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Impact of Bioclimatic Design Strategy on Indoor Thermal Comfort Perception: Case Study of Selected Postgraduate Hostel Buildings in Northwest Nigerian Universities

YAKI, Benjamin Musa, OLANIYAN, S. A. & AROSANYIN, M.V.
Department of Architecture, University of Ilorin, Ilorin, Nigeria
Corresponding Author's email: yakibenjamin6@gmail.com

This study investigates impact of bioclimatic design strategy on users' perception of indoor thermal comfort in selected postgraduate hostel buildings located in the hot-dry climatic region of Northwest Nigeria. Using purposive sampling technique, three universities with purpose-built postgraduate hostels, Kaduna State University (Kaduna), Ahmadu Bello University (Zaria), and Bayero University (Kano) were selected for the study. The research employed a mixed methods approach, combining administration of structured questionnaire through a survey, and appraisal of bioclimatic checklist, to assess the building performance. Adopting Cochran formula, a sample size of over 178 participants, was determined from the overall population of 332. Thus, a set of 178 questionnaire was administered on the identified resident students, with the return rate of about 85% after completion. The results of the analysis on the bioclimatic assessments of the postgraduate hostels reveal a moderate performance as features like *building form* and *building envelope* were rated well. However major shortfalls in integration of *building orientation* and *water-cooling elements* were observed. Users' perception indicated dissatisfaction with daytime indoor thermal comfort, as 43.3% of the respondents reported feeling too hot often, 36% sometimes, 18.7% always, and 2% rarely. Nighttime comfort seems better perceived as 52% of the respondents expressed feeling too cold rarely, and 42% sometimes, 5.3% often, and 0.7% never. The findings suggest the need for adequate consideration of bioclimatic design features in evolving postgraduate hostels for the Northwest Nigeria. This is with a view to integrating such relevant strategies inclusive of shading devices, evaporative cooling systems, proper building orientation, and appropriate building envelopes, for enhanced students' indoor thermal comfort, productivity and overall well-being.

Keywords: Bioclimatic, Building Envelope, Postgraduate Hostel, Students' Perception, Thermal Comfort

Introduction

The global average temperature during the last 100 years has increased dramatically by 0.74°C resulting in extreme temperatures and intense precipitations experienced across the globe (Ehsan, Abbas, Ibrahim, Ahmad, and Farooque, 2021). Rising global temperatures are causing heat waves to occur more frequently and prolonged, which might bring about indoor overheating, a condition where a building indoor air temperature extends beyond the human comfortable level for a duration of time. This often results in thermal discomfort, reduced productivity and health risks (Chima, Leah, and Simi, 2024).

The health, well-being and productivity of building occupants is greatly influenced by the thermal environment in which they reside in; thus, thermal comfort is directly connected to our health and productivity (Fadly, Rozita, Norfazilah, Mazni, & Mohd, 2023). Thermal comfort as defined by Ricardo, Natalia, and Roberto (2015) refers to the feeling of being satisfied with the air temperature, humidity, air velocity, and radiant temperature, based on a person's perception and subjective evaluation. According to Emmanuel, Oluseye and Raphael (2017), efficiency and health of occupants are significantly impacted by the performance of a building. An essential factor to bear in mind is the indoor thermal comfort of a building (Emmanuel, Oluseye and Raphael, 2017). Thermal Comfort design is a fundamental aspect that profoundly impacts the physical, mental, and emotional well-being of residents. As scholars have noted, the built environment significantly influences occupants' health, productivity, and overall quality of life. The idea of thermal comfort is based on an individual's perception of feeling hot or cold. This perception is affected by various external factors, such as the air temperature and relative humidity of the environment, as well as personal factors like clothing, level of physical activity, age, gender, and body weight (Afolami and Adegbie, 2022). Therefore, prioritizing thermal comfort in building design is essential for creating supportive living spaces that foster a conducive environment for rest, study, and social interaction.

The environmental performance of a building (indoor air quality, indoor thermal comfort, visual and acoustics levels) plays a role in affecting the health, wellbeing, and satisfaction of the occupants of a building (Dahlan, Jones, Alexander, Salleh, and Alias, 2009). Yazeed and Halil (2018) note that thermal discomfort can affect the quality of sleeping environment and subsequently, the performances of daytime functions. Sleep is also an important factor that affects a person`s health and well-being. Health symptoms like fatigue, headache, stress and tiredness, undesired physiological stress on the body and aggressiveness are common scenario faced by occupants due to lack of quality sleep and bad thermal comfort conditions (Yazeed and Halil, 2018).

