Design Strategies for Thermal Comfort in Faculty of Architecture Building, Port-Harcourt Nigeria

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Abstract
The field of architecture, encompassing the artistic and practical aspects of building design and construction, plays a crucial role in ensuring thermal comfort within buildings. This encompasses a wide range of factors, including construction methods, materials, finishes, occupancy levels, and spatial dimensions. The significance of establishing thermal comfort design strategies for architecture schools in Port-Harcourt, Nigeria, particularly within the Faculty of Architecture, cannot be overstated, as it has the potential to enhance students' educational experiences. This study aims to identify and propose effective thermal comfort design strategies for the Faculty of Architecture in Port-Harcourt, providing guidance for architects and designers to create thermally sustainable environments that optimize the learning experiences of architecture students. The research methodology employed involves an exploratory literature review, which entails analysing existing research to gain valuable insights and assess the strengths and limitations of design strategies. As a result, the research recommends the implementation of passive cooling strategies to support learning spaces and improve students' academic performance and overall learning outcomes.

Keywords: *Faculty of Architecture, Thermal-comfort, Students, Learning outcome*

1. INTRODUCTION

According to ASHRAE Standard 55 (2017) thermal comfort is the state of mind indicating contentment with the thermal conditions, which is subjectively evaluated (Eddy et al., 2017). It can be described as the state where the human mind is in balance with the thermal environment without experiencing discomfort due to feeling too hot or too cold overall or due to unnecessary heating or cooling of specific body parts. Following a critical examination of the definition, Hensen (2021) identified thermal dissatisfaction as the point at which an individual's mental state no longer reflects contentment with the surrounding thermal conditions. Hensen (2021) described thermal dissatisfaction as the condition that arises when an individual's mental state no longer reflects contentment with the surrounding thermal environment. Furthermore, Hensen (2021) identified several factors that strongly impact thermal comfort, including air temperature, radiant temperature, air velocity, humidity, as well as personal and situational factors such as metabolic rate, clothing insulation, gender differences, and psychological factors.

Statement of the Problem

The Nigerian University Commission (NUC) and the Architects Registration Council of Nigeria (ARCON) have established standards for architecture faculties in Nigeria to enhance the quality of learning environments and thermal comfort. These standards focus on ensuring optimal indoor air quality, minimizing indoor temperature fluctuations, and providing sufficient studio facilities and teaching aids. Research by Sitelogiq (2021) and Tumusiime (2013) has identified challenges associated with inadequate thermal comfort, which can impact student collaboration and performance, particularly in cases where clustered seating arrangements are used instead of circular or row arrangements during design tasks. In response to these issues, the study "Design strategies for thermal comfort in the faculty of architecture building, Port Harcourt, Nigeria" will be conducted to address these concerns and align with the expectations of NUC and ARCON. It is anticipated that by addressing thermal comfort issues, this study will help improve students' learning outcomes and enhance staff productivity.

Aim And Objective of The Study

The aim of this study is to determine design strategies for thermal comfort in faculty of architecture buildings in Port-Harcourt Nigeria with the objectives as listed below;

a. To determine design strategies for thermal comfort
b. To determine construction materials that improve thermal comfort
c. To determine the design principles that improve thermal comfort for the design of faculty of architecture in Port-Harcourt Nigeria.

2. LITERATURE REVIEW OF THERMAL COMFORT

The imperative for society and researchers to intensify their focus on thermal comfort is underscored by the ongoing efforts to reduce carbon emissions. While Taylor et al. (2018) have pointed out the potential challenges of achieving thermal comfort without the use of fossil fuels in certain climatic regions, it remains possible to achieve thermal comfort for a significant portion of the year in specific locations through the implementation of tailored strategies. The profound impact of thermal comfort on health outcomes cannot be overstated, as it transcends mere satisfaction with ambient temperature and plays a crucial role in overall health. According to Sakkas (2022), the human body responds to temperature fluctuations by either sweating to cool down in response to heat or shivering as a protective mechanism when the outdoor temperature is not conducive to maintaining the core body temperature of 37 °C.

When the temperature in an indoor learning environment exceeds 30 °C, it can have a negative impact on the cognitive abilities of students, leading to a decrease in their ability to study and work effectively. Eddy et al. (2017) conducted a study that confirmed the importance of regulating indoor climate to provide a comfortable and healthy environment for the occupants. Moreover, Karimi et al. (2020) argued that building design should not only focus on providing a space but also prioritize the health and safety of the occupants, with thermal comfort being the primary consideration. They also emphasized the significance of day-lighting comfort and visual comfort in creating a satisfying and healthy indoor environment, which can be achieved through thermal balance.

According to Thesaurus (2024), thermal balance is reached when all parts of a system are at an equal temperature. Thermal equilibrium, also known as thermal balance, occurs when the sum of heat entering and leaving a building is zero. This signifies that the building is maintaining a stable heat level. Humans can maintain thermal balance through the thermoregulatory system, which ensures the body's internal temperature remains constant. The body's ability to regulate temperature is supported by various thermoregulatory processes (Osilla et al., 2023).

