

**Proposed College of Engineering for Bowen University, Iwo, Osun State.
(Thermal Comfort Strategies in Educational Buildings)**

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**Being a MSc Thesis Submitted to the Department of Architecture, Faculty of
Environmental Design and Management, Lead City University, Ibadan, Oyo State,
Nigeria**

**In Partial Fulfillment for the Requirements of the Award of Master Degree (MSc) in
Architecture**

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Certification

This is to certify that Babatunde Temitope OSIBOWALE with matriculation number LCU/PG/002154 carried out this research work titled “Thermal Comfort Strategies in Educational Buildings” in the Department of Architecture, Faculty of Environmental Design and Management, Lead City University, Ibadan, Oyo state, for the award of Master Degree (MSc) in Architecture and that this has not been previously submitted.

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Dedication

This research work is dedicated to God Almighty for the gift of life and for giving me the grace to achieve this feat in my academic pursuit.

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Acknowledgement

I am grateful to the management of Lead City University for given me the privilege to study and acquire knowledge. I also wish to express my profound gratitude to the following Universities for the opportunity given to be able to carry out this research; Bowen University Iwo Osun State, Bells University College of Engineering, Ota Ogun State, Ladoke Akintola University of Technology, Ogbomosho, Oyo state.

I gratefully acknowledge the enthusiastic support of my supervisor Dr Arc. Adedire Funmilayo who is also the Head of Department of Architecture, Lead city University, Ibadan. I appreciate the lecturers Dr. Arc. Ayanleke B, Arc. Adeola A, Arc. Ajijola K, Arc. Olugbesan N, Arc. Fasheun-Motesho J, Dr. Arc. Adegoke A, Arc. Aseyan B, Arc. Olaniyan M, Arc. Oguntunde D, Dr. Arc. Obaleye O, of the Department of Architecture for being supportive and creating an enabling environment.

I would also want to appreciate my wife Mrs Abiodun Osibowale and my children Samuel, Isaac and Samantha Osibowale for their continuous support and understanding when undertaking my research, their prayers and support was what sustained me this far.

Even though the above-mentioned institutions and persons have assisted in the process of this research work, I alone stand responsible for the errors, if any, found in the work.

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Abstract

In modern societies, people spend over 90% of their time indoors. Students spending more time at school than in any other building except at home highlights the importance of providing comfortable indoor thermal conditions in these buildings. Thermal comfort since has been related to productivity and well-being and energy conservation in schools has gained importance in recent years. This paper presents an overview of thermal comfort field surveys in educational buildings over the last five decades. The studies are reviewed in two sections; the first covering the field study methodologies including the objective and subjective surveys, and the second reviewing study results based on the climate zone, educational stage, and the applied thermal comfort approach. Confounding parameters have been discussed to outline priorities for the future research agenda in this field. Reviewed studies have assessed the thermal environment in classrooms compared to common thermal comfort standards. Most of the studies concluded that students' thermal preferences were not in the comfort range provided by the standards. Ventilation as an essential determinant of indoor air quality and thermal comfort has been highlighted in most studies. The wide disparity in thermal neutralities underlines the need for micro-level thermal comfort studies

Keywords: Thermal comfort, Classroom, Adaptive, educational building.

Word count: 209

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Thermal comfort is the condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation (ANSI/ASHRAE Standard 55). It simply means when a person is neither too hot nor too cold. The Health and Safety Executives estimates that reasonable comfort can be established when a minimum of 80% indoor occupants are feeling comfortable with the thermal environment. Thermal comfort is also refer to the perceived feeling on the human body as a result of the effect of heat and cold sources in the environment.

Thermal comfort has been related to productivity and well-being and energy conservation in schools and it has gained importance in recent years. Performance, productivity, attendance, and health of both students and teachers depend significantly on the indoor conditions in educational facilities (Zomorodian,2016).Thermal comfort is one of the most important factors of indoor environmental quality, an undesirable thermal environment may lead to sick building syndrome symptoms such as running nose, headache, dry skin and lethargy which also affects occupants' performance and productivity. (Sykes, 1988).

Strategies used in achieving thermal comfort in buildings includes the use of passive cooling elements aimed at minimizing overheating and reducing summer energy consumption, such as thick walls, orientation according to the summer sea breeze, use of stone materials acting as thermal mass, white coloured walls. Thick or well-insulated walls, proper openings, screening systems, and outdoor spaces like

courtyard offering shade and natural ventilation are some of the possible solutions to increase thermal comfort and at the same time to save energy.

Facades and roofs which are most exposed to solar radiation, offer important heat exchange surfaces. Their design can help in the reduction of overheating in the building, without energy wastage. Using green roofs and facades, painting roofs with reflecting colours or using roof tile vents, strategic distribution of trees also helps to increase airflow and reduce the impact of solar radiation.

Hi-tech solutions can also play a very important role, this include sensors that allow a fine monitoring of thermal conditions and hence an optimized fine-tuning of air conditioning and ventilation, and even the orientation of shading panels according to real-time insolation conditions. Sensors and digital thermal regulation devices can also be coupled with management measures for demand, that help to reduce the impact of cooling demand on peak loads when the electrical system is under stress. (Freewan,2019).

In as much as these strategies mentioned helps in achieving thermal comfort they still have their limitations. In orientation of building to achieve thermal comfort some researchers still have the notion that some portion of the building will suffer from thermal discomfort, as in the case of courtyard the area required and the space that the courtyard takes may pose a major challenge. Opening in roofs may allow insect and dust to penetrate into the indoor space and likewise the cost of constructing undulating form of roofs like dome and vaults are on the high side. The use of sun breakers also has its limitation because while it protects the windows from intensive solar radiation, the glass area is not totally protected especially in the hot zones.(Hassan Leen & Segyuoh 2016)

Thermal comfort in educational buildings is highly essential because the students spend considerable amount of time in the classroom so the building should provide a better environment that will enhance good learning atmosphere for the staff and the students.

This research therefore aim at investigating thermal comfortability in selected educational buildings by identifying various thermal comfort strategies and implementing such in the proposed design of College of Engineering for Bowen University, Iwo Osun State.

1.2 Statement of the Problem

Schools and educational buildings usually have a big number of users in compare to other facilities and buildings. students spend most of their time in enclosed academic spaces more than any other building enclosures except their dwelling spaces. Thermal distraction, discomfort, and physiological responses usually decrease student performance.

Uncomfortable indoor space of the building as a result of solar heat gain has a detrimental health effect on the occupants of the buildings such effect include insomnia, fatigue, boredom, reduction in the rate of productivity and work efficiency (Haruna & Oraegbune, 2018; Munonye, 2018)

Sick Building Syndrome (SBS) is a major issue at schools and educational buildings which can influence education quality (Berglund, & Lindvall, 1986). The impact of SBS on people is a number of symptoms which have been seen and reported mostly at working environments like offices or educational buildings. The most common symptoms are itching, loss or lack of concentration, running nose, headache, dry skin, lethargy, dryness or irritation of throat and dry eye (Sykes, 1988).

Recent researches show that educational buildings have serious indoor environmental problems, and ventilation rates are not adequate according to standards (Daisey, 2003). Sick building syndrome is a major concern in all types of buildings nowadays as it affects the user in various dimensions but it is even more important in certain cases as it directly affects the productivity and health of the users. This expresses how crucial it is to provide an encouraging indoor thermal environment where high productivity and concentration is required.

1.3 Aim and Objectives

1.3.1 Aim

The aim of this study is to identify various functional thermal comfort strategies and the implementation in the design of College of Engineering, Bowen University, Iwo Osun State.

1.3.2 Objectives

1. To identify existing functional strategies that can be used employed in achieving thermal Comfort in buildings
2. To examine studies of academic building that have achieved thermal comfort
3. To integrate identified strategies in achieving thermal comfort in the College of Engineering, Bowen University, Iwo, Osun State.

1.4 Research Questions

1. What are functional strategies in maximising thermal comfort in educational building?
2. are there existing cases of thermal comfort strategies in educational Building?
3. How can identified strategies be used in the thermal comfort designs of a College of Engineering, Bowen University, Iwo, Osun State.

1.5 Significance of the Study

The research will be beneficial to the students because good comfort leads to optimal performance and profitability, This research will be beneficial to the lecturers and administrators because it will contribute to their well being and also improve their level of productivity. This research would also be beneficial to future researchers because they can get some information that might be useful in their research.

1.6 Scope of the Study

The scope of the proposed project is limited to College of Engineering building Bowen University, Iwo, Osun state focusing on thermal comfortability in lecture rooms, workshops, laboratories, offices, departmental offices, etc; using identified existing strategies. however it is important to note that other buildings like hotels, shopping malls, cinemas, hospital, etc; also requires thermal comfort but this research is limited to thermal comfort in academic building

1.7 Operational Definition of Terms

Thermal comfort is the condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation (ANSI/ASHRAE Standard 55). The human body can be viewed as a heat engine where food is the input energy.

Temperature is a measure of an organism's ability to generate and get rid of heat. The human body has mechanisms to maintain its internal temperature within a relatively narrow, safe range despite relatively large variations in temperatures in which the body exists Educational buildings are building used as a university, college, technical institute, school, academy, research laboratory, lecture hall, convent, monastery, public library, public art gallery or museum. Thermal discomfort is the exposure to either excess cold or excess heat

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CHAPTER TWO

LITERATURE REVIEW

This session covers the review of related literature, theories and concepts on thermal comfort in buildings as it relates to health and productivity

2.1.0 Thermal comfort and indoor air quality

Human being usually found comfort in an enclosed space and found indoor spaces to be more safer and today 80-90 percent of human life were spent in an enclosed spaces. Thermal comfort has gained importance because the place where we work, live and have fun are all in an enclosed space. (Michael, 2006).

The indoor comfort problem is not only valid for residential buildings, more problems are encountered in structures such as offices, health and education buildings which are not controlled. The air of these enclosed spaces could become polluted by indoor and outdoor pollutants. Various studies emphasized on the causes of physiological and psychological effects of pollutants on humans when the pollutants exceed a certain level. In international studies, it is shown that substances, related to the indoor air quality (IAQ), which threaten the human health, are handled with the experimental studies and the subject is analyzed in different aspects. (Michael, 2006).

2.1.1 Thermal comfort in transient conditions:

In the past decade different methods were engaged to determine thermal comfort i.e predicted mean vote and predicted percentage of dissatisfy (Fanger 1972) and pierce two-node model of human thermoregulation (Gaggen,1986), with all theses methods several thermal comfort standard were established (Fanger 1980, ASHRAE 1981).

Most work related to thermal comfort has concentrated on steady-state conditions. This is expressed by the fact that only one of the above standards (ASHRAE 1981) also specifies limits for changing environmental parameters, because of the thermal interaction between building structure, occupancy, climate and HVAC system, pure steady-state conditions are rarely encountered in practice. For example, Madsen (1987) found indoor temperature fluctuations between 0.5 °C and 3.9 °C (during 24hours with a constant set point) which depended on the combination of heating and control system. Sometimes it may even be advantageous to allow the environmental conditions to change. This was demonstrated in a field experiment (Hensen 1987) where it was found that decreasing the acceleration heating of the room thermostat in a dwelling resulted in a lower fuel consumption. This led however to considerably increased variations in indoor temperature, but it was not clear at the time whether these fluctuations would be acceptable or not to inhabitants.

2.2.0 Thermal comfort and its parameters

ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) defines it as 'the condition of mind which expresses satisfaction with the surrounding environment of the occupants'. Thermal comfort is generally defined as that condition of mind which expresses satisfaction with the thermal environment (ISO 1984). Dissatisfaction may be caused by the body being too warm or cold as a whole, or by unwanted heating or cooling of a particular part of the body (local discomfort)

Thermal comfort is connected to many parameters, such as, human dimensions, age, sex, nutrition, form of the body, subcutaneous fat, height and weight, activity, clothing and personal differences, there are no exact limits (Sekhar, 2016).

In accordance with the purposes of usage, certain comfort condition features, which are indicators of user's satisfaction in an environment should be met on account of health and efficiency in a living space. some general conditions are expected to be maintained in the environment in accordance with the characteristics of users.

The comfort conditions in an enclosed environment are affected by thermal comfort, indoor air quality, and visual and auditory comfort parameters. Thermal comfort conditions consist of factors such as, relative humidity, air flow rate and radiant temperature, visual comfort conditions consist of light, lighting, color, view, while, auditory comfort conditions consist of factors such as sound and noise. ; Sekhar, 2016). In general, parameters that are affective in thermal comfort could be categorized as personal and environmental parameters. While, ambient temperature, ambient relative humidity , ambient air speed and average radiant temperature are named as environmental parameters; personal parameters consists of the person's metabolic activity level and clothing (Kaynaklı and Yiğit, 2003)

2.2.1 Air temperature

Human body exchanges heat through heat conduction mechanisms for establishing thermal balance. The metabolic heat produced by the body is removed through, 30% convection , %40 radiation, %20 evaporation and %10 respiration (Ceylan, 2011).

Body temperature differs according to the hour of the measurement, age, sex or any other personal factors .the body temperature of a baby is higher than that of an adult. Temperature could be perceived differently according to the activity engaged by an individual. A person who sits in an office and a person who is constantly in motion could perceive temperature values differently. Similarly, women like heat more than men. Somebody naked and someone with clothe will perceive temperature

differently .Indoor air could be perceived differently in relation to heat. In low temperatures the air is perceived as clean. (Ongel and Mergen, 2009).

The average radiance temperatures of wall, floor, ceiling and coating material surfaces in the built environment affect the ambient temperature. The warm or cold colorings of building materials affect people's perception. The presence of warm surfaces and the components exposed to high solar radiation affect the average radiance temperatures. The temperature difference between two surfaces should not exceed 5°C in a certain environment. The maximum temperature difference between the indoor air and the surfaces should be 3°C. It should not be forgotten that the body temperature rises with the increasing average radiance temperature (Ceylan, 2011; Atmaca and Yiğit; 2005)

2.2.2. Relative Humidity

Humidity is defined as the water vapor in air and other gasses. There are three type of humidity; absolute humidity, relative humidity and specific humidity. Certain amount of humidity should be present in the air in terms of health and comfort of human beings. Relative humidity is the one that has an effect on humans and other living beings. Relative humidity is the ratio of humidity in the air to the saturated humidity. The necessary amount of water vapor to saturate the air with humidity changes in relation to the ambient temperature. There is a reverse relationship between temperature and relative humidity, when temperature increases the relative humidity decreases. Indoor humidity constantly affected by the outside humidity (URL1; Akyazı, Usta, Akpınar, 2011).

Parameters that affect the indoor relative humidity are; number of users, the type of activity, characteristics of the space, personal factors and temperature etc. The water vapor caused by the breathing and sweating of the people in the environment affects the relative humidity (Ceylan, 2011). The amount of humidity in an environment

should be between 40-60% in terms of human health and productivity. Low values of humidity causes dryness in respiratory tracts, skin, eye and hair in people. Together with dryness harmful substances enter the body faster and the amount of water vapor in the air decreases. Also, low levels of humidity in an environment create static electricity problems. It decreases the electrical qualities of building materials. High humidity levels make it difficult for individuals to sustain their thermal balance while with clothing it causes dampness on the surface of the body. In high humidity reproduction of microorganisms is accelerated (Usta, 2011).

2.2.3. Air flow rate

One of the environmental factors that affect indoor air quality is the air flow rate. Air flow rate is the value of an air movement in a certain direction measured in unit of time. Ambient air flow rate, however, is the average of many readings taken from the environment and is expressed in units of m/sec (Arıcı and Seçilmiş, 2005)

The indoor air flow rate is affected by the location of air inlets and outlets, the location and size of the windows, climatic properties, type of activity, the level of activity, number of users, if it exits the location of the ventilation in the environment, its power, angle and the amount of air it provides, relative humidity and temperature in the environment. Air flow is determined by air velocity and the amount of ventilation (Ceylan and Yakut, 2013).

While low air speeds are defied as airless, in high speeds it is felt as windy and uncomfortable. The necessary limit values of air flow rates for an environment to obtain comfort conditions are determined by standards. According to ASHRAE, in order for an environment to obtain comfort conditions the air speed must be 0, 15 m/sec

Ambient air speed affects the user's thermal comfort. As the air speed increases, the water on the body surface evaporates more and the person starts to get cold. As the increased air speed reduces the available still air mass around the person by dispersing it, chilling will increase. While this situation is beneficial in summer, it is felt as uncomfortableness in the winter. Therefore, the ambient air flow rate should be kept between specified standard values. During the design process or during usage, the air should be given in low air speeds and homogeneously for user's comfort (Ongel and Mergen, 2009).

Personal parameters are categorized as clothing insulation value and activity level. A piece of clothing directly affects the heat transfer between the body and the environment and supports the heat flow. Also, it protects the humidity balance of the body. Clothes decrease the loss of heat and exhibit resistance to the transfer of heat energy. Heat insulation value of clothes is affected by fiber, thread and weaving patterns, fabric thickness and its components. In literature, there are many scientific studies done with test models (mannequins) in test rooms for measuring the thermal insulation values of clothes (Atmaca and Yiğit, 2005; Öngel and Mergen, 2009; Marmaralı, Dönmez Kretzschmar Özdil, Gülsevin Oğlakcıoğlu, 2006).

2.2.4 Indoor air quality and its effects on human health

The importance of air breathed in for vital activities is quite huge. According to ventilation standard released by ASHRAE in 1999, acceptable indoor air quality is defined as the air in which the ratio of harmful substances do not exceed the limit values and with which the majority (at least 80%) of the people exposed are satisfied with this situation. In order to provide the desired conditions in standards, the required limit values are given. Humans, by their nature, are dependent on air. A person

consumes 400-500 million liters of air. Since air is a compulsory and top priority requirement, the quality of air is important both indoors and outdoors.

Indoor air quality has a great importance in ensuring the comfort conditions that are suitable for people. When it is considered that people spend most of their time indoors, they interact with pollutants mostly indoors either.

Pollutants can be classified in several forms such as particulate or gas, toxic or non-toxic, organic or inorganic, solid, liquid or gas and according to the particle size (Atmaca and Yigit,2009). Some pollutants may originate basically from the outside, but they can also originate from the indoor materials, hardware, furniture, cigarettes, activity, chemical products used, and the building itself. Outdoor air pollutants can be classified as biological pollutants, UOB, sulfur oxides, ozone, lead compounds caused mostly by motor vehicles, hydrocarbons and benzene, nitrogen oxides, carbon constituents, and radon. The pollutants originating from the building interior are listed as building components and chemicals released from the materials used, pollutants resulting from human and machine activities, gases leaking from the outside, and biological pollutants such as fungi, mold, house dust, pets, and pests (Tatlı,,2011).

Indoor air pollutants are examined in three categories as biological pollutants, gases and chemicals, and particles and fibers.

2.2.5 Biological pollutants

Biological pollutants are composed of allergens such as microbiological factors, virus, bacteria, mite, mold, algae, fungus, pollen, and sports and micro organic particles are called “bio aerosol”. Pollutants from house dust, pets, and insects are also included in this category. These organisms are dangerous and fast-spreading. The effect of these pollutants is understood too late. They can be seen both in indoor air and in outdoor air. They can spread from the existing vegetation around the built environment, wet

building elements, openings, living things, activities, air conditioning system components, moisture holders, water collection channels, drainage troughs, channels, and filters (Kuş, 2007; Ceylan, 2011).

2.2.6 Gas and chemical pollutants

Gas and chemical pollutants are air pollutants in the form of gas and vapor under normal temperature and pressure. The most important gas pollutants can be listed as UOB, PVC, CO, CO₂, ozone, sulfur oxides, nitrogen oxides, radon, formaldehyde, pesticides, organic gases, and cigarette smoke. These pollutants can be found in the spaces which are inadequately ventilated and where indoor air circulation is low, air conditioning system is used, and materials releasing chemicals are used. They diffuse to indoor spaces through ventilation, cigarette smoke, soil-contacting parts of the building parts, construction materials, and coating materials (Kuş, 2007; Yurtseven, 2007).

The pollutants should not exceed certain limit values in order not to threaten human health. The health effects of air pollution are very complex. Air pollution is an environmental pollution that constantly affects the society throughout the life cycle and that is often exposed unwittingly. In order to understand the effects of air pollution on human health, identification of the source, the way of exposure to pollutants, and the interaction of the pollutants with their surrounding environment should be examined.

