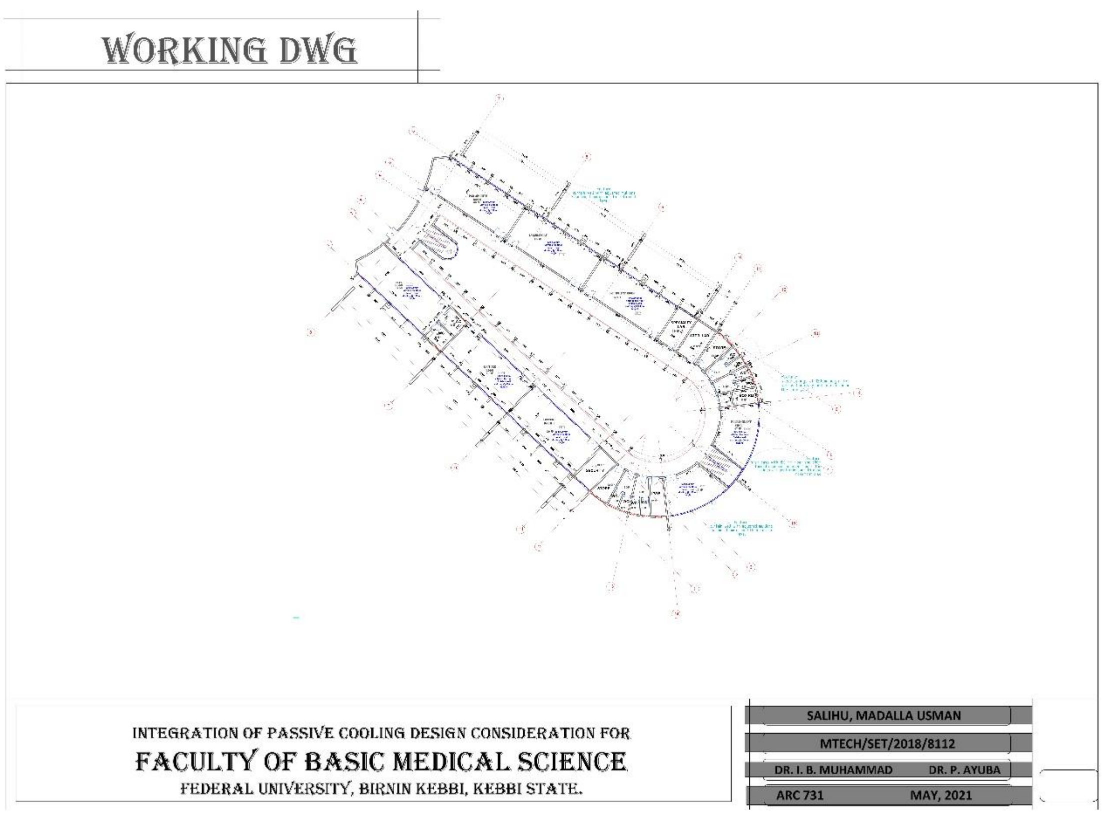
Appendix O: Elevations



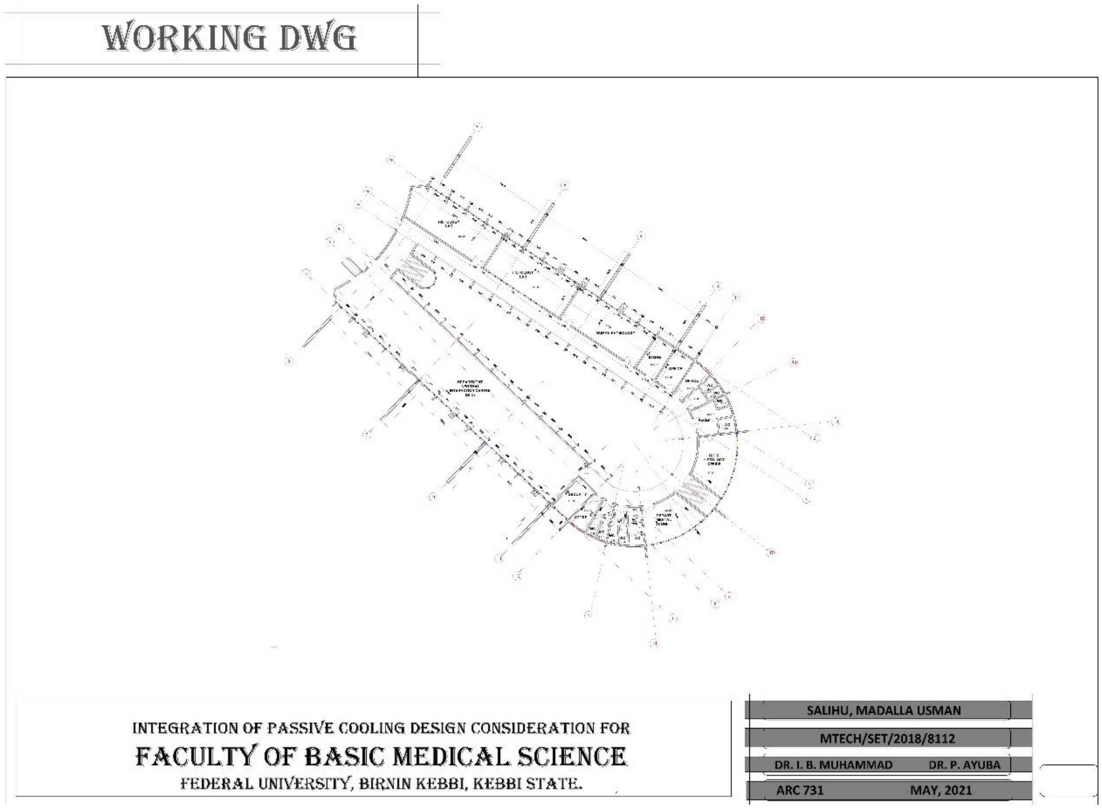
Appendix P: 3D visualization