In light of the aforementioned discussions, it is imperative to underscore the importance of focusing on thermal comfort to garner the interest of more researchers. This is a pressing issue in the built environment, and further exploration is needed to enhance human thermal comfort receptivity while also accommodating the evolving needs of users in indoor environments. By integrating basic strategies for thermal comfort to address emerging needs in the learning environment, it is feasible to enhance users' performance and improve learning outcomes in schools.

3. METHODOLOGY

The research methodology employed involved an exploratory literature review, which entails analysing existing research to gain valuable insights and assess the strengths and limitations of design strategies. The research explored various literatures comprising studies on climatic condition of Port-Harcourt, general design strategies for thermal comfort, design strategies for thermal comfort in hot humid regions of Nigeria which formed the framework upon which design strategies for thermal comfort in faculty of architecture building, Port-Harcourt Nigeria was determined.

4. RESULTS AND DISCUSSIONS

4.1. Climatic Condition of Port-Harcourt, Rivers State Nigeria

The climatic conditions in Port Harcourt are typical of a tropical climate, with a significant amount of precipitation observed in the majority of months. Although there is a short dry spell, it has minimal impact on the overall weather patterns. Port Harcourt experiences oppressive weather throughout the year, characterized by warm, cloudy wet seasons and hot, mostly cloudy dry seasons. The average annual temperature ranges between 21°C and 34°C consistently.

i. Rainfall

The annual rainfall in Rivers State averages 300 mm, but this figure varies greatly from month to month. The lowest monthly average is 21 mm, while the highest is 375 mm. These fluctuations present significant challenges for architects in terms of designing structures and selecting appropriate building materials, as they must account for the diverse and unpredictable nature of the region's rainfall patterns (weather spark, 2015).

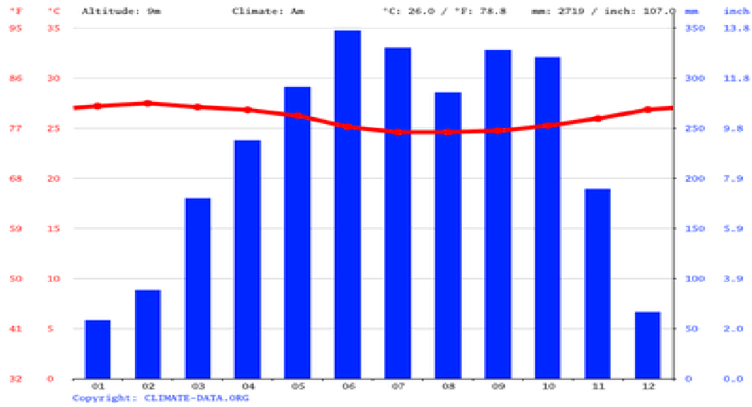

Figure 4.1: Graph of Rainfall
Source: (weather spark, 2015).

ii. Relative Humidity

The humidity levels in Port Harcourt usually range from 70% to 80%. The most comfortable relative humidity falls between 40% and 60%. Anything below 20% is considered low humidity, which can lead to discomfort as a result of excessively dry air causing woodwork to shrink and fracture. When the humidity level exceeds 70%, the atmosphere becomes damp and challenging to live in. It is essential to implement proper measures to prevent high relative humidity-induced dampness from causing harm to structures and construction components.

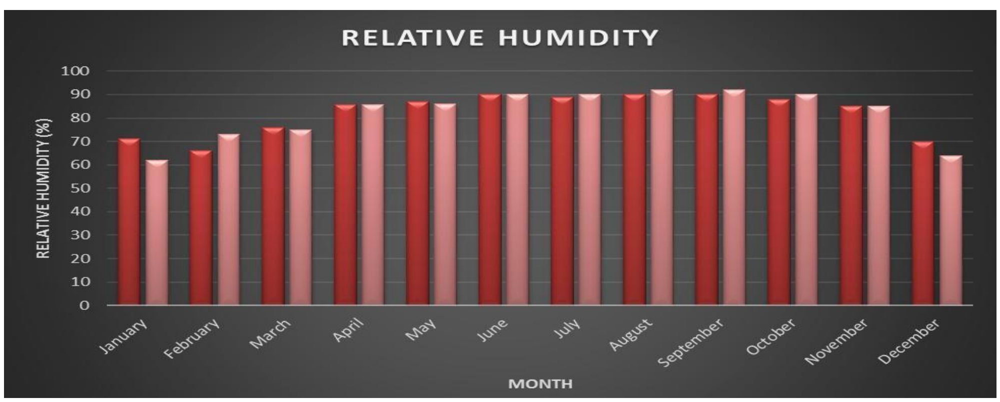

Figure 4. 2: Graph of Relative Humidity

Source: (weather spark, 2015).

iii. Temperature

The period from February to May, known as the dry season, sees the highest temperatures, with the average annual temperature fluctuating between 21°C and 34°C. On the other hand, the wet season in July and August records the lowest temperature readings, ranging from approximately 16°C to 24°C, which can create comfortable conditions. Temperatures below 16°C are typically very cold and uncomfortable. The texture and appearance of materials such as paints and untreated wood can be influenced by high temperatures, as demonstrated in temperature studies. To shield building materials from the impact of elevated temperatures, it is crucial to consider important factors, as they can also transform the texture of materials like plastic and bitumen. Furthermore, the presence of sufficient ground cover vegetation is necessary to enhance the microclimate by reducing heat radiation from the ground.

