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Evaluating the Appropriateness of Passive Techniques Used in Achieving Thermal Comfort in Buildings: A Case of Lautech College of Health Sciences, Ogbomoso

Ilelabayo I. Adebisi, Yetunde R. Okeyinka, Abdulrasaq K. Ayinla

***Abstract*—**Architectural design is a complex process especially when the issue of user's comfort, building sustainability and energy efficiency needs to be addressed. The current energy challenge and the seek for an environment where users will have a more physiological and psychological comfort in this part of the world have led various researchers to constantly explore the concept of passive design techniques. Passive techniques are design strategies used in regulating building indoor climates and improving users comfort without the use of energy driven devices. This paper describes and analyses the significance of passive techniques on indoor climates and their impact on thermal comfort of building users using LAUTECH College of health sciences Ogbomoso as a case study. The study aims at assessing the appropriateness of the passive strategies used in achieving comfort in their buildings with a view to evaluate their adequacy and effectiveness and suggesting how comfortable their building users are. This assessment was carried out through field survey and questionnaires and findings revealed that strategies such as Orientation, Spacing, Courtyards, window positioning and choice of landscape adopted are inadequate while only fins and roof overhangs are adequate. The finding also revealed that 72% of building occupants feel hot discomfort in their various spaces and hence have the urge to get fresh air from outside during work hours. The Mahoney table was used to provide appropriate architectural design recommendations to guide future designers in the study area.

***Keywords*—**Energy challenge, passive cooling, techniques, thermal comfort, users comfort.

I. Introduction

THE seek for effective comfort in buildings has been a critical point of focus in the history of human settlement. In the past and before the advent of mechanical driven devices, attention of builders and designers was concentrated on natural means of achieving desirable comfort in buildings i.e., before the evolvement of designs, an in-depth study of the micro climate was made to guide the choice of appropriate natural cooling techniques. However, recently, much attention has been shifted away from thermal comfort and functionality to aesthetics. The success of buildings is no longer determined by their adaptation to climatic conditions, rather they have become expressions of the owners' wealth and profligacy [1]. This has caused a prevalent and abusive use of active driven mechanical devices such as fans, heaters and air conditioning systems to achieve comfort in buildings which have not only caused a psychological discomfort for building users but have constituted series of environmental problems as a result of severe energy consumption and CO_2 emissions and have also led to energy crises as a result of low generation, high cost and epileptic supply in this part of the world.

Reference [16] indicated that buildings consume about 40% of the world's energy production. As a result, buildings are involved in the production of more than one-third of all the greenhouse gas emissions and environmental degradation leading to physiological and psychological discomfort of building users [13],[15].

The current energy challenge and the demand for a more comfortable environment where working or pleasure tasks can be carried out unhindered physically and psychologically across the world have led to various authors and researchers constantly exploring the concept of passive designs [2].

Passive cooling (design) refers to technologies or design features used to cool buildings naturally without power consumption i.e. without the use of active driven mechanical devices. Reference [3] noted that passive design techniques, if effectively implemented, is one key way which can allow a drastic reduction in building energy consumption. Reference [4] also indicated that it is a significant way of providing a comfortable environment where physical and psychological tasks can be carried out unhindered.

To achieve appropriate passive design techniques in warm humid regions, certain parameters have been highlighted by various scholars. These parameters include choice of proper site of the buildings, developing proper shape and size for the buildings, proper layout and orientation of the buildings, providing good ventilation, providing adequate window sizes for natural ventilation, providing appropriate vegetation, selecting adequate building fabrics etc. [1], [5], [6].

This paper evaluates the appropriateness of passive design strategies adopted in buildings in LAUTECH College of Health Sciences, Ogbomoso. A thermal comfort survey was conducted on users to make comparison with field results and appropriate architectural solutions were recommended using the Mahoney table. This is in a bid to enlightening future

I. I. Adebisi is with the Department of Architectural Technology, Osn State Polytechnic, P.M.B 301, Iree, Osun State, Nigeria (Corresponding author, phone: +234 703 503 7254; e-mail: ilelabayoadebisi@gmail.com).