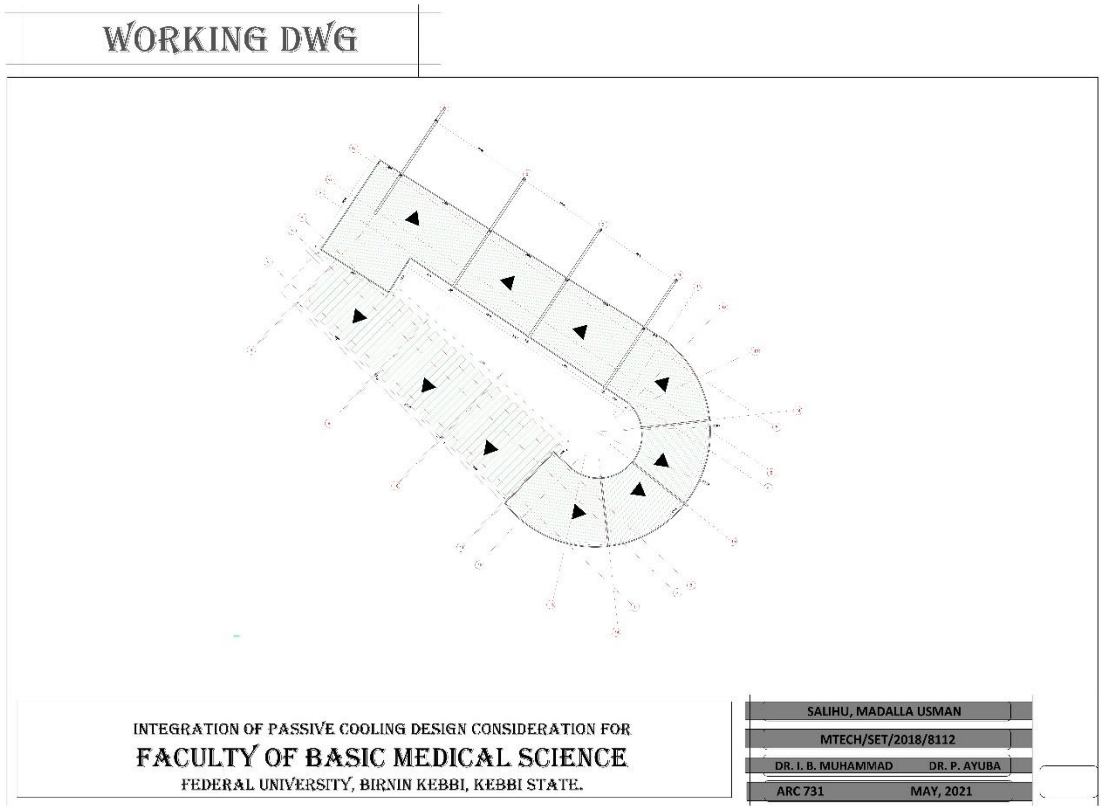
Appendix Q: Ground Floor Plan



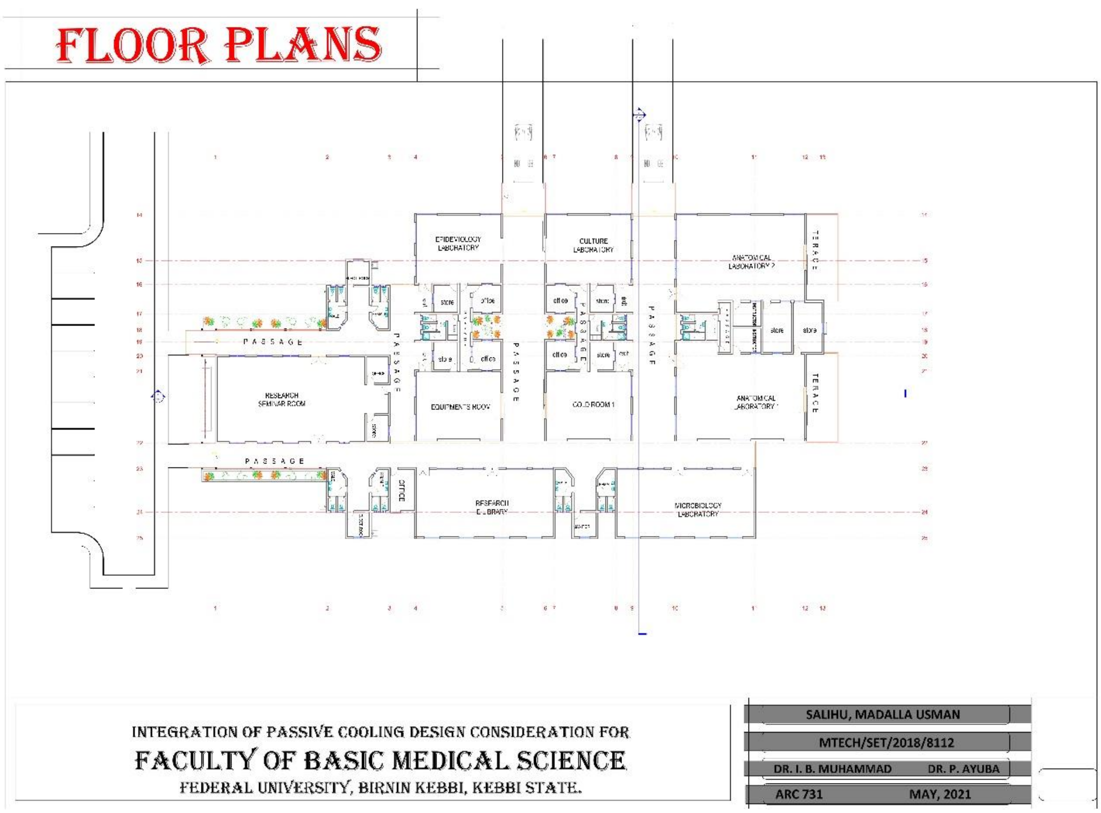
