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Sustainable Ventilation Strategies in Institutional Buildings: A Case Study of Edozien Lecture Theater, Bells University of Technology, Ota, Ogun State, Nigeria

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Abstract:- Buildings have been highlighted as one of the primary contributors to environmental difficulties at various phases of construction and operation. Extensive research has been conducted to improve green building designs by employing alternative sustainable construction technologies and operational approaches to reduce energy consumption while optimizing the value of natural resources. One of the methods that have recently become popular in building management is optimizing the potential utilization of natural ventilation inside an interior building space. The purpose of this research is to offer an analytical literature review based on numerous papers and journals to gather and analyze the many sustainable ventilation systems utilized in institutional buildings to promote and improve the quality of airflow within the building. Furthermore, the limits of present studies and future research potential are explored. The findings of this study help to improve the efficacy of sustainable ventilation systems in institutional buildings and give direction for future research on sustainable ventilation in institutional buildings.

Keywords:- *Ventilation, Sustainability, Institutional Buildings, Lecture Theatre, Energy Saving.*

I. INTRODUCTION

The building sector increases the usage of resources, particularly energy during occupancy periods. Buildings are said to consume around 40% of all energy in the world (Timuçin Harputlugil, 2021). The majority of a building's energy use is accounted for by ventilation and air conditioning, particularly in the lecture theatre. Lecture theatre frequently consumes more energy than other types of structures. The utility of energy in lecture theatre ranges from 100 to 1000 kWh per m^2 depending on the location, size, and kind of equipment used. In the United States of America, for example, the average energy consumption intensity is 300 kWh per m^2, with lighting and ventilation accounting for almost 79 percent of that total. These two elements account for 72 percent of all energy used in the UK (S Attia, 2020). Furthermore, it is expected that in the next 15 years, the quantity of energy utilized would double, growing from 1,200 Mm^2 to 2200 Mm^2, a 50% rise.

Several new buildings with an emphasis on energy saving are now in the design, planning, and construction stages. Commercial and residential structures, both new and old, are among the GBI's (Green Building Index) categories, lecture theatre.

Although the bulk of the strategies employed in these buildings are aimedis either boosting the use of clean, renewable energy or minimizing energy usage. This provides researchers with a wonderful opportunity to explore and assess the efficacy and efficiency of such cutting-edge construction and building operating techniques that have previously been applied. Natural ventilation may be used in lecture ththe eatre, which not only saves building owners money on energy costs but also significantly reduces the cost of ventilation operation.

Several studies have been conducted on the various methods of achieving sustainable ventilation strategies and practices in buildings by different researchers but little or no research has been conducted on sustainable ventilation strategies used in institutional buildings. The purpose of the research is to discuss sustainable ventilation, how ventilation operation occurs in buildings, the suitable ventilation strategies used in institutional buildings in Nigeria, and the impact of the outdoor spaces on the efficiency of natural ventilation in buildings. The study is limited to the various strategies of sustainable ventilation used in institutional buildings in Nigeria: A case study of Edozien Lecture Theatre (ELT), Bells University of Technology, Ota, Ogun state, Nigeria.

II. LITERATURE REVIEW

A. Sustainable Ventilation

Natural ventilation is vital for environmentally friendly buildings. Rather than relying on mechanical means, fresh air is supplied into the interior areas and evacuated through a temperature and wind force differential (Hussein, et al., 2022). Natural ventilation adds to the cooling loads of the building's total energy usage and overall affects the return on investment. This passive approach decreases HVAC systems' environmental effect by minimizing their carbon footprint and energy outputs. This cost-effective strategy, which saves power, health, and operational expenses, is expected to result in lower expenditures.

By enhancing interior air quality and thermal comfort, natural ventilation also helps to prevent sick building syndrome (SBS). Spaces may be used efficiently from floor to ceiling because no ducts or pipes are required. However, natural ventilation is not always sufficient. In core business areas with strong traffic zones and busy highways, noise and air pollution are frequent. This hostile atmosphere can be reduced by incorporating acoustical louvres anlouversred ducts into a hybrid ventilation system. Microclimates change as a result of gradients in humidity, vapor, ambient temperature, and precipitation. There are several methods and criteria for properly integrating natural ventilation.