Y. R. Okeyinka and A. K. Ayinla are with the Department of Architecture, Ladoke Akintola University of Technology, P.M.B 4000, Ogbomoso, Oyo State, Nigeria (e-mail: yrokeyinka@lautech.edu.ng, rasaqayinla@gmail.com).

designers on how to improve on thermal comfort through passive means and save users from the prevalent use of active energy.

II. Study Context: LAUTECH College of Health Sciences, Ogbomoso

Ladoke Akintola University of Technology (LAUTECH), College of Health Sciences, Ogbomoso is an Academic facility housing the health related departments of the University. It is located along Oyo-Ilorin road in Ogbomoso, Oyo state, sharing boundary with Ogbomoso North Local government secretariat and not too far from the University main campus. The facility covers approximately 20 acres of land with a total of 11 buildings.

Ogbomoso lies on latitude 8º10¹ North of the equator and longitude 4º10¹ East of the Greenwich Meridian within the derived Savannah region of Nigeria. It is the second largest city in Oyo State, South Western part of Nigeria and serves as the gateway to the northern part of the country from the southwest [4].

Climate

Like every other towns in Nigeria, Ogbomoso is in the warm humid zone [4]. The South west trade wind occurring for approximately 8 months in a year and the North-East trade winds occurring for approximately 4 months in a year are the two predominant driving factors bringing about the two distinct seasons experienced in the town - the wet or rainy season from April to October and the dry or harmattan season from November to March [4]. Reference [4] noted that like every other warm-humid zone, Ogbomoso is characterized by high temperature with the maximum temperature rising above 33 ^{o}C in some months, high humidity (humidity rising above 89% in some months), high rainfall and a relatively low wind velocity.

III. Methodology

Data on thermal comfort sensation were obtained with the use of questionnaires to know the physiological and psychological comfort of users and evaluation of passive design techniques adopted in their buildings was achieved by physical inspection.

Appropriate design recommendations for future designs were given with the use of the Mahoney table. This was achieved by subjecting the climate of Ogbomoso to the Mahoney table for proper climate analysis.

Focus.

Out of a total of 11 buildings in the study area, the study is directed at only the eight academic buildings housing lecture rooms, offices and laboratories. This is because the remaining three buildings are residential and are underutilized.

IV. Result Analysis and Discussion

Inferential and statistical analyses were used for illustrating the data. The data are illustrated below.

Building Orientation

To achieve a good thermal comfort through passive means devoid of mechanical cooling devices in buildings in the warm humid regions, proper building orientation should be ensured [5]. References [1] & [7] stressed that reducing exposure of buildings to the sun will not only help to achieve proper orientation but will also enhance cool breeze penetration and minimize hot radiation received by building walls. This is best achieved by orientating buildings with their longer sides on East-West axis [1]. However, findings revealed that all buildings in the study area are orientated with their longer sides along North-South axis. The implication of this is that all the buildings are exposed to solar radiation which heats up their interiors thereby causing thermal discomfort for the users. Building orientation in the study area can hence be said to be inappropriate.

Location and Orientation of Windows

Ventilation is the replacement of used air in buildings with fresh ones from outside [8]. The amount of ventilation in buildings depends on the size and position of windows [9]. To achieve a good and effective exchange of air in buildings in the warm humid regions, windows should be located along north and south walls i.e. windows along east and west walls should be reduced or avoided [7]. However, it was observed that most windows in the study area are located on east-west walls in all buildings. This is because the buildings are badly orientated and most internal spaces are positioned along east-west axis. This will not only reduce breeze penetration but will also induce heat buildup in internal spaces, thereby causing hot discomfort for users.

Spacing

Buildings standing within the network of others affect each other in numerous ways including air circulation, through and about them. To provide effective and sufficient air circulation in warm humid regions, an open settlement pattern is the appropriate response. Reference [5] indicated that buildings should be scattered and separated with large free spaces between them, compacts design should be avoided and they should be arranged in a line across the prevailing winds. Reference [4] also stressed that buildings should be spaced five times their height to ensure an adequate air circulation through and about them. However, studies revealed that only two buildings representing 25% of buildings in the study area benefitted from adequate free and open space, the remaining six representing 75% are closely built. Despite having heights ranging from between 12 and 20 meters, the average space between them is 6 meters. This implies that air movement around them will be hindered thereby causing hot discomfort for users.

