Effect Of Passive Cooling On The Indoor Thermal Quality Of An Institutional Building In Tropical Savannah Climate

Mansur Yahaya Abdussalam, Prof. Dr. Halil Zafer Alibaba

Abstract: Passive cooling techniques and their application have become more dependable and are frequently used in regions with hot climate conditions. The foremost techniques adopted are building orientation which helps with spatial organisation of the building based on function, external environment and weather factors and the other is the use of shading devices integrated through design to the building or its immediate environment. The building under study holds a set of lecture rooms, offices and a commercial space is located in a tropical savannah climate region. This papers evaluates the effects of the passive cooling techniques adopted in the building on indoor thermal quality as perceived by the students and other users of the building, considering the high temperature in the region. The research identified how the orientation of the building reduced the surface of the building heated as a result of solar radiation and also how the longer sides of the building have windows facing the direction of the prevailing winds capturing the breeze for cross ventilation which in turn reduces the indoor temperature. Shading devices and trees are used to cover the longer sides of the building to deflect direct solar radiation hence reducing the glare and reflections that may disrupt activities in the lecture rooms. Questionnaires that were distributed and a physical survey of the building site are the main source for the research findings. It is imperative for more research work to be done in areas like this to reduce the energy use in buildings located in hot regions used for cooling. This would also encourage the reduction of green house gases coming from mechanized cooling devices which cost significantly high to run in these regions.

Key Words: Building Orientation, Passive Cooling, Institutional Buildings, Thermal Comfort, Indoor Environment, Air Quality, Shading devices.

INTRODUCTION

Thermal comfort is defined as the psycho-physiological satisfaction of individuals, regarding the terms of their thermal environment (Nikolopoulou, 1963), meaning it is important for an institutional building (a place of learning) to have adequate thermal comfort to ensure the students have the required atmosphere. Most individuals spend 85-90% of their time indoors thus providing a thermally comfortable and healthy environment is imperative. (ISO 7730). In different areas of the world, thermal comfort needs may vary based on the climate condition. Generally, humans do not perform well under thermal stress, people's performances under thermal stress is about 11% lower than their performance at normal thermal condition thermal conditions, (Hancock, Ross, Szalma, 2007). The combination of high temperature and high relative humidity serves to reduce thermal comfort and indoor air quality, (Fang, Wyon, Clarkson, FANGER, 2004). Since the beginning of the last century, several studies were conducted in an attempt to translate the combined outcome of factors affecting the thermal comfort into a single parameter/index, allowing them to set ranges of comfort for this same parameter. Almeida (2010). Human concerns for the thermal comfort are generally indisputable; especially with the recent increase in crave for habitat modification and environmental sustainability. (Adebayo, 1991). Orientation of building is a very important factor that is directly connected the standards of thermal comfort within the building. It is guided by natural elements like sunlight and its intensity, direction of wind, seasons of the year and temperature variations (Bekkouche, 2009). The identified problem is the degree of thermal dissatisfaction experienced by the users of institutional buildings due to improper/poor building orientation and the difficulty of finding a suitable means for measuring the thermal performance of a building. The aims of this research is to evaluate the passive cooling techniques as used in this institutional building and how it affects the thermal quality of its users. To highlight how building users experience thermal quality, and to explore how shading devices help to reduce the heat absorbed by the building and perceived by its users. The area of study for this research project would be limited to studying building orientation and how the new lecture hall building for social sciences and its users are affected by it. The building studied is the social sciences new lecture hall, Samaru Campus, ABU, Zaria. The scope is also restricted to the building's performance without electricity. The variables to be used to derive the building's response would be limited

⇒ Building Orientation
⇒ Shading Techniques

LITERATURE REVIEW

In this chapter, more insight is presented into what building orientation is, how to optimize building orientation, and why building orientation is an important means of achieving thermal comfort for building users. Also, an attempt is made to discuss thermal comfort, its factors, how it can be assessed, what effects it has on a building users. More light would also be shed on the importance of thermal comfort in institutional buildings

Institutional Buildings: During the nineteenth century as population grew and became more urbanized, the organization of society required institutions to focus and concentrate activities for the individual and mutual benefit. These institutions required buildings to accommodate their activities and, typically, the Victorians built them with great civic pride. Consequently, the designs could achieve high standards and

- *Mansur Yahaya Abdussalam is currently pursuing Master's degree program in Architecture in Eastern Mediterranean University, TRCN, PH- +905338409195. E-mail: MansurAbdussalam@gmail.com*
- *Dr. Halil Zafer Alibaba is an Asst. Prof. in the Faculty of Architecture in Eastern Mediterranean University, TRCN, E-mail: halil.alibaba@gmail.com*

many institutional buildings are now listed (Kirklees, 2011). This term covers "public" buildings such as hospitals, schools, offices etc. Institutional buildings typically contain people interacting to accomplish a general or specific purpose. Institutional buildings usually contain large numbers of people (Kirklees, 2011). The buildings usually public buildings tend to cater for different people every group carry out a certain activity or the other some less strenuous than others. Since Institutional buildings generally have high occupancy as they convey a large numbers of people, it is essential that the required work is done to provide an area with acceptable working condition. Hence, the need for thermal comfort to be provide within the building.