Appendix R: First floor Plan



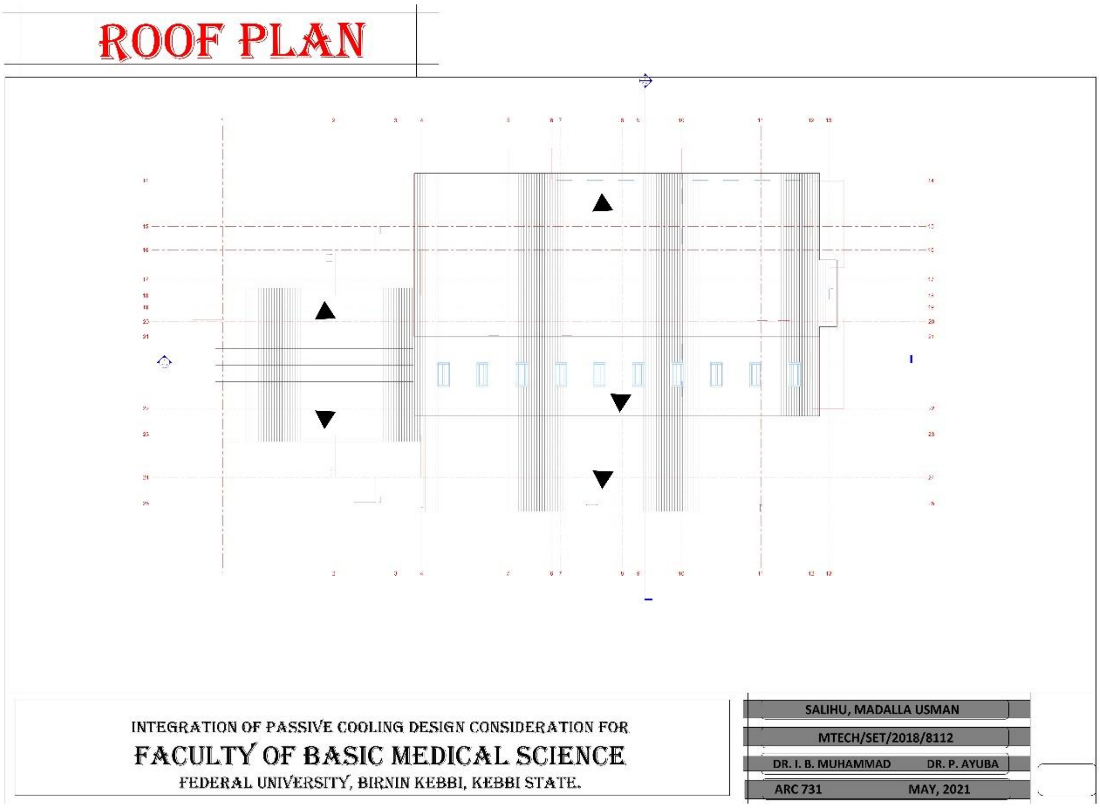
Appendix S: Second Floor Plan



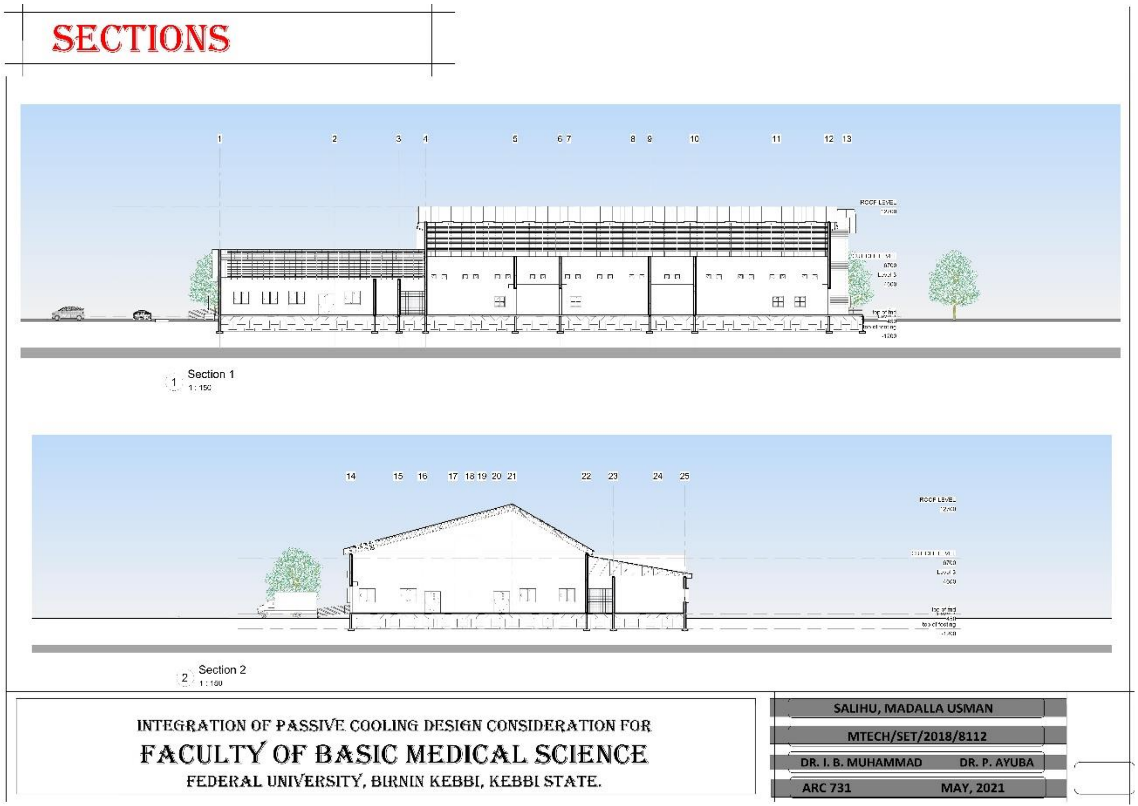