B. Natural Ventilation Operation in Buildings

In general, air movement is the most significant aspect in the ventilation process, and it is critical to keep this in mind while integrating the structure's forms, apertures, and orientation. Among the variables to be gathered under "air movement" are air velocity, temperature, relative humidity, and pollutant air flow pattern. These specifics are critical for determining, analyzing, and simulating the thermal comfort and indoor air quality offered by the building under consideration or in the planning and design phase. There are two forms of natural ventilation in buildings: air pressure ventilation, also known as wind force, and stack effect ventilation, also known as heat force. Air pressure ventilation is the horizontal airflow differences in air pressure between the interior and outside surroundings. Because the air inside is significantly warmer, cold air will enter through window and door openings or building claddings. Airflow holes can be described as follows: Procedia Engineering Cross or double side ventilation, as well as 0.000-0.000 single (where air flows in and out of the same apertures on the same facade), are all possibilities (where the airflow at different openings on different facades).

In contrast, stack effect ventilation is a vertical air movement condition in which warm air travels up and out of the building through a chimney and an air well after being warmed by human activity and the functioning of interior machinery.

C. Strategies of Natural Ventilation

In classic constructions, passive ventilation systems are established long before the air conditioning system. However, some of the components remain and are often utilized in both old and new structures. Some green constructions include the design and operation elements of these passive designs in their instruction operations. In general, the components that provide proper air changes and ventilation rates in buildings may be classified into two broad groups.

➢ *Physical elements*

Construction aspects that can be viewed, measured, examined, and assessed objectively on a physical level fall under these categories. The components that serve to change the direction that airflow into or out of specified parts or zones of a structure are included under this category. These consist of:

- *Air Well Design*

This design idea aids in vertical air flow circulation by replacing spent hot air with cool incoming air via the stack effect process. The air well design, also known as an air tower or wind catcher in some arid locations, was one of the first passive designs utilized in human construction history. It ventilates by pulling in outside air via apertures at the front of the building and venting warm or unclean air through a vertical duct that runs from the basement to the roof. This stack effect allows for appropriate and effective filtering and disposal of polluted indoor air, especially during the day.

However, the utility of the ventilation design is limited in numerous ways. These constraints include the possibility of outside insects and dirt, unpredictability of airflow, and limited use in low-air-velocity settings. Chimneys and stack air ducts are alternatives to small-scale ventilation systems for specific building zones. It is utilized to provide stack effect ventilation within a building area for larger air wells, which are commonly referred to as atriums. To ensure adequate air circulation, the atrium will grow in size as the buildings rise in height. However, the effectiveness of the atrium design is limited since it must account for local airflow. The passive cooling effect can be enhanced by furthering artificial fountains or evaporative cooling systems to deliver cooled air streams inside the buildings.

- *Building Façade*

The building façade also serves the aim of conveying outdoor fresh air into the building zones by providing 'rough' surfaces to induce turbulent effects (A.L.S. Chan, 2009). The building façade is made up of the roof, walls, and other openings such as doors and windows. These components control the airflow in and out, and they provide one option for maintaining the interior environment by combining clean inside air with clean outside air. As a result, the perfect façade design may significantly minimize the cooling load while also reducing the size of mechanical components. These include double-skinned façade designs, which, when combined with an air barrier and a reflecting glass wall, reduce the amount of heat entering a structure. Wing walls are an alternative façade design approach for directing outside air flow wairflowe structure by extending portions of the walls perpendicularly from the windows (M.Haase, 2009). These must, however, consider the local wind direction, air velocity, and the owners' intended aesthetic criteria.