Building Orientation: Building orientation refers to the way a building is situated on site and the positioning of windows, rooflines, and other features. A building oriented for solar design takes the advantages of passive and active solar strategies. (US DOE, 2011). Building orientation is an important & foremost step during the construction of building which is taken in such a way so that every proposed space receives proper lighting and ventilation. Orientation of building should be decided in all significant manners in order to construct environment friendly and cost effective building.(Serene interiors, 2013). Passive strategies use energy from the sun to heat and illuminate buildings. Building orientation also facilitates temperature moderation and day lighting. (Green, “building manual”, 2011)./According to (Holger, 1999), in hot humid regions, the long axis of buildings should be East-West oriented in order to minimize the area of exposition of solar irradiation. Considering this statement, buildings that have the long façade E-W oriented have a good thermal performance. Just like natural air, natural ventilation through inflow of air and compatible lighting is necessary in every building. Providing apt air vents, windows and open areas in the building is essential for all inhabitants.

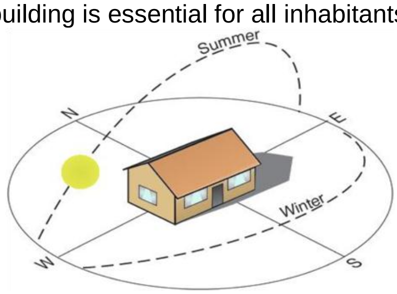

Figure 1.0. *showing a simple orientation format.*
Source: *Pinterest.com*

Optimizing Building Orientation: It is best to incorporate passive solar systems into a building during the initial design. Passive solar systems utilize basic concepts incorporated into the architectural design of the building. They usually consist of Rectangular floor plans elongated on an east-west axis, light/overhangs, and thermal storage medium exposed to the solar radiation. (Green, “building manual”, 2011). Building orientation is a well -known method adopted by architects and construction engineers when trying to achieve a passive building as it compliments thermal comfort when appropriately used. When talking about building orientation, some certain factors have to be considered like:

- Location of the building
- Weather and climate of the area,
- Size and type of the building,
- Number of users and its
- Function. of the building.

All of these determine the approach that could be adopted when deciding on how a building should be oriented. Since you work in a building throughout the year in all seasons, you should design it for the entire year. It is important to be comfortable all yearlong and not just for a single season. The building orientation can have an impact on heating, lighting and cooling costs. By maximizing southern exposure, for example, one can take optimal advantage of the sun for daylight and passive solar heating. Minimizing western exposures will result in lower cooling costs, where it's most difficult to provide shade from the sun. (BSNL, 2012). Branz, (2012) said Just like natural air, natural ventilation through inflow of air and compatible lighting is necessary in every building, which must be carefully pondered upon during orientation. Providing apt air vents, windows and open areas in the building is essential for all inhabitants.

Sun And Wind Orientation: According to Skat, (2003) buildings are generally orientated to interact with the sun, or the wind and in some cases both attributes are combined to ensure more efficiency. A building can have very good solar considerations in its design allowing for it to capture the sun’s heat during the winter and could be orientated in a manner that allows it to gain adequate ventilation from the wind. In most cases, it is essential for a building to be orientated to achieve the two of them. The orientation of a building is influenced by the amount of solar radiation falling on different sides at different times (skat, 2003). Sun Orientation gives preference to heat capture in buildings because the buildings would have their longer walls facing the sun and their openings allowing the sun rays directly in to the building. Protection from solar radiation is particularly important during times of excessive heat when there can be a difference of as much as 3°C in air temperature in a building between the best and least favorable orientation. This helps those that are in areas where there is little sunlight, as they would need a medium to create warmth within their buildings. The wind orientation is mainly for ventilation, to capture the trade winds, and provide a cooler temperature within the building. Buildings that have such orientations are generally viewed as well oriented because there is little heat transfer from the sun into the building as it has its longer walls facing the north south as against the east-west orientation. Main walls and windows should face the prevailing (cool) wind direction in order to allow maximum cross-ventilation of the rooms

Building Response To Orientation: Orientation, layout and location on site will all influence the amount of sun a building receives and therefore its year-round temperatures and comfort (Level, 2014). Haruna, (2014) agrees that Proper orientation of buildings reduces the impact of unfavorable weather conditions like solar radiation. In the house, the rooms should be located in such a way that the ones frequently used should be elongated along the east - west dimensions to mitigate heat gain in summer and also making efficient use of winters sun. By proper positioning the windows, air movement can be created in the rooms. Vegetation should not be too close to the building in order to avoid diversion of wind away from the openings, thereby reducing airflow within the building.