Findings of studies like Yazeed and Halil, (2018), Hamza, Adamu and Saeed (2022), Adedayo, Ayuba, Oyetola, and Buhari (2013), Umar and Halil (2018), as well as Abdullahi (2020) show that buildings in hot-dry climate of Nigeria are faced with challenges related to natural daylighting, natural ventilation, and indoor thermal comfort. Bioclimatic design on the other hand is considered the epitome of architectural innovation, as it integrates the interdependent connection between the built environment and natural components, to create a unified and functional architecture. Bioclimatic design is an approach to the design of buildings and landscapes based on the local climate (Watson, 2017). It optimises interactions between a building and its environment, thus reducing heating and cooling needs for improved occupant's comfort. The relationship between architecture, climate, and human comfort is a major concern in energy-efficient designs (Musa, Muhammed, and Abbas, 2022).

For a comfortable indoor environment to be achieved, the microclimate analysis of the local context in which the design would be sited should be carried out and properly integrated (Abdullahi, 2020). However, the existing literature lacks a solid, context-specific justification for applying bioclimatic design principles to various building typologies in northwestern Nigeria's hot-dry climate, leaving a gap in understanding how custom microclimatic strategies can improve indoor thermal comfort in the region. Thus, this research is set to investigate the relationship between students' perception of indoor thermal comfort and bioclimatic design in Northwestern Nigerian universities' postgraduate hostels.

Indoor Thermal Comfort

Thermal comfort is the state of mind of an individual that expresses satisfaction or dissatisfaction of their indoor space regarding temperature and climatic conditions (Wodu, Weli, and Nwagbara, 2020). Djongyang, Tchinda, and Njomo (2010) further define thermal comfort as a subjective state of mind of an individual expression of satisfaction with the thermal environment they are in. Thermal comfort level is influenced by objective factors, such as air temperature, air movement, relative humidity, and surrounding objects, temperature and subjective factors, such as age, sex, health and geographical origin, which determine how cold or hot an individual feels in an environment (Kameni, Tchinda, and Ricciardi, 2023). These factors can be manipulated to improve the thermal comfort level of the occupants. Thermal comfort is subjective and varies from one individual to another, however, there are objective factors that influence the general perception of thermal comfort.

Bioclimatic Design with Consideration for Hot-Dry Climate

The term "bioclimatic architecture" was coined by the Olgyays brothers in the 1960s as it defines a design approach which takes advantage of climate through the application of the appropriate design elements and building technologies to achieve energy efficiency and comfortable indoor conditions (Nnaemeka-Okeke, Okeke, Okwuosa and Sam-Amobi, 2019; Ayinla, Olaniyan and Okeyinka, 2013). Bioclimatic design principles are based on the understanding of site climatic conditions through the analysis of factors which include solar radiation, temperature, rainfall, sunshine, humidity, wind direction and velocity with the aim of creating buildings in harmony with their environment (Peter, 2016). Jamal and Maisa (2016) define bioclimatic architecture as a design approach that integrates climate considerations to achieve thermal comfort. It is an approach that adapts to natural and environmental conditions of a site, showcasing functional mastery, thoughtful selection of materials, forms, and architectural elements (Tri, Purwanita and Sarah, 2020). Bioclimatic architecture harmonizes with nature, considering climate and environmental conditions, to create thermally comfortable buildings for occupants (Nnaemeka-Okeke, Okeke, Okwuosa .and Sam-Amobi,2019).

The northwest geopolitical zone has a hot and dry tropical savanna climate with scorching temperatures, limited rainfall, and distinct dry and wet seasons, impacting both the region's ecology and the daily lives of its inhabitants. Relentless sun rays dominate the region as the average annual temperature is 28°C. The highest recorded temperature was 33°C in May, and the lowest was in January. Intense heat is felt from March to May, but an unexpected change occurs after sunset. The region experiences substantial temperature fluctuations between day and night. The wet season, from May to September, brings most of the annual precipitation, ranging from 500mm to 1000mm. August is the wettest month, while December is the driest. August is also the most humid month, with an average humidity of 80% (Climate in Northwest Nigeria, 2024). The vegetation in the Northwest region is affected by the combination of heat and aridity as the area is mostly covered by savannas, which are defined by their scattered trees and drought-resistant shrubs.

