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ACHIVEMENT OF ENVIRONMENTALLY FRIENDLY NEIGHBOURHOODS IN MAIDUGURI

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Abstract: *Maiduguri, being one of the hottest regions in Nigeria with an approximate temperature range of 29°C to 50°C is unbearable to live in during the peak of the hot season, usually between March and September annually. The traditional ways of protection from this harsh weather are rather inadequate or overwhelmed due to factors like industrialisation, modernisation and rapid urbanisation. The few existing measures for battling this problem are either non-functional or neglected. As such, it has greatly affected virtually every other activity in the metropolis, which has served as a major retarding factor, impeding the effective achievement of a comfort zone and hence, a sustainable environment. This paper, therefore, examines the household characteristics and their neighbouring surroundings. This was achieved by distributing questionnaires in Umarari and Bolori settlements totalling 18. The data was analysed, and solutions were provided to achieve comfort and a conducive environment.*

Keywords: *Comfort, thermal performance, ventilation, orientation.*

INTRODUCTION

Urban development has serious effects on global environmental quality, including the quality of air, increase in temperature and traffic congestion. Buildings are related to global changes in the increase of urban temperatures, the rate of energy consumption, the increased use of raw materials, pollution and the production of waste, conversion of agricultural land to developed land, loss of biodiversity and water shortages (Santamouris et al., 2001). Buildings provide the microclimate required for human existence and define spaces for all human activities. As observed by Lawal (2008), buildings are essential modifiers of the microclimate, a space isolated from climate temperature and humidity fluctuations, sheltered from prevailing winds and precipitation, and with enhancement of natural light. Urban areas without high climatic quality use more energy for air conditioning when the weather is hot and even more electricity for lighting. Moreover, discomfort and inconvenience to the urban population due to high temperatures, wind tunnel effects in streets and unusual wind turbulence due to incorrectly designed high-rise buildings are widespread (Bitan, 1992). This has led to the creation of a climatic, environmental problem known as the urban "heat island", which is a climatic phenomenon in which urban areas have higher air temperatures than their rural surroundings (Shahmohamadi et al., 2010). It has also been observed that the effect of extreme climatic conditions, which is discomfort, could be reduced by the provision of environmental services (Luff, 1984). Parameters like temperature, relative humidity and solar radiation should be considered in building general neighbourhood design (Doxiadis, 1996).

Thermal performance and the buildings of a tropical environment

The climate-responsive design of buildings and the surrounding environment is crucial not only for user comfort and energy efficiency but also for the conservation of vital planetary resources (La Roche & Liggett, 2001). environment-conscious design necessitates a comprehensive study of the local environment and the implementation of various tactics and systems to establish a favourable microclimate with minimal active energy usage. Jackson and Jackson (1997) identified several methods for moderating the indoor climate within buildings: (1) selecting an appropriate site, (2) designing suitable shapes and sizes, (3) ensuring proper orientation, (4) facilitating effective ventilation, (5) incorporating adequate window sizes for natural airflow, (6) integrating appropriate vegetation, and (7) choosing suitable building materials. The techniques mentioned above are passive energy strategies that architects should implement to regulate the indoor environment. Also, Larsen (1998) suggested that body comfort should drive building design in the tropics and beyond.

The attainment of a high level of comfort in buildings (residential and public) depends a great deal on the amount of solar radiation excluded from the interior spaces (Ajibola, 2001).

Design concerns influencing human health, comfort, and well-being in buildings should focus on mitigating solar radiation and ensuring sufficient illumination. Neglecting these elements results in excessive active energy consumption for air-conditioning and lighting to provide optimal thermal and visual comfort in buildings. Passive design solutions aim to decrease a building's active energy use by optimising the use of natural light and ventilation through careful consideration of orientation, insulation, window placement, and design (Larsen, 1998). Chand (1976) asserted that the passive design methodology utilises natural energy from the environment, accessible to the building via the microclimate and architectural form. There is a global demand for comfortable settings that facilitate the execution of work or leisure activities without physical or mental hindrance (Page, 2000). Air and surface temperatures, humidity, air circulation, and air quality are crucial factors in attaining a comfort zone. The attitudes of space users, the arrangement of indoor environments, colour palettes, and various other elements can significantly affect our mood and work productivity, influenced by physical factors such as sound, light, spatial volume, radiation, air circulation, temperature, fresh air, gravitational force, relative humidity, and atmospheric pressure.