Courtyard

Courtyards, especially central courtyard is one of the generic strategies available for architects and engineers in their quest to provide sustainable and environmental suitable buildings. Courtyards maximize the thermal interaction between buildings and their outdoor environment; control air movements and create their own individual microclimate [10].

Fig. 1 Building Spacing in the study area

Fig. 2 Hard landscape around buildings in the study area

Reference [7] analyzed that courtyards if properly designed, increase external window area and enhance physiological and psychological comfort of occupants. Furthermore, it is a major way of reducing active energy consumption in the warm humid regions because buildings may not require the use of mechanical cooling devices due to the fact that they will receive ventilation and lightning naturally from the courtyards. However, despite the important roles that courtyards play in achieving thermal comfort in buildings, it was observed that courtyard is hardly adopted in the study area as only one building representing 12.5% adopted courtyard concept while seven, 87.5%, do not have courtyards. This however led to the use of double banked walls and hence, forced openings to be created along internal corridors of 1.2 m in width in a bid to ensure cross ventilation in their spaces.

Landscape and Vegetation

Landscape and vegetation always play a vital role in the design of buildings; it is an effective means of protecting buildings from unwanted solar gains and redirecting wind flow to enter the house for natural ventilation design [1]. Soft landscape and vegetation are used to moderate the micro climate by preventing the sun's radiation from reaching the ground or the building because their surfaces absorb heat through evapotranspiration [5]. Proper landscape and vegetation do not only create more physically comfortable and energy conscious buildings but also provide greater psychological and aesthetic comfort.

Findings revealed that the area covered by grass (soft landscape) in the study area is minimal and far from buildings, hard landscape is noticed around buildings i.e., the surrounding of buildings is either tiled or paved; car parks which are tarred with bitumen are seen to be very close to buildings without trees to shield them from solar radiation and the massive road network on site cannot be over looked. This is a bad landscape choice because it further induces heat gains thereby heating up building interiors.

Shading with Fins and Overhangs

The high and intense solar radiation in the warm humid regions calls for buildings with large roof overhangs and fins. Fins could be vertical, horizontal or crate (combination of vertical and horizontal). Apart from their structural usefulness, fins and overhangs have been found to be one of the elements suitable for achieving thermal comfort in buildings through passive means.

Reference [11] stressed that fins and roof overhangs help to protect windows from direct sunrays, they cast shadows on walls and prevent them from getting heated up.

Studies revealed that egg-crate fins (combination of vertical and horizontal fins) are adopted in most of the buildings in the study area, appropriate window hood is used for protection against direct sunray in the lone building where fin is not adopted and roof overhang of not less than 600 mm is adopted in all buildings in the study area. To a great extent, this is a good passive technique choice.

Fig. 3 Egg-crate fins used on building walls in the study area

Shading with Trees and Shrubs

References [1] & [12] asserted that shading can lower the effective temperature experienced by building occupants by approximately 8 ^{o}C. Hence, it should be the first line of defence if ingress of solar gain is to be impaired. Vegetation and trees in particular, shade and reduce heat gain effectively [13].

High trees with wide shading crowns provide significant protection from solar radiation with the advantage to shade roof, walls and windows and can reduce surrounding air temperatures and therefore should be incorporated as much as possible into any landscape planning in the warm humid regions [5]. However, findings revealed that trees and shrubs as shading devices are not adopted in the landscape of the study area to protect buildings, thereby leaving them exposed to direct solar radiation.

Building Heights

In warm humid regions, there is need to minimize direct radiant heat from hitting buildings. Building heights should not exceed 2-storeys (3 floors) because higher buildings receive too much radiant heat from the sun thereby heating up the indoor spaces and causing hot discomfort for building users [5].

Studies show that out of eight buildings studied, two, representing 25%, are single floor, three, 37.5%, have three floors (2-storeys), two, 25%, have four floors (3-storeys) and one, 12.5%, has six floors (5-storeys). This means that only three, 37.5%, exceeds SKAT's recommendation while five, 62.5%, are in line with SKAT'S recommendation.