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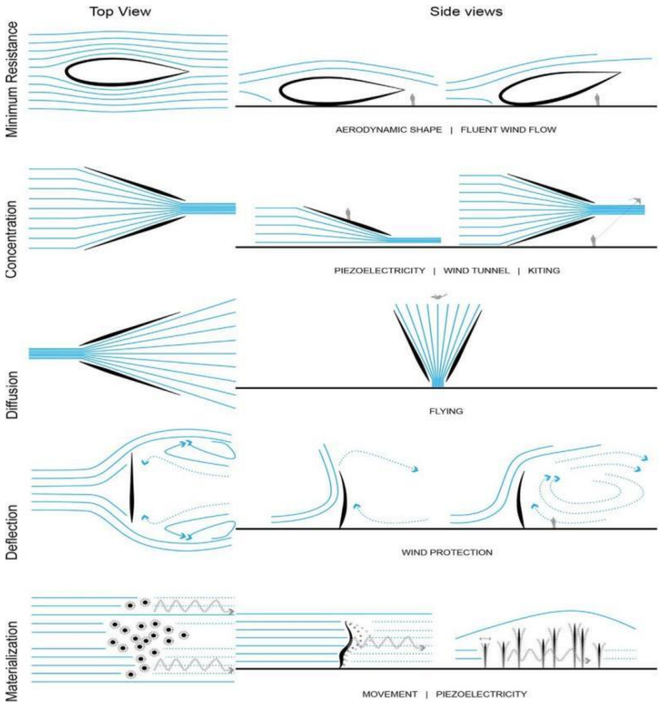

Fig 1: Architectural Facade affecting the wind flow (Kormanikova et al, 2018).

- *Ventilation Openings*

When ventilation ports are built with a windward or leeward orientation, the effects of the difference in air pressure between the interior and outside areas are used to direct the entry of fresh air and the outflow of assured air, respectively. Because the number of windows, doors and other openings on a building's façade influences how successfully ventilation is implemented, these components must be carefully considered and developed throughout the design process. Window apertures are one of the most important factors in controlling the flow of natural light and ventilation while limiting the usage of artificial lighting and ventilation. The location and orientation of the windows, in addition to the opening sizes, will define the distribution pattern of airflow inside a building zone (Roulet C.-A., 2005). Other natural ventilation openings include vents and louvers, the location of which is determined by the demands of building designs as well as interior activities. In essence, single-sided ventilation apertures may reduce cooling requirements by 30%, and single-sided night ventilation can achieve the same benefits. If these two ventilation systems are implemented in the same building zone, the overall reduction in cooling demand would be around 40% (Santamouris, The function of natural ventilation, in Cristian Ghiaus & Francis Allard (Eds), 2005).

- *Corridors and shading*

Building corridors and balconies, in general, assist to channel and deliver airflow to the necessary building zones. These elements are the connecting points between the inner building regions and the open spaces outside (M.F. Mohamed, 2008). According to (M.F. Mohamed, 2008), attempts to include the usage of corridors in buildings is one of the strategies to design a building in response to the local environment. This means that corridors may act as a conduit for transferring outside air into the essential building zones. However, the efficacy of these passive elements will be limited according to wind intensity and draught levels. In buildings ventilated by an air-conditioning system, air leakage and heat transfer through gaps in apertures will occur. As a result, the HVAC system will run less efficiently and consume more energy. In general, building corridors and balconies help to channel and deliver airflow to the essential building zones (E.Y.T. Ministerio de Industria, 2013). These elements serve as linkages between the inner building regions and the open spaces outside. Attempts to incorporate the use of corridors in buildings is one of the techniques to design a building in response to the local climate, according to (M.F. Mohamed, 2008), this implies that corridors can serve as a conduit for moving outside air into the necessary building zones. However, the efficacy of these passive components will be limited due to the strength of the airflow and the draught levels. Air leakage and heat transmission through gaps in apertures will occur in buildings ventilated by an air conditioning system. As a result, the HVAC system will run less efficiently and consume more energy. More green space around corridors and separating corridors from contaminating sources, on the other hand, can mitigate these drawbacks. The corridors that encircle the building facades will provide an air pressure zone for external air to move into, and the amount of air pressure amplification will be increased by precise design and interaction with other passive features.