If possible, the rooms should be cross-ventilated so that there is outflow of the hot air and inflow of the cool air. Livability of dwellings can be improved by optimizing thermal comfort, especially through maximizing natural air-flow. Dwellings can be oriented, designed and manipulated to improve thermal comfort (QUC, 2015).Research on thermal comfort has shown that occupants of naturally ventilated buildings are comfortable in temperatures that closely reflect the outdoor climate. Survey results from the QUT Livability study indicated two thirds of respondents rated the average temperature of their living space as comfortable, while 12% reported that it was too warm and 1% reported that it was too cold. Residents highlighted a range of features that contributed to thermal comfort including atural air-flow and control over exposure to the sun's heat and light, dwellings with balconies and other outdoor living areas, internal and external modifications (e.g.shades and blinds), and orientation of the dwelling to maximize breezes.

Thermal Comfort: Thermal comfort is defined as the psycho-physiological satisfaction of individuals, regarding the terms of their thermal environment (Nikolopoulou, 1963), (BS EN ISO 7730) also defines thermal comfort as that condition of mind which expresses satisfaction with the thermal environment, meaning it is important for an institutional building (a place of learning) to have adequate thermal comfort to ensure the students have the required atmosphere. Most individuals spend 85-90% of their time indoors thus providing a thermally comfortable and healthy environment is imperative. (ISO 7730)**.** One of the main goals of building design is to provide a comfortable space for living or a suitable environment for working. The environment should be designed and controlled so that occupants' comfort and health are assured. (Amir, Ommid, 2007). The most commonly used indicator of thermal comfort is air temperature – it is easy to use and most people can relate to it. But although it is an important indicator to take into account, air temperature alone is neither a valid nor an accurate indicator of thermal comfort or thermal stress. Air temperature should always be considered in relation to other environmental and personal factors. (HSE, 2015)**.** The six factors affecting thermal comfort are both environmental and personal. These factors may be independent of each other, but together contribute to a worker's thermal comfort.

- Ø Air temperature
- Ø Air speed
- Ø Humidity
- Ø Mean Radiant Temperature
- Ø Metabolic rate
- Ø Clothing levels (HSE, 2015).

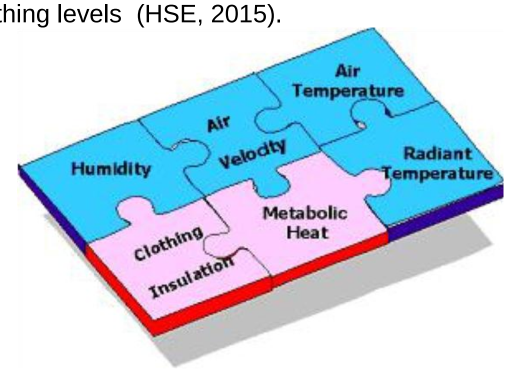

Figure 1.2. *Showing a combination of environmental and individual factors*
Source: *Pinterest.com*

Factors That Effect Of Thermal Comfort

Air Temperature: This is the temperature of the air surrounding the body. It is usually given in degrees Celsius (°C) or degrees Fahrenheit (°F) (HSE, 2015). Air temperature is a measure of how hot or cold the air is. It is the most commonly measured weather parameter. More specifically, temperature describes the kinetic energy, or energy of motion, of the gases that make up air. As gas molecules move more quickly, air temperature increase. (Fondriest.com, 2010)

Radiant Temperature: The mean radiant temperature (MRT) is defined as the uniform temperature of an imaginary enclosure in which the radiant heat transfer from the human body is equal to the radiant heat transfer in the actual non-uniform enclosure. (Wikipedia, 2015). Radiant temperature has a greater influence than air temperature on how we lose or gain heat to the environment. Our skin absorbs almost as much radiant energy as a matt black object, although wearing reflective clothing may reduce this. (HSE, 2015) The Mean Radiant Temperature of an environment is defined as that uniform temperature of an imaginary black enclosure that would result in the same heat loss by radiation from the person as the actual enclosure. (Innova, 2002)

Air Velocity: This describes the speed of air moving across the worker and may help cool the worker if it is cooler than the environment. Air velocity is an important factor in thermal comfort because people are sensitive to it. Still or stagnant air in indoor environments that are artificially heated may cause people to feel stuffy. It may also lead to a build-up in odor. Moving air in warm or humid conditions can increase heat loss through convection without any change in air temperature. (HSE, 2015)

Passive Cooling: Passive cooling refers to technologies or design features used to cool buildings without power Consumption (wikipedia, 2010) It is called passive (and not active) because it does not involve the use of mechanical and electrical devices. Natural ventilation is one of the pioneering strategies of passive design, where occupants use operable windows as a conventional method to arrange indoor space thermal conditions and provide fresh air in naturally-ventilated buildings (Alibaba, 2018). The key to designing a passive solar building is to best take advantage of the local climate. Elements to be considered include window placement and glazing type, thermal insulation, thermal mass, and shading. Passive solar design techniques can be applied most easily to new buildings, but existing buildings can be adapted or retrofitted (wikipedia, 2010).