Appendix T: Roof Plan



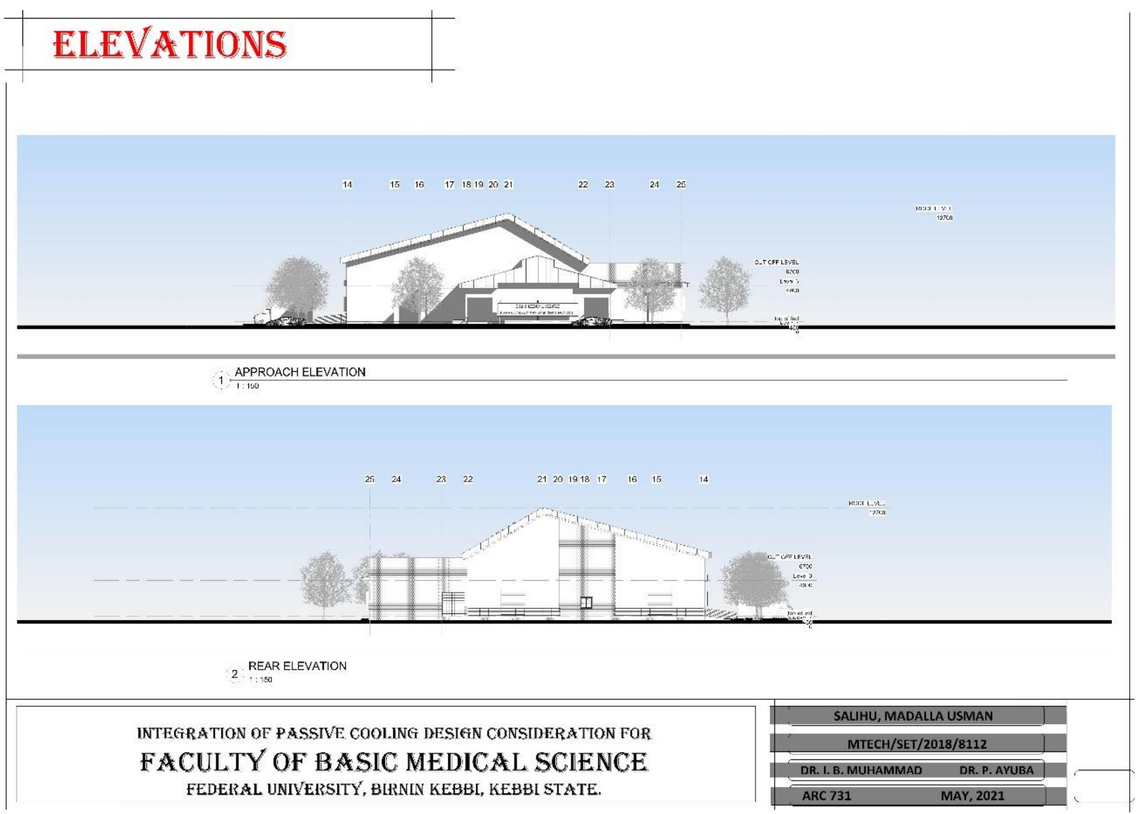
Appendix U: Floor Plan of Research and Development Facility