Building Shapes

Shape is a major factor to be considered if thermal comfort through passive means is to be achieved in the warm humid region. It is best to inculcate corners in walls (especially on eastern and western walls) to provide shade against direct sun rays [14].

Findings revealed that five buildings representing 62.5% have rectangle shapes and without corners, one, 12.5%, has corners on north and south walls and two, 25%, have irregular shapes and corners on east and west walls. The implication of this is that 75% of buildings in the study area are exposed to direct solar radiation, heating up the walls and causing hot discomfort in their interior spaces.

TABLE I
SUMMARY OF FIELD RESULTS

Adopted passive design techniques	Appropriate	Inappropriate
Orientation		✓
Location and orientation of windows		✓
Spacing		✓
Courtyards		✓
Landscape and vegetation		✓
Shading with fins and roof Overhangs.	✓	
Shading with trees and shrubs		✓
Building heights.	✓	
Building shapes.		✓

Thermal Comfort Sensation

Survey of thermal comfort sensation was done by administering questionnaires to building users. 50 questionnaires were administered to staff and students on campus, covering 34 males and 16 females, out of which 36 are students and 14 are staff. Questionnaire results show that 38 respondents representing 76% spend between 5-8 hrs in their office/lecture rooms per day while 12, 24%, spend below 5 hrs per day. 30 respondents, 60%, said that their office space/lecture rooms are not crossly ventilated while 20, 40%, said that their office/ lecture rooms are crossly ventilated.

Percentage of respondents that feel naturally comfortable in their various spaces without the need for active circulation systems is calculated to be 28 while 36 respondents, 72%, said that they feel either hot or extremely hot in their spaces and prefer cooler environments.

32 respondents (64%) said that they use artificial ventilation systems to supplement natural ones while in their office spaces/lecture rooms and have the urge to get fresh air from outside anytime active energy is out of supply. 18 respondents (36%) said they do not require artificial circulation systems. 36 respondents (72%) recommended a more natural circulation system/natural environment while 14 (28%) said more artificial circulation systems should be provided.

The thermal comfort survey results are in close agreement with the field results. The study has shown that the design strategies adopted for achieving comfort in buildings in LAUTECH College of health sciences, Ogbomoso is below the required gauge of comfort required by building users. The inappropriateness of adopted passive strategies in buildings in the University College had led to the low comfort level of users. This invariably led to severe and abusive use of artificial circulation such as fan and air conditioning systems to achieve desirable comfort in their buildings.

V. ARCHITECTURAL DESIGN RECOMMENDATIONS USING THE MAHONEY TABLES

Architectural design recommendations were given using the Mahoney table approach, in doing this, the climate of Ogbomoso was subjected to the Mahoney table for proper analysis and sketch design recommendations were deduced. This method had been used by various scholars. See Tables II-VII.

TABLE II
GEOGRAPHIC LOCATION OF OGBOMOSO

Location	Ogbomoso, Oyo state, Nigeria
Longitude	4° 10' East
Latitude	8° 10' North

TABLE III
AIR TEMPERATURE °C OF OGBOMOSO

	Jan.	*Feb.*	*Mar.*	*Apr.*	*May*	*Jun.*	*Jul.*	*Aug.*	*Sep.*	*Oct.*	*Nov.*	*Dec.*	*Highest*	*AMT*
Monthly Mean Max.	33.5	34.5	34.0	33.0	32.0	31.0	29.5	28.5	29.5	31.5	33.0	33.0	34.5	26.75
Monthly Mean Min.	19.5	20.5	23.0	22.5	22.0	21.5	21.5	21.0	21.0	20.0	19.0	21.0	19.0	15.5
Monthly Mean range.	14.0	14.0	11.0	10.5	10.0	09.5	08.0	07.5	08.5	11.5	14.0	12.0	*Lowest*	*AMR*