Air Flow Through Buildings: As no satisfactory and complete theory is available, airflow patterns can only be predicted on the basis of empirical rules derived from measurements in actual buildings in wind tunnel studies. Such empirical rules can give a useful guide to the designer but in critical cases it is advisable to prepare a model of the design and test it on a wind simulator. Natural ventilation is the most effective way of saving energy and improving indoor air quality. Ventilation techniques for buildings that are not using any mechanical devices can be termed as natural ventilation. (Alibaba, 2018).

Orientation: Building orientation is alignment of building in relation to cardinal points (Badiru, 2012). There are two factors that determine building orientation

a) Solar path: This is the alignment of building in such a way that minimum portion of the building is exposed to solar radiation. Figure 1.3 illustrate east west building orientation. In this case buildings are aligned which the longer axis along east west orientation.

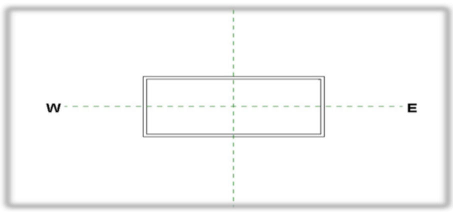

Figure 1.3 *showing solar path*
Source: *Pinterest.com*

b) Direction of prevailing wind: Buildings should be aligned in such a way that openings are positioned to face the windward sides. Figure 1.4 shows the direction of prevailing wind. For instance in Nigeria, buildings should be aligned to take maximum benefit of the south west trade wind which is fresh, moist and very good for ventilation. While the north east trade wind which is dusty, dry, and brings harmattan. (Ogunsote, 2002) .

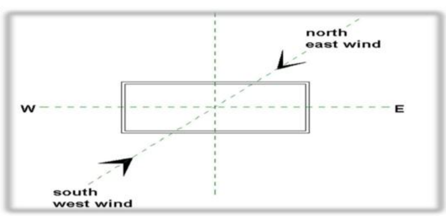

Figure 1.4 *the two prevailing wind direction*
Source: *Pinterest.com*

RESEARCH METHODOLOGY

Case Study: Abdulazeez, (2014) describes case studies are used for exploration and detail comprehension of complex ideas within a specific context. "Through case study methods, a researcher is able to go beyond quantitative statistical results and understand the behavioral conditions through the actor's perspective" (Zainal, 2007). Case studies can be Explanatory, Descriptive or Exploratory. Explanatory case studies examine data closely both on the surface and at a deep level to explain the phenomena in the data. Descriptive case studies describe the phenomena, which occur within the data. Exploratory case studies explore the phenomena in the data that serves as a point of interest to the researcher (Maina, 2015). In this study, the new lecture hall building for social sciences in A.B.U, Zaria's Samaru campus is carefully studied to identify it response to its orientation, and what effects it has on its users. The study would be carried out through checking the building's orientation and attempting to understand the benefits and advantages of its orientation and also how it affects the building's users in terms of thermal comfort. Following the above definition, this research study conducted survey on the new lecture hall building for social sciences through, Data collection instrument for Case studies and Surveys in architectural research includes but are not limited to the following; personal observation, photographs, sketches, physical scaled drawings, interviews and questionnaires (Maina, 2018).

Questionnaire: Questionnaires were administered to students attending lectures in the building during the daytime. The questionnaire comprised of three (3) sections requesting them to provide their information, thoughts and experiences in the building. Out of 200 questionnaires distributed within the building over a 3-day period to get response from different users, only 182 of them were returned and computed. The questionnaires required the respondents to give information they were sure of and the questions were asked in a manner they would quite easily be familiar with. The questionnaire was distributed in the lecture rooms with each room targeting fifty (50) respondents, while thirty (30) was distributed among those doing their businesses within the building and also those occupying the offices in the buildinsThe areas considered during the physical survey of the building include the following;
⇒ The building's shape and orientation,
⇒ Walls with more windows and the directions they faced,
⇒ Shading elements used for shading to prevent sun glare.

In general, the survey was carried out throughout the building to identify and observe passive strategies. With all these steps followed, the objective has been achieved.

DATA ANALYSIS, REPRESENTATION AND DISCUSSION OF RESULT

Data collected from the case study through surveys and questionnaire to be analyzed and discussed to arrive at a rational result showing the effect of building orientation and shading. A general discussion on the research findings and statistical data are also included.

Orientation: the building has is entrance façade is directly facing the north.

Figure 1.5 *showing the bird's eye view of the building and site*
Source: *Google Earth Application*

Windows: Most of the openings in the building are situated on the two opposite facing walls on each side of the building.

Figure 1.6 *Showing Approach Elevation*
Source: *Physical Survey*

Natural Shading: While the northwest wall on the other side has more rooms, trees planted whose shadows are casted on the walls to provide shade and avoid glaring. More light goes into the building from this side its windows open to a vast area of space.