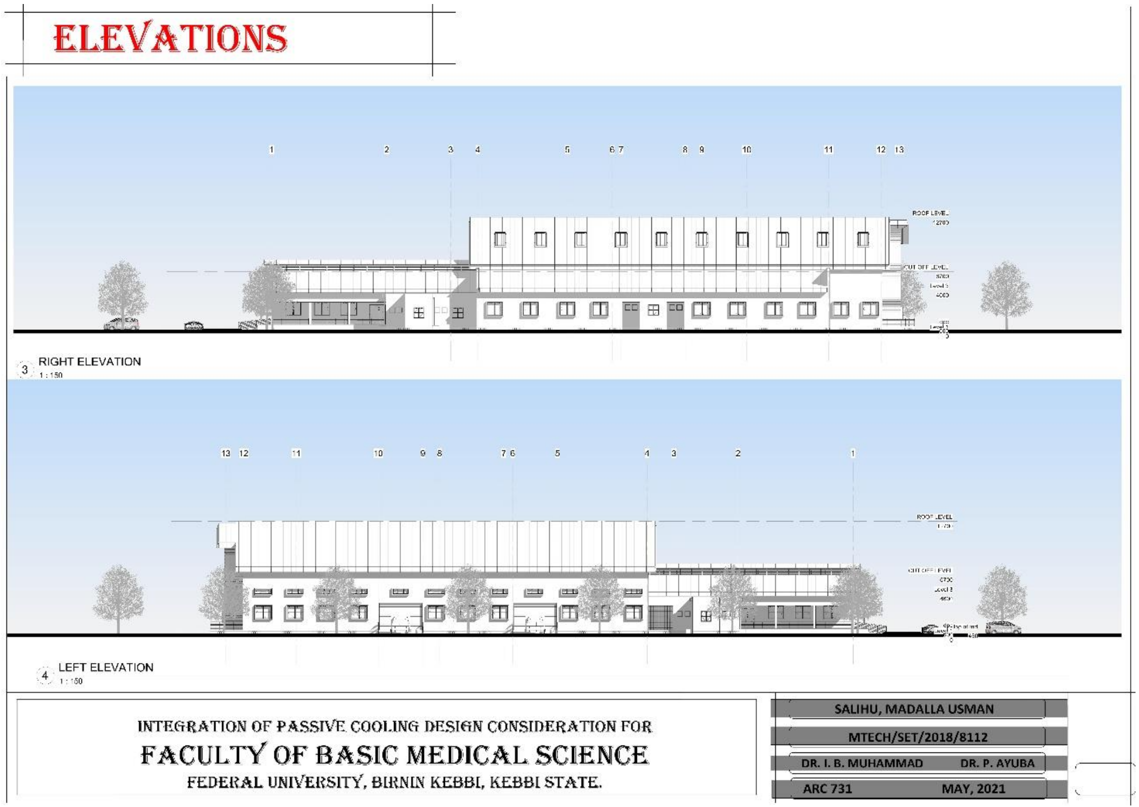
Appendix V: Roof Plan of Research and Development Facility