- *Blockage and Partitions*

Aside from all of the helpful design aspects that improve the process of air circulation in buildings, variables such as walls and partitions may also need to be considered (Cara H. & Marianne F., 2021). However, these minerals are required for essential human functions like storage and privacy. As a result, an optimum ratio is developed to provide optimization for both space utility efficiency and ventilation efficacy.

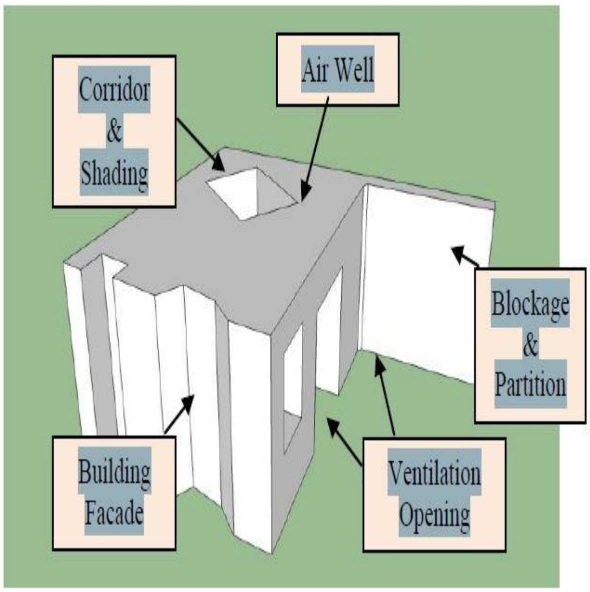

Fig 2: Blockage and Partitions in a building (Siew et al, 2011).

➢ *Non-Physical Elements*

The norms, cultures of conduct, and even the habits and strategies utilized all help to lowering energy usage while providing enough interior comfort during the occupancy period. These are as follows:

- *Night Ventilation*

Night ventilation can boost the cooling impact of the interior environment by delaying the time to switch on the air conditioning system and using less energy to cool the office spaces due to reduced heat loss and a higher ventilation rate (Shuangping, Zhiwen, Xinyan, & Yuguo, 2019).

- *Changes Made by the Occupants*

This is given that the occupants are free to modify their surroundings, such as opening a window or turning on a fan, as well as how they are dressed, to maintain their degree of comfort (F., B.W., B., & G., 2014). Thus, the exact temperature at which a person feels comfortable varies from person to person.

D. Impacts of Outdoor Spaces on The Efficiency of Natural Ventilation In Buildings

Because the efficiency of natural ventilation in building zones is greatly reliant on the characteristics of the surrounding site, the impact of outside spaces should not be overlooked in this study. Geography, wind direction, and open areas may all affect air volume. Navigating the structure's regions (M. Luiz, 2015). As a result, the physical design of the building is affected in the following ways:

➢ *Building Orientation*

Integrating a structure's orientation with natural ventilation may be challenging since designers must examine how the wind's pattern, direction, and exposure influence the building to offer the optimum ventilation benefits possible. A thorough site feasibility investigation is required (Tariq, Prashant, & Laetitia, 2021). Check that the cooling method may be utilized.

➢ *Building Shape*

The height of the building, the stack effect, and issues about air velocity and air flow directions all have an impact on ventilation efficiency (Vasileios, Jakub, & Kevin, 2021). Ventilation efficacy can be boosted further by implementing specific recent advancements in opening design onto the building façade (P., M., & R., 2020).

E. School Design And Demand Profiles In Schools

Schools make up one of the most significant types of civic structures. There are more than 80,000 schools in the Mediterranean area, which are major energy consumers.

1. School design is based on the sensible structuring of spaces. Typically, classrooms are placed together and may be reached via a hallway. The circumstance in question is shown in figure 3. Additionally, classrooms feature large windows that allow for natural lighting. There are also high windows in the hallways that may be utilized for cross ventilation and lighting.