Figure 1.7 *showing natural shading at the east elevation*
Source: *Physical Survey*

Artificial Shading: The way the building is situated has allowed for a natural means of shading from three sides, leaving the south east and south west open. On the south elevation, the verandahs and passages have been screened with hollow bricks to allow for just the required amount of light to come and also significantly reducing the glaring from the sun that would go into the classroom and offices located in that area of the building.

Figure 1.8 *showing integrated shading at the south elevation*
Source: *Physical Survey*

Figure 1.9 *showing integrated shading at the south elevation*
Source: *Physical Survey*

Glaring: the respondents agreed that there wasn't much sun glare as a result of shading using trees and screen walls. Also aiding this is neither of the building's elevation is directly facing the east or west.

Figure 2.0 *showing natural shading at the west elevation*
Source: *Physical Survey*

Clothing: Most of the respondents said they dress lightly in terms of quantity, which also allows for easy passage of air to their bodies. Only a select few dress heavily due to either religious beliefs for some females or personal preference.

Ventilation: Ventilation is adequate in all the lecture room. The respondents admit to enjoy good indoor air quality throughout the time they spend within the building.

Figure 2.1 *showing natural shading at the west elevation*
Source: *Physical Survey*

FINDINDGS FROM QUESTIONNAIRE

The following Pie charts and Column graphs would show the findings from the Questionnaires administered in the building to its frequent users.

Respondents: Not all of the questionnaires distributed were returned. Only (182) out of (200) questionnaires distributed was returned as seen in the figure below.

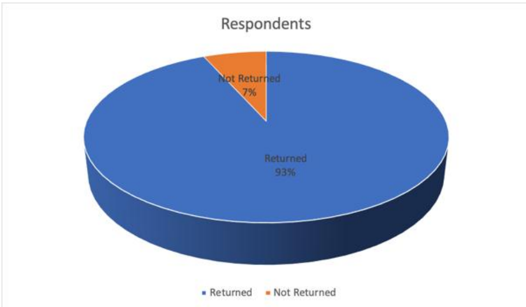

Figure 2.2 *Pie-chart showing number of respondents.*
Source: *Microsoft PowerPoint*

Affiliations: Among the users of the building are staff, students and others including a shop owner as seen below.

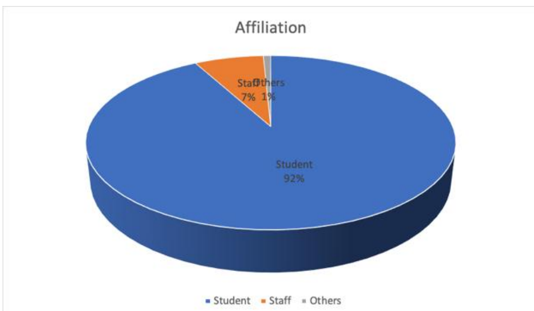

Figure 2.3 *showing affiliation distribution*
Source: *Microsoft PowerPoint*

Gender: The respondents are made up of eighty-five (85) females and ninety-seven (97) males consisting of Students and staff as seen in the figure below.

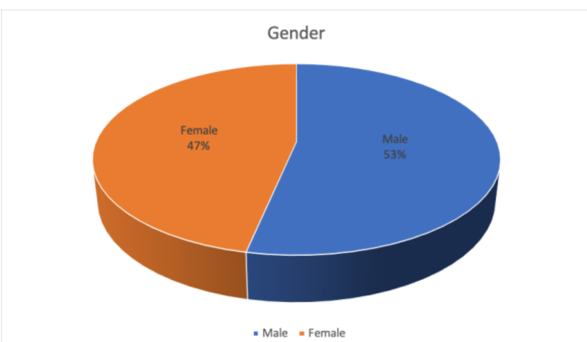

Figure 2.4 *showing gender distribution*
Source: *Microsoft PowerPoint*

Age: The age distribution as shown in fig.2.5 is largely consisted of students within the age bracket of twenty (20) and thirty (30).

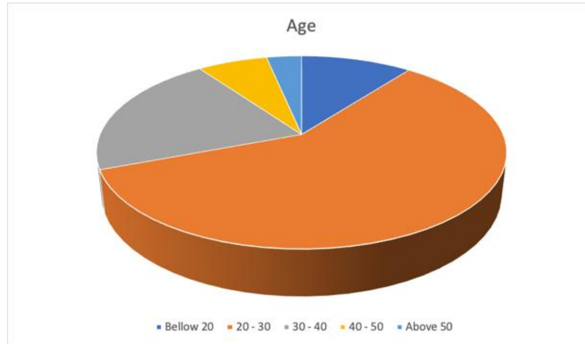

Figure 2.5 *showing age distribution*
Source: *Microsoft PowerPoint*

Temperature: More than seventy-five percent (75%) of the respondents gave positive remarks about the suitability of the indoor temperature for learning, agreeing that the temperature of the learning environment can affect output.