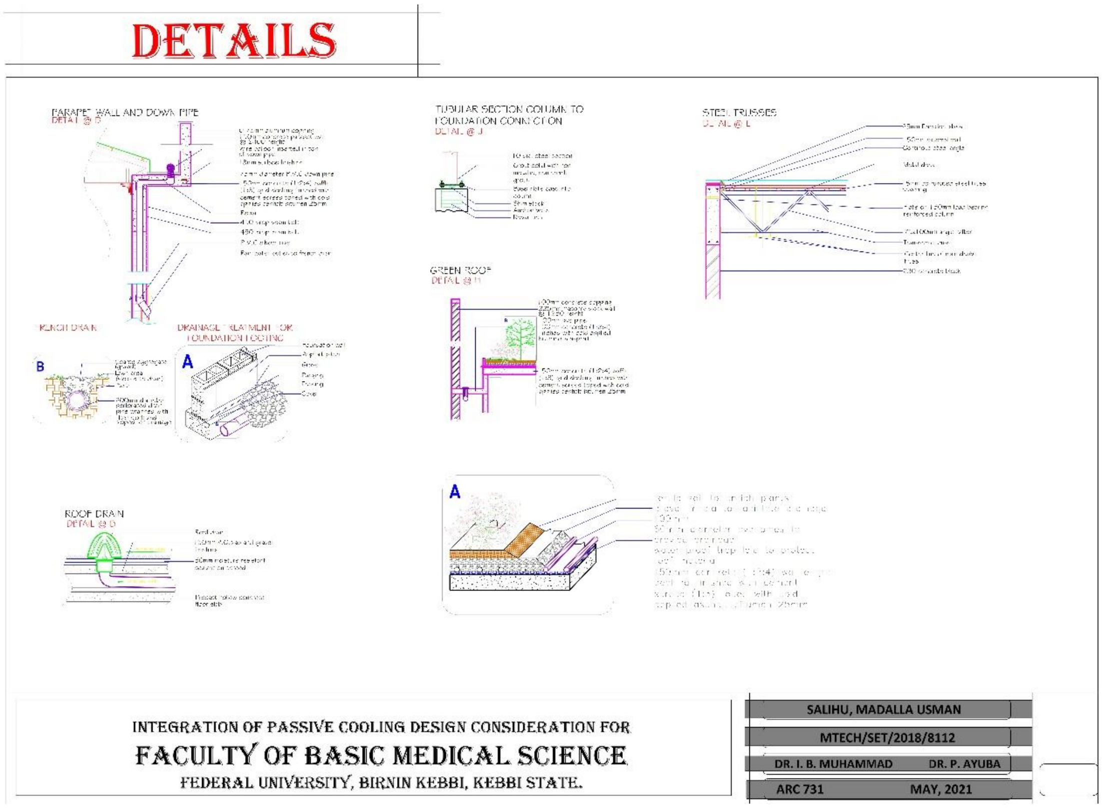
Appendix W: Sections of Research and Development Facility



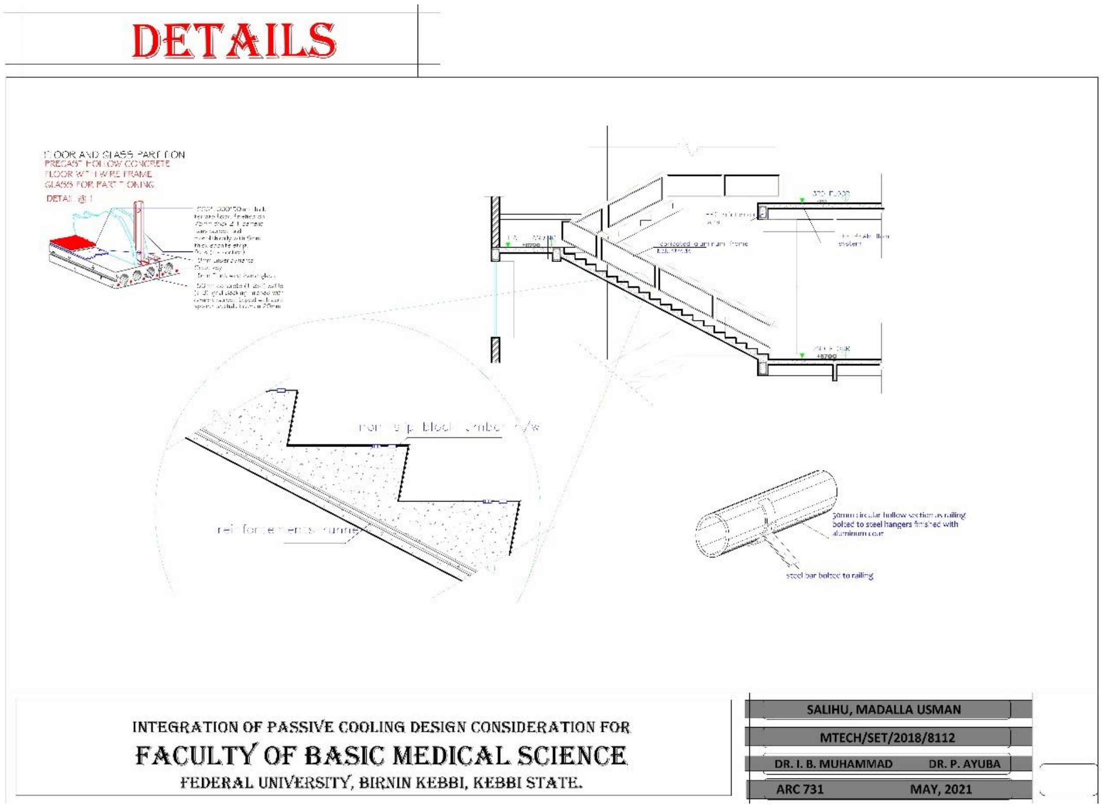
Appendix X: Elevations of Research and Development Facility