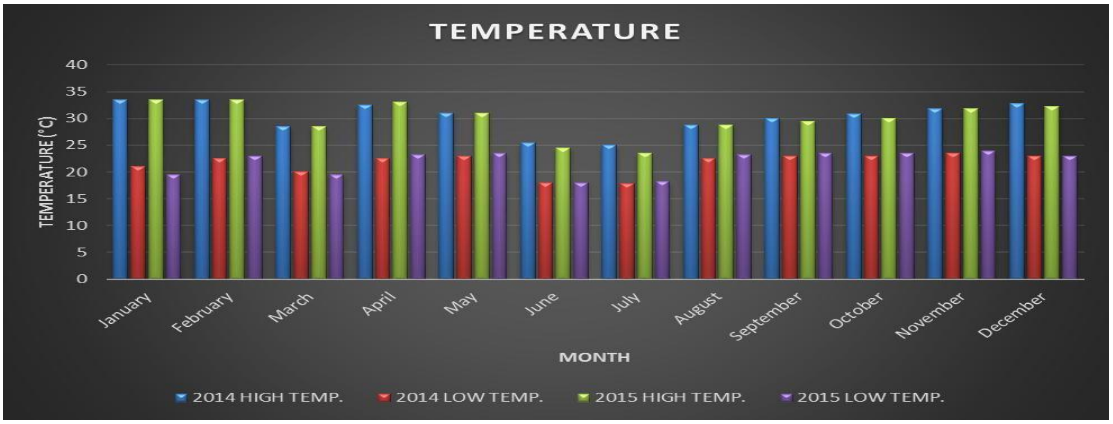

Figure 4. 3: Graph of Temperature

Source: (weather spark, 2015).

iv. Sunshine

Observations and data indicate that there is a substantial amount of sunshine during the dry season, contrasting with the limited sunshine experienced during the heaviest period of the rainy season. This discrepancy is primarily a result of the cloud cover prevalent throughout the rainy season. Notably, in August and April, the average sunshine duration is a mere 1.7 hours. Managing the entry of excessive solar heat into the building's interior poses a significant challenge for the architect. To mitigate the discomfort arising from the glare caused by sunshine, certain considerations must be made.

1. Pay special attention to how the spaces are oriented, with the longest axis facing east-west and the fewest openings facing north-south.
2. In order to lessen glare, balconies and window overhangs might be added.
3. The addition of a courtyard will improve interior building illumination.
4. Use sun-shading structures (vertical and horizontal), such as pergolas, fins, and canopies to block direct sunlight from entering the building.
5. The use of reflective materials and the material's colour selection. Dark colours absorb heat, whereas light colours reflect it.
6. Having sufficient overhanging eaves.

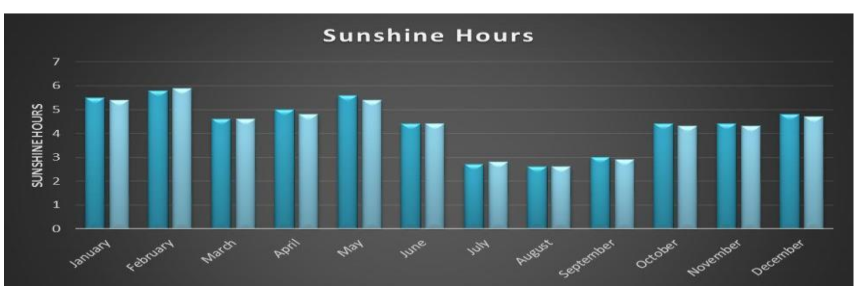

Figure 4. 4: Graph of Sunshine Hours
Source: (weather spark, 2015)

v. Clouds

The city of Port Harcourt exhibits notable seasonal fluctuations in the average cloud cover percentage in the sky throughout the year. The period characterized by clearer skies typically starts around November 20 and lasts for approximately 2.8 months, ending around February 13. December emerges as the clearest month in Port Harcourt, with the sky being clear, mostly clear, or partly cloudy for about 38% of the time on average. In contrast, the cloudier phase begins around February 13 and extends for roughly 9.2 months, concluding around November 20. April is identified as the cloudiest month in Port Harcourt, with the sky being overcast or mostly cloudy approximately 89% of the time on average. These variations are determined by the percentage of cloud cover in the sky during different periods of the year.