TABLE IV
HUMIDITY AND RAINFALL OF OGBOMOSO

REl. Humidity (%)	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*Jun.*	*Jul.*	*Aug.*	*Sep.*	*Oct.*	*Nov.*	*Dec.*	Total
Monthly mean Max. (a.m)	*65.71*	*68.16*	*73.27*	*77.11*	*80.76*	*84.66*	*89.16*	*85.85*	*85.51*	*86.04*	*83.06*	*74.23*	
Monthly mean Min. (p.m)	*40.43*	*37.20*	*46.75*	*60.78*	*66.03*	*69.60*	*72.76*	*73.27*	*73.33*	*68.54*	*54.26*	*44.60*	
Average	*53.07*	*52.68*	*60.01*	*68.95*	*77.40*	*77.13*	*80.96*	*79.56*	*77.42*	*77.29*	*68.66*	*59.42*	
Humidity Group (HG)	*3*	*3*	*3*	*3*	*4*	*4*	*4*	*4*	*4*	*4*	*3*	*3*	
Rainfall (mm)	*11.76*	*20.79*	*82.14*	*128.51*	*167.02*	*187.58*	*171.87*	*137.58*	*237.65*	*198.03*	*79.19*	*13.21*	*1435.33*

TABLE V
DIAGNOSTIC TABLE

		Jan.	*Feb.*	*Mar.*	*Apr.*	*May*	*Jun.*	*Jul.*	*Aug.*	*Sep.*	*Oct.*	*Nov.*	*Dec.*
Humidity group		*3*	*3*	*3*	*3*	*4*	*4*	*4*	*4*	*4*	*4*	*3*	*3*
Temperature (oC)													
Monthly mean Max.		33.5	34.5	34.0	33.0	32.0	31.0	29.5	28.5	29.5	31.5	33.0	*33.0*
Day Comfort	*Max*	*29*	*29*	*29*	*29*	*27*	*27*	*27*	*27*	*27*	*27*	*29*	*29*
	Min	*23*	*23*	*23*	*23*	*22*	*22*	*22*	*22*	*22*	*22*	*23*	*23*
Monthly mean Min.		19.5	20.5	23.0	22.5	22.0	21.5	21.5	21.0	21.0	20.0	19.0	21.0
Night Comfort	*Max*	*23*	*23*	*23*	*23*	*21*	*21*	*21*	*21*	*21*	*21*	*23*	*23*
	Min	*17*	*17*	*17*	*17*	*17*	*17*	*17*	*17*	*17*	*17*	*17*	*17*
Thermal Stress													
	Day	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*H*
	Night	*C*	*C*	*-*	*-*	*H*	*-*	*-*	*-*	*-*	*C*	*C*	*C*

TABLE VI
INDICATOR TABLE

	Jan.	*Feb.*	*Mar.*	*Apr.*	*May*	*Jun.*	*Jul.*	*Aug.*	*Sep.*	*Oct.*	*Nov.*	*Dec.*	*Total*
Humid													
H1 Air movement (essential)	⌋	⌋	⌋	⌋	⌋	⌋	⌋	⌋	⌋	⌋	⌋	⌋	*12*
H2 Air movement (desirable)													*0*
H3 Rain protection									⌋	⌋			*2*
Arid													
A1 Thermal storage													*0*
A2 Outdoor sleeping													*0*
A3 cold-season problem													*0*

TABLE VII
RECOMMENDED SPECIFICATIONS

Indicator total from Table VI						***Recommendations***	
Humid			*Arid*				
H1	*H2*	*H3*	*A1*	*A2*	*A3*		
12	*0*	*2*	*0*	*0*	*0*		
						Layout	
			0 - 10		*5 - 12*	*1. Buildings orientated on east-west axis to reduce exposure to sun*	✓
			11- 12		*0 - 4*	*2. Compact courtyard planning*	
						Spacing	
11 or 12						*3. Open spacing for breeze penetration*	✓
2 - 10						*4. As A3, but protect from cold hot wind*	
0 or 1						*5. Compact planning*	
						Air movement	
3 - 12			*0 - 5*			*6. Rooms single banked. Permanent provision for air movement*	✓
1 or 2	*2 - 12*		*6 - 12*			*7. Double- banked rooms with temporary provision for air movement.*	
0	*0 or 1*					*8. No air movement requirement.*	
						Openings	
			0 to 1		*0*	*9. Large openings, 40 – 80 % of N and S walls, at body height*	✓
			11 or 12		*0 or 1*	*10.Very small openings, 10 – 20 %*	
			Any other conditions			*11.Medium openings, 20 -40 %*	
						Walls	
			0 – 2			*12.Light walls; short time lag*	✓
			3 - 12			*13.Heavy external and internal walls*	
						Roofs	
			0 – 5			*14.Light insulated roofs*	✓
			6 - 12			*15.Heavy roofs; over 8 hours' time lag*	
						Outdoor sleeping	
				2 - 12		*16.Space for outdoor sleeping required*	
						Rain penetration	
		3 - 12				*17.Protection from heavy rain needed*	