Buildings in hot-dry climates require specific design considerations such as solar protection, controlled window sizes, substantial thermal inertia, protection from hot-dry and dusty winds (Abdullahi, 2020). Incorporating patios and central courtyards to shade the building during the day and allow heat dissipation at night enhances the overall indoor thermal comfort and reduces heat gain.

In view of the harsh climatic conditions associated with the Northwest Nigeria Climate (Abdullahi, 2020), a brief review of integration of some bioclimatic design principles to reduce the impact of the weather elements in the climatic region are referenced below. These design principles include Cooling strategy (Nnaemeka-Okeke, Okeke, Okwuosa and Sam-Amobi, 2019; Barbara, 2015), Passive design (Kamal, 2012), Solar Shading (Olaniyan, Adebisi and Onigbogi, 2023; Olaniyan, Sulaiman, and Onigbogi, 2023; Abdullahi, 2020; Tri et al, 2020; Peter, 2016), Building Orientation (Olaniyan, Onigbogi, and Sulaiman, 2023; Jain, Jain, and khare, 2018; Akande, 2010), Thermal Mass Effect (Olaniyan, 2023a; Abdullahi, 2020; Umar and Halil 2018; Aminu, 2015), appropriate Window and Opening sizes (Lechner, 2014;

Koenigsberger et al., 1973), Cross Ventilation (Elwan and Rizk, 2018; Lechner, 2014), Evaporative cooling (Sonawane, Dube, Chaudhari, Sonawane, and Patil, 2015; Lechner, 2014), appropriate Landscaping (Girei, Dodo, Abdul, Bornoma, Abubakar, and Kawuwa, 2013) as well as integration of appropriate Renewable energy sources (Olaniyan, 2023b; Abdullahi, 2020). Integration of each of these design principles towards arriving at comfortable indoor living conditions in the region and other related tropical environments are well illustrated by the respective authors.

Study Area

The study area, Northwest Nigeria lies between latitude 11°N and 14°N, as well as longitude 6°15'E and 12°10'E. This region is characterized by a hot and dry climate with average temperatures ranging from 24ºC to 35ºC and annual rainfall varying between 900mm and 1400mm (Mashilo, Shimelis, & Ngwepe, 2025; Salihu, Olukunle, Adenubi, Mbaoji & Zarma, 2018). The northwest geopolitical zone has a hot and dry tropical savanna climate with scorching temperatures, limited rainfall, and distinct dry and wet seasons, impacting both the region's ecology and the daily lives of its inhabitants. Relentless sun rays dominate the region as the average annual temperature is 28°C. The highest recorded temperature was 33°C in May, and the lowest was in January. Intense heat is felt from March to May, but an unexpected change occurs after sunset. The region experiences substantial temperature fluctuations between day and night. The wet season, from May to September, brings most of the annual precipitation, ranging from 500mm to 1000mm. August is the wettest month, while December is the driest. August is also the most humid month, with an average humidity of 80%. The vegetation in the Northwest region is affected by the combination of heat and aridity as the area is mostly covered by savannas, which are defined by their scattered trees and drought-resistant shrubs (Gabriel et al, 2023; Abdussalam, et al, 2014).

Research Method

This study employed a mixed method approach that investigated bioclimatic performance of postgraduate student hostels in the Northwestern Nigeria Universities. The research employed a descriptive design approach which combined quantitative and qualitative data for better comprehension of the effectiveness of the hostel buildings in providing a comfortable indoor thermal environment for its users. From the existing sixteen (16) universities (Federal and State), only three with purpose built postgraduate students' hostels were selected through purposive sampling procedure. Table 3.1 and 3.2 shows the list of state and federal universities in Northwest Nigeria and those selected with a purpose-built postgraduate hostel, number of student occupants per room and total number of rooms per hostel