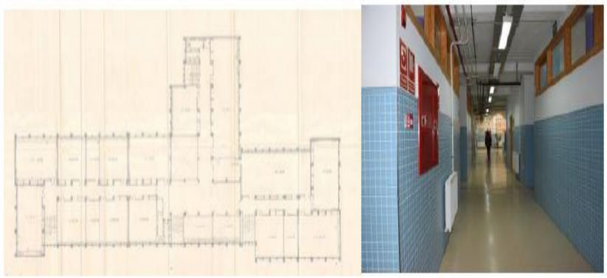

Fig 4: Typical school building plant distribution. a) Left plant, b) right corridor window (Maite et al, 2017)

2. Because of the moderate weather and internal benefits achieved by high-density occupation, schools, particularly in mild climes, have lower heating requirements. However, ventilation needs are severe and persistent throughout the academic year.
3. Schools are open for around 175 days out of the year, with a two-and-a-half-month summer vacation and Christmas and Easter holidays. An example of a common school occupation pattern.

F. How Is Natural Ventilation Superior To Artificial Ventilation?

The word "natural ventilation" is generally dismissed by novice construction workers since they all have visions of fans, respirators, and different intake and check valves in their heads. And other components, which are saturated by any mechanical ventilation system. The difficulty is that albeit still quite young, experience Foremen have seldom ever encountered something so natural. Using building ventilation as an example (most of them are self-taught).

G. Natural Ventilation's Advantages And Drawbacks

Both natural and artificial ventilation have advantages and disadvantages. Understanding the advantages of natural ventilation versus artificial ventilation necessitates a detailed examination of the device's operation. Up until the 1990s, the ventilation system in residential constructions was natural, albeit most people were ignorant of it: plastic windows, different types of insulation, smart home components, and natural ventilation were pushed to the edge, where it spent decades being built. A natural ventilation system does not rely on a powerful motive force, such as a fan or other mechanical device. Air traction occurs as a result of the pressure drop, and natural ventilation functions are based on tare temperature indications that differ between the building and the street. The greater the difference, the better the air exchange in the rooms.

Natural ventilation that is properly installed has various advantages, including the fact that it is free, functions automatically, and regulates the temperature of the space. There are several disadvantages, such as the obsolete technology employed for the ventilation system. You must carefully calculate the airflow now, especially if you're doing everything by hand, or you risk experiencing drafts or a lack of oxygen. Such work is deemed suitable for the master. However, because natural ventilation is less expensive than artificial ventilation, you can manage it yourself. If an error occurs, correcting it will be easier and less expensive. The term "manual ventilation" refers to ductless ventilation, in which fresh air is delivered through open windows or windows in the rooms and kitchen, while expended air masses are evacuated by exhaust grids in the kitchen and bathrooms.

Only when the system is "built using the channel approach" can natural ventilation be computed. If you want to create your house ventilation system, you must first do a simple natural ventilation calculation. It is not necessary to be familiar with SNiPs; only basic arithmetic and a few constants are required. You should be aware that a flow rate of 30 m per hour is considered standard. Depending on latitude, the usual draft ranges from 20 meters per hour in the north to 40 meters per hour in the south. Because the air in the north is denser and colder, it is not advisable to overburden the heater with aggressive air exchange. Because the air density is lower in the south, people's metabolisms are faster. A space of less than 1 to 2 cm should exist between all doors.

Due to odors, exhaust natural ventilation in the kitchen and bathroom should be stronger; also, these rooms should always be as far away from residential as possible.

H. Edozien Lecture Theatre (Case Study)

The Edozien Lecture Theatre is a 500-seater theatre located in Bells University of technology ota Ogun state Nigeria. It is located near the college of natural and applied sciences, opposite the building is a group of classrooms and lecturer offices. In the Edozien Lecture Theatre, the natural ventilation methods are little to none thereby causing discomfort for students and occupants of the building.