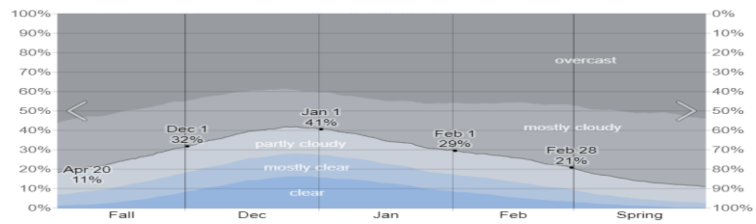

Figure 4. 5: Graph of Sunshine Hours

Source: (weather spark, 2015)

vi. Wind

During the rainy and dry seasons, the south-west and north-west winds are dominant, respectively. In Port Harcourt, the predominant wind is the south-west wind. For comfortable indoor conditions, wind speeds between 0.1 and 5.0 m/s are ideal, while buildings become stuffy and uncomfortable within this range. High winds can cause damage to construction projects and buildings, necessitating the implementation of essential safety measures. It is important to consider the following factors in order to maximize the effects of the wind:

1. Buildings should be positioned to maximize the benefits of the predominant wind conditions.
2. They should ideally face east and west, with the fewest openings on the north and south.
3. Utilizing windbreakers
4. There should be enough space between buildings to allow for wind infiltration.

4.2. General Design Strategies for Thermal Comfort

The productivity of individuals in a work environment is greatly influenced by the level of thermal comfort they experience. ASHRAE Standard 55 (2017) cited by Cubick (2017), defines thermal comfort as a subjective state of mind that reflects satisfaction with the thermal conditions and is subjectively evaluated. This definition underscores the individualistic nature of thermal comfort assessment, making it challenging to regulate thermal conditions in a shared environment to meet everyone's needs. Building codes that address indoor environmental quality (IEQ) factors, such as indoor air quality (IAQ), prioritize minimizing thermal discomfort rather than completely eradicating it. This approach acknowledges the complexity of physiological differences among individuals and other variables that affect comfort levels, making it impractical to achieve universal comfort for all. Cubick (2017) identifies four key strategies for achieving thermal comfort through effective architectural design, construction, and maintenance. These are as discussed below.

1. The Use of Heating, Ventilation and Air Conditioning (HVAC) system

By regulating and balancing the mean radiant temperature (MRT), this system allows for the attainment of thermal comfort for a greater number of individuals within indoor spaces, particularly through the implementation of a radiant cooling and heating system. The radiant cooling and heating system proves to be more efficient than traditional air-based alternatives in managing the thermal environment in a serene and spatially effective manner, as it does not directly impact air temperature or control ventilation or indoor air quality (IAQ). Consequently, the system is combined with other systems, such as a dedicated outdoor air system (DOAS), to collectively perform these functions (Cubick, 2017).

2. Minimize leakage

The effective upkeep of an HVAC system is vital to maintaining its premium functionality and preventing any air leakage, whether it occurs through the building envelope or within the system itself. This maintenance is critical for ensuring the proper distribution and upkeep of efficient indoor air quality (IAQ) by facilitating the smooth flow of air in and out of the HVAC system, thereby enhancing thermal comfort. The presence of leaks in either the HVAC system or building envelope can have a negative impact on thermal comfort by diminishing the energy efficiency of air transfer, especially when air bypasses the air handling unit (AHU) and energy recovery wheel. This can result in challenges when it comes to regulating indoor conditions effectively (Cubick, 2017).

3. Design and build for some occupant control

Cubick (2017) suggested that in order to achieve efficient performance and proper control of indoor air quality, it is advisable to allow individuals to regulate the temperature and air flow using a thermostat for HVAC systems and operable window blinds to enhance thermal comfort. Passive cooling strategies, such as natural ventilation and solar radiation, are recommended to maintain indoor temperature and reduce energy consumption in HVAC systems while also giving users control over their indoor air quality. However, in environments with multiple users, individual control of HVAC systems may be challenging, as it could lead to conflicts and reduce overall indoor environmental quality. As outlined by Devlin (2017), males and females have differing thermal comfort requirements, with females typically exhibiting lower skin temperatures despite both genders sharing a core temperature of 37 °C, albeit slightly higher in females. Given the diverse health conditions and metabolic rates found in shared spaces, it is imperative to consider incorporating passive cooling strategies into design schemes, recognizing that these strategies may not be universally effective. The most effective approach to achieving personalized thermal comfort involves individualized control mechanisms, such as wearing clothing tailored to one's specific health and metabolic needs. This can be achieved through the use of layered clothing and insulation materials, allowing individuals to fine-tune their personal thermal environment without the need to adjust the overall temperature of the space.

4. Maintain the Thermal Environment, And Make Changes as Necessary

The maintenance of HVAC equipment plays a critical role in ensuring its efficiency. Opting for a radiant cooling or heating system can provide benefits in terms of lower maintenance costs and reduced effort compared to conventional all-air systems. It is also important to make seasonal adjustments in areas with varying climates to uphold thermal comfort. International building codes, such as ASHRAE Standard 55, recommend different indoor air temperatures for summer and winter to manage relative humidity and air temperature effectively. This adjustment not only contributes to maintaining thermal comfort but also leads to substantial energy savings by decreasing the workload of the HVAC system in maintaining desired temperatures. Achieving thermal comfort is a complex issue that can be addressed through effective design, construction, and maintenance practices.