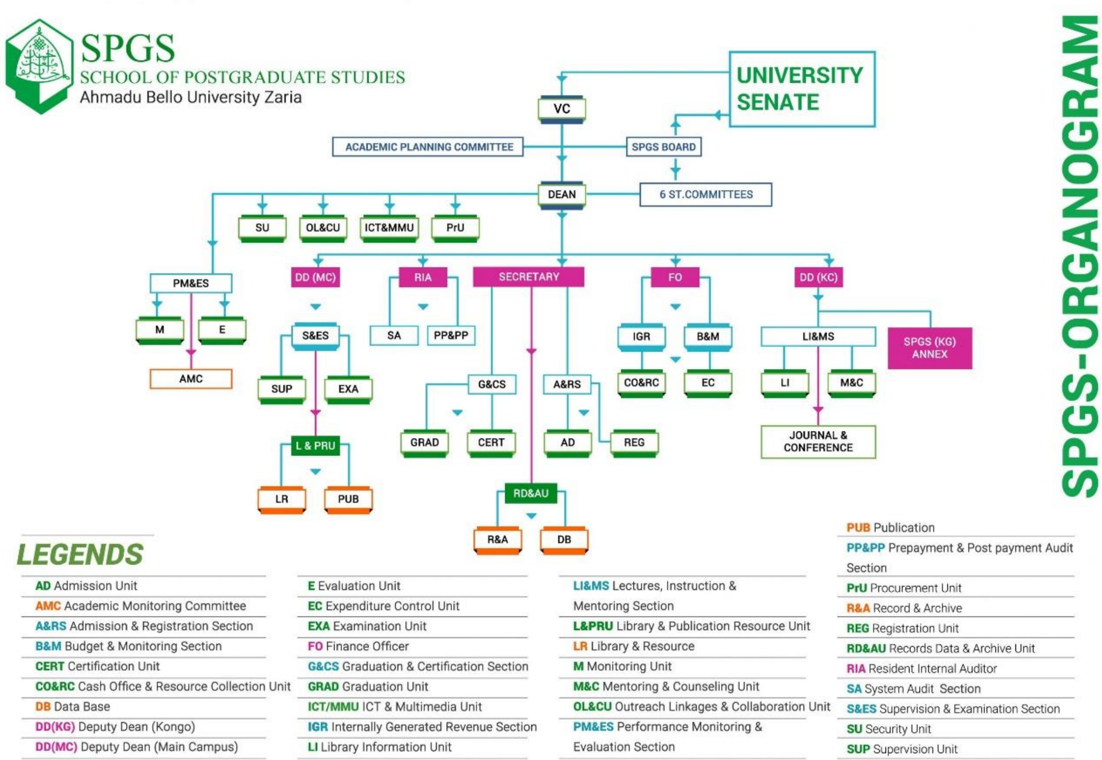
Appendix Y: Elevations Research and Development Facility