Highlighted below are some of the factors affecting natural ventilation in Edozien Lecture Theatre:

➢ *The size of the building*

The size of the building affects the quality of air in the building. The total size of the edozien lecture theatre is 37300m by 24800m. There are ventilation openings on both sides of the building but the width of the building from wall to wall is 20000m which is too far apart making the row in the middle subject to a lot of thermals did is discomforts window system in the building

The type of windows being used in the structure of the buildings high length sliding windows with top fixed casement which when opened 50% of natural air is brought into the building while 50% of air is lost. The dimensions for the size of the existing is 2400m by 1800m.

➢ *Interior Finishing*

The existing wall cladding reduces the rate of air circulation within the building due to the flat coating finish on the wall. This finish t, therefore, reduces the air speed before reaching the center of the building which causes thermal discomfort to the occupants of the building.

➢ *Shading and air filtration*

There are existing trees around the building to reduce the glare from ventilation openings and to improve the air quality entering the building from the surrounding or its environment.

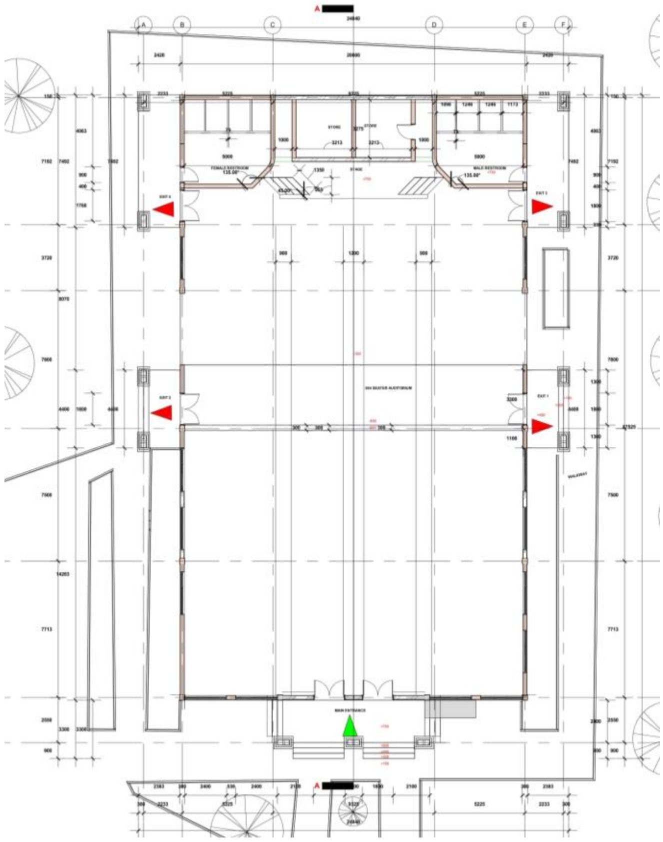

Plate 1: Ground floor plan of Edozien Lecture Theatre
Source: Author's Fieldwork, 2022

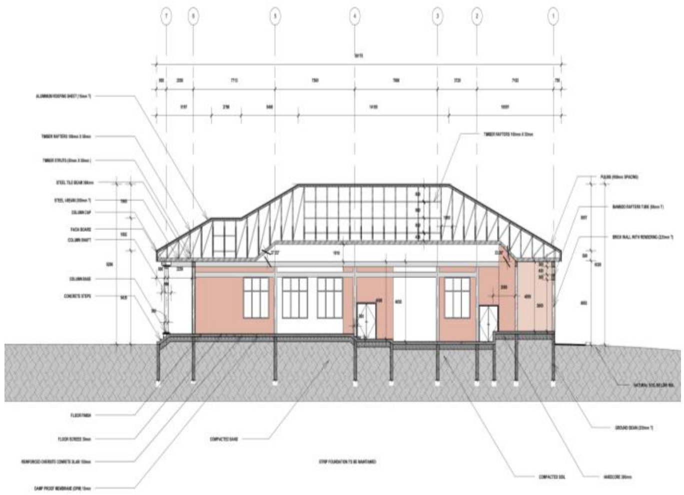

Plate 2: Section y-y of Edozien Lecture Theatre
Source: Author's Fieldwork, 2022

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➢ *Existing Natural Ventilation in Edozien Lecture Theatre*