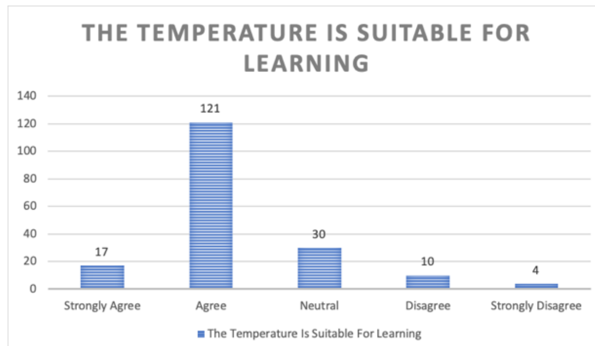

Figure 2.6 *cshowing respondents perception of the temperature*
Source: *Microsoft PowerPoint*

Sun Glare: From the figure shown below, about seventy-seven percent (77%) of the respondents agree that there isn't any discomfort from glare in the building. This is as a result of well planted trees across the east and west elevations.

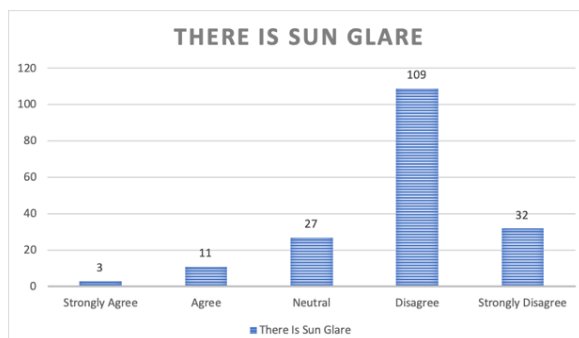

Figure 2.7 *showing respondents perception of the glare*
Source: *Microsoft PowerPoint*

Indoor Thermal Quality: The Indoor thermal quality as perceived by the respondents is comfortable with eighty percent (80%) confirming it to be conducive. The figure below shows that only a very few of the respondents found the interior thermal quality discomforting.

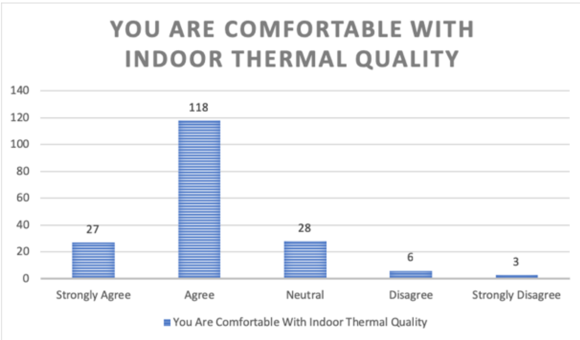

Figure 2.8 *showing respondents perception of the indoor thermal quality*
Source: *Microsoft PowerPoint*

Familiarity of Research Topic: Familiarity of the research topic is the most agreed upon question in the study with more than eighty-three percent (83%) of the respondets having prior knowledge of it as can be seen in figure 2.9 below.

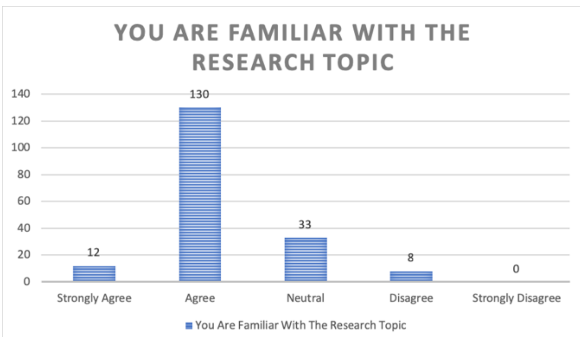

Figure 2.9 *showing respondents familiarity with research topic*
Source: *Microsoft PowerPoint*

Effect Of Thermal Quality: More than seventy percent (70%) of the respondents agree that the indoor thermal quality has a positive effect on their behavior, this can reduce stress levels and encourage concentration in lectures and other academic activities within the building.

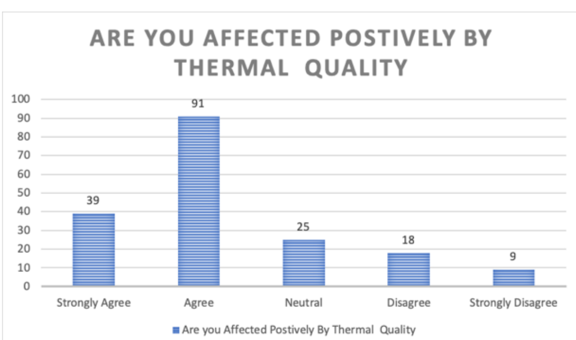

Figure 3.0 *showing respondents perception of thermal quality*
Source: *Microsoft PowerPoint*

Air Temperature: Although the air temperature is not very cool, the number and arrangement of the windows for cross ventilation causes there to be a constant flow of breeze through the interior spaces maintaining a comfortable indoor environment.