Table 3. 1: List of state and federal universities in Northwest Nigeria

SN	Name	Location	Year of Establishment	Selection
1	Kaduna State University	Kaduna State	2004	■
2	Aliko Dangote University of Science and Technology	Kano State	2000	□
3	Sule Lamido University	Jigawa State	2013	□
4	Kebbi State University	Kebbi State	2006	□
5	Umar Musa Yar' Adua University	Katsina State	2006	□
6	Sokoto State University	Sokoto State	2009	□
7	Zamfara State University	Zamfara State	2018	□
8	Shehu Shagari University	Sokoto State	2022	□
9	Sa'adatu Rimi University of Education	Kano State	2023	□
Kaduna State University and Aliko Dangote University of Science and Technology are the oldest state universities in the Northwest. Only Kaduna State University has a purpose-built postgraduate hostel.				
1	Ahmadu Bello University	Kaduna State	1962	■
2	Bayero University	Kano State	1975	■
3	Federal University Dutse	Jigawa State	2011	□
4	Federal University Birnin Kebbi	Kebbi State	2013	□
5	Federal University Dutsen Ma	Katsina State	2011	□
6	Usman Danfodiyo University	Sokoto State	1975	□
7	Federal University Gusua	Zamfara State	2013	□
ABU and BUK are the oldest universities in the northwest region, with a long history of postgraduate education and they are the largest with significant postgraduate student populations.				

Source: researcher (2024)

Table 3. 2: Selected Universities PG Hostel Analysis

Sn	Name	No of Pg Hostels	Selection	No of Rooms	No of Occupants	
1	Ahmadu Bello University	3	1	56	2	
2	Bayero University	3	1	56	2	
3	Kaduna State University	1	1	52	2	
	Total population					332

Source: researcher (2024)

The study consists of two sections involving questionnaire survey and building survey (using bioclimatic design checklist). Data collections for the two sections were done simultaneously considering time allocated for access to the building premises. The residence records for the resident students were obtained from the hostels' administrators. Given the total population of 332 across the identified hostels, a sample size of 178 (n=178) was determined to be representative, using Cochran formula (Opegbemi, Olaniyan and Adeyemi, 2025; Cochran, 1977). However, to mitigate the risk of non-response. Systematic sampling method was employed with layouts of the hostel rooms (i.e. room numbers, floor by floor), from which participants were randomly selected. Thus, a set of 178 questionnaires was administered on the identified resident students, with the return rate of about 85% after completion (i.e. 151 were returned after completion). While a section of the questionnaire investigated user's perception of indoor thermal comfort, the building survey section focused on assessing the application of bioclimatic design features with respect to indoor thermal regulations. Each design parameter was assigned with a 5-point Likert scale from poor to excellent. Quantitative data were analysed using Statistical Package for the Social Sciences software (SPSS) and presented on frequency Table. Qualitative data were analysed using thematic analysis. Given below is a description of each of the three universities selected for the study:

(i) Kaduna State University is situated in Kaduna State, Northwestern Nigeria. It has two campuses situated in Kaduna and Kafanchan. The Postgraduate hostel is situated at the main campus in Ungwan Rimi, Kaduna. Plate 4.1 and Figure 4.1 show the picture of the hostel, and the floor plans

Plate 4. 1: Front view of the hostel
Source: Researcher's fieldwork (2024)

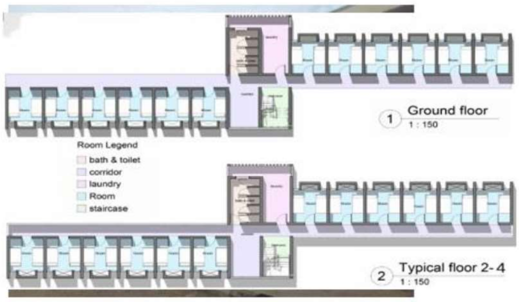

Figure 4. 1: Floor plans.
Source: Researcher's fieldwork (2024)

Case Study Two: Mohammed Rumfa Hall, Block N, Bayero University, Kano (B.U.K)

Bayero University is situated in Kano State, Northwestern Nigeria. It was founded in 1962. The university has eighteen (18) faculties with over ninety (90) departments. Muhammed Rumfa hostel is situated at the old campus just outside the ancient walls of Kano city. Plate 4.2 and Figure 4.2 show the picture of the hostel and floor plans

Plate 4. 2: Front view of the hostel.
Source: Researcher's fieldwork (2024)

Figure 4. 2: Floor plans.
Source: Researcher's fieldwork (2024)

Case Study Three: Queen Amina Hall Postgraduate Block, A.B.U Zaria

Ahmadu Bello University is situated in Zaria, Kaduna State, Northwestern Nigeria. It was founded in 1962. The university has twelve (12) faculties with over eighty-two (82) departments, having two campuses in Samaru and Kongo. Queen Amina Hall hostel is situated at the main campus, opposite Student Social Centre and Basketball Court. Plate 4.3 and Figure 4.3 show the pictures of the hostel and floor plans