In the human body, nose and lungs are primary organs that are exposed to air pollution, depending on the characteristics of the pollutants and personal factors, the body systems, especially the respiratory system, and various parts are affected. (Atmaca and Yiğit, 2009)

The size of the effect depends on the diameter of the pollutants as well as on the individual factors. As the particulate size decreases, the adverse effect on health increases, small particles with a diameter of 10 microns can pass through the mouth and nose to the respiratory system. Small particulates of 2-3 microns in diameter pass through the lungs and stick to the alveoli. Those smaller than 0.1 micron, called fine particles, can hold on to the alveoli and stay longer than the other ones (Kong, 2015).

Discomforts that can be seen in people exposed to dirty air can be listed as dry mouth and dry nose, fever, tremor, muscle pain and muscle twitching, headache, nausea, allergy symptoms, dermatitis, coughing, phlegm, chest tightness, cold, bronchitis, asthma, legionnaires' disease, Pontiac fever, and lung cancer.

The impacts of environmental air pollution on health have been proven in the literature via examination on a large scale with many experimental and epidemiological approaches. Controlled exposure of living organisms to pollutants, long-term and short-term effects of the pollutants, possible diseases, personal sensitivities and exposure levels have been addressed in the studies (Can, 2015). Standards provide the amount of clean air required for human comfort, the limits of air pollutant concentrations, and exposure times that can be tolerated in response to a number of criteria such as the function, type, and size of the environment as well as the number of people, activity of people, and sensitivity of people.

2.2.7 General IEQ satisfactions

Since 2002, the Center for the Built Environment (CBE) has administered an online indoor environmental quality (IEQ) survey that asks about occupants' satisfaction in areas such as thermal comfort, light, indoor air quality, acoustics, and noise (Huizenga et al., 2003), because of its standardized form and longstanding use, this survey

provides an excellent benchmarking database that has been analyzed in many ways over the years.

The first large-scale analysis of the database was in 2006 when the survey had been administered in 215 buildings. Huizenga et al. (2006) examined the 20% dissatisfaction criterion of ASHRAE standard 55 and found that it was being achieved in only 11% of buildings in the database. Many of the other buildings were nowhere near the 20% mark: fully half of the buildings surveyed had more than 40% thermal dissatisfaction. Overall, 43% were dissatisfied with the temperature.

Considering occupants with and without access to thermostats, operable windows, portable heaters, and portable fans, they found significantly lower dissatisfaction ratings for those with access to thermostats (24%) and operable windows (33%) but higher dissatisfaction rates for those with access to portable fans (56%) and portable heaters (49%).

The database has been used extensively to assess the differences in IEQ between green or LEED-certified buildings and the rest of the database. Studies from 2003, 2005, and 2006 when the database contained results from 45-215 buildings found a significantly higher mean satisfaction score in green or LEED buildings than in more conventional ones (Abbaszadeh et al., 2006; Huizenga et al., 2005, 2003).

Brager and Baker (2008) compared the IEQ satisfaction in 12 mixed-mode buildings to the other 370 buildings that were in the database at the time. They found that all of the mixed-mode buildings were in the top half of the percentile ranking for temperature satisfaction. Newer buildings and those in milder climates (fewer heating degree days) tended to have higher rates of temperature satisfaction. They did not indicate how the age of the MM buildings compared to the rest of the database.

Kim and de Dear (2012) also looked at the effect that cooling strategy has on IEQ satisfaction, including temperature. It was observed that in AC buildings dissatisfaction with temperature had a larger impact on overall satisfaction than satisfaction with temperature did, so they concluded that it is a basic factor—occupants expect to be satisfied with temperature and when they are not, it detracts from their overall satisfaction with the building.

Thermal comfort and productivity in a school building

Starting from ancient times to the present day, creating a thermally comfortable environment has been a continuous struggle. Recently, the invention of modern technologies has offered better indoor environmental quality for inhabitants. Nevertheless, people had tried to reach thermally comfortable indoors by applying passive techniques such as natural ventilation [1,2], wind-catchers [3,4], or appropriate building materials [2,5] even in the past when the technology was far less advanced. Therefore, it is evident that the indoor quality of where people live has been one of the most challenging issues in human life.

Researches reveal that people spend most of their life indoors. On the other hand, students spend up to one-third of the day in classrooms and school buildings [[6], [7], [8]]. In this regard, the environmental quality of the school buildings, where students spend most of their time, is also significant. Considering the link between indoor quality and productivity, the thermal comfort of indoor environments has become more critical.

Occupant perception and performance usually reach the highest level in a place if the place is thermally comfortable. A considerable number of researches have already presented the link between indoor environmental quality, productivity and health [[9],

[10], [11], [12], [13]]. As far as academic performance is concerned, indoor air quality remains one of the significant factors, as most of the researchers suggest [14]. Hoque and Weil [15] investigated the relationship between academic performance and comfort perceptions in university classroom buildings. According to results, thermal discomfort has lowered test scores and affected academic performance negatively in university classrooms.

Mendell and Heath [16] also reviewed the effect of the thermal environment on student performance. The review study shows that poor indoor environmental quality in school buildings utterly affects students' performance and attendance. Bako-biro et al. [17] analyzed the importance of ventilation on students. According to the study, lower ventilation ratios significantly reduce student performance by causing thermal discomfort. In a similar study, Norback and Nordström [18] investigated ventilation rates in schools. Parallel to other studies, better air quality and ventilation ratios led to better performances. Haverinen-Shaughnessy [19] et al. also showed that the temperatures and ventilation rates affect the students' health and performance.

Since a substantial number of researches implying the significance of indoor air quality on academic performance are present in the literature, different strategies are evaluated by researchers to improve indoor environmental quality. Wang et al. [20] carried out an optimization study regarding classroom thermal comfort and energy performance. The study investigates different strategies, such as set point variation, pre-ventilation, and sun-shading system adjustment. Such interventions led to an increase in energy efficiency and comfort levels. Jung and Jazizadeh [21] evaluated the effect of different mechanical system operational strategies. It is found that change of temperature set-points in most cases increased thermal comfort.

Stazi et al. [22] developed an automated window system to optimize thermal comfort in classrooms. The automated window system helped to adjust the opening schedule of windows. Barbhuiya and Barbhuiya [23] investigated ventilation and lighting strategies on both energy consumption and thermal comfort in an educational building. The recommended dimming profiles for lighting control and ventilation strategies led to better conditions. Lau et al. [24] examined different ventilation strategies on a tropical university campus. It is found that hybrid ventilation spaces have notable advantages compared to natural ventilation and air conditioning strategies. Besides, Dhauillin and Limam [25] also considered both natural and hybrid ventilation strategies used in classrooms for thermal comfort and energy approach. Thermal, visual, and acoustic comfort is measured, and questionnaires are filled out by the occupants in the classrooms. Results of different strategies showed that in summer conditions, the automated window opening system controlled by air temperature is one of the most effective solutions.

In another research, Di Perna et al. [26] dealt with optimizing ventilation strategies in school buildings. The authors proposed optimized solutions and made comparisons with the relevant regulations. On the other hand, Mustapa et al. [27] investigated the effect of free running and cooling strategies on thermal comfort in a Japanese university building. In the light of measurements and surveys, the mean comfort temperature was found as 26.6 °C for both cases. It is concluded that the cooling mode was adequate to satisfy the indoor thermal conditions, while in free-running mode, slight adaptive behaviors were noticed. Baldi et al. developed an automated smart occupant management scenario that resulted in 15% energy consumption savings with a 25% thermal comfort increase [28]. Camacho-Montano et al. [29]

investigated the overheating problem in educational buildings, and they offered a natural ventilation strategy and ceiling fans, which helped to overcome the problem.

CHAPTER THREE

RESEARCH METHODOLOGY (CASE STUDIES)

3.1 Introduction

Research is simply the process of arriving at dependable solutions to problem through the planned and systematic collection, analysis and interpretation of knowledge, for promoting progress and for enabling man to relate more effectively to his environment, to accomplish his purpose, and to resolve his conflicts. Research methodology could also be simply referred to the various processes, procedures, methods and instrumentalities by which data are secured, specified, collated, processed and analyzed (Wikipedia 2022).

3.2 Case Studies

For the purpose of this research, five case studies are carried out on some existing Faculty of Engineering building in two different Nigerian Universities and three foreign Universities. The case studies carried out are to serve as existing example or as a guide towards achieving a realistic design and also to learn through their analysis, the merits and demerits of their design so that the proposed design can inculcate some of these merits and then improve on the demerit especially in attaining a unique designed form that will provide the thermal comfort needed in the building.

The Case studies are however carried out on the Faculty/College of Engineering of the following Universities;

- i. Faculty of Engineering and Technology, Ladoke Akintola University of Technology, Ogbomosho, Oyo State.
- ii. College of Engineering, Bells University of Technology, Ota, Ogun State.
- iii. Faculty of Engineering, University of Manitoba, Winnipeg, Canada
- iv. Washkewicz college of Engineering, Cleveland State University
- v. Lancaster University, School of Engineering

3.3 Case Study One

3.3.1 Faculty of Engineering and Technology, Ladoke Akintola University of Technology, Ogbomosho, Oyo State.

Brief History

The Faculty building was a converted secondary school building in 1990, alongside with several other blocks in rows used as department building, which consist of six departments; Civil Engineering, Mechanical Engineering, Chemical Engineering, Agricultural Engineering, Electrical and electronic Engineering and Computer Engineering. Among other adjoining structure within the site layout are the 4 floors Lecture halls called HIGH RISE Building, and Laboratory to each department.

Location

The Faculty complex is located behind the 1000 Management lecture theater, it can be easily accessed from any part of the university.

3.3.2 Description of the building/Facilities

The Faculty of Engineering building is a bungalow, the color of the building is Brown and cream. The building consists of the Head of Department office, Dean's Office, record and Secretary Office, Conference room and several offices for senior lecturers.

The High rise building (Faculty of Engineering) contains the lecture rooms for each department, and lecturer offices. The department blocks contains Exam officer's office, Level Advisor's office, Course coordinator.

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3.3.3 Thermal comfort strategies

Proper openings and outdoor spaces are engaged to allow for natural ventilation, increase thermal comfort and at the same time to save energy. The use of light colors on the external walls to reduce the heat gain into the building. There is vegetation around the building which allows breeze and fresh air to penetrate inside the building. Mechanical cooling device were used in the offices to reduce the thermal load generated by computers and lighting fittings to create a comfortable indoor environment.

Building Material used

The major building materials used for the construction of the Faculty of Engineering are sandcrete block, reinforced concrete, wood, steel, glass and Aluminum



Plate 1: Satellite image showing site layout of the faculty of Engineering and Technology, Ogbomosho, Oyo State.
Source: Google Earth, 2022



*Plate 2: Approach view of the Faculty of Engineering and Technology building
Ladoke Akintola University of Technology, Ogbomosho, Oyo State.*

Source: Researcher's Field Work, 2022.

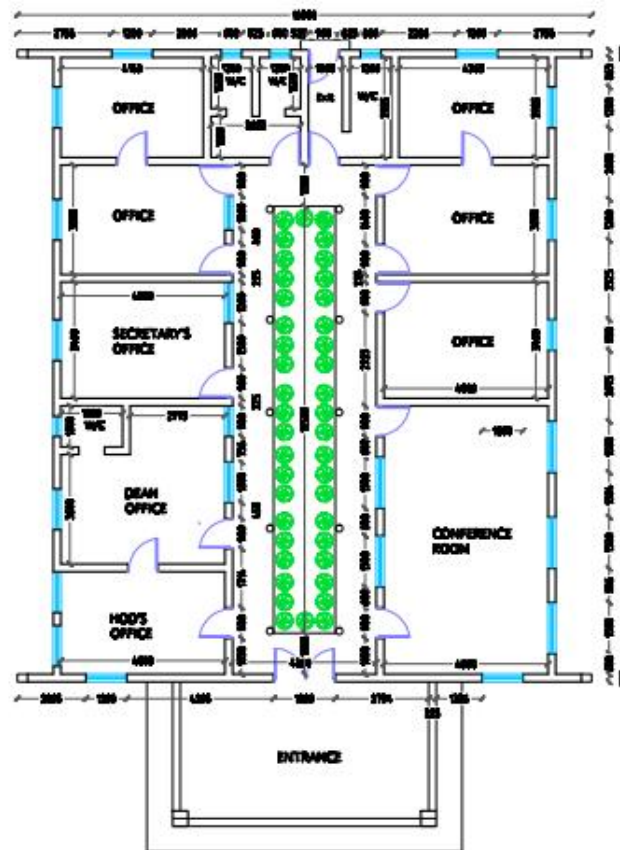


*Plate 3: Showing the Side view of the Faculty building, showing openings,
vegetation and outdoor units of the mechanical cooling device*

Source: Researcher's Field Work, 2022



Plate 4: An interior view showing the court yard of the Faculty building
 Source: Researcher's Field Work, 2022.



GROUND FLOOR PLAN

Figure 1: Showing ground floor plan of The Faculty of Engineering and Technology,
 Ladoke Akintola University of Technology, Ogbomoso, Oyo State.
 Source: Researcher's Field Work, 2022.



*Plate 5: Views showing rows of departmental buildings within the faculty
Source: Researcher's Field Work, 2022.*



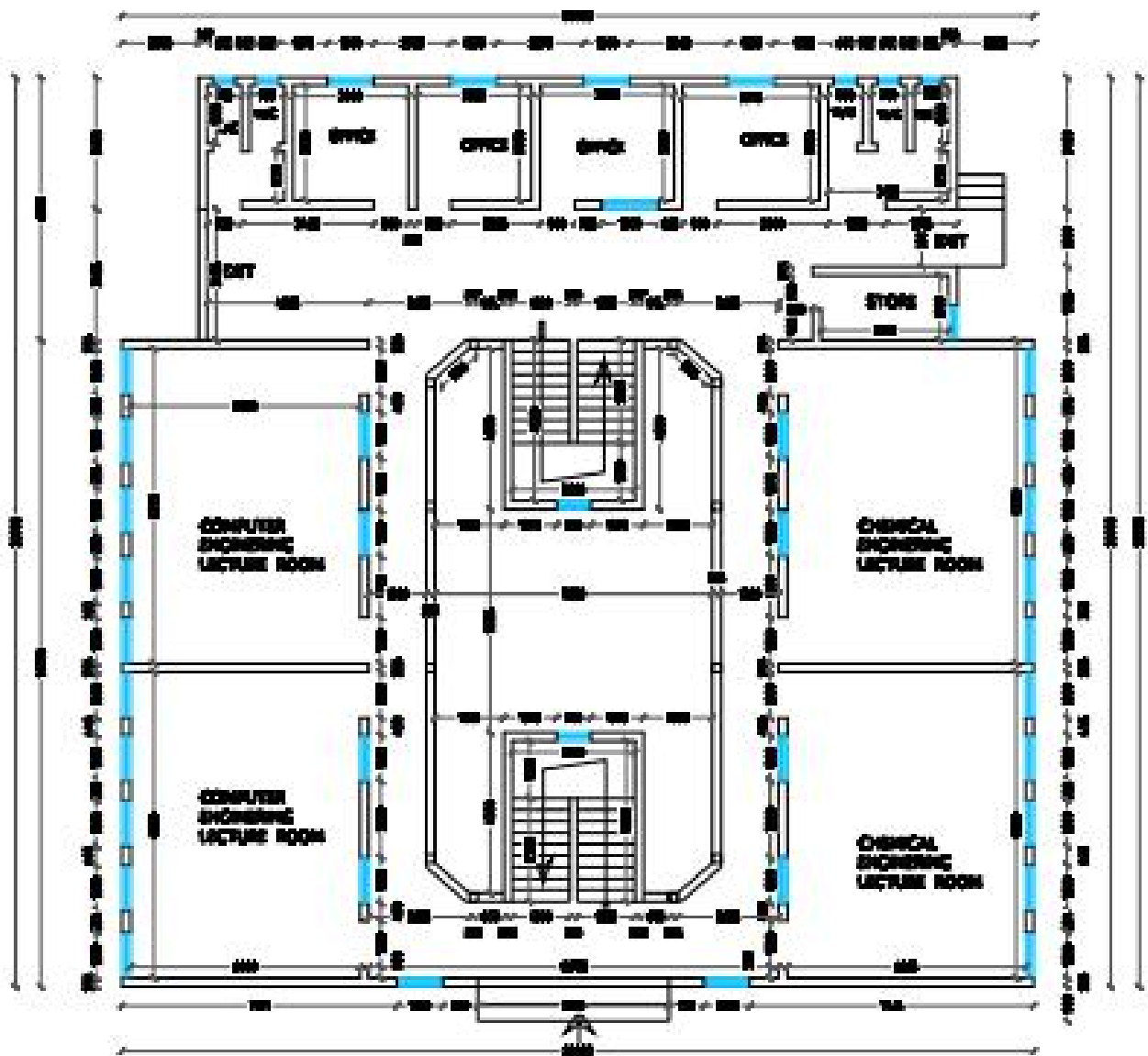
*Plate 6: view showing the Faculty of Engineering and Technology, lecture hall known as the High rise building
along the departmental blocks, Ladoko Akintola University of Technology, Ogbomoso, Oyo State.
Source: Researcher's Field Work, 2022.*



*Plate7: Approach view of the High rise lecture Hall, for the faculty of Engineering and Technology, Ladoke Akintola University of Technology, Ogbomosho, Oyo State.
Source: Researcher's Field Work, 2022.*

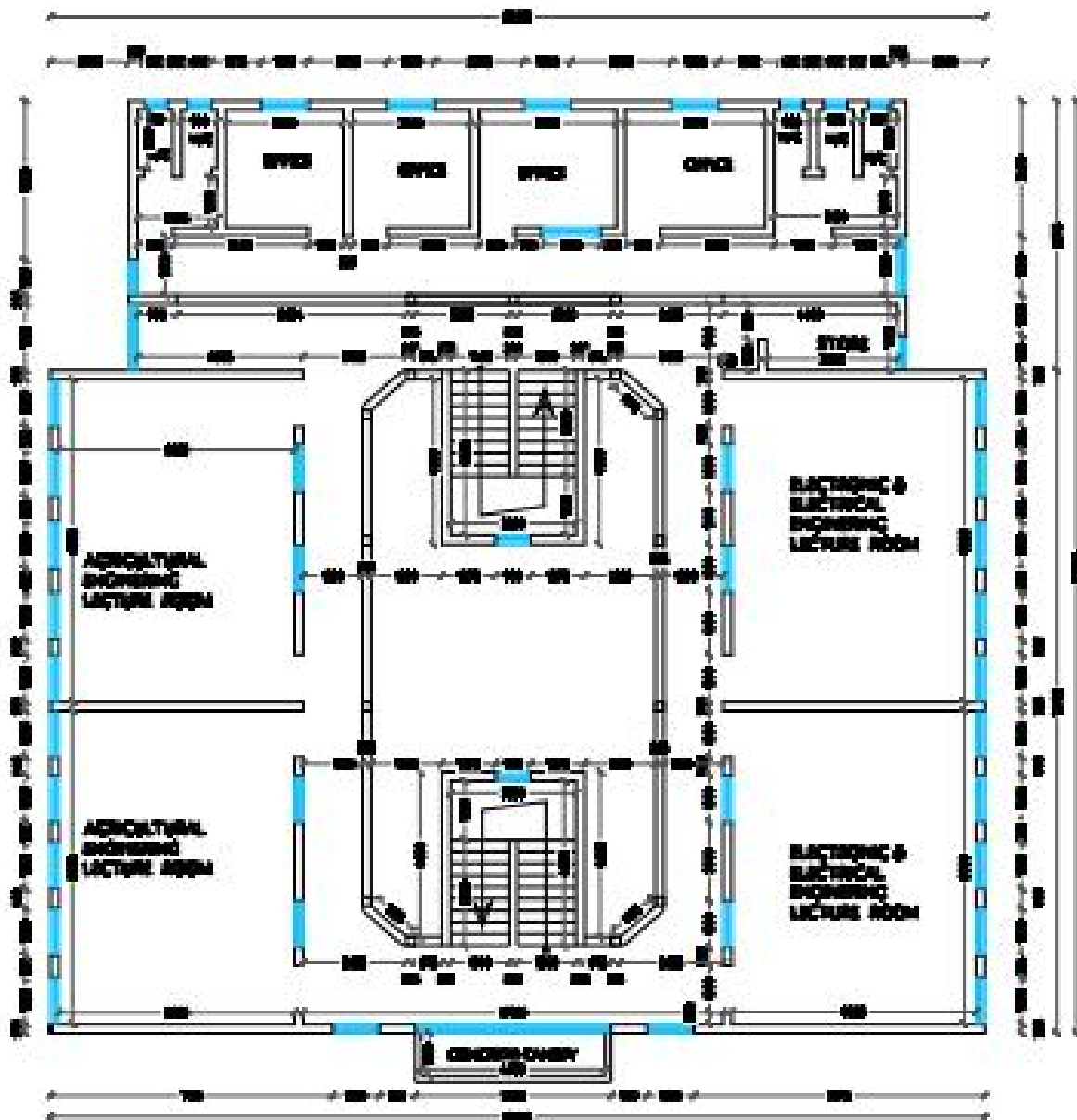


*Plate 8: Side view of the high rise lecture hall building, Faculty of Engineering and Technology, showing openings in the lecture rooms.
Source: Researcher's Field Work, 2022*