Natural Ventilation is one of the most fundamental techniques to reduce energy usage in buildings, It is the intentional passive flow of outdoor air into a building through planned openings, Cross Ventilation is a phenomenon of natural ventilation. Natural Ventilation originates from two natural forces: Wind from the surrounding environment, as well as buoyancy forces that develop to temperature gradients within the building. The existing natural ventilation systems in the Edozien Lecture Theatre are achieved through the use of purpose-built, building envelope openings such as Windows & Doors. The headroom of the building differs because it's raked from the entrance towards the podium

Plates 3: Image showing purpose-built, building envelope openings in the Edozien Lecture Theatre
Source: Author's Fieldwork, 2022

➢ *Existing Artificial Ventilation in Edozien Lecture Theatre*

The identified artificial ventilation strategies found in the Edozien Lecture Theatre consist of 16 ceiling fans and 6 large split air conditioning units arranged with 3 units situated on either wing of the lecture hall. The ceiling fans arranged on the high recessed ceiling at a headroom of 5.61m channel hot air gathered in the hall upwards while the air conditioning units in tandem with the windows provide cross ventilation and introduce a cooling effect into the hall. However, they appear to be inadequate in controlling the thermal comfort in the hall as the units are either too few or far apart or in need of maintenance to function desirably.

Plate 4: Image showing the AC condenser unit
Source: Author's Fieldwork, 2022

Plate 5: Image showing the Ceiling Fans & Air Conditioning Systems in the Edozien Lecture Theatre
Source: Author's Fieldwork, 2022

III. METHODOLOGY

In the course of this research/study, qualitative analysis was implemented as the basis for the data collection and analysis, information was derived from existing journals, books, and research that gave a better understanding of the research topic and field observation was also a method used for collecting data and information about the case study through pictures taken to give an in-depth understanding of the case study.

IV. RECOMMENDATIONS

There are various sustainable ventilation strategies utilized in institutional buildings but not all can be successfully implemented in the Edozien Lecture Theatre without major renovations. In tackling the existing problems discussed in the literature review highlighted below are some of the proposals that can be implemented without major renovations to the building:

- Adaptation of 3d walls into the interior of the building to aid the movement or flow of air in the building
- Replacement of existing window system to casement windows of similar dimensions to ensure 100% air penetration into the building
- Planting of trees to improve the indoor air quality and protect the occupant from glare from windows.

V. CONCLUSION

In this paper/ research natural ventilation strategies have been analyzed as a feasible option to improve the sustainability of institutional buildings in Nigeria. Conclusions derived from there are:

1. Indoor air quality required to promote sustainably and enhance the living experience for the students is controlled with the sustainable ventilation strategies discussed in this research
2. Natural means of ventilation systems are highlighted as a feasible and sustainable strategy to reduce energy consumption in institutional buildings.
3. A natural ventilation system presents particularities to consider in the design

- When considering NVS (natural ventilation system) it must be sent during the first stage of the design
- The type of window used and its placement in the façade in the design.

REFERENCES

[1]. A.L.S. Chan, T. C. (2009). Energy and Buildings,. *Investigation on energy performance of double skin façade in Hong kong, 11*(41), 1135-1142.

[2]. Cara H., L., & Marianne F., T. (2021, april). Suite-level air tightness and compartmentalization in multi-unit residential buildings: How do we achieve our intended goals? *Building and Environment, 192*. doi:https://doi.org/10.1016/j.buildenv.2021.107600

[3]. E. Gratia, I. B. (2004). How to use natural ventilation to cool narrow office buildings. *Building and environment,, 39*(10), 1157-1170.

[4]. E.Prianto. (2003). Contribution of N3S numerical simulation (2) in investigating the influence of internal division design on indoor air speed. *International Journal on Architectural Science, 4*(3), 114-122.