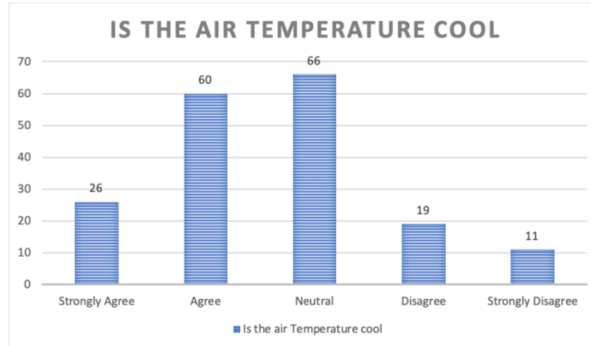

Figure 3.1 *showing respondents perception of the air temperature*
Source: *Microsoft PowerPoint*

Dressing: From figure 3.2 below, we can see that the respondents dress lightly due to the general climate conditions in the region and as a result, it helps them maintain a comfortable thermal perception when indoors.

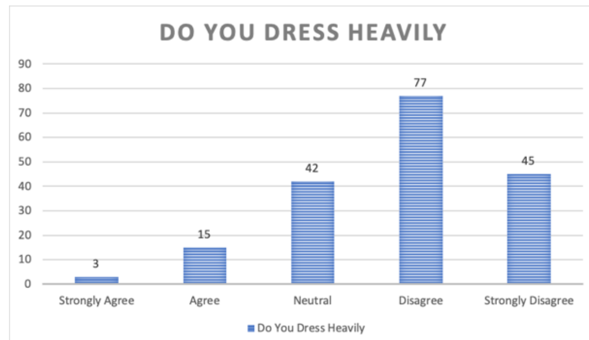

Figure 3.2 *showing the respondents manner of dressing*
Source: *Microsoft PowerPoint*

CONCLUSION

The data gotten from the physical survey shows how the new lecture hall building attains a thermally comfortable environment for its users. Some of these include

⇒ Designing the building with an appropriate orientation.
⇒ Following the basic orientation methods and steps.
⇒ Providing large windows in the appropriate areas.
⇒ Proper arrangement of the windows for cross-ventilation.
⇒ Using trees and screen walls as shading devices in areas with possibility of sun glare.
⇒ Having the longer sides of the building away from direct solar radiation.
⇒ Placing the windows to capture passing air i.e. trade winds and cross ventilation

The other data collected and analyzed through interviews and questionnaire provided much needed information about the building and how its users adapt to its thermal conditions. Also gathered from these instruments is information regarding the effect and role of the building's performance rating on the behavior, and performance output levels of those operating within the building. Going by the results obtained from the findings of this research study, the orientation of the new lecture hall building has a good thermal performance as a result of its orientation, integrated shading and natural shading. The users of the new lecture hall building agree that institutional building users require good indoor air quality as they feel it promotes the mood and atmosphere within their working and learning environments. There is a significant effect a well-oriented building has on the thermal comfort of its occupants as related and agreed by the building users. This results in a morale boost as the students, staff and other users of the new lecture hall building feel that the thermal comfort they experience within the building encourages learning as their lecture rooms and offices are more conducive.

RECOMMENDATION

From the results obtained from the research study, the following can be recommend;

⇒ That more emphasis is placed on the need to study building orientation as an effective tool for achieving passive cooling.
⇒ There should be emphasis on integrating shading devices to building design and also more use of the soft landscape i.e. (trees) to achieve effective shading.
⇒ That existing literature on the relationship between building orientation and thermal comfort could be revised to enrich research.
⇒ Thermal comfort of Building users should be put as an important consideration in Design.

That students be encouraged to make more research in areas that affect their learning process and performance.

REFERENCES

[1] A.A. Adebayo, Sustainable construction in Africa: agenda 21 for sustainable construction in developing countries, Africa Position Paper (2002).

[2] Abdulazeez. (2014). Retrieved from https://www.coursehero.com/file/16530817/Abdulaziz-Alshuaibi-Xerox-case-study/

[3] Adebayo, A.A. (2004). Mubi Synthesis: A Geography Synthesis, First Edition. Paraclete Publishers, Yola.

[4] Alibaba, H. Z. (2018) Heat and Air Flow Behavior of Naturally Ventilated Offices in a Mediterranean Climate .https://www.researchgate.net/publication/327660643_Heat_and_Air_Flow_Behavior_of_Naturally_Ventilated_Offices_in_a_Mediterranean_Climate [accessed Dec 26 2018].

[5] Alibaba, H. Z, Ozdeniz, M. B. Energy performance and thermal comfort of double-skin and single-skin facades in warm climate. Journal of Asian Architecture and Building Engineering, 15, 2016, pp. 635–642.