GROUND FLOOR PLAN

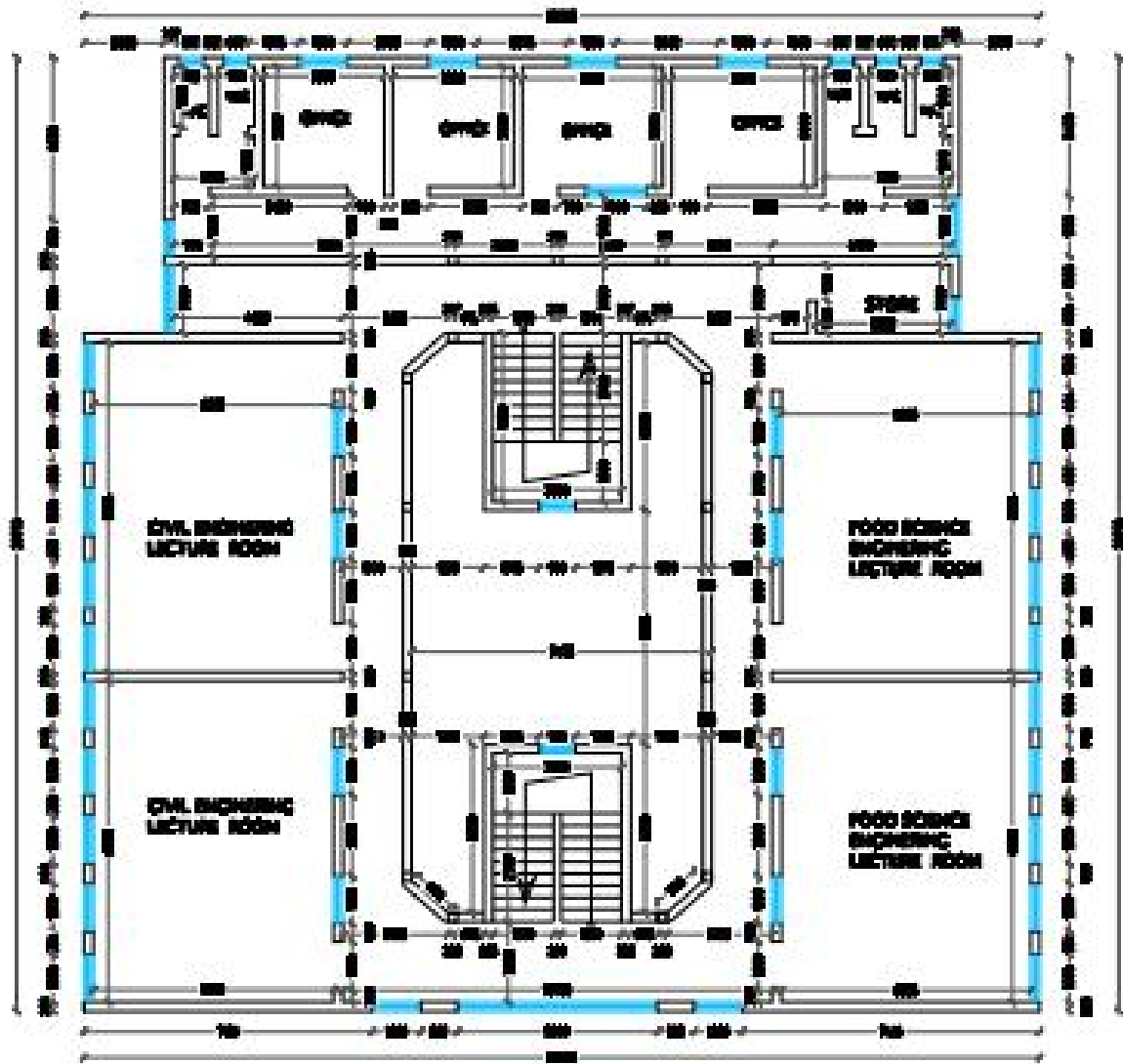
Figure 2: Showing the ground floor plan of the Lecture hall
 Source: Researcher's Field Work, 2022



FIRST FLOOR PLAN

Figure 3: Showing the frist floor of the Lecture hall

Source: Researcher's Field Work, 2022



SECOND FLOOR PLAN

Figure 4: Showing the Second floor of the Lecture hall

Source: Researcher's Field Work, 2022

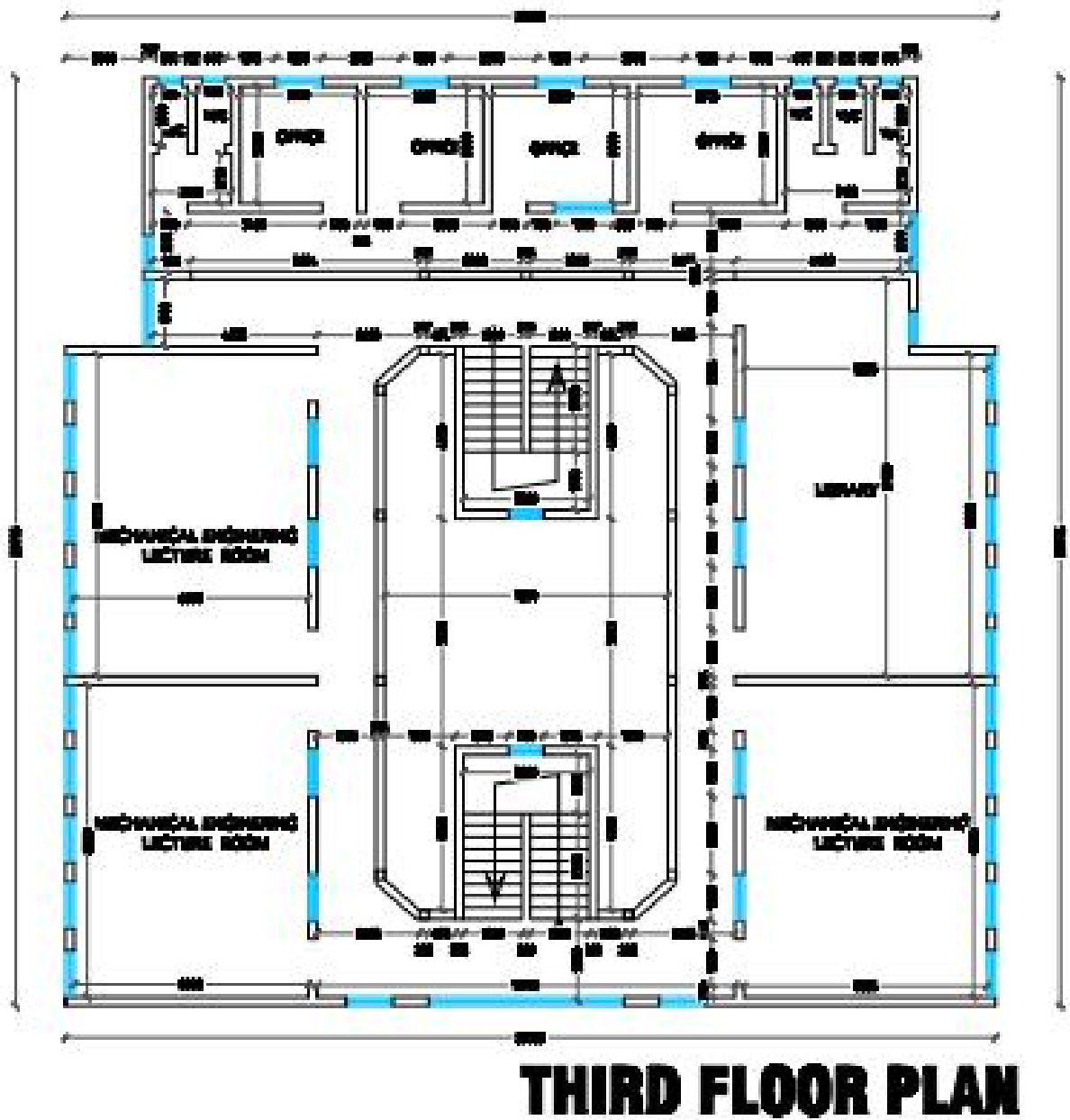


Figure 5: Showing the third floor of the lecture hall

Source: Researcher's Field Work, 2022.

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Plate 9: An interior view showing the high rise lecture hall, Faculty of Engineering and Technology, Ladoke Akintola University of Technology, Ogbomoso, Oyo State.

Source: Researcher's Field Work, 2022

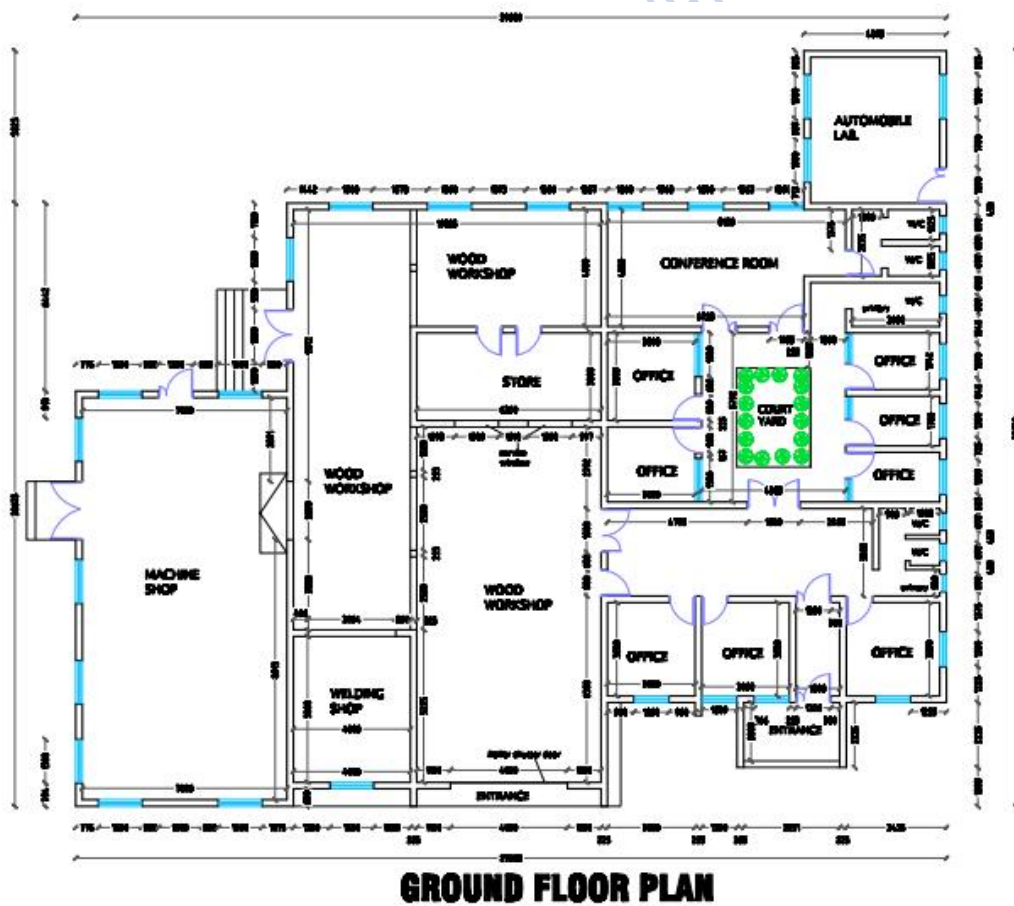


Figure 6: showing ground floor of mechanical workshop, Faculty of Engineering and Technology, Ladoke Akintola University of Technology, Ogbomoso, Oyo State.

Source: Researcher's Field Work, 2022.



Plate 10: Approach view of mechanical engineering workshop, Faculty of Engineering and Technology, Ladoke Akintola University of Technology, Ogbomosho, Oyo State.

Source: Researcher's Field Work, 2022.



Plate 11: Interior view of mechanical engineering workshop, Faculty of Engineering and Technology, Ladoke Akintola University of Technology, Ogbomosho, Oyo State.

Source: Researcher's Field Work, 2022

Appraisal

Merits

1. The Faculty of Engineering building can easily be accessed from any part of the campus
2. There is provision of adequate windows in the lecture Hall to give room for natural ventilation
3. Good orientation of the building
4. There is provision of courtyard to enhance the thermal condition of the building
5. Trees were planted around the departmental buildings to reduce the impact of solar radiation (Plate 5)
6. Plants are planted around the building to create a beautiful outlook and also serve as means of cooling the environment

Demerits

1. No shading devices to reduce the impact of sun rays into the building.
2. The courtyard at the departmental buildings are not wide enough
3. No adequate lighting within the workshop
4. No proper ventilation within the workshop

3.4 Case Study Two

3.4.1 College of Engineering, Bells University of Technology, Ota, Ogun State.

Brief History

Bells University of Technology, also known as Bellstech, is the first private university of technology established in Nigeria. It was established in 2004. It is located in Ogun State of Nigeria. Bells University of Technology offers innovative degrees and diploma option in Mechatronics, Mechanical, Electrical, Telecommunications, Civil, Biomedical, and Computer Engineering.

Location

The College of engineering, Bells University of Technology is located at Km. 8 Idiroko Rd, Benja Village 112104, Ota. Ogun State.

3.4.2 Description of the building

The College of engineering consist of administration office blocks for each department, wood workshop, Lecture hall, ICT building.

3.4.3 Thermal comfort strategies

Proper openings and outdoor spaces are engaged to allow for natural ventilation, increase thermal comfort and at the same time to save energy. The use of clay bricks on the external and internal walls to reduce the heat gain into the building. There is vegetation (Hedges, shrubs etc...) around the building which allows breeze and fresh air to penetrate inside the building. Mechanical cooling device were used in the offices and ICT to reduce the thermal load generated by computers and lighting fittings to create a comfortable indoor environment.

Building Material used

The major building materials used for the construction of the Faculty of Engineering are clay bricks, reinforced concrete, wood, steel, glass and Aluminum.



Plate 12: Satellite image showing site layout of the College of Engineering, Bells University of Technology Ota, Ogun State.

Source: Google Earth, 2022



Plate 13: View showing the Administration block of the college of engineering, Bells University of Technology Ota, Ogun State.

Source: Researcher's Field Work, 2022



Plate 14: View showing the court yard of the Administrative office block, College of Engineering, Bells University of Technology, Ota, Ogun State.

Sources: Researcher's Field Work, 2022.



Plate 15: Approach view of the college of engineering workshop (Auto Service Center), Bells University of Technology Ota, Ogun State

Source: Researcher's Field Work, 2022.



Plate 16: View showing the interior of the wood workshop, College of Engineering, Bells University of Technology Ota, Ogun State.

Sources: Researcher's Field Work, 2022



Plate 17: View showing the interior of the Hydraulics Laboratory, College of Engineering, Bells University of Technology Ota, Ogun State.

Sources: Researcher's Field Work, 2022

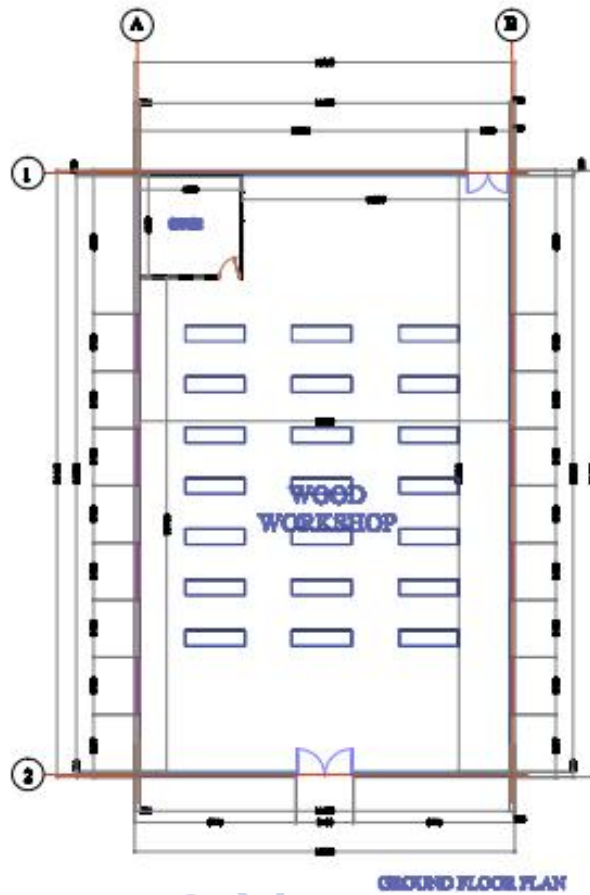


Figure 7: Showing the ground floor plan of the college of engineering workshop, Bells University of Technology, Ota Ogun State.

Source: Researcher's Field Work, 2022

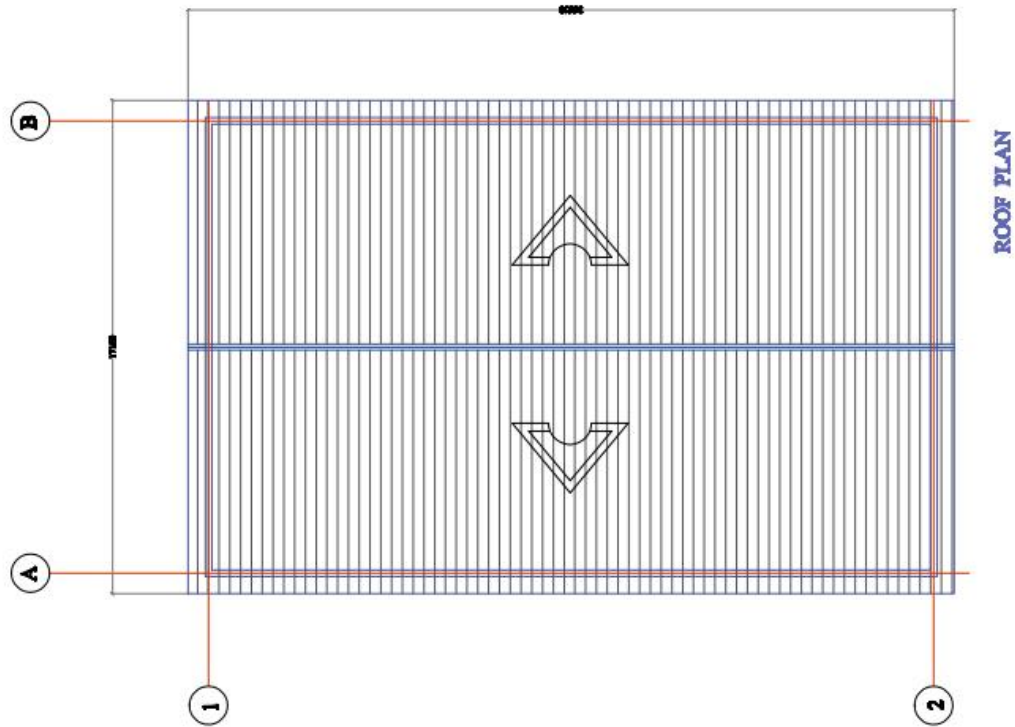


Figure 8: Showing the roof plan of the college of engineering workshop, Bells University of Technology, Ota Ogun State.

Source: Researcher's Field Work, 2022



Plate 18: Perspective view showing the ICT Of the college of engineering, Bells University of Technology Ota, Ogun State.

Sources: Researcher's Field Work, 2022.