4.3. Design Strategies for Thermal Comfort in Hot Humid Regions of Nigeria

According to Pourvahidi (2020), the hot, humid climate is also known as the tropical rainforest climate or the equatorial monsoon. This climate is influenced by the monsoons from the South Atlantic Ocean, which are brought into the area by the maritime tropical (MT) air mass, characterized by warm, moist sea surface winds. The high humidity and warmth of the air cause it to ascend strongly, resulting in a large amount of rainfall due to the condensation of water vapor in the rapidly rising air. The southern part of Nigeria, which is a hot and humid region, encompasses states such as Abia State, Rivers State, Akwa Ibom State, Cross River State, and other South-East and South-South States. The temperature in this region remains consistently high with a very small temperature range, resulting in almost constant temperature levels throughout the year. The hottest month experiences temperatures of up to 28 °C, while the coldest month sees temperatures as low as 26°C. According to Pourvahidi (2020), the region experiences very high humidity throughout the year, leading to slow evaporation and heavy rainfall. The humidity percentage in this area ranges from 70–90%. Rainfall is heavy and short in duration, often accompanied by frequent storms. The region is characterized by abundant vegetation, including mangrove swamps and freshwater swamps. The settlement pattern in this area is open and widespread due to the high humidity levels.

i. Orientation of the Building

The foremost principle to be adopted in achieving thermal comfort in a building is the orientation of the building because it determines the part of the building that will face the sun when there is a need to harness the thermal factors of the sun and the major winds prevalent in the area. Husini and Syaheeza (2021) stated that the east and west sides of a building while facing the true north are more exposed to solar radiation; therefore, it is better to have a minimum number and size of windows within these axes in order to reduce solar penetration into the building, which will benefit in enhancing the energy efficiency of the building, as failure to do that will cause a double amount of solar radiation into the building when compared to facing the building within the north and south axis. To reduce the amount of solar radiation on the building structure and elements, it is best to use the east-west orientation because it will help protect the building envelope from excessive solar radiation effects. The diagram below illustrates the solar radiation orientation received from the east, west, and south sides of a building.

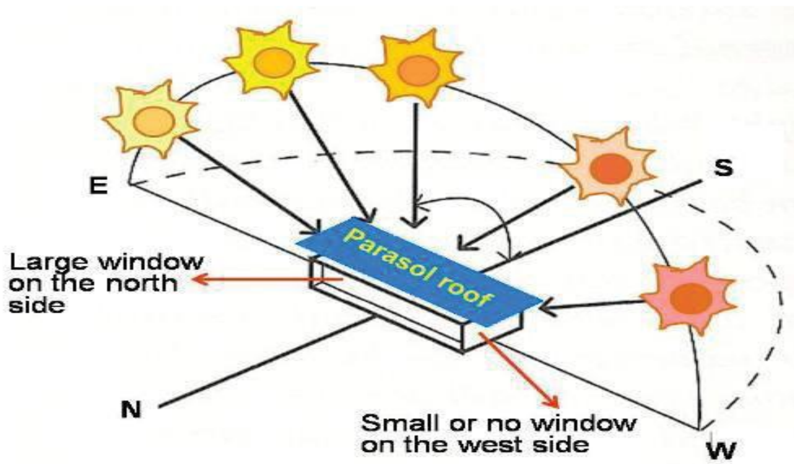

Figure 4.6: Passive Building Design Strategies for Houses in tropical climates
Source: (Husini & Syaheeza, 2021)

ii. Windows Position and Openings for Air Circulation

To promote cross-ventilation in a hot and humid climate, it is essential to optimize air circulation within a building. Single-bed room arrangements and large windows are effective strategies to enhance air movement. By incorporating openings at the topmost part of interior walls near the ceiling, hot air can be expelled from the building while cool air is drawn in from the lower part. This process aids in reducing heat gain efficiently. The design approach of a building significantly influences air movement within indoor spaces, affecting evaporation rate and bodily heat loss. The movement of natural air is influenced by the temperature contrast between indoor and outdoor air, which is known as thermal forces. As the air inside a building is heated, it expands and rises, leading to a decrease in density and volume. The presence of openings at various levels in the building is advantageous as it facilitates the influx of air, with higher pressure near the ceiling and lower pressure at lower levels. This continuous air exchange, referred to as the "stack effect," is characterized by the inward flow of air from the bottom and the outward flow of hot air from the top when air is released from the building due to thermal forces.

In their research, Husini and Syaheeza (2021) investigated the thermal comfort in a building in Bangladesh by monitoring the indoor air quality of different rooms. The findings demonstrated that the room with natural ventilation exhibited better indoor air quality in comparison to the room that solely relied on mechanical methods such as air conditioning. The study conducted in a residential building highlighted that the air-conditioned room had higher levels of carbon dioxide, while the naturally ventilated room had notably lower levels. A recent investigation into contemporary terrace houses has revealed that in order to achieve thermal comfort, a room relying solely on mechanical cooling from an air conditioner requires 48 hours of cooling, whereas a naturally ventilated room only needs 8 hours. Interestingly, the study found that a room naturally ventilated with the addition of fans offers superior thermal comfort compared to a room that is air conditioned. According to Husini and Syaheeza (2021), air-conditioned rooms have the potential to induce 'sick building syndrome' (SBS) as a result of excessive cooling by the air conditioner.