Design Recommendations According to the Mahoney Tables

After analyzing the climatic data in Tables II-VII, some sketch design recommendations were formulated, giving recommendations on building layouts, spacing, air movements, openings, walls, roofs and rain protections. The following is the summary of design recommendations for the study area.

a. Layout: Buildings orientated on east-west axis to reduce exposure to sun
b. Spacing: Open space for breeze penetration
c. Air movement: Rooms single banked. Permanent provision for air movement
d. Openings: Large openings, 40-80%, positioned at N and S walls and at body height
e. Walls: Light walls; short time lag
f. Roofs: Light insulated roofs

VI. Conclusion

The outcome of the study has clearly revealed that building designs in LAUTECH College of health sciences did not conform to design recommendations for the region.

The study revealed that buildings in the study area are orientated with their longer sides along the north-south axis; this is against the east-west axis recommended for the region. The implication of this is that their buildings are exposed to direct solar radiation.

It was also observed that buildings in the study are closely built; they are ornamented with hard landscape and courtyard system is hardly adopted. Building shapes adopted does not offer shading against direct solar rays just as trees were not planted to shield them. The only passive technique seen to be adequate is the fins and roof overhang systems. Interviews conducted on building users revealed that 60% of their spaces are not crossly ventilated and 72% of them feel hot discomfort during work hours if active energy is not used as supplement. Apparently, this has not only led to a severe and abusive use of active energy in a bid to achieve thermal comfort in their spaces but has also led to physiological and psychological discomfort for building users as 64% of them said they always have the urge to get fresh air from outside during work hours whenever active energy is out of supply.

VII. Recommendations

It is recommended that designers and builders in the warm humid regions should be encouraged to take the issue of passive design techniques into consideration when designing as it is one key method of achieving thermal comfort in buildings

Design decisions should be made at the early part of the design stage to cater for natural means of achieving thermal comfort and major elements such as orientation, window positioning (fenestration), spacing, courtyards and landscape should be concentrated on rather than minor ones like fins and overhangs.

Finally, if possible, research in this area should be encouraged through grants and conferences.

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Ilelabayo, I. Adebisi (B.Tech, M.tech) Studied Architecture at the Federal University of Technology Akure. He bagged his M.Tech in the same institution and is currently licensed to Practice Architecture in Nigeria.

He currently lectures in the Department of Architectural Technology, Osun State Polytechnic Iree. His research focus is on Bioclimatic Architecture, Architectural climatology and Sustainable designs.

Yetunde, Y. Okeyinka (B.Tech, M.Sc, Ph.D, Mnia) Studied Architecture at

the Ladoke Akintola University of Technology, Ogbomoso. She obtained her M.Sc and Ph.D at the Obafemi Awolowo University Ile-Ife, Osun State.

She is a member of the Nigeria Institute of Architects and currently lectures in the Department of Architecture, Lautech, Ogbomoso. Her research focus is on Housing and Traditional Architecture.

Abdulrasaq, K. Ayinla (B.Tech, M.tech, M.Phil, Mnia) Studied Architecture to M.tech level at the Ladoke Akintola University of Technology, Ogbomoso. He bagged his M.Phil at Obafemi Awolowo University Ile-Ife, Osun State.

He is a member of the Nigeria Institute of Architects and currently lectures in the Department of Architecture, Lautech, Ogbomoso. His research focus centered on Bioclimatic Architecture, Architectural climatology and Sustainable designs.