Plate 19: An interior view showing the space arrangement of the College of Engineering ICT, Bells University of Technology Ota, Ogun State

Sources: Researcher's Field Work, 2022

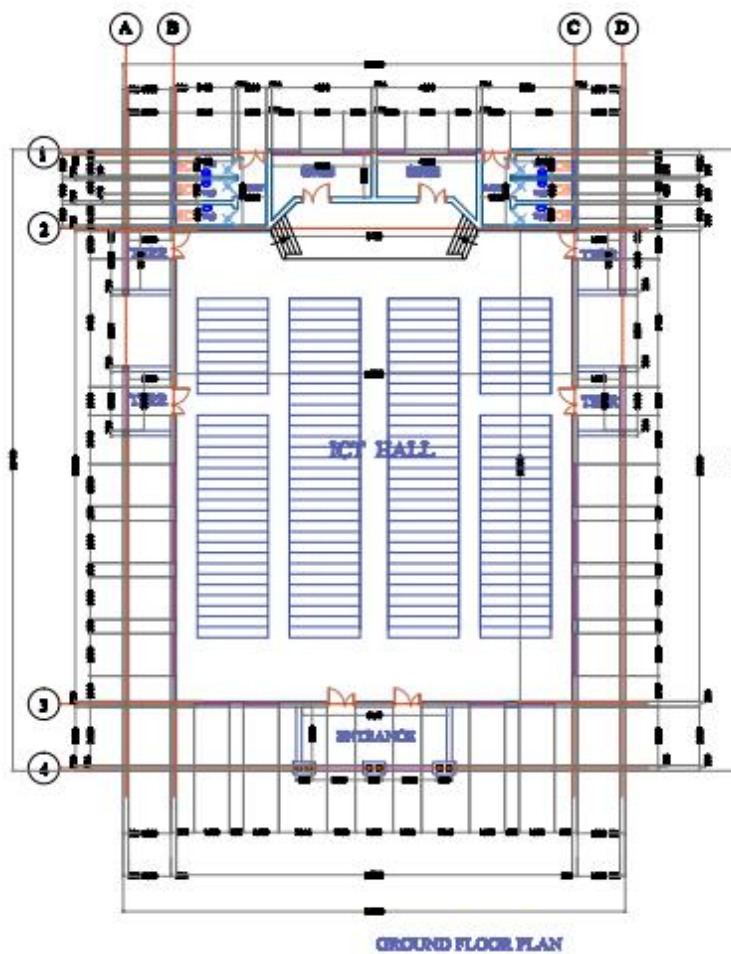


Figure 9: Showing the ground floor plan of the college of engineering ICT, Bells University of Technology Ota, Ogun State.

Sources: Researcher's Field Work, 2022.

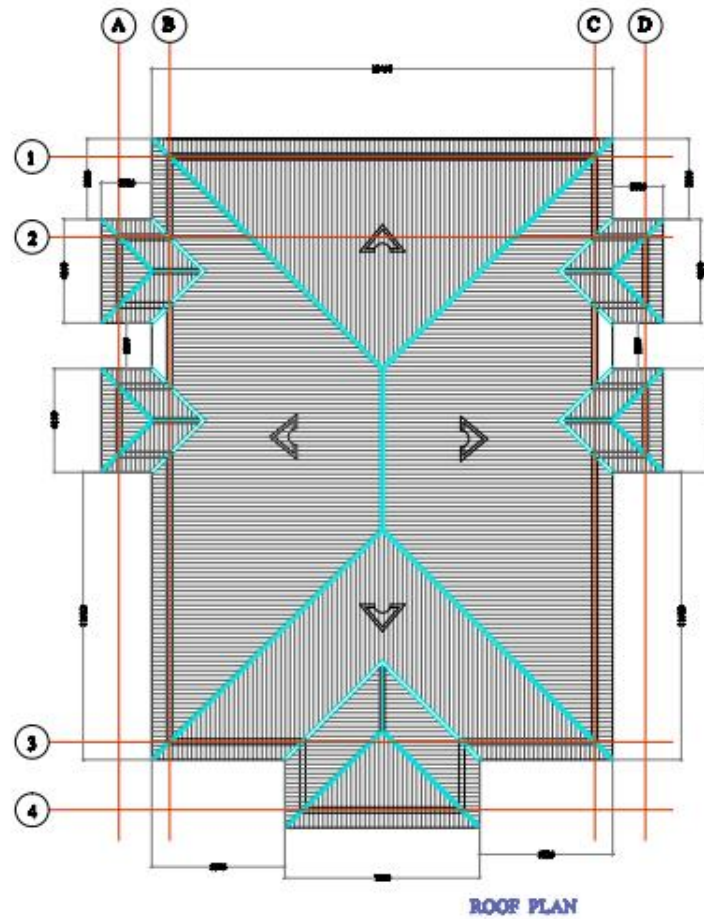


Figure 10: Showing the roof plan of the college of engineering ICT, Bells University of Technology Ota, Ogun State.

Sources: Researcher's Field Work, 2022.



Plate 20: Showing the approach view of the lecture room, college of engineering, Bells University of Technology Ota, Ogun State.

Sources: Researcher's Field Work, 2022.



Plate 21: An interior view of the lecture room, College of engineering, Bells University of Technology Ota, Ogun State.

Sources: Researcher's Field Work, 2022.

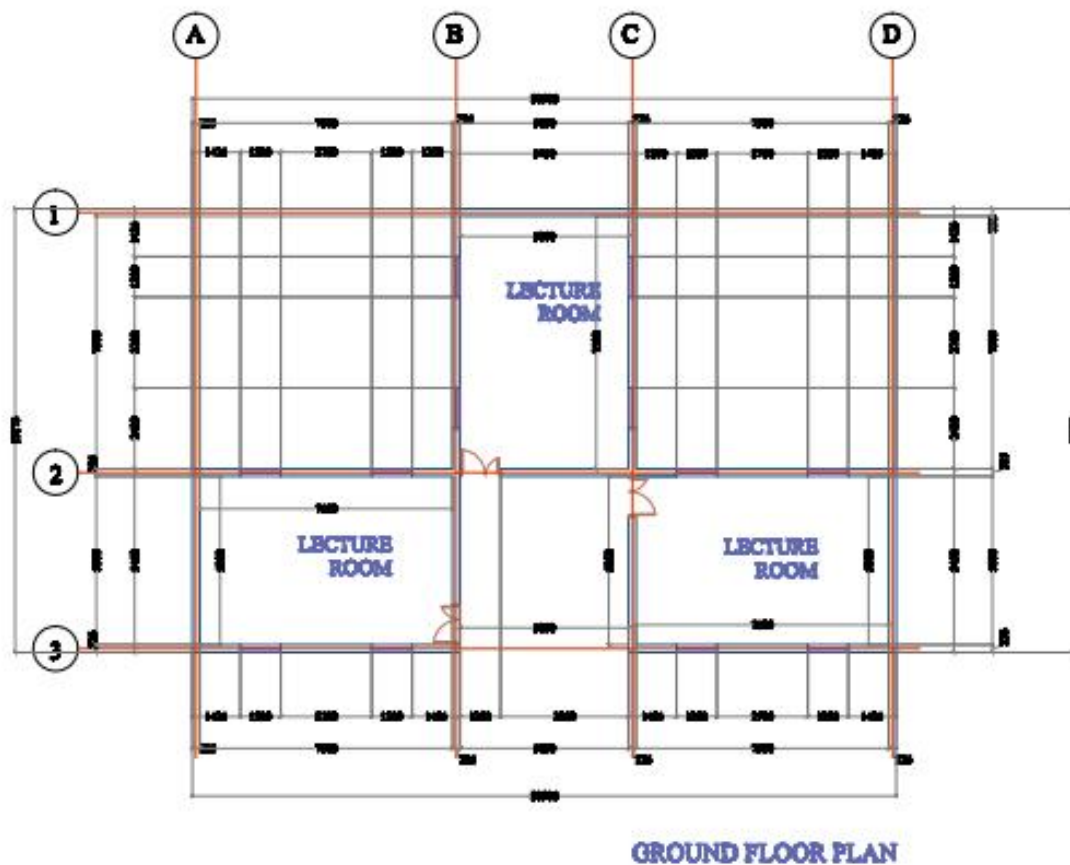


Figure 11: Showing the ground floor plan of the lecture room, College of engineering, Bells University of Technology Ota, Ogun State.

Sources: Researcher's Field Work, 2022.

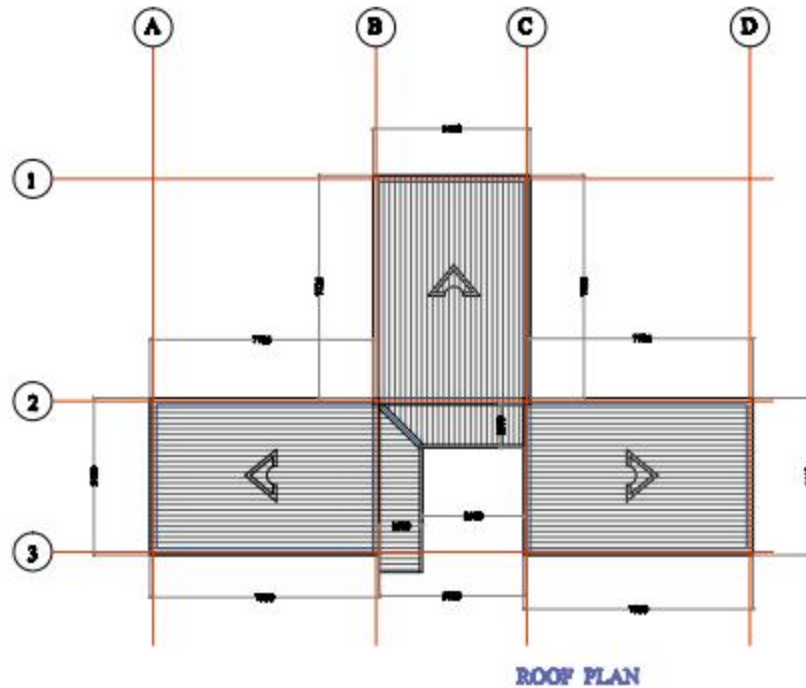


Figure 12: Showing the roof plan of the lecture room, College of engineering, Bells University of Technology Ota, Ogun State.

Sources: Researcher's Field Work, 2022.

3.4.4 Appraisal

Merits

1. The College of Engineering building can easily be accessed from any part of the campus
2. There is provision of adequate windows in the lecture Hall to give room for natural ventilation
3. Good orientation of the building
4. There is provision of courtyard to enhance the thermal condition of the building
5. Plants are planted around the building to create a beautiful outlook and also serve as means of cooling the environment
6. There is adequate lighting within the building.
7. There is proper ventilation within the building.

Demerits

1. No shading devices to reduce the impact of sun rays into the building.
2. Absence of escape route at the lecture hall.

3.5 Case Study Three

3.5.1 Faculty of Engineering, University of Manitoba, Winnipeg, Canada

Brief History

University of Manitoba was established in 1877, while the faculty of engineering was enrolled in 1907 and the oldest engineering school in western Canada, the undergraduate programs are Bio systems, Civil (including Environmental Option), Computer, Electrical, and Mechanical (including Aerospace and Manufacturing Options).The

Location

The University is located at No. 75 Chancellors Cir, Winnipeg, MB R3T 5V6, Canada.

3.5.2 Description of the building

The Faculty of engineering building consist of following spaces: Biomedical Engineering Lab, Electrical Engineering Lab, Undergraduate study space, project garage, project support space, electric vehicle Lab, Graduate student space, Geomatics Lab, CEP2E2 Space, IEEQ Space, Miatacs office, second floor circulation connection.

Architects: Stantec Architecture

Area: 4275 m²

Engineering: Stantec Consulting Ltd

3.5.3 Thermal comfort strategies

Proper openings and outdoor spaces are engaged to allow for natural ventilation, increase thermal comfort and at the same time to save energy. The use of clay bricks

on the external walls to reduce the heat gain into the building. There is vegetation around the building which allows breeze and fresh air to penetrate inside the building.

Building Material used

The major building materials used for the construction of the Engineering building are bricks, reinforced concrete, wood, steel, glass and Aluminum.



*Plate 22: Satellite image showing site layout of the faculty of Engineering, University of Manitoba, Winnipeg, Canada.
Source: Google Earth, 2022*



Plate 23: Showing the approach view of the Stanley Pauley Engineering Building, University of Manitoba, Winnipeg, Canada.

Sources: Researcher's



Plate 24: View of a glazed skywalk which provide internal circulation circuit connecting all engineering buildings at the second floor.

Sources: Researcher's Field Work, 2022.

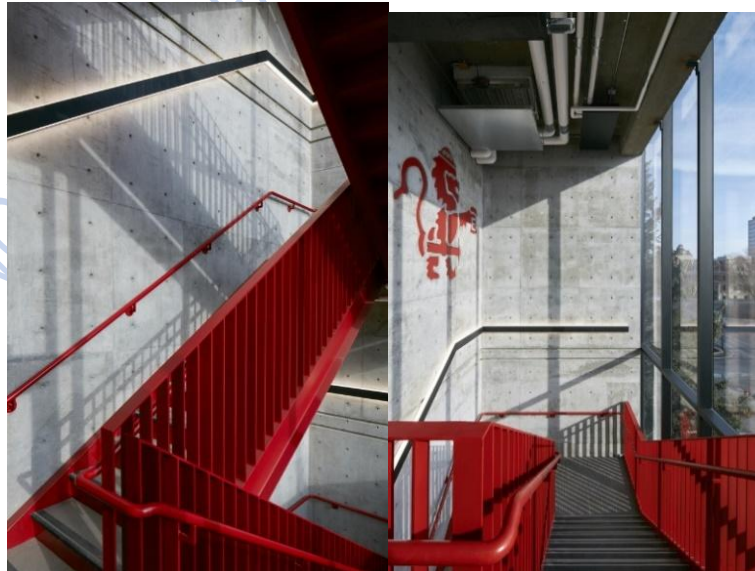


Plate 25: View showing the stair case, faculty of engineering, University of Manitoba, Winnipeg, Canada.

Sources: Researcher's Field Work, 2022.



Plate 26: View showing the civil Laboratory, faculty of engineering, University of Manitoba, Winnipeg, Canada.

Sources: Researcher's field, Work, 2022.

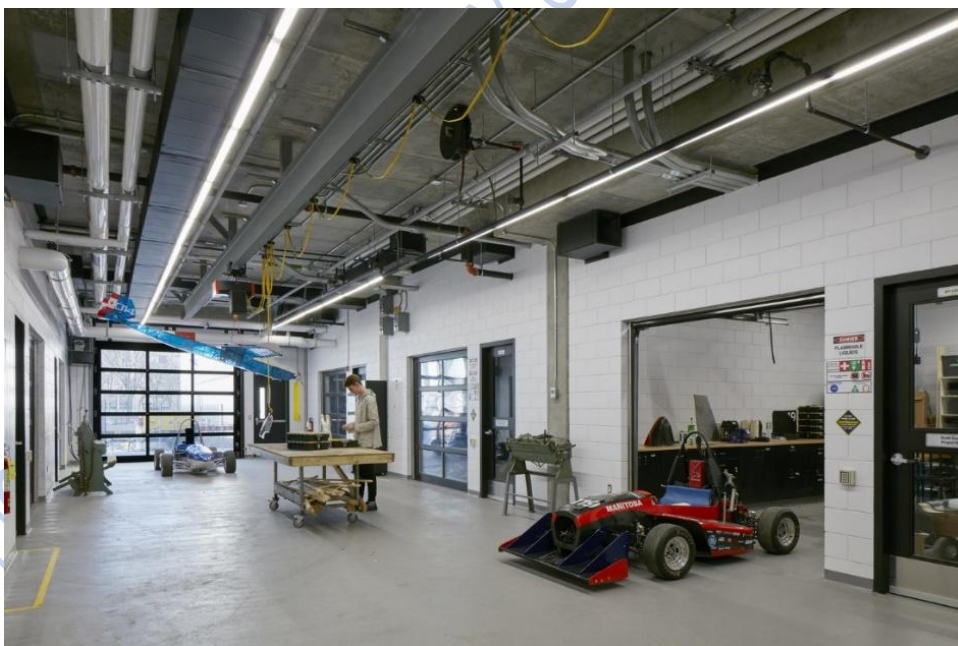


Plate 27: Showing an interior view of the workshop, faculty of engineering, University of Manitoba, Winnipeg, Canada.

Sources: Researcher's Field Work, 2022.



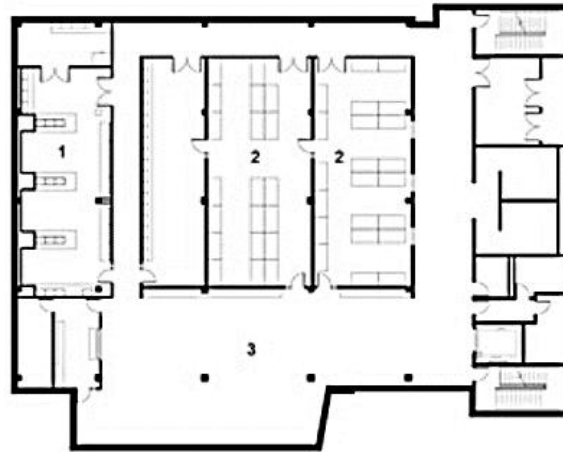
Plate 28: view showing the biomedical Lab, faculty of engineering, University of Manitoba, Winnipeg, Canada.

Sources: Researcher's Field Work, 2022.



Figure 13: Showing the 4 floor levels of the University of Manitoba, Faculty of engineering, Winnipeg, Canada.

Sources: Researcher's Field Work, 2022.



100 LEVEL - BELOW GRADE

Figure 14: Showing the basement floor, faculty of engineering, University of Manitoba, Winnipeg, Canada.
 (1).Biomedical Engineering Lab. (2). Electrical Engineering Lab, (3).Undergraduate study space

Sources: Researcher's Field Work, 2022.

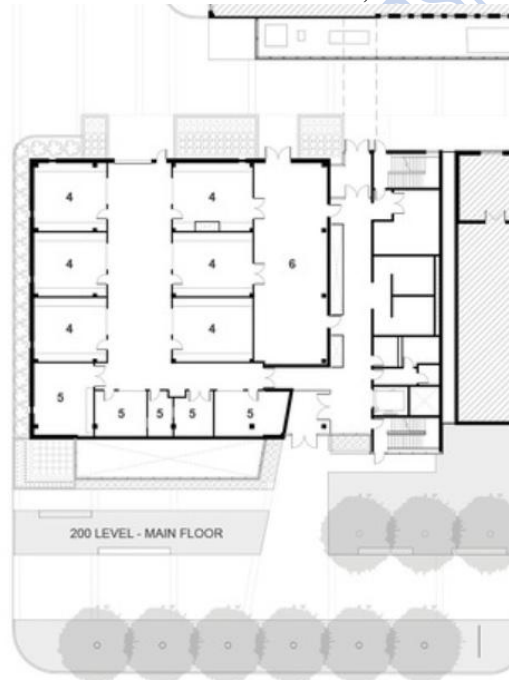
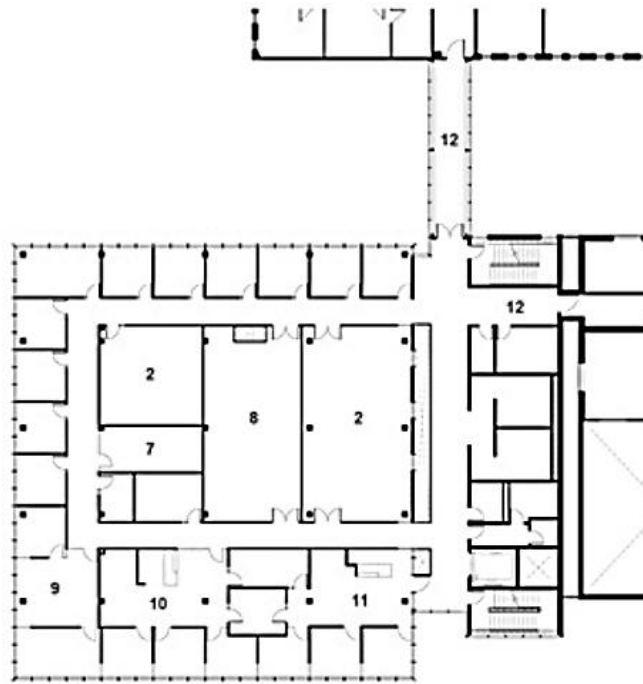


Figure 15: Showing the ground floor plan, faculty of engineering, University of Manitoba, Winnipeg, Canada
 (4).Project garage, (5).Project Support Space, (6).Electrical Vehicle Lab.