iii. Window Sizes and Shape

In a study of a tropical country, Koranteng C, Essel C, and, Nkrumah J (2015), observed significant decreases in indoor air temperature in rooms when the glazed area ratio of windows was altered from 50 to 25%. Additionally, the study highlighted the impact of window size, shape, and location on ventilation and the psychological well-being of building occupants. Lowenhaupt Collins (1975) suggested that the ideal level of psychological contentment is achieved when the proportion of windows constitutes 15 to 30% of the wall area. In a study conducted by Koranteng C, Essel C, and, Nkrumah J (2015), the impact of window sizes and positions on indoor temperature was investigated using parametric simulation. The research revealed that window sizes falling within the range of 10–30% are considered optimal for residential buildings, while a window size of 40% is deemed acceptable. The study introduced an adaptive model that establishes a connection between outdoor climate conditions and indoor temperature, indicating a significant correlation between the two variables. It is recommended that designers and builders take into account adaptive measures such as orientation, shape, and shading during the design and construction process. Furthermore, the study suggested the utilization of shading devices like overhangs, awnings, and fins to manage solar heat gain and reduce indoor discomfort.

iv. Shading Devices

Mikler, V., Bicol, A., Breisness, B., and Labrie (2009) posit that the primary function of a shade system is to shield the transparent sections of a structure from detrimental sun radiation. Fixed shading systems, moveable shading systems, and other shading systems are the three distinct types of shading systems. By intercepting incoming daylight, a shading apparatus can modify the energy consumption of a building. In tropical climates, the hot temperatures and significant solar radiation lead to buildings overheating during the day. This results in high indoor temperatures as the sun penetrates the building and heats up the building fabrics. To address this issue, effective shading techniques are necessary. Overhanging shading devices on the east and west windows, as well as projected fins on the north and south windows, can help manage the overheating of buildings in tropical climates. It is essential to install these shading devices parallel to the sun's rays.

The shading of the building can be done by

1. **Interior shading:** This entails the use of blinds at the openings to control the penetration of the sun into the building.
2. **Exterior shading:** This entails the use of devices that act parallel to the sun's rays, preventing them from having direct penetration into the building's openings and windows.
3. **Solar transmittance of materials:** This entails the use of materials that do not transmit or transfer heat when heated by the sun. These materials are considered to be in direct contact with the sun, such as walls, windows, and roofs.

The transmittance level of finishing materials such as glass can greatly affect interior spaces; therefore, specialists advise that glass with a lower transmittance level should be used in tropical climates.

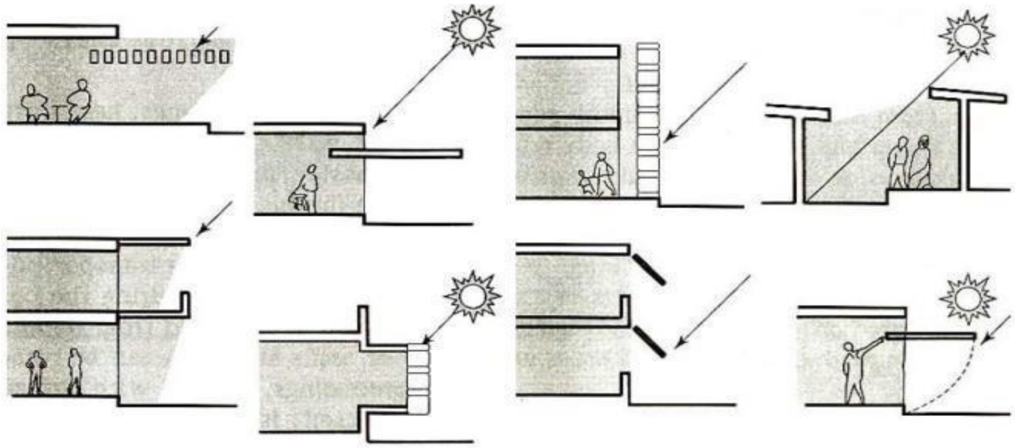

Figure 4. 7: Different type of shading devices
Source:(Mohammad Arif Kamal, 2011) quoted in (Monis & Rastogi, 2022)

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

Figure 4. 8: Criteria of Shading for Various Climatic Zones
Source: (Mohammad Arif Kamal, 2011) quoted by (Monis & Rastogi, 2022)

v. Roof and Wall Insulation

The utilization of building insulation proves to be extremely advantageous in the implementation of passive design strategies, as it plays a crucial role in ensuring thermal comfort for occupants within the building. Insulating the walls, roof, and floor in passive design involves the use of materials with low conductivity to prevent heat and cold loss. Insulating roofs in tropical regions is crucial to combating the heat generated by solar radiation on the roof during the day. One method of insulating the roof involves using pitched roofs with high internal volumes, which can effectively isolate the heat from entering the building by creating a vacuum between the ceiling and the roofing sheet. Additionally, roofs with openings, such as parasol roofs, can be employed to enhance cross ventilation and create a stack effect, allowing for the efficient release of hot air from the building. This is particularly significant in tropical regions, where many developing countries face challenges related to electricity shortages and inadequate energy supply (Husini & Syaheeza, 2021).