[5]. E.Y.T. Ministerio de Industria. (2013). 137.

[6]. F., R., B.W., O., B., I., & G., R. (2014). Energy Build. *81*, 326–336.

[7]. H. Erhorn-kluttig, H. E. ((2014)). Energy Procedia 48, . 1468–1473 .

[8]. H. Erhorn-kluttig, H. E. (2014). Energy Procedia. 48, 1468–1473.

[9]. Haghighat., L. Z. (2005). *Optimization of ventilation system design and operation in office environment, Part I: Methodology. Building and Environment,, 4*(44), 651-656.

[10]. Hussein, M. M., Mohammad, A. A., Khaled, E., Enas, T. S., Ali, R., Hegazy, R., . . . Olabi, A. (2022, August). A REVIEW OF SOLAR CHIMNEY FOR NATURAL VENTILATION OF RESIDENTIAL AND NON-RESIDENTIAL BUILDINGS. *Sustainable Energy Technologies and Assessments, 52*. doi:10.1016

[11]. M. Luiz, M. P. (2015). 1–5 .

[12]. M.F. Mohamed, D. a. (2008). *A study on balcony nd its potential as an element of ventilation* .

[13]. M.F. Mohamed, D. a. (2008). *A study on balcony nd its potential as an element of ventilation control in naturally ventilated apartment in hot and humid climate*, 173-180.

[14]. M.Haase, F. d. (2009). Energy and Buildings,. *Simulation of ventilated facades in hot and humid climates., 4*(41), 361-373.

[15]. Omer, A. M. (2008). Green energies and the environment. *Renewable and Sustainable Energy Reviews, 12*(7), 1789-1821.

[16]. P., B., M., D., & R., F. (2020, may). Modelling and simulation-based analysis of a façade-integrated decentralized ventilation unit. *Journal of Building Engineering*. doi:doi.org/10.1016/j.jobe.2020.101183

[17]. Roulet, C. G.-A. (2005). Strategies for natural ventilation. *Natural Ventilation in the Urban Environment: Assessment and Design*, 136-157.

[18]. Roulet, C.-A. (2005). *Natural Ventilation in the Urban Environment: Assessment and Design*. London: Earthscan.

[19]. S Attia, N. S. (2020). *Developing two benchmark models for nearly zero energy schools*.

[20]. Santamouris, M. (2005). *Natural Ventilation in the Urban Environment: Assessment and Design*, 1-19.

[21]. Santamouris, M. (2005). The role of natural ventilation. In Cristian Ghiaus & Francis Allard (Eds). London: Earthscan. .

[22]. Shuangping, D., Zhiwen, L., Xinyan, Y., & Yuguo, L. (2019, February 1). The impact of building operations on urban heat/cool islands under urban densification: A comparison between naturally-ventilated and air-conditioned buildings. *Applied Energy, 235*, 129-138. doi:https://doi.org/10.1016/j.apenergy.2018.10.108

[23]. Siew, A. I.-A.-T. (2011)).

[24]. Tariq, A., Prashant, K., & Laetitia, M. (2021). Renewable and Sustainable Energy Reviews. *Natural ventilation in warm climates: The challenges of thermal comfort, heatwave resilience and indoor air quality*. doi:/10.1016/

[25]. Timuçin Harputlugil, P. W. (2021, January). Energy Research & Social Science. *The interaction between humans and buildings for energy efficiency: A critical review, 71*.

[26]. Vasileios, F., Jakub, K., & Kevin, M. S. (2021, march 1). The impact of wind pressure and stack effect on the performance of room ventilation units with heat recovery. *Energy and Buildings, 234*. doi:/10.1016/
[27]. Y. Wang, F. Z. (2014). Energy Build. *81*, 9–17.
[28]. Zhang Lin, T. C. (2009). Effect of internal partitions on the performance of under floor air supply ventilation in a typical office environment. *Building and Environment*,, 534-545.