Plate 4. 3: Front view of the hostel.
Source: Researcher's fieldwork (2024)

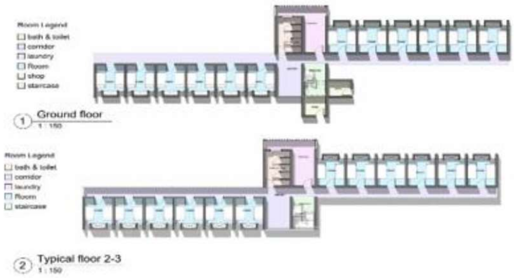

Figure 4. 3: Floor plans.
Source: Researcher's fieldwork (2024)

Results and Discussion

Assessment of Bioclimatic Design Features of Case Studies Buildings.

In this sub-section of the study, assessment was done using a building checklist adopted from Abdullahi (2020) and Hamza et al (2022) and further modified with a view to understanding the bioclimatic design features employed in the buildings. The variables used to assess the buildings are building form, building orientation, ventilation and openings, daylighting and shading, site landscaping, building envelope, building material, and water-cooling elements.

Tables 4.1 shows assessment and analysis regarding the postgraduate hostels in the study area. A 5-point Likert scale was used to assess the buildings. This is done by assigning values of weight to different degrees of responses as shown:

Poor = 1; Fair = 2; Good = ;3 Very good = 4; Excellent= 5.

Table 4.1 presents the assessment of bioclimatic design features across three postgraduate residential buildings. The results reveal excellent performance in building form and daylighting. However, poor performance is observed in building orientation, cross ventilation, local building materials, and water-cooling elements. Moderate performance in shading devices, site landscaping, and building envelopes.

Overall, the total mean weight value is 3.1, indicating while there is room for improvement, the buildings demonstrate a fair level of sustainability and indoor thermal comfort.

Table 4. 1: Summary of the assessment of bioclimatic design features of case studies.

Bioclimatic Design Feature		**K.A.S.U PGH**	**B.U.K MRH**	**A.B.U QAH**	**Mean Weight value**
Building form	Shape of the building composition	5	5	5	**5**
Building orientation	Position of building in relation to climate	1	5	1	**2.3**
Ventilation and openings	Cross ventilation	5	1	1	**3.5**
	Stack-effect ventilation.	1	5	5	
	100% operable window openings	4	5	5	
Daylighting and shading	daylighting	5	4	4	**3.8**
	Use of shading devices	2	4	4	
Site Landscaping	Use of soft landscape	3	3	4	**3.3**
Building envelope	Wall (external wall treatments that are bright in color to radiate heat and lessen heat absorption)	4	4	4	**3.5**
	Roof (use of lighter, cooler roofs that reflect sunlight and absorb less heat, clay, terra cotta, metal, and slate)	3	3	3	
Building material	Use of local materials	1	1	1	**3.0**
	Use of modern materials	5	5	5	
Water: cooling element	Evaporative cooling	1	1	1	**1.0**
	Total mean weight value				**3.1**

Source: Researcher's fieldwork (2024)

Users' Perception of Indoor Thermal Comfort

In this sub-section of the study, data was analyzed using SPSS with a view to understand the multitude of respondents' responses on perception of indoor thermal comfort of their hostel rooms. The indicators used to measure the variable (indoor thermal comfort) are daytime temperature, night-time temperature and air circulation.

Table 4.2 shows perception with indoor thermal comfort regarding the postgraduate hostels in the study area. A 5-point Likert scale was used to weigh the degree of perception of indoor thermal comfort. This is done by assigning values of weight to different degrees of responses as shown:
Never = 1; Rarely = 2; Sometimes = 3; Often = 4; Always = 5.
Very dissatisfied = 1; Somewhat dissatisfied = 2; Neutral = 3 Somewhat satisfied = 4; Very satisfied = 5

Table 4. 2: Perception index of thermal comfort

Indicator	Ranking Frequency (percentage)						Mean	Std. Deviation
	N	5	4	3	2	1		
Daytime temperature	151	**28** 18.7	**65** 43.3	**54** 36.0	**3** 2.0	**0** 0	3.79	0.765
Nighttime temperature	151	**0** 0	**8** 5.3	**63** 42.0	**78** 52.0	**1** 0.7	2.52	0.610
Room air circulation	151	**6** 4.0	**39** 26.0	**41** 27.3	**41** 27.3	**23** 15.3	2.76	1.121

Source: Researcher's fieldwork (2024)

It is observed in Table 4.2 that the mean score for daytime temperature is 3.79, indicating that respondents generally feel too hot during the daytime "often". The ranking frequency shows that 65% of respondents feel hot "often", while 28% feel hot "always", and only 3.6% feel hot "rarely".