Ensuring effective insulation of buildings against solar radiation and transmission is of utmost importance, especially in urban areas and industrial zones characterized by high population density and rapid urban growth. The challenges of energy distribution in such areas, due to scarcity, often lead to interruptions in electric power supply, making it unfeasible for buildings to rely solely on electric-powered mechanical cooling and heating systems. The surge in energy demand has consequently driven up costs, with tropical countries struggling to meet their electricity needs (Husini & Syaheeza, 2021). Adoption of different passive building strategies plays a crucial role in promoting airflow and comfort, consequently enhancing productivity levels. Studies reveal that in humid climates, productivity can decline to as low as 44% in the absence of adequate airflow. Conversely, a minimal airflow rate of 0.7 m/s has the potential to increase users' productivity twofold. The benefits of passive building strategies are indispensable for the well-being of occupants and the success of architectural endeavours. The improved energy efficiency resulting from passive building design positively impacts users in a multitude of ways.

1. Minimal emissions of carbon dioxide emissions from operational energy usage
2. Improved thermal comfort for workers
3. Improved indoor air quality
4. Reduced cost of energy to users through reduced electricity bills
5. Security of the energy supply
6. Cheaper than operational energy
7. Positive contribution to climate change strategies through a reduction in total societal energy usage.

In the contemporary period, there is a growing need for the development of multi-unit residential buildings that optimize land usage to accommodate a significant number of occupants, which often poses challenges in maintaining passive design principles, particularly in tropical regions where buildings rely heavily on natural ventilation and heating due to limited infrastructure. The importance of following passive energy-efficient designs cannot be overstated as it contributes to lower energy usage and the creation of a thermally comfortable indoor environment. Passive design strategies are geared towards improving occupants' comfort, positively impacting productivity, and reducing energy consumption from non-renewable sources like electricity and natural gas. The research conducted by Husini and Syaheeza (2021) has extensively explored human performance, specifically examining the influence of hot and cold environments on physiological processes. Within office settings, the heating system serves as a critical tool in managing extreme temperature effects to prevent over-arousal and discomfort among occupants. The discomfort stemming from temperature fluctuations can result in reduced productivity as individuals allocate time to adjust heating controls. Similar challenges can emerge in warm environments, where vasodilation aids movement but sweating can hinder grip and cause distractions. Psychological stress may also arise as individuals strive to maintain productivity in adverse conditions, leading to exhaustion and diminished performance over time. The impact of these responses on movement and execution will vary based on the task at hand and the individual involved.

vi. Airtight construction

The possibility of air leakage exists when the structure of the structure of the air barrier is compromised, allowing air to escape. This structure acts as a shield enveloping the building, regulating the flow of air in and out. Monis and Rastogi (2022) point out that insufficient architectural and engineering detailing during construction, along with the creation of numerous openings and penetrations in the air barrier due to substandard workmanship, can lead to unresolved air control issues. Airtightness is essential, especially in areas prone to drought and dust particles, to improve energy efficiency by preventing the infiltration or exfiltration of hot or cold air based on specific requirements. In situations where leakage is possible, air can escape through the air barrier structure designed to enclose the building and control airflow. Monis and Rastogi (2022) emphasize that inadequate architectural and engineering detailing during construction, as well as the presence of multiple openings and penetrations in the air barrier due to poor workmanship, can result in unresolved air control issues. The significance of airtightness cannot be overstated, particularly in regions susceptible to drought and dust particles. Airtightness is crucial for enhancing energy efficiency by minimizing the ingress or egress of hot or cold air as needed for the building's thermal comfort and performance.

vii. High Performance Glazing

Building envelope do not stand alone as many have windows attached to it. These windows in our modern days are usually made of glass which allows light to pass through it. The glazing systems adopted for this window play a Crucial role to determine the level of heat that would be in the building through the penetration of the sun. Noting the fact that windows may not be able to achieve the same level of insulation accrual to the walls in the same degree due to their purpose, this therefore makes the windows to be a source of concern because of their vulnerability to the transmission of heat. To achieve energy efficiency it is important to recognize the climatic condition of the site under review and therefore specify a window typology that will work well in such location in order to lower the energy consumption by avoiding or eliminating the possibility of heat transfer through the windows using several forms of glass such as aerogel glazing vacuum, smart glazing, and prismatic glazing Which can enhance the energy performance of windows as it regards thermal conductivity (Jin & Overend, 2017).

viii. Eliminating Thermal Bridges

Weak thermal performance in specific areas of the building is identified as thermally deficient regions of the building's exterior. These regions are responsible for the infiltration of solar radiation in the form of heat into the building, resulting in energy loss as resources are utilized for cooling indoor spaces (Alhawari & Mukhopadhyaya, 2018). Thermal bridging often arises from the contrast in temperature between the inadequately insulated portion of the building and other exterior sections. Heat typically travels through materials with higher thermal conductivity than the surrounding environment, resulting in the formation of thermal bridges. Possible areas where thermal bridging may occur encompass structural joints, connections, floor edges, corners, internal walls with exterior walls, cantilever balconies, and slabs (Monis & Rastogi, 2022).