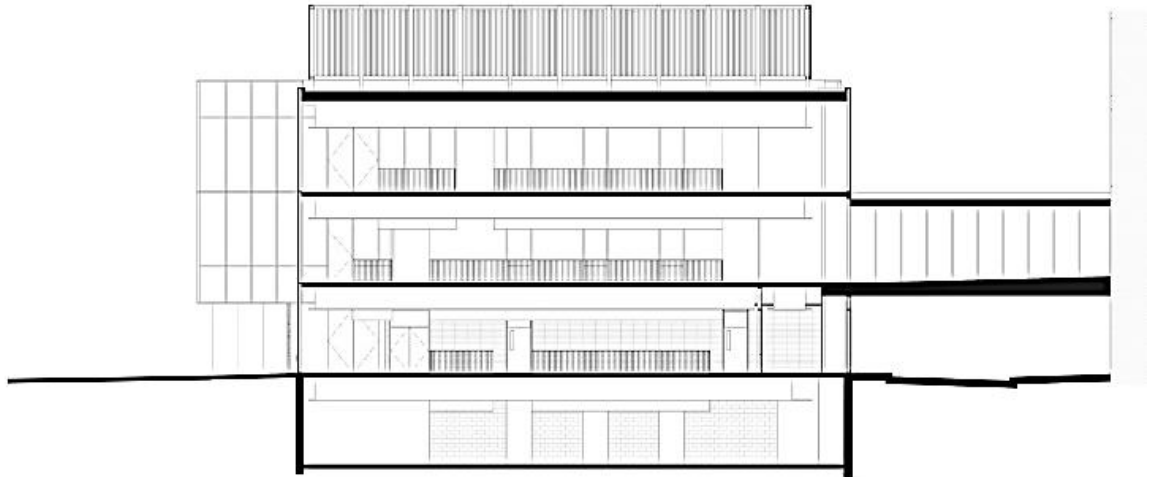
Sources: Researcher's Field Work, 2022.



300 LEVEL - CONNECTION FLOOR

Figure 16: Showing the first floor plan, faculty of engineering, University of Manitoba, Winnipeg, Canada
 (2).Electrical Engineering Lab, (7).Graduate student space, (8).Geomatics Lab, (9).CEP2E2 Space, (10).IEEQ Space, (11).MITACS Office, (12).Second floor circulation connection.

Sources: Researcher's Field Work, 2022.



BUILDING SECTION

Figure 17: view showing the section of the building, University of Manitoba, Winnipeg, Canada.

Sources: Researcher's Field Work, 2022

3.5.4 Appraisal

Merits

1. The Faculty of Engineering building can easily be accessed from any part of the campus
2. There is provision of adequate windows in the building to give room for natural ventilation
3. Plants are planted around the building to create a beautiful outlook and also serve as means of cooling the environment
4. There is adequate lighting within the building.
5. There is proper ventilation within the building.

3.6 Case Study Four

3.6.1 Washkewicz college of Engineering, Cleveland State University

Brief History

Since 1923, the Washkewicz (Fenn) College of Engineering at Cleveland State University has provided a tradition of high quality undergraduate and graduate education in engineering and engineering technology. In today's technology-driven world, engineering is increasingly important to the global marketplace. Because the present and future well-being of the United States is intrinsically linked with continued industrial growth, trained engineering professionals and technologists are thus increasingly in great demand.

Location

The University is located at 2121 Euclid Ave, Cleveland, OH 44115, United States

3.6.2 Description of the building

The Washkewicz College of Engineering addition expanded the original Fenn Hall to create a world-class facility that furthers these goals with state-of-the-art engineering facilities, including a multi-story maker space that forms the intellectual “hub” of both the building and the campus community—attracting students from the engineering, fine arts, and business disciplines to build, refine and test new products. The facility includes laboratory spaces for Chemical and Biomedical Engineering, Civil and Environmental Engineering, Electrical and Computer Engineering, Engineering Technology, and Mechanical Engineering. It also includes classrooms, collaborative learning spaces, and faculty offices.

3.6.3 Thermal comfort strategies

Proper openings and outdoor spaces are engaged to allow for natural ventilation, increase thermal comfort and at the same time to save energy. The use of clay bricks on the external walls to reduce the heat gain into the building. There is vegetation around the building which allows breeze and fresh air to penetrate inside the building. Duct pipe were used to transport air from heating, ventilation and air conditioning and lighting fittings to create a comfortable indoor environment.

Building Material used

The major building materials used for the construction of the Engineering building are bricks, reinforced concrete, wood, steel, glass and Aluminum.



Plate 29: Satellite image showing site layout of Washkewcz College of Engineering, Cleveland State University

Source: Google Earth, 2022



Plate 30: Showing the Perspective view of Washkewcz College of Engineering, Cleveland State University

Sources: Researcher's Field Work



Plate 31: Showing the approach view of Washkewcz College of Engineering, Cleveland State University

Sources: Researcher's Field Work, 2022



Plate 32: Showing the interior view of a collaboration space, Washkewcz College of Engineering, Cleveland State University

Sources: Researcher's Field Work, 2022



*Plate 33: View showing the interior of a teaching Lab.
Washkewcz College of Engineering, Cleveland State University*

Sources: Researcher's Field Work, 2022.



*Plate 34: View showing the classroom,
Washkewcz College of Engineering, Cleveland State University*

Sources: Researcher's Field Work, 2022

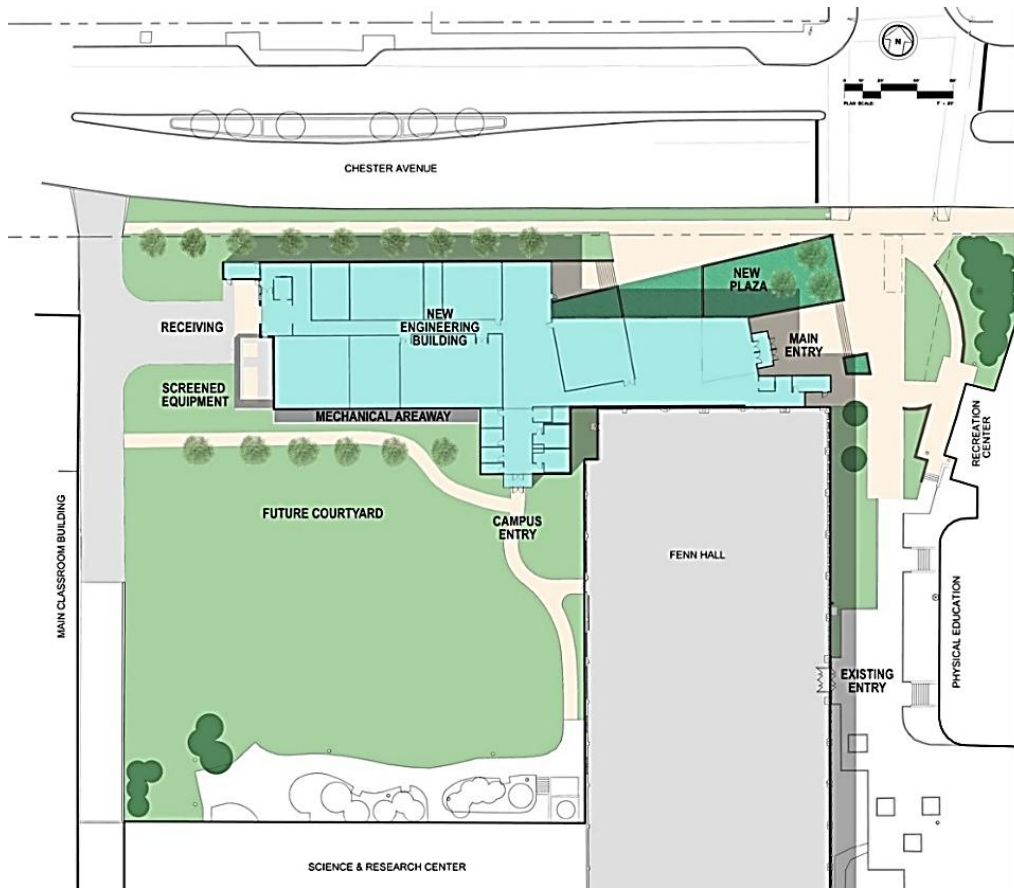


Figure 18: Showing the Site plan of Washkewcz College of Engineering, Cleveland State University

Sources: Researcher's Field Work, 2022



Figure 19: Showing the Basement plan of Washkewcz College of Engineering, Cleveland State University

Sources: Researcher's Field Work, 2022



Figure 20: Showing the ground floor plan of Washkewcz College of Engineering, Cleveland State University

Sources: Researcher's Field Work, 2022

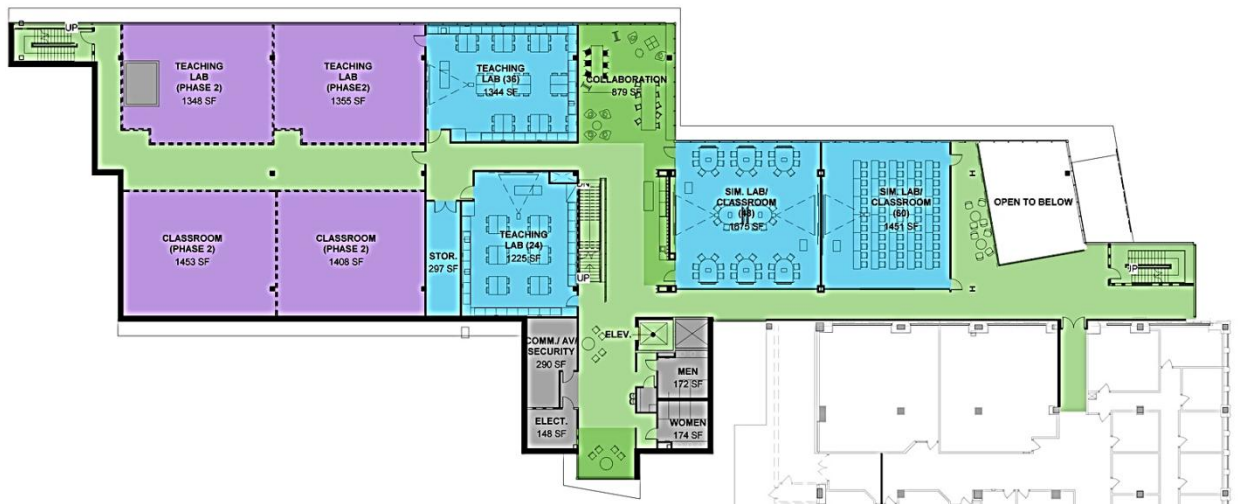


Figure 21: Showing the first floor plan of Washkewcz College of Engineering, Cleveland State University

Sources: Researcher's Field Work, 2022



Figure 22: Showing the second floor plan of Washkewcz College of Engineering, Cleveland State University.

Sources: Researcher's Field Work, 2022



Figure 23: Showing the third floor plan of Washkewcz College of Engineering, Cleveland State University

Sources: Researcher's Field Work, 2022

3.6.4 Appraisal

Merits

1. The College of Engineering building can easily be accessed from any part of the campus
2. There is provision of adequate windows in the building to give room for natural ventilation

3. Good orientation of the building
4. Plants are planted around the building to create a beautiful outlook and also serve as means of cooling the environment
5. There is adequate lighting within the building.
6. There is proper ventilation within the building.

3.7 Case Study Five

3.7.1 Lancaster University, School of Engineering

Brief History

Lancaster University (legally The University of Lancaster) is a collegiate public research university in Lancaster, Lancashire, England. The university was established by royal charter in **1964**, one of several new universities created in the 1960s

Location

Located at New Engineering Building, Lancaster University, Gillow Ave, Bairigg, Lancaster LA14YW, United Kingdom

3.7.2 Description of the building

The School of Engineering at Lancaster is a broad-based engineering center, with a record of innovative teaching, world-class research and integration with industry. The School of Engineering at Lancaster University provides a diverse range of workshops; laboratories and academic offices, accommodating a variety of highly-specialist disciplines. In addition to providing new academic space for an expanding cohort of staff and students the University's brief was twofold; to create a building which would improve the public face and working environment of the department, and to build a highly sustainable facility achieving BREEAM Outstanding.

3.7.3 Thermal comfort strategies

Proper openings and outdoor spaces are engaged to allow for natural ventilation, increase thermal comfort and at the same time to save energy. The use of clay bricks on the external walls to reduce the heat gain into the building. There is vegetation around the building which allows breeze and fresh air to penetrate inside the building. Duct pipe were used to transport air from heating, ventilation and air conditioning and lighting fittings to create a comfortable indoor environment.

3.7.4 Building Material used

The major building materials used for the construction of the Engineering building are bricks, reinforced concrete, wood, steel, glass and Aluminum

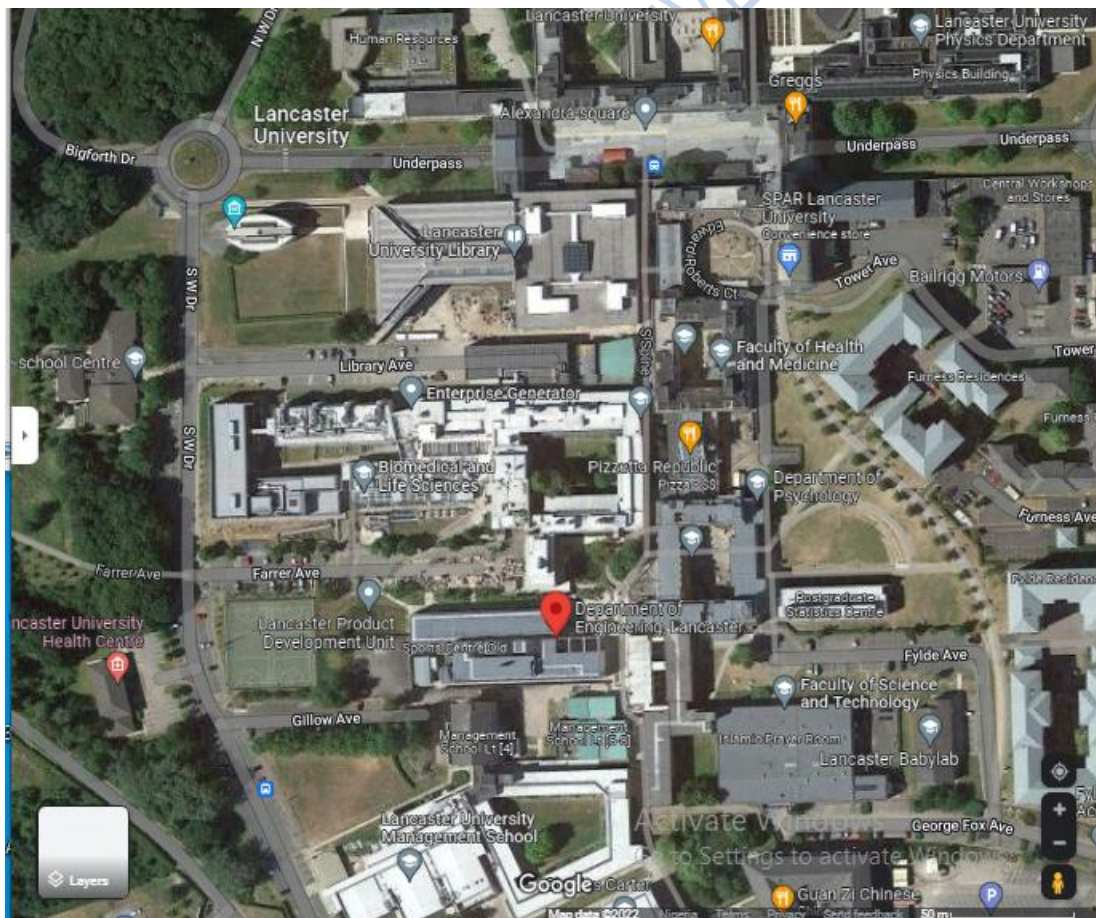


Plate 35: Satellite image showing site layout of School of Engineering, Lancaster University

Source: Google Earth, 2022



Plate 36: Showing the Perspective view of the school of engineering, Lancaster University

Sources: Researcher's Field Work, 2022



Plate 37: Showing the entrance view of the school of engineering, Lancaster University

Sources: Researcher's Field Work, 2022



Plate 38: Showing the approach view of the school of engineering, Lancaster University

Sources: Researcher's Field Work, 2022



Plate 39: Showing the lobby of the school of engineering, Lancaster University

Sources: Researcher's Field Work, 2022.



Plate 40: View showing the interior and the stair along the lobby of the school of engineering, Lancaster University

Sources: Researcher's Field Work, 2022.



Plate 41: View showing the workshop of the school of engineering, Lancaster University

Sources: Researcher's Field Work, 2022

ENGINEERING BUILDING | GROUND FLOOR PLAN

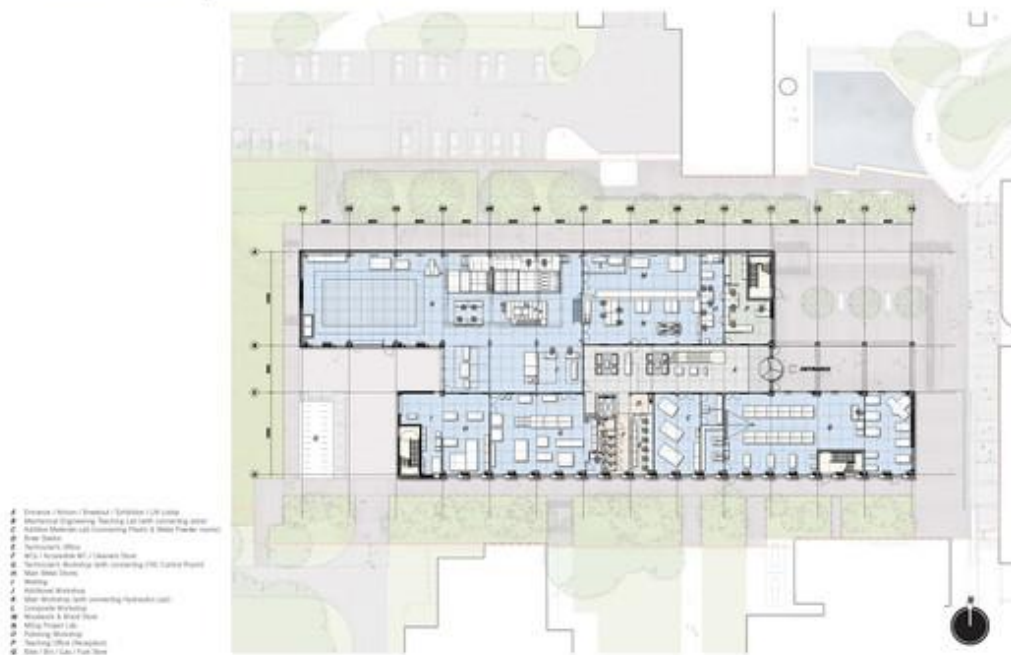


Figure 24: Showing the ground floor plan of the school of engineering, Lancaster University

Sources: Researcher's Field Work, 2022

ENGINEERING BUILDING | FIRST FLOOR PLAN

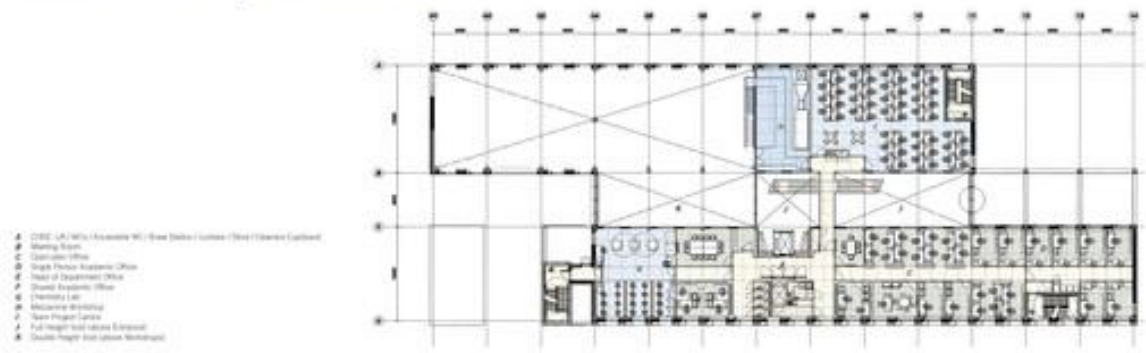


Figure 25: Showing the first floor plan the of school of engineering, Lancaster University