[6] Alibaba, H. Z, Abdullah, H. K, Towards Nearly Zero-Energy Buildings: The Potential Of Photovoltaic-Integrated Shading Devices To Achieve Autonomous Solar Electricity And Acceptable Thermal Comfort In Naturally-Ventilated Office Spaces.

[7] ASHRAE (2001b) “ASHRAE Standard 62–2001: Ventilation for Acceptable Indoor Air Quality”, (Rajesh Sharma, 2014)

[8] ASHRAE STANDARD, Thermal Environmental Conditions for Human Occupancy, American Society of Heating. Refrigerating and Air-Conditioning Engineers, INC.55-2004

[9] Baharuddin, Mohd Nurfaisal & Che-Ani, A & Goh, Nurakmal & Mohd Tahir, Mazlan & Mohd Tawil, Norngainy & Utaberta, Nangkula. (2011). BUILDING USER MANUAL: A VITAL COMPONENT OF THE MALAYSIAN GREEN BUILDING INDEX. (Green Seal, Siemens Industry Inc, September, 2011)

[10] Bekkouche, T. Benouaz, A. Cheknane (2009), “A Modelling Approach of Thermal Insulation Applied to a Saharan Building” , THERMAL SCIENCE: Vol. 13 (2009), No. 4, pp. 233-244.

[11] Branz. (2017, November 13). Retrieved from http://www.level.org.nz/passive-design/ventilation/

[12] Fanger, L. F. (August, 2004). Impact of indoor air temperature and humidity in an office on perceived air quality, SBS symptoms and performance. International Journal For Indoor Environment and Health (pp. 74-81). Wiley Online Library.

[13] Green Seal, Siemens Industry Inc. (September, 2011). Green Building Operations & Maintenance Manual.

[14] Hancock, Pete & M Ross, Jennifer & Szalma, James. (2007). A Meta-Analysis of Performance Response Under Thermal Stressors. Human factors. 49. 851-77. 10.1518/001872007X230226.

[15] Ibrahim U. Haruna, I. M. (2014, March 3). Improvement Of Thermal Comfort In Residential Buildings. INTERNATIONAL JOURNAL OF SCIENTIFIC & TECHNOLOGY RESEARCH, 3(3), 180 - 183.

[16] Innova. (2018, November 21). Retrieved from https://www.designingbuildings.co.uk/wiki/Mean_radiant_temperature

[17] ISO 7730: (2005), Ergonomics of the thermal environment — Analytical determination and interpretation of thermal comfort.

[18] ISO, En. "7730: 2005:“Ergonomics of the thermal environment–Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria”." International Organization for Standardisation, Geneva (2005).

[19] Kolokotsa, D and Nicolaou, T, (2007), Contribution of shading in improving the energy performance of buildings, 2nd PALENC Conference and 28th AIVC, Island and Greece (Branz, 2017)

[20] Maina, J. J. (2015). Architects and Interdisciplinary research: Reflections from Ethnographic and Measured Fieldwork. In: Samuel Laryea & Roine Leiringer (Eds.), Procs, 6th West Africa Built Environment Research (WABER) Conference, 10-12 August 2015 (pp. 131-144). Accra, Ghana: WABER.

[21] Maina, J. J (2018). RELIABILITY OF SELF-ASSESSMENT QUESTIONNAIRES: DO ARCHITECTURE POSTGRADUATE STUDENTS OVERESTIMATE THEIR EMPLOYABILITY SKILLS? FEEDBACK FROM GRADUATES AND EMPLOYERS. 6. 71-81.

[22] Nikolopoulou, Marialena. (2011). Outdoor thermal comfort. Frontiers in bioscience (Scholar edition). 3. 1552-68. 10.2741/245.

[23] Nematchoua, Modeste & Tchinda, Réné & A. Orosa, José. (2014). Adaptation and comparative study of thermal comfort in naturally ventilated classrooms and buildings in the wet tropical zones. Energy and Buildings. 85. 321–328. 10.1016/j.enbuild.2014.09.029.

[24] Ogunsote, O.O. (1991) Introduction to building climatology: A basic course for architecture

[25] students. Zaria: Ahmadu Bello university Press.

[26] Rajesh Sharma, D. (2014, August). Energy efficient facades for Hot and Dry climate in India. International Journal of Innovative Science, Engineering & Technology, 1(6), 536 - 542.

[27] Shittu O.J. and Ifesanya, A.O. (2003): “Effects and cost implications of climate on building Design: An overview of Nigerian situation”. International Journal of Environmental Issue, Vol. 1 No. 2, pp. 164-180.

[28] Saberi Ommid, Saneei Parisa, Javanbakht Amir, Thermal Comfort in Architecture

[29] QUT (2009-15), High-Density Liveability Guide, <http://www.highdensityliveability.org.au/dwe_ventilation_thermal_comfort.php>

[30] Zainal, Zaidah. (2007). Case study as a research method. Jurnal Kemanusiaan. 9.