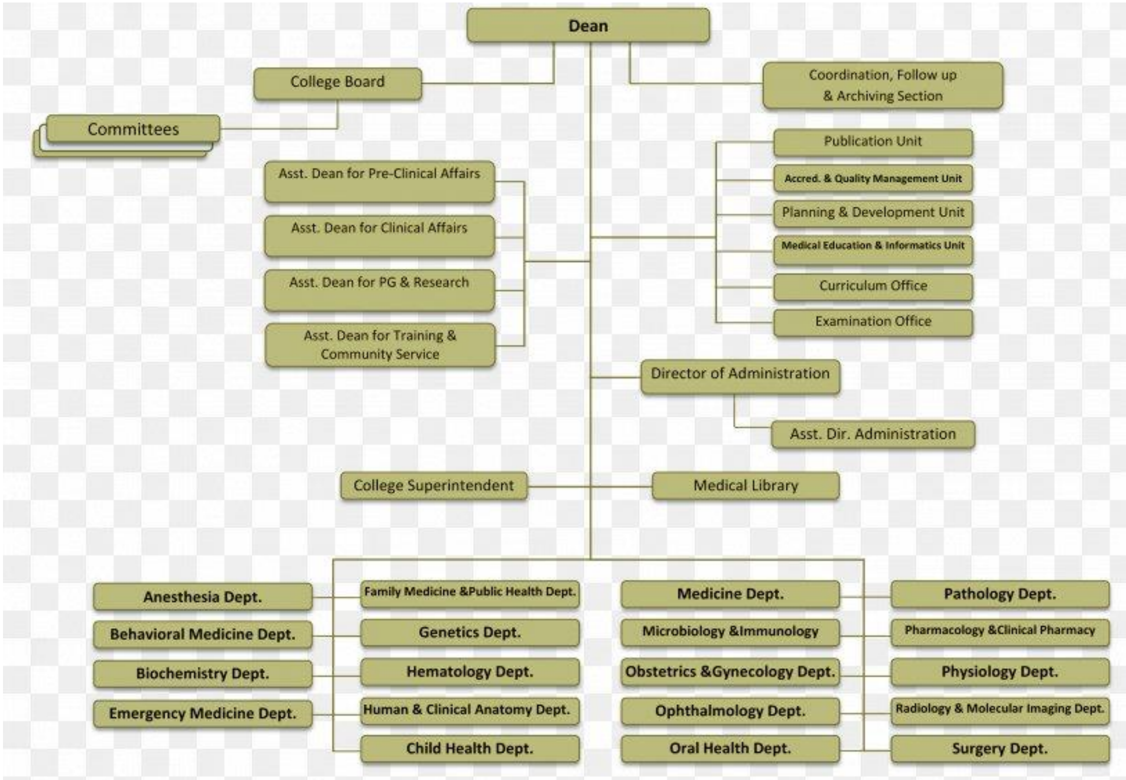
Appendix Z: Details



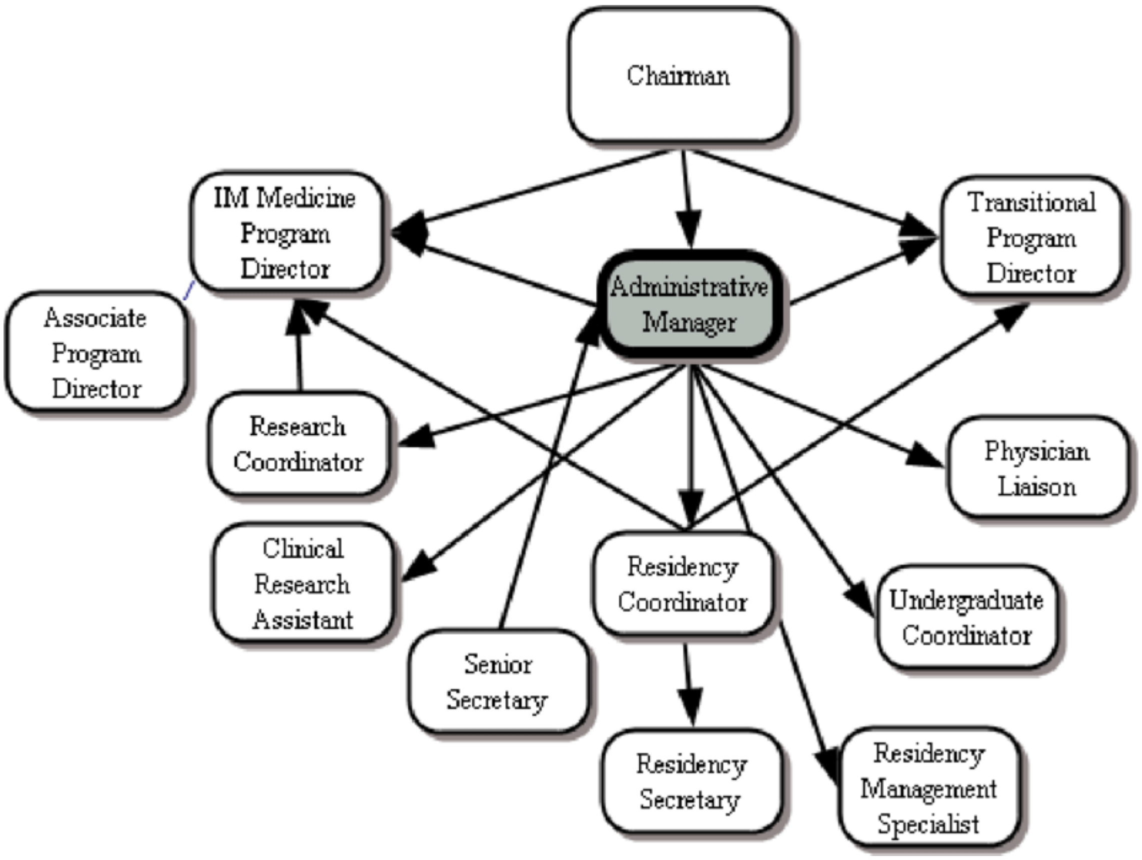
Appendix AA: Details



Appendix BB: Details



Appendix CC: Details



Appendix DD: Details