Sources: Researcher's Field Work, 2022

ENGINEERING BUILDING | SECOND FLOOR PLAN

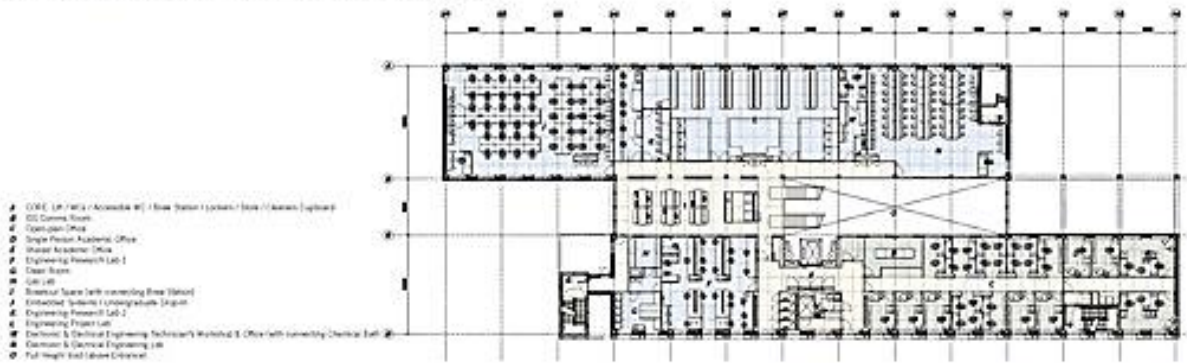


Figure 26: Showing the second floor plan of the school of engineering, Lancaster University

Sources: Researcher's Field Work, 2022

ENGINEERING BUILDING | THIRD FLOOR PLAN

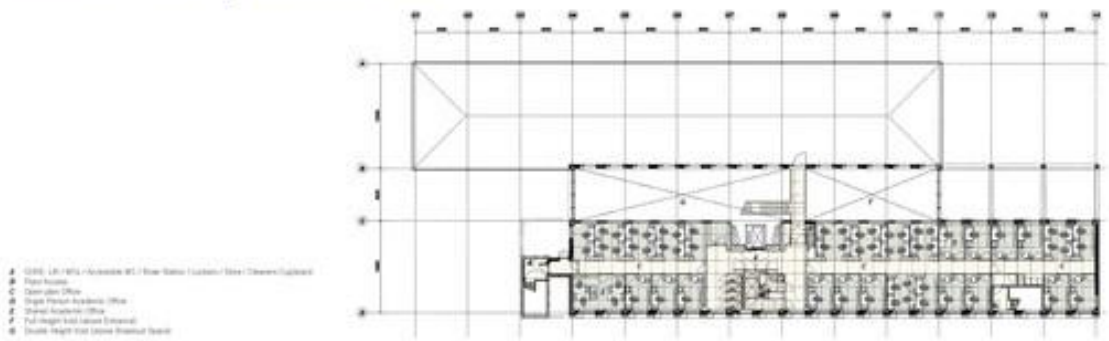
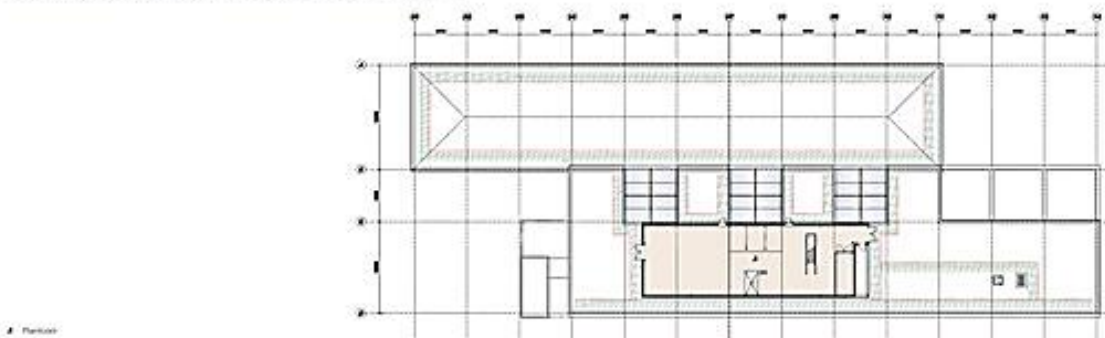


Figure 27: Showing the third floor plan of the school of engineering, Lancaster University

Sources: Researcher's Field Work, 2022

ENGINEERING BUILDING | FOURTH FLOOR PLAN



Fig

Figure 28: Showing the fourth floor plan of the school of engineering, Lancaster University

Sources: Researcher's Field Work, 2022

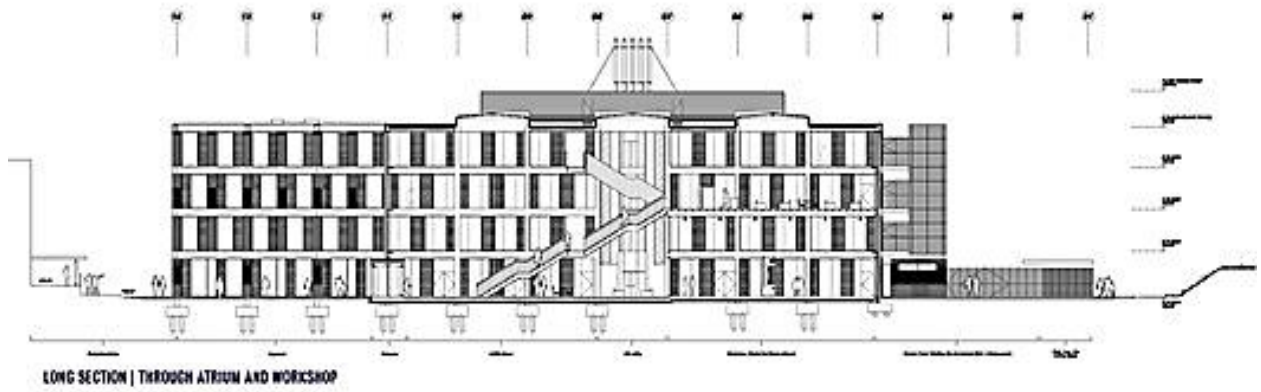


Figure 29: Showing the cross section of the school of engineering, Lancaster University

Sources: Researcher's Field Work, 2022

ENGINEERING BUILDING | ELEVATIONS

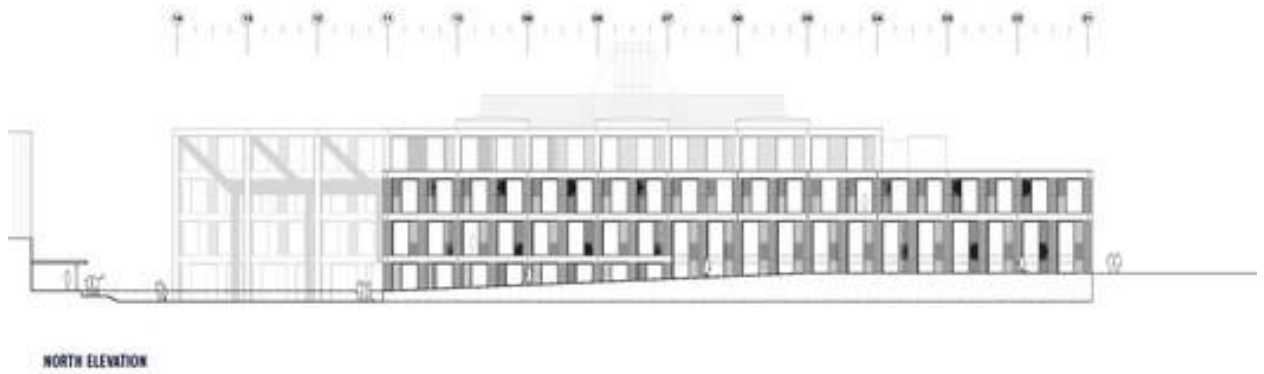


Figure 30: Showing the Front elevation of the school of engineering, Lancaster University

Sources: Researcher's Field Work, 2022

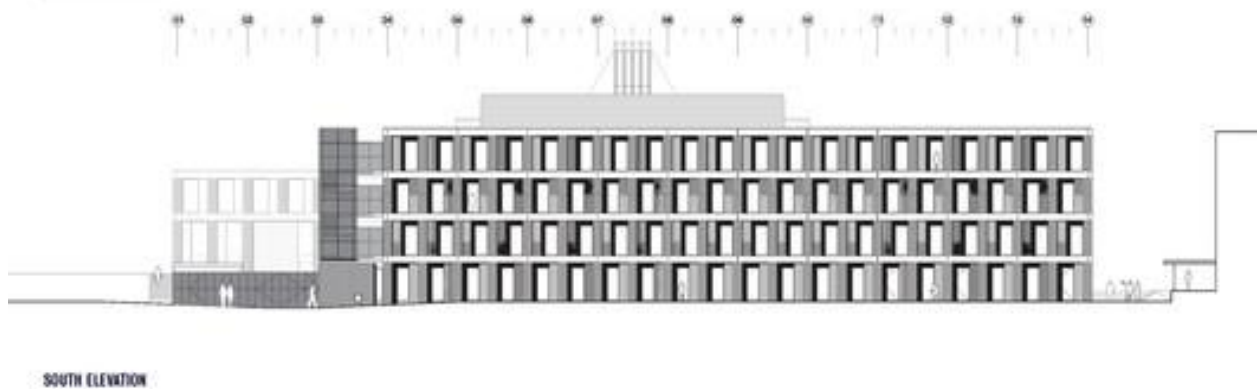


Figure 31: Showing the Back elevation of the school of engineering, Lancaster University

Sources: Researcher's Field Work, 2022



Figure 32: Showing 3D view of the school of engineering, Lancaster University

Sources: Researcher's Field Work, 2022

3.7.5 Appraisal

Merits

1. The College of Engineering building can easily be accessed from any part of the campus
2. There is provision of adequate windows in the lecture Hall to give room for natural ventilation.
3. Good orientation of the building
4. Plants are planted around the building to create a beautiful outlook and also serve as means of cooling the environment
5. There is adequate lighting within the building.
6. There is proper ventilation within the building.

CHAPTER FOUR

SITE / PROJECT ANALYSIS AND DESIGN SYNTHESIS

4.1 Study Area/Site Selection

4.1.1 History of Osun State/Iwo

Nigeria is situated in the West African region, sharing a border with Benin, Niger, Chad and Cameroon. To the south, it borders the Gulf of Guinea, part of the Atlantic Ocean and lies between longitudes 3 degrees and 14 degrees and latitudes 4 degrees and 14 degrees. It has a land mass of 923,768 sq.km, It is divided into 36 states and the Federal capital territory. Osun is the ninth smallest in area and nineteenth most populous with an estimated population of about 4.7 million as of 2016.

This region has a tropical climate. When compared with winter, the summers have much more rainfall. The climate here is classified as Aw by the Köppen-Geiger system. Osun State occasionally known as the State of Osun by the state government, is a state in southwestern Nigeria; bounded to the east by Ekiti and Ondo states. Osun State is divided into three federal senatorial districts, each of which is composed of two administrative zones. The state consists of thirty (30) Local Government Areas and Area offices, the primary (third-tier) unit of government in Nigeria.

Iwo Local Government Area has its administrative headquarters located in Iwo Town, others includes Agberire, Olubusan, Olupo Jolu, Omoba, Omosan-Igbo, Osa Ogunala, Osunjobi, Papa, Sade, Sekona, Tantan, Yakoyo, Adana, Adekolu, Awuje, Bara, Dauda, Denu etc Iwo is a center of industry and Yoruba culture.



Figure 33: Map of Nigeria showing all the states in the south-west of Nigeria.

Source: Google Image, 2022.



Figure 34: Map of Osun State showing all the Local Government in Osun State.

Source: Google Image, 2022.



Figure 35: Map showing the satellite image of Iwo, Osun State

Source: Google Image, 2022.

4.1.2 History of Bowen University, Iwo, Osun State

Bowen University is a private Baptist Christian Nigerian university owned and operated by the Nigerian Baptist Convention. Bowen University is located at Iwo in Osun State, Nigeria, and is housed in the old 1,300-acre (6 km²) campus of the Baptist College, a teacher-training institution on a hill just outside the city.

The University was founded on 17 July 2001 by the Nigerian Baptist Convention. The Federal Government of Nigeria approved the establishment of the university and it was subsequently licensed to operate by the National Universities Commission.

Bowen is one of the oldest private institution of higher education in Nigeria, established in 2001 by the Nigerian Baptist Convention (NBC). The major foundation of what has become Bowen University today was laid in 1854. That year, the family of the late Rev. Thomas Jefferson Bowen started a school in Ijaiye Orile in the present Oyo State of Nigeria. The School, comprising five stewards of the late Bowens, five

other laborers, and a few others drawn to the fledgling school by sheer curiosity, has grown from this little beginning in 1854 into thousands of Baptist Primary and Secondary Schools scattered across the country. By 1960, there was a Baptist school almost everywhere there was found a Baptist congregation.

The idea of establishing a Baptist University in Nigeria was first conceived in 1938. This was borne out of the Baptist commitment to assist the people to develop their potentials to the fullest. The first bold step towards actualizing this vision was not taken until 1956 when a proposal was presented to the meeting of the Baptist Mission held in Eku from 11th to 14th December, 1956. On 16th and 17th July, 1957, the joint meeting of the Executive Committees of the Baptist Mission of Nigeria and the Nigerian Baptist Convention endorsed the idea. Since then, the Nigerian Baptist Convention has worked tirelessly, committing time, material and human resources to actualizing the vision. Today, all these efforts have crystallized into the establishment of Bowen University, a significant landmark in the academic heritage of the Nigerian Baptist Convention, making it the first Baptist University in Africa.

On 17th of July, 2001, the Federal Government of Nigeria approved the establishment of Bowen University and was subsequently licensed to operate by the National Universities Commission (NUC).

On 4th November, 2002, Bowen University commended academic activities with 506 pioneering students admitted into its three faculties: Agriculture, Science and Science Education, and Social and Management Sciences.

In 2009, the National Universities Commission (NUC) gave approval to the University to offer the degree programs in Medicine (MBBS), Anatomy (B.Sc.) and Physiology (B.Sc.). In June 2011, NUC also gave approval to the University to establish the Faculty of Humanities and Faculty of Law. The Faculty of Humanities

began immediately in 2012 while the Council of Legal Education sent its own Panel of Facility Visitation in August 2012 and gave approval in December the same year. These programs have commenced in earnest.

Academic activity started on 4 November 2002, with 500 students admitted into the Faculties of Agriculture, Science, Science Education, and Social and Management Sciences.

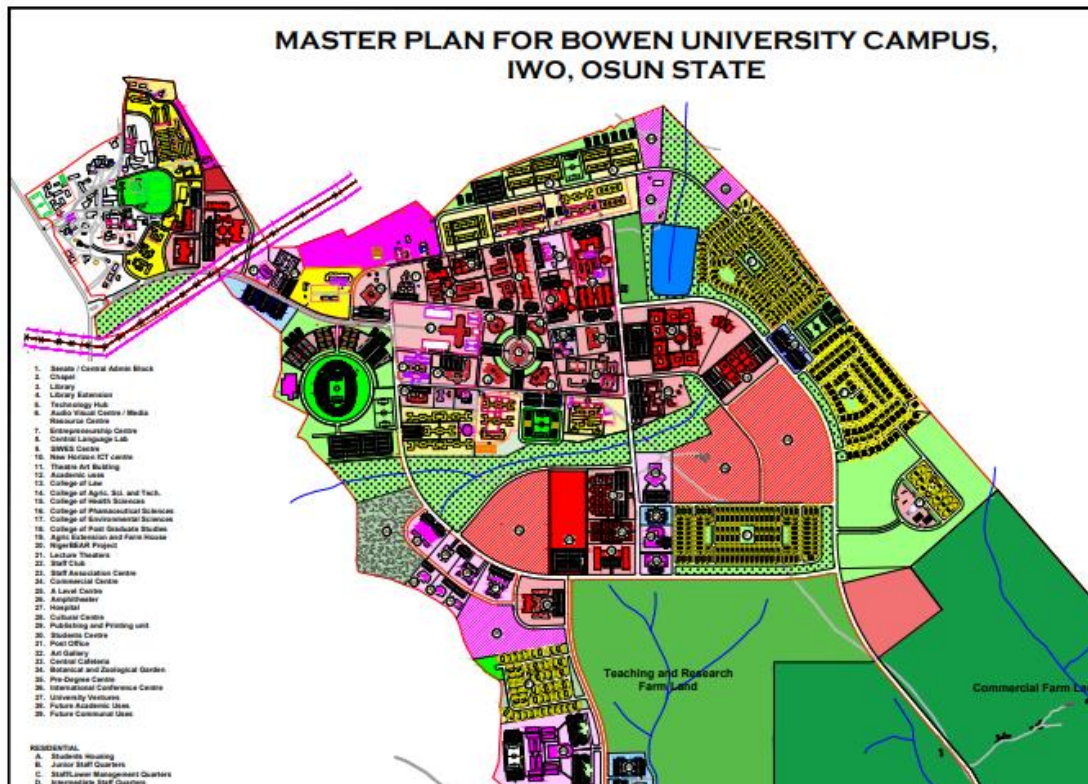
Site Selection

Before any site could be selected for a Faculty building, some qualities and conditions need to be taken into consideration. These are:

1. The site should be large enough to give room for future expansion.
2. The site should be accessible to the major roads.
3. The site should not be exposed to air pollution such noise, smoke, dust and industrial pollutants.
4. The location of the site should have functional relationship with other faculties and activities of the University.
5. The building should be placed on site so that additions can be made as program develops and as enrolment increases.
6. Adequate parking facilities should be provided for students and staff.
7. The direction of prevailing wind should be studied

4.1.3 Site Location/Description

The proposed site is located within the academic core of Bowen University, Iwo Osun State, along Ikire-iwo road.



*Figure 36: Bowen University Master Plan.
Source: Physical Planning Unit, Bowen University, 2022.*

Site Location Criteria

Due to the peculiar nature of the design, Site was selected according to the school's master plan as space was already allocated for the faculty of engineering construction. However it should be noted that the faculty is located at the core academic area of the school. The following criteria are considered:

- Existing access road and pedestrian walkway
- Relatively flat land with a suitable soil for construction
- Proximity to student hostels
- Access to power and communication networks

Site Accessibility

This site has easy and convenient access for both vehicular and pedestrian. This site is accessed from any part of the campus

Nearness to Public Utilities

The site has adequate access to basic infrastructures e.g. Good Roads, Electricity, Water, Telecommunications, Security etc.

Site Analysis/Inventory

The site is very important aspect of design proposal being the point at which the tangible percentage of a development emerges or starts making an impact. The site chosen for any project hence goes a long way in determining the final resultant composition of the solution-in-all aspects. The site and its environment determine the solution in terms of contextual appropriateness measured the geographers, geologist, and geometrics. The specific aspect of the site, its micro-climate are thus a complex interaction of any factors, orientation, scope, topography, temperature patterns, humidity, precipitation, vegetation, presence or absence of water, seasonal availability of sunlight especially in urban areas, the influence of other buildings. The success of any design in this case “Faculty of Engineering building” to a large extent depends on a good site selection.

The layout of the building on site will greatly be determined by the topography and physical features (such as access road, trees, existing drainage, local climate, utility lines) seen on site. The existing structures within the campus will greatly influence the character of the building to be built in terms of forms, beauty and economy of the design. A thorough analysis of the project site that enhances an in-depth understanding of its suitability to the intended purpose is necessary. The reason is to

achieve the aim of the design. Site analysis helps in the functional development of the relationship that exists between the site and the structure. Every design solution aspires to be a function of the site and also a direct reflection and adaptation of its environment.