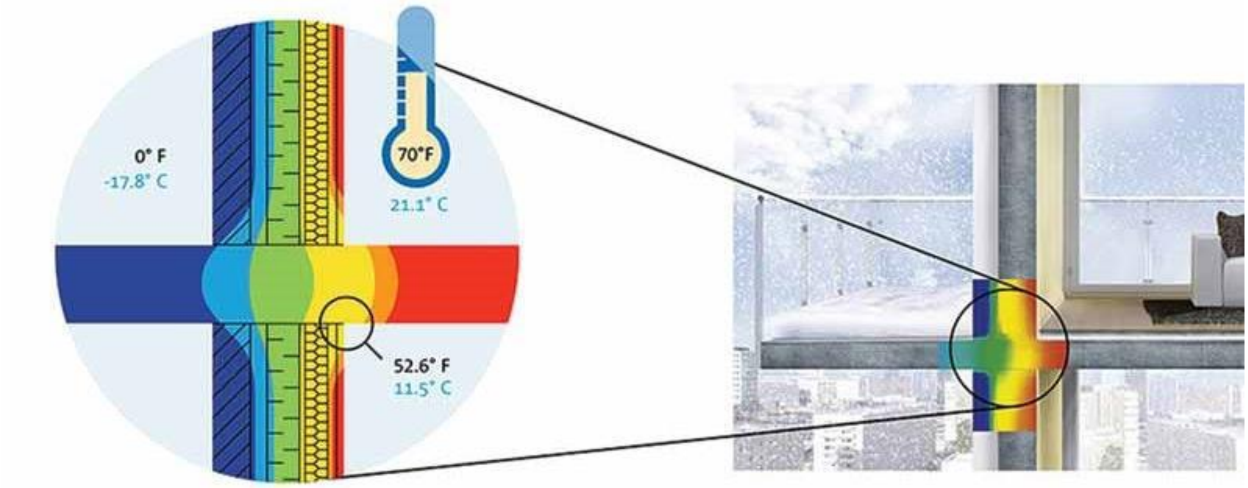

Figure 4. 9: Thermal Bridge
Source: (Monis & Rastogi, 2022)

ix. Color of External Surfaces

The colour used on the surfaces of buildings has an effect on how the building fabric receives or blocks solar radiation. Many studies have been done to uncover defects in the colour of the external surface as it relates to the assumption and transmission of heat through solar radiation on the external surface. According to Monis and Rastogi (2022) bright colours do not absorb heat from the sun, unlike dark colours; therefore, architects and building designers are advised to use bright colours with the understanding that the surfaces of the building help to enhance their ability to resist solar penetration and heat gain.

4.4. Design Strategies for Thermal Comfort in Faculty of Architecture Building, Port-Harcourt Nigeria

These design strategies are focused on designing faculty-of-architecture buildings that are aesthetically pleasing, ecologically friendly, and have a low construction cost. The concept reduces energy that would have been required if the buildings were to be designed without passive design principles and, in the process, creates thermal comfort. This principle focuses on using passive techniques for solar radiation, shading, and ventilation of the building, combined with extremely high-insulating materials. Olatunde et al. (2013) stated that passive cooling is a resultant effect of passive ventilation, which can be achieved through natural (passive) strategies. Considering the climatic conditions of Port-Harcourt, Rivers State, Nigeria, which falls within the hot, humid climatic region, below are the design strategies to be adopted for thermal comfort in the faculty of architecture generated from the design strategies for thermal comfort in a hot, humid climatic region.

1. building orientation
2. cross ventilation

3. Roof walls and floor insulation
4. window size and location
5. choice of construction materials

5. CONCLUSION

From the research carried out, various design strategies for thermal comfort were discussed, and some had deficiencies in providing adequate natural ventilation and lighting, thereby increasing the energy cost required to cool the spaces as it will depend mostly on mechanical energy to achieve thermal comfort. This research identified different general passive cooling strategies that could be adopted to enhance thermal comfort in the hot, humid climate of Nigeria, such as

i. Orientation of the Building
ii. Window Position and Openings for Air Circulation
iii. Window Sizes and Shapes
iv. Shading Devices
v. Roof and wall insulation
vi. Airtight construction
vii. High-Performance Glazing
viii. Eliminating thermal bridges and
ix. The use of light-colored external surfaces

The study identified various specific design strategies to be adopted to achieve thermal comfort in the faculty of architecture building in Port Harcourt, Nigeria. These strategies include the use of building orientation, cross ventilation, roof walls and floor insulation, window size and location, and choice of construction materials. This study identified that these strategies, if adopted, will improve thermal comfort within the faculty of architecture in Port Harcourt.

6. RECOMMENDATION

To achieve thermal comfort in architecture learning spaces within a hot, humid climatic region such as Port Harcourt, passive cooling strategies, as discussed above, will be appropriate to be adopted as design principles to be taken into consideration in designing spaces that are thermally sustainable for both architecture students and staff, which will improve staff productivity and student performance through achieving a thermally conducive academic environment.

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