In contrast, the mean score for nighttime temperature is 2.52, suggesting that respondents generally feel cold during the nighttime "sometimes", but closer to "rarely". The ranking frequency reveals that 63% of the respondents feel cold "sometimes", while 42% feel cold "rarely". Only 8% feel cold "often".

The mean score for room air circulation is 2.76, indicating that respondents are generally "neutral" to "somewhat dissatisfied" with the room air circulation. The ranking frequency shows that 41% of respondents are "neutral" while 39% are "somewhat satisfied". However, 27.3% are "somewhat dissatisfied", and 15.3% are "very dissatisfied".
However, these findings suggest that there may be opportunities to improve indoor thermal comfort during both daytime and nighttime, as well as room air circulation.

Discussion

The assessment of the buildings' bioclimatic features reveals excellent scores in building form, and daylighting, but poor scores in building orientation, cross ventilation, and use of local building materials. When considering the user perception analysis, a relation between the buildings' bioclimatic design features and user experience becomes apparent.

The buildings good form and daylighting may contribute to the high frequency of respondents feeling hot "often" during the daytime, suggesting that the buildings' design effectively harnesses natural sunlight and heat. However, the poor building orientation and lack of cross ventilation may be contributing factors to the respondents feeling cold "sometimes" during the nighttime, indicating inadequate passive heating or insulation. This finding validates the opinion of Abdullahi (2020) on the research titled "Evaluation of Bioclimatic Principles in Design of office Building in Hot Dry Climate Region of Nigeria" where contributory role of excessive use of hard landscape towards indoor thermal discomfort was identified in the study area. Additionally, buildings with suboptimal orientation towards solar exposure and prevailing winds often resulted in excessive heat gain, leading to high levels of users' dissatisfaction with thermal comfort (Olaniyan, Adebisi, and Onigbogi, 2023).
Furthermore, the poor performance in cross ventilation and lack of local building materials may be linked to the respondents' neutral to somewhat dissatisfied response to room air circulation. This suggests that the building's design may not be effectively utilizing natural ventilation strategies, leading to stagnant air and reduced user satisfaction. This finding aligns with the findings of Umar and Halil (2018), that any building designed for good thermal comfort typically uses materials with high thermal resistance, enhanced with north-south orientation of its longer sides.

The relationship between the buildings' bioclimatic performance and user perception highlights opportunities for improvement. By addressing the building's orientation, cross ventilation, and incorporation of local building materials, the building's design can better support user indoor thermal comfort and satisfaction. By leveraging the strengths of the building's form and daylighting while addressing its weaknesses, the building can provide a more comfortable and sustainable environment for its users.

Conclusion

This study highlights and assesses the importance of indoor thermal comfort on occupants' satisfaction in postgraduate hostel buildings. The research findings show a lack of proper bioclimatic design principles integration, which indicate a negative impact on indoor thermal comfort perception in the student hostels. Indoor thermal comfort levels can significantly be improved through effective implementation of bioclimatic design strategies. Thus, there is the need for Architects and other professionals in the building industry to identify the factors affecting indoor thermal comfort in the early phase of the design process with a view to addressing them and ensuring their utilization in the post design phase. Such factors include: adoption of East-West long axis building orientation with compact courtyard planning; introduction of open spaces for breeze penetration, but with adequate protection from hot and cold winds; adoption of single banked rooms with permanent provision for air movement; provision for large openings (ranging between 40% - 80% of the walling areas, but with protection from rain and direct sunlight); positioning of openings in the North and South facing walls; use of heavy external and internal walls; adoption of heavy roofs with over 8-hour heat time-lag, and; provision of adequate rainwater drainage, effective evaporative cooling techniques, and adequate soft landscape. All these would have positive impacts on strategies aimed at improving the indoor thermal comfort particularly, with regard to the peculiarities of the study area, Hot-Dry Northwestern region of Nigeria.

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