4.1.4 Design Considerations

Building orientation

Direct solar radiation causes a building's indoor temperature to rise. Therefore, good orientation of the building is crucial because it can improve access to natural light, increase protection from excessive solar radiation, and can influence the extent of the prevailing winds on the façades of the building.

The building should be positioned in such a way that the longer side does not face the eastern and the western side in order to reduce the insolation of glare into some spaces like, lecture rooms, offices and laboratories. In situation where this cannot be avoided totally provision will be made for shading devices and vegetation to reduce the effect of the solar radiation.

Natural ventilation

Ventilation is the process of removing stale air and replacing it with fresh air, either through mechanical systems or by natural methods. When no mechanical systems are employed, it is referred to as natural ventilation or passive ventilation. The lecture Rooms should be designed such that the natural day light is sufficient and there is minimum dependency on artificial lighting. Glare must be avoided and windows for teaching spaces should be horizontal.

Natural ventilation is important because it is an effective passive cooling design technique that reduces the need for electricity. Two advantages of natural ventilation

are that it reduces the energy use while increasing thermal comfort. Openings on the upper level let the warm air inside the building escape, while the cooler fresh air infiltrates through openings at a lower level in the building.

Building Components and finishes

Windows should be double glazed, easy to clean and maintain, and have high and low level opening sashes and it should be positioned such that sashes must be easy to operate with natural ventilation and an adequate level of safety.

Doors should be easy to Operate. The door, frame, and opening mechanism to should be designed so as to protect against injury to fingers, etc.

Acoustic conditions in schools should facilitate clear communication of speech between teacher and student, and between students without interfering with study activities.

Floor finishes must safe, hardwearing, non-slippery, chemically resistant, durable, resistant to wear & easily cleaned. The Health and Safety implications of the selected flooring should be considered.

Building materials with high thermal mass take a long time to heat up and also to cool down; therefore, lightweight, low-thermal-mass materials are recommended such as wood and hollow clay tiles.

The use of light colors or reflective paints for external surfaces reduces the temperature at the surface of a building and, hence, the building's incidental heating.

Outdoor and transition spaces

The intermediate space between the inside and outside of a building, also called transition spaces, can provide a shaded space for a building that has a cooling effect

on the incoming air. There are many types of transition spaces that can be used in building design, such as balconies, terraces, atria, and corridors. Natural vegetation can also be added to these transition spaces, which provide an added cooling effect.

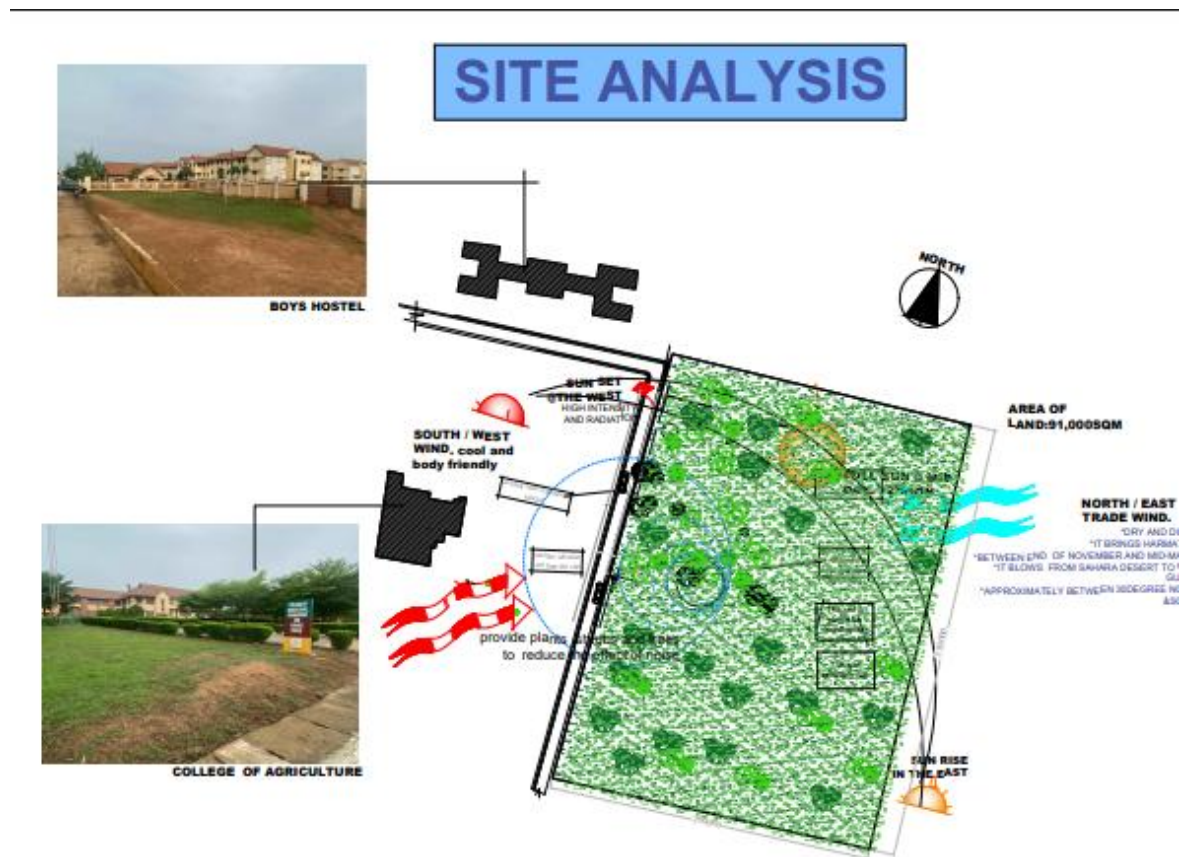


Figure 37: Site Analysis.

Drainage and Topography

The site is relatively flat land with a suitable soil for construction, with a height of 32 meter above the sea level. It is necessary therefore to provide strip foundation for the construction and as well as proper drainage

Vegetation

Iwo is located within the tropics, hence it enjoys two distinct seasons which are the wet and dry seasons. This enables a wide range of vegetation ranging from thick undergrowth, short grasses to evergreen trees on the sites immediate vicinity. Soil is loamy, and it is presumed to have adequate bearing capacity, since another building of such size and magnitude exist on similar site conditions. The Site has relatively good and firm grounds with good load bearing capacity suitable for the construction of the proposed faculty of engineering. There are no landform on the project site save for trees and shrubs. The site is covered with shrubs, thick grass, and vegetable leaves and trees. All the vegetables and shrubs are to be removed. At the time of conducting the site investigation on the proposed project site, the site displays a relatively thick vegetation cover that is; there are tall grasses, shrubs as well as big trees.

Soil Condition

It has a firm laterite soil with good sub-surface condition for construction and landscaping. It gives satisfactory geological and soil condition with no rock crops.

Wind Direction

The north-east trade wind brings cold, dust, harmattan and these cause discomfort. The south west trade wind brings cold humidity which gives comforting effect to the people. Proper ventilation is considered as part of the building effective arrangement.

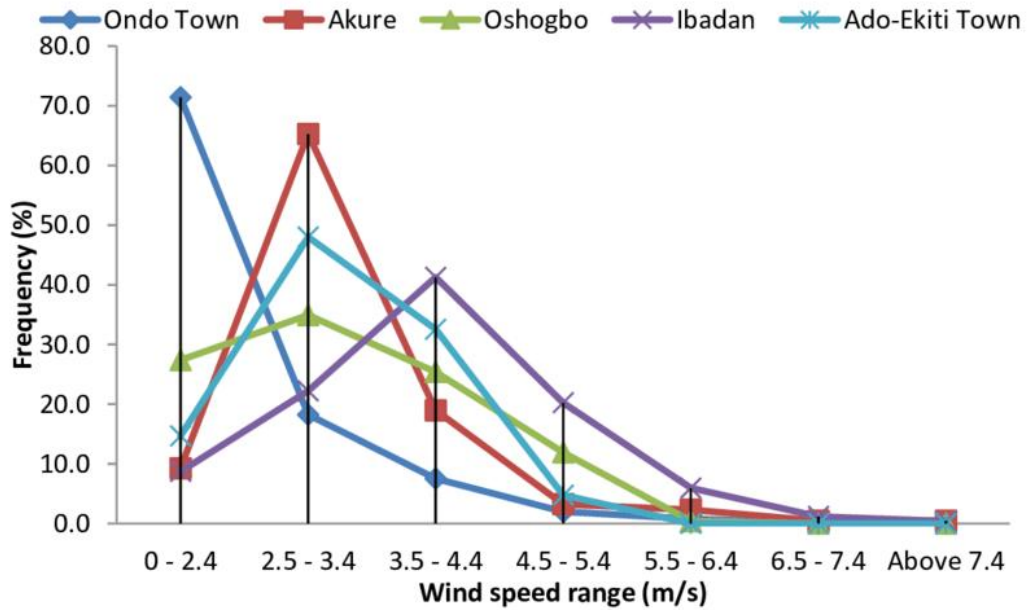
The shorter side of the proposed building should face the direction of the north-east trade wind while the longer side should face the south-west trade wind. Also there should be buffer solution like planting of trees along the north east trade wind to prevent direct impact of the wind into the proposed Faculty of Engineering building.

4.1.5 Geographic/Climate Data of Study Area

Osun falls on the tropical rain forest zone. It covers an area of approximately 14,875 sq. km and lies between latitude 7° 30' 0" N and longitude 4° 30' 0" E. Though a landlocked state. The climate is characterized under a tropical climate, when compared with winter, the summers have much more rainfall (koppen-Geiger system). The climate features of the project site include Rainfall, temperature, prevailing winds, relative humidity and sunshine. Osun typically receives about 127.75 millimeters (5.03 inches) of precipitation and has 237.62 rainy days (65.1% of the time) annually. This makes the need for adequate drainage necessary. Maximum monthly temperature also never falls below the comfort limits. There are two rainy seasons with the heaviest rain fall from April to July and a weaker rainy season in October and November with a brief dry spell in August and September and a longer dry season from January to March.

Prevailing Wind

For design purposes it is necessary to know the direction of prevailing and secondary wind as well as the maximum and mean wind velocities. The wind pressure which is proportional to wind velocity is used in ventilation. The duration of high-speed gusts is also needed for structural design. The determination of wind loads for roof design should reflect maximum values to avoid blowing off of such roofs. Southwest trade winds blows for about 8 months in a years between the month of March to October each year while the Northeast trade wind blows for about 4 months in a year between the month of November to February



(a)

Figure 38: Wind speed Graph for Osun

Source: Google Image, 2022

Relative Humidity

From November to January there is a general reduction in the relative humidity; during the rainy season (April to October), the temperature also drops with a corresponding rise in the relative humidity.

Precipitation/Rainfall

Monthly rainfall between May and July averages over 300mm, while in August and September it reduces to 75mm and low at 35mm in January. The main dry season is accompanied by harmattan winds from the Sahara Desert, which is between December and early February.

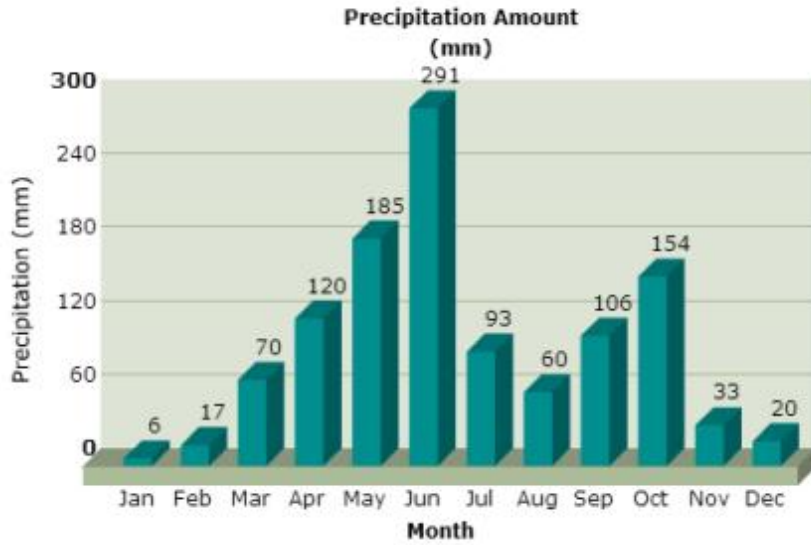


Figure 39: Precipitation Graph for Osun state

Source: Google Images, 2022.

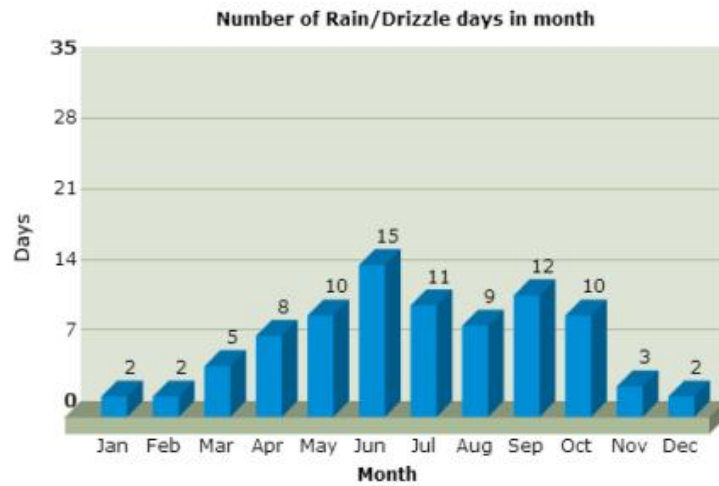


Figure 40: Rainfall Graph for Osun

Source: Google Images, 2022.

Temperature

The average temperature in January is 27°C and for July 25°C. On the average, the hottest month.



Figure 41: Average and Extreme Temperature Graph for Osun

Source: Google Images, 2022.

4.1.6 Conclusion

The proposed site for the Proposed Faculty of Engineering for Bowen University, Iwo, Osun State, meet up with the situation of an ideal site selection. The site is accessible and free from all encumbrances.

4.2 Project Analysis/Design Synthesis

In the design of an Engineering faculty project, certain parameter must be taken into cognizance in ensuring through organization and use of space, the comfort of the users population and functionality of the total environment in meeting their educational physiological, protective and social needs. The limiting control guidelines impose restrictions on the design of site. A properly located building achieved harmony, increased functional efficiency and minimized drainage problem. The orientation, the plan arrangement, the design of the building and the materials used can contribute to the quality of comfort achieved and minimized cost.

4.2.1 Design Criteria

Designing a functional and comprehensive Faculty of Engineering, requires several design consideration to be considered with respect to their impact on the overall building. They include

- a) Site selection
- b) Space requirements
- c) Structure-Economical structural spans and spacing modules
- d) Thermal comfort
- e) Ventilation (natural means)
- f) Air temperature (passive cooling)
- g) Lighting – daylight, bright lit walls with energy efficient technology (Solar panel)
- h) Acoustic – Sound absorptive materials
- i) High performance features (green Architecture)
- j) School population and accommodation schedule

4.2.2 Brief Analysis

Bowen University, Iwo was founded in the 2001 is presently composed of five colleges which are; college of Agriculture, college of Science , college of Social and Management Sciences and college of Engineering. The proposed college of Engineering building will accommodate a minimum of 200 students in each departments consisting of Civil Engineering, Mechanical Engineering, Bio-medical Engineering, Electrical and Electronics Engineering, Mechatronics Engineering. However, considering the future growth, a population of 2500 students is envisaged

once expansion and developmental projects have been completed. Hence the design is to accommodate a minimum of 1200 students within its available spaces.

Furthermore, the design is to incorporate modern technology in knowledge acquisition. This will involve the use of computers and Technology.

4.2.3 Brief Development

The proposed Faculty of Engineering for Bowen University will be an inquisition to learning. It will provide the minimum required standards for a Faculty of Engineering building in Nigeria. Hence in conforming to a set standards, spaces to provide includes;

- a) Departmental Offices
- b) Academics
- c) Non-Academics
- d) Lecture Rooms
- e) Workshop
- f) Computer Rooms
- g) Library
- h) Seminar Rooms
- i) Reception
- j) Research Laboratory
- k) Lecture Theatre
- l) Conveniences

Faculty of Engineering requires unbroken flow of space, this is to allow for flexible configuration and a free line of sight. The lecture rooms, workshops and research laboratories are provided for each department, the Faculty library will serve each

department, while the seminar rooms will serve the purpose of seminar, conference and general meetings that require spacious and acoustically suitable environment.

4.2.4 Space Allocation/Schedule of Accommodation

Space Allocation and schedule is a result of the functional requirements of spaces. It is also determined by a hierarchical property as well as its relationship to other proposed spaces. A faculty building, as an academic building, should therefore be devoid of obstruction to movement. It should be able to incorporate the free flow of users, equipment's, materials as well as services. This will reduced traffic build up, prevent accidents, and increase efficiency of services and ultimately user satisfaction. Activities in the faculty building revolve around studying, researches, and academics purpose. The Faculty of engineering should therefore provide accommodation for engineering equipment and studies, provide accommodation for the administrative element and finally accommodation for the student and other end-users. Therefore functionality can be broadly classified into two (2). They are Administration (staffs), and other facilities.

Administration areas

These will include the academics and non-academics

Academics

1. Departmental offices
2. Lecturers
3. Senior Lecturers
4. Provost
5. Deputy provost
6. Seminar rooms

Non-academics

1. Laboratory attendants
2. Studio attendants
3. Receptionist
4. Technologist
5. Secretaries
6. Cleaners

Other facilities include the following in which student can access directly

1. Lecture rooms
2. Workshop
3. Computer rooms
4. Library
5. Research laboratory
6. Lecture theatre

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Table 1: Schedule of Accommodation

ENGINEERING FACULTY BUILDING			
Names of Spaces	Numbers of Units	Floor Area (m²)	Total Floor Area (m²)
Provost	1	5,000 x 8,500	42.5
Deputy Provost	1	5,000 x 7,500	37.5
Secretary	1	3,000 x 5,000	15
Faculty Officer	2	5,000 x 5,000	50
Chief Technologist	1	4,500 x 5,000	22.5
Asst. Chief Technologist	1	4,000 x 5,000	20
Principal Technologist	1	4,000 x 5,000	20
Technologist	2	3,000 x 5,000	30
SWISS Coordinator	1	5,000 x 5,000	25
Switch Room	2	2,000 x 2,000	10
Seminar Room	1	7,300 x 10,000	73
Board Room	1	7,500 x 5,000	3.5
Data Processing	1	7,500 x 5,000	37.5
Biz Centre	1	2,500 x 5,000	12.5
Toilets	12	1,000 x 1,700	20.4

**DEPARTMENT OF MECHATRONICS ENGINEERING
(6 YEARS DURATION OF STUDY)**

Names of Spaces	Numbers of Units	Floor Area (m²)	Total Floor Area (m²)
Head of Dept. Office	1	5,000 x 6,500	42.5
Secretary Office	1	5,000 x 7,500	37.5
Professors Office	1	10,000 x 5,000	15
Redial/Sub Professor	1	9,000 x 5,000	45
Sen. Lecturers Office	2	6,500 x 5,000	65
Lecturer 1	2	6,500 x 5,500	71.5
Lecturer 2	2	5,000 x 5,000	60
Asst. Lecturer	1	4,600 x 5,000	23
Graduate Asst.	1	4,000 x 4,500	16
Switch Room	2	2,000 x 2,500	10
Seminar Room	1	7,500 x 10,000	75
Board Room	1	7,500 x 10,000	75
Plc Lab	1	14,000 x 8,000	112
Lecture Hall	3	7,500 x 12,500	261.25
Toilets	20	1,000 x 1,700	34
Dept. Library	1	5,500 x 10,000	55
Electronic Lab	1	10,500 x 10,000	105
Digital Logic Design Lab	1	9,500 x 10,000	95
Electrical Circuit Lab	1	15,000 x 15,000	225
Electrical Machine	1	15,000 x 15,000	225
Post Graduate Hall	1	7,500 x 8,000	60
Drawing Hall	1	12,500 x 8,000	100
Pneumatic Lab	1	15,000 x 20,000	300
Microcontroller Lab	1	15,500 x 10,000	155
Computer Lab	1	14,500 x 10,000	145

DEPARTMENT OF ELECTRICAL / ELECTRONIC ENGINEERING(5 YEARS DURATION OF STUDY)

NAMES OF SPACES	NUMBERS OF UNITS	FLOOR AREA(Msq)	TOTAL FLOOR AREA(msq)
HEAD OF DEPT. OFFICE.	1	5.000 X 8.500	42.5
SECRETARY OFFICE	1	5.000 X7.500	37.5
PROFESSORS OFFICE	1	10.000 X5.000	15
REDIAL/ SUB PROFESSOR	1	9.000 X5.000	45
SEN LECTURERS OFFICE	2	6.500 X5.000	65
LECTURER 1	2	6.500 X5.500	71.5
LECTURER 2	2	5.000 X5.000	50
ASST LECTURER	1	4.000 X5.000	23
GRADUATE ASST	1	4.000 X4.500	16
SWITCH ROOM	2	2.000 X2.500	10
SEMINAR ROOM	1	7.500 X10.000	75
BOARD ROOM	1	7.500 X10.000	75
LAB SUPERVISOR	1	5.500 X5.000	27.5
LECTURE HALL	3	7.500 X12.500	281.25

TOILETS	20	1.000 X1.700	34
DEPT LIBRARY	1	5.500 X10.000	55
POWER LAB	1	10.500 X10.000	105
ELECTRONIC/TELE-COMMUNICATION LAB	1	7.500 X10.000	75
INSTRUMENTATION/ MEASUREMENT LAB	1	10.500 X10.000	105
TECHNICAL WORKSHOP FOR ELECTRICAL DRAWING LAB	1	15.000 X15.000	225
POST GRADUATE HALL	1	7.500 X8.000	60
ELECTRICAL COMPUTER LAB FOR ELECTRICAL DRAWING USING MICROSOFT VISION	1	12.500 X8.000	100
DRAWING HALL	1	10.500 X8.000	84

DEPARTMENT OF MECHNICAL ENGINEERING(5 YEARS DURATION OF STUDY)

NAMES OF SPACES	NUMBERS OF UNITS	FLOOR AREA(Msq)	TOTAL FLOOR AREA(msq)
HEAD OF DEPT. OFFICE.	1	5.000 X 8.500	42.5
SECRETARY OFFICE	1	5.000 X7.500	37.5
PROFESSORS OFFICE	1	10.000 X5.000	15
REDIAL/ SUB PROFESSOR	1	9.000 X5.000	45
SEN LECTURERS OFFICE	2	6.500 X5.000	65
LECTURER 1	2	6.500 X5.500	71.5
LECTURER 2	2	5.000 X5.000	50
ASST LECTURER	1	4.600 X5.000	23
GRADUATE ASST	1	4.000 X4.500	18
SWITCH ROOM	2	2.000 X2.500	10
SEMINAR ROOM	1	7.500 X10.000	75
BOARD ROOM	1	7.500 X10.000	75
LAB SUPERVISOR	1	5.500 X5.000	27.5
LECTURE HALL	3	7.500 X12.500	281.25
TOILETS	20	1.000 X1.700	34
DEPT LIBRARY	1	5.500 X10.000	55
WELDING LAB	1	10.500 X10.000	105
FORGING LAB	1	7.500 X10.000	75
FOUNDRY LAB	1	10.500 X10.000	105
FITTING WOOD LAB	1	15.000 X15.000	225
POST GRADUATE HALL	1	7.500 X8.000	60

CNC LAB	1	12.500 X8.000	100
DRAWING HALL	1	10.500 X8.000	84

DEPARTMENT OF COMPUTER ENGINEERING(5 YEARS DURATION OF STUDY)			
NAMES OF SPACES	NUMBERS OF UNITS	FLOOR AREA(Msq)	TOTAL FLOOR AREA(msq)
HEAD OF DEPT. OFFICE.	1	5.000 X 8.500	42.5
SECRETARY OFFICE	1	5.000 X7.500	37.5
PROFESSORS OFFICE	1	10.000 X5.000	15
REDIAL/ SUB PROFESSOR	1	9.000 X5.000	45
SEN LECTURERS OFFICE	2	6.500 X5.000	65
LECTURER 1	2	6.500 X5.500	71.5
LECTURER 2	2	5.000 X5.000	50
ASST LECTURER	1	4.800 X5.000	23
GRADUATE ASST	1	4.000 X4.500	18
SWITCH ROOM	2	2.000 X2.500	10
SEMINAR ROOM	1	7.500 X10.000	75
BOARD ROOM	1	7.500 X10.000	75
LAB SUPERVISOR	1	5.500 X5.000	27.5
LECTURE HALL	3	7.500 X12.500	281.25
TOILETS	20	1.000 X1.700	34
DEPT LIBRARY	1	5.500 X10.000	55
SOFTWARE LAB	1	7.500 X10.000	75
HARDWARE LAB	1	7.500 X10.000	75
NETWORKING LAB	1	7.500 X10.000	75
CENTRAL LAB	1	10.000 X15.000	150
POST GRADUATE HALL	1	7.500 X8.000	60

DEPARTMENT OF CIVIL ENGINEERING(5 YEARS DURATION OF STUDY)

NAMES OF SPACES	NUMBERS OF UNITS	FLOOR AREA(Msq)	TOTAL FLOOR AREA(msq)
HEAD OF DEPT. OFFICE.	1	5.000 X 8.500	42.5
SECRETARY OFFICE	1	5.000 X7.500	37.5
PROFESSORS OFFICE	1	10.000 X5.000	15
REDIAL/ SUB PROFESSOR	1	9.000 X5.000	45
SEN LECTURERS OFFICE	2	6.500 X5.000	65
LECTURER 1	2	6.500 X5.500	71.5
LECTURER 2	2	5.000 X5.000	50
ASST LECTURER	1	4.600 X5.000	23
GRADUATE ASST	1	4.000 X4.500	18
SWITCH ROOM	2	2.000 X2.500	10
SEMINAR ROOM	1	7.500 X10.000	75
BOARD ROOM	1	7.500 X10.000	75
LAB SUPERVISOR	1	5.500 X5.000	27.5
LECTURE HALL	3	7.500 X12.500	281.25
TOILETS	20	1.000 X1.700	34
DEPT LIBRARY	1	5.500 X10.000	55
STRUCTURAL LAB	1	10.500 X10.000	105
SURVEY STUDIO	1	7.500 X10.000	75
SOIL LAB	1	10.500 X10.000	105
TRANSPORTATION& HIGH LAB	1	15.000 X15.000	225
POST GRADUATE HALL	1	7.500 X8.000	60

CONCRETE LAB	1	12.500 X8.000	100
DRAWING HALL	1	10.500 X8.000	84

DEPARTMENT OF BIOMEDICAL ENGINEERING(5 YEARS DURATION OF STUDY)

NAMES OF SPACES	NUMBERS OF UNITS	FLOOR AREA(Msq)	TOTAL FLOOR AREA(msq)
HEAD OF DEPT. OFFICE.	1	5.000 X 8.500	42.5
SECRETARY OFFICE	1	5.000 X7.500	37.5
PROFESSORS OFFICE	1	10.000 X5.000	15
ASST/ SUB PROFESSOR	1	9.000 X5.000	45
SENIOR LECTURERS OFFICE	2	6.500 X5.000	65
LECTURER 1	2	6.500 X5.500	71.5
LECTURER 2	2	5.000 X5.000	60
ASST LECTURER	1	4.600 X5.000	23
GRADUATE ASST	1	4.000 X4.500	18
SWITCH ROOM	2	2.000 X2.500	10
SEMINAR ROOM	1	7.500 X10.000	75
BOARD ROOM	1	7.500 X10.000	75
LAB SUPERVISOR	1	5.500 X5.000	27.5
LECTURE HALL	3	7.500 X12.500	281.25
TOILETS	20	1.000 X1.700	34
DEPT LIBRARY	1	5.500 X10.000	55
HUMAN FACTOR LAB	1	10.500 X10.000	105
BIOSENSOR LAB	1	7.500 X10.000	75
MECHANICS LAB	1	10.500 X10.000	105
BIOMEDICAL LAB	1	15.000 X15.000	225

POST GRADUATE HALL	1	7.500 X8.000	60
DRAWING HALL	1	12.500 X8.000	100

Functional Relationship

The functional relationship chart shows the degree of relationships among the various spaces in the faculty. It helps the designer to see at a glance which spaces are not related to one another. This helps the designer to locate related spaces within easy proximity of each other and isolate those which are not related. It also aids zoning of spaces and functionality of the design. General functional relationship principles taken into consideration include:

1. Separation of the various traffics from one another i.e. vehicular, pedestrian, staff, students etc.
2. Orientation of building to create maximum thermal comfort and convenience.
3. Orderliness, functionality, aesthetic, unity.
4. Green areas with soft and hard landscaping.
5. Ample parking spaces.

Conceptual Development

This refers to the ideas derived from specific instances, in architecture, five (5) main types of concepts have been identified, and they are:

- i. Analogous i.e. looking at other things
- ii. Metaphor i.e. looking at abstraction
- iii. Essence; looking beyond the function
- iv. Pragmatic; looking at the function
- v. Ideal; solving architectural problems.

The concept used for this design is the combination of analogous and pragmatic i.e looking at the shape of an engineering logo which is derived from one of the

engineering tools. The six arms represent each department with their various functions while the remaining two arms represent the common facilities that bind the six departments together.

Site Concept

This site concept deals with the ideal behind the initial and overall planning of site activities in relation to the site's existing physical situation. This is influenced by existing buildings and the way they have been organized; physical features such as roads and vegetations will be taken advantage of. The site for the proposed Faculty of Engineering has been planned and designed to take advantage of the nature of the environment as it relates to the wind, the sun, topography and existing services.

Building Concept

A pragmatic approach was taken towards the generation of the building form and arrangement of spaces. Technical requirements such as area of space per person, circulation of space requirements for different activities among others were considered for the spaces so as to achieve the desired user capacity. Flexibility in the layout of spaces was also an important consideration.

CHAPTER FIVE

APPRAISAL, RECOMMENDATION AND CONCLUSION

5.1 PROJECT APPRAISAL

5.1.1 Construction Method and Material

The location of the facility will influence the choice material as well as method of construction. Faculty building being a facility that accommodate large vast of activities and people, it is expected that durable and modern type of the building materials should be used. All structure works and configurations should be handled by a certified structural engineer registered by COREN as designs of columns, beams, and reinforcements and so on will be required. Several analyses will also be required to know the soil safe bearing capacity, effect of wind load among others on the facility. Reinforced concrete and steel shall be main structural elements in the design. The choice of finishes will take into cognizance the acoustic design, the thermal insulation and other factors in finishes. The use of each interior space shall also determine the choice of finishes.

A. Pre-Construction Operations

The pre-construction operations are the operations that are carried out by the contractor and other concerned agencies. The operations are evaluation of health and safety aspects of the project, provision of on-site documentation, provision of facility access and security. A preconstruction conference should be organized to allow all the parties involved to get clear understanding of the procedures involved in contractor submittals, sampling and testing, construction surveys, inspections by outside agencies, payment requests, claims and disputes, unforeseen job conditions and change order requests.

B. Substructure

The substructure of the building comprise of mainly foundation. The soil within the site is firm, well compacted, with good load bearing capacity and has the presence of rock boulders running underneath the soil layer. Normal strip foundation would be employed in this case because of the favorite characteristics of the soil. The quality of the foundation materials will offer resistance to chemical and pose adequate compressive strength; this will aid in conveying the weight of the building without any form of differential settlement. The operations that are mainly involved in substructure stage are:

- i. **Site clearing:** all obstruction on the space to be occupied by the buildings is to be removed to allow for other operations to follow. Trees and other plants that exist on the building site must be removed.
- ii. **Site hoarding:** it is the erection of barrier around the perimeter of the site to improve security and protection of equipment and materials. The material to be used for the hoarding is corrugated galvanized zinc sheets nailed on timber frames.
- iii. **Removal of topsoil:** the removal of the topsoil over the space on the land covered by the buildings. The top soil on the other spaces should be retained to be used for landscape planting. The average depth for top soil removal is 150mm.
- iv. **Setting out:** the transfer of dimensions on the building drawings to the site is called setting out. The buildings are to be set out in relation to the existing road that is the reference point for the buildings. The setting out is to be done with the use of theodolite to achieved higher degree of accuracy compared to other methods.

- v. **Excavation to trenches:** after the setting out has been completed and certified by the consultants. The trenches are to be done by excavators to the specified depth by the structural engineer. The trenches are to be checked and signed off before the blinding will be put in place.
- vi. **Casting of blinding, foundation footing and column bases:** Concrete piles will be driven deep down into the water bed with all piles having pile caps. The foundation footing is to be laid to adjust to the slope of the site. The column bases are to be reinforced to structural engineer's specification and location.
- vii. **Laying of foundation block wall:** The foundation block walls are to be 230mm sandcrete block wall laid in stretcher bond. The foundation block walls are to be filled to solid with concrete. The concrete will improve the strength of the foundation block wall.
- viii. **Hard-core filling:** the hard-core should be 300mm thick weathered rock. It should be well compacted and levelled.
- ix. **Damp proofing:** the damp proofing material should be in 3 plies of bituminous felt laid over the area of the foundation. It is to disallow capillarity of water to the floor slab.
- x. **Casting of in-situ ground floor slab:** the ground floor slab is to be constructed to a thickness specified by the structural engineer. The floor slab should be reinforced. It must be checked and signed off by the structural engineer before progress of work.

C. Superstructure

The building will be concrete framed structure. Reinforcement concrete will be used for columns, beams, and slabs. Sand Crete and non-flammable light partition for walls.

The ceiling and doors will be fire rated and the floors will be finished generally in non-slippery vitrified floor tiles of different materials and textured in different places. Fire resistant finishes will be used. Mechanized anti-fire equipment will however complement the anti-fire efforts. The superstructure comprises of five basic components namely; floors, walls, doors & windows, ceiling and roof.

- i. Floors:** The floor as a structural member should meet necessary requirements according to structural specification. It should be able to withstand imposed loads and prevent damp penetration. It should have the ability to absorb heat and sound, and fire resistance; ease of maintenance; allow for good appearance, comfort, safety, cleanliness etc. Reinforced concrete floor slab are used for the floors and they are finished with PVC tiles, marble tiles, vitrified tiles, ceramic tiles and cement screed.
- ii. Walls:** Walls are elements that contribute majority to the image and the appearance of the building. It should be designed to protect against wind, dust, animals and to have good aesthetics. Strength and stability are most importance as well as resistance to dampness, thermal and sound insulation along with fire resistance. Both internal and external walls will be of 225mm sandcrete hollow blocks. Some of the walls for the conveniences will be of 150mm sandcrete hollow blocks. Stair walls should be made of extensive 170 concrete to act as defenses against fire thereby facilitate the easy and safe evacuation of people from the building when there is a fire outbreak.
- iii. Doors and Windows:** Both internal and external doors will be 2100mm in height with respective width at 750mm, 900mm, 1200mm, 1500mm, 1800mm as well as 2400mm.

- iv. **Ceiling:** In contemporary times, new ceiling materials have been developed ranging from the dry to the wet ones. Suspended ceiling will be used in most spaces to help in housing major light fittings and for acoustic considerations; the ceiling materials used is 600x600mm cellulotex ceiling boards. The boards are to be installed according to the pattern specified by the architect.
- v. **Roof:** For a roof to be functional it must meet the following requirements; strength and stability, durability, fire resistance and occasionally, sound insulation, lighting, ventilation. The span and nature will determine the construction method used in the various unit. Flat concrete roof will also be used. The roof is a wooden structure of rafters and tie-beam and reinforced concrete columns, with 7mm thick aluminum insulated roof panel covering. The dominant roof design is a hip-type with 750mm roof gutter to serve as roof drainage.

5.1.2 Building Service

It is essential that utility services be provided in order to put the building into maximum effective use. Very crucial among this are, circulation, ventilation, lighting, water supply, electricity supply, and sewage disposal and fire protection.

i. Circulation

This is the movement of people from one point to another on the site. In the proposed project, vehicular and pedestrian circulation accesses are provided. In a faculty building, movement vertically and horizontally is irresistible. In this design, provisions were made for movement of people and equipment between the floors. Circulation is an important factor to consider in faculty of engineering design, therefore large circulation spaces are provided for within the faculty complex for easy and free flow movement of staff and students.

ii. Ventilation

Ventilation generally may be natural or artificial/mechanical. Natural ventilation requires effective temperature difference or wind action to induce air movement, while artificial ventilation through air-conditioning is the process of treating air in an internal environment to establish and maintain required standards of temperature, humidity and air movement. The faculty building will be ventilated and cooled by both natural and artificial means of ventilation. Artificial ventilation is through a combination of central air-conditioning system and extractor fans.

iii. Lighting

In the design of a faculty of engineering, lighting is an important factor to consider because of its physiological and psychological effect on people. The sense of wellbeing associated with day lighting and the orientation that comes with being connected with the exterior. The faculty is designed to have access to the natural daylight.

iv. Water Supply

Direct water supply system shall be used by linking through the available water mains from the dedicated water reservoirs constructed to serve the University Community as a whole. Provision shall be made for borehole and also electricity operated pump to supply water always to the building. Storage cisterns shall be made available at required places for different distribution

v. Electrical Systems

The Ibadan Electricity Distribution Company (IBEDC) lines from the University shall serve the building. Distribution network shall be provided on site to supply every floor and space with the required power. The wiring system shall be conduit,

well designed and wired following all specifications of the electrical engineer and services engineer. Type of wire cable shall be of high conductivity and good resistance. Also there will be an alternative power supply (generator) to cater for the power needs in times of power failure. The generator automatically switches over whenever the PHCN power is out and likewise a solar generated light will be installed to also provide an alternative means of generating power.

vi. Fire Protection

The Faculty of Engineering building needs to be well protected from fire outbreak because of the large number of people it accommodates. The objective of fire protection is to prevent the start and spread of a fire, stem the spread of smoke and facilitate the escape or rescue of persons. Active and passive precautions will be taken to effectively put out fires in the event of an outbreak. Active precautions are systems that are automatically deployed in the event of fire and they include the installation of heat-activated sprinklers which control a fire at its source through the release of discrete volumes of water sufficient to extinguish a blaze. Other important fire safety measures include convenient and well- 173 marked exist, smoke and heat detectors, smoke and fire alarm systems, water spray extinguishers, CO2 extinguishers, etc. Passive precautions are construction solutions in the building and its components that will help in reducing the spread of fire. These include minimum structural sections, casings and coatings, installation of fire doors and windows, construction of supporting floors etc.

vii. Sewage Disposal

Facilities for the handling, storage and collection of refuse are provided with access for frequent collection. The facilities are conveniently located, well ventilated and comply with all fire safety and public health requirements. The

waste are to be disposed appropriately and the users are to be sensitized on the way to dispose waste. Wastes are also collected separately on every floor in a large container and then transferred to a collection point in the ground floor. Garbage chute is provided for every floor with the collection point on the ground floor. Incinerators are also provided on the site.

viii. Acoustic

Good acoustic is one of the most important consideration for the faculty of engineering design. Room acoustic begins with establishing the basic size, shape and finish materials of a given space to achieve a certain room sound and the location, shape of sound reflecting and absorbing surfaces. These criteria are based on the intended function and occupancy of the room. Acoustic consideration at the lecture rooms of the proposed building will be controlled by the use of absorptive materials like fibrous materials, volume resonators, foam, acoustic tile on wall and ceiling. While acoustics at the other places in the faculty would be achieved through the use of shaped plane of hard building materials including gypsum board, wood, glass, masonry and concrete.

ix. External Works

When the external scaffold and the good hoist have been completely removed, the external works such as sewage treatment plant, Kerbs, soft and hard landscaping will commence.

1. Plant

Plant designs include lawns, trees, shrubs, ground cover and seasonal planting. Planting shall be maximized as an aid environmental quality and to serve in the effort to contain and eradicate damaging pest and pathogen.

2. Side Walk and Road-ways

Project shall generally provide for new street sidewalks curbs and road-way pavements, consultation with physical Planning department of Bowen University, Iwo will be done in this regard.

3. Parking

All parking lots should be paved unless otherwise required in the specific requirement or task order. Porous pavements are desirable when budget and site condition allows.

4. Street Tree

The site shall provide for new street trees. Appropriate tree pits and grates are required.

5. Drainage

All surface storm water shall be collected on site, in an underground drainage system.

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