Climate Responsive Design Strategies in Hot and Humid Regions

The climate-responsive design of buildings is crucial for user comfort and energy conservation, as well as for the preservation of critical planetary resources (La Roche & Liggett, 2001). Regrettably, contemporary building envelope designs are created to fulfil client specifications with insufficient regard for the local environment and a lack of intent to promote energy conservation. This has unequivocally overlooked the climate as a design factor in the building envelope design process. Consequently, these factors have led to suboptimal thermal performance in the structures, increasing reliance on artificial methods to maintain a comfortable thermal environment, resulting in elevated energy usage.

Impact of Envelope Design on Thermal Performance
The building envelope is a critical element concerning the total heat gain of the entire structure and the overall heat transfer coefficient, which governs heat gain through the building envelope. An examination of building energy consumption in Hong Kong, Singapore, and Saudi Arabia reveals that the building envelope design contributes 36%, 25%, and 43% to the peak cooling load, respectively (Lam & Li, 1999; Cheok, 2008; Al-Najem, 2002).

Influence of Varied Orientation
Choosing the optimal building orientation is a crucial energy-efficient design decision that can significantly influence the energy performance of the building envelope by minimising direct solar radiation through windows, openings, and external opaque walls. A full-glazed building will have the greatest impact. Syed-Fadzil & Sia (2004) investigated the impact of direct sunlight infiltration and daylight dispersion in a structure featuring 12 bays of continuous orientation situated in a tropical climate in Penang. The findings revealed that the optimal bay for minimal solar exposure is oriented at 0 degrees, while the least favourable orientation is at 240 degrees. The orientations 30°, 60°, 90°, 120°, 150°, 180°, 210°, 270°, 300°, and 330° are shown sequentially. In this context, the bay with less direct sunshine exposure is seen as optimal, as it experiences the least heat increase, hence diminishing the cooling load and conserving energy. This bay has the least glare issues. Dirk et al., (2007) conducted a study examining the effects of alterations in orientation and insulating devices. They exhibited a cooling load reduction of up to 43%. Results have also demonstrated a beneficial effect on electrical power consumption. The case studies were conducted on two distinct residential buildings designed in Malacca, Malaysia (Dirk et al., 2007).

Influence of Natural Ventilation
Natural ventilation refers to the deliberate movement of external air into an enclosure, driven by wind and heat forces, via adjustable openings. It can proficiently regulate temperature, especially in hot and humid environments. Natural ventilation is frequently the sole method for achieving temperature regulation in the absence of mechanical air-conditioning (Rofail, 2006). Natural ventilation is characterised by the enhancement of a building's thermal performance resulting from augmented natural air movement, employed as a passive cooling approach. In a tropical climate, the enhancements in comfort due to natural ventilation vary from 9% to 41% (Kuala Lumpur in April). In a temperate climate, the enhancements range from 8% to 56%. The findings indicated that natural ventilation possesses significant potential in tropical and temperate areas (Haase et al., 2008).

Influence of Glazed Fenestration Systems
Windows, doors, and skylights substantially influence the thermal efficiency of the building envelope. Windows significantly impact the use, productivity, and comfort of the building's occupants. Research by Jinghua (2006) indicated that heat gain from outside windows constitutes 25-28% of overall heat gain, contributing to penetration. It reaches up to 40% in regions characterised by hot summers and frigid winters. Glazed windows are increasingly integral to modern architecture. They permit natural illumination, facilitate visual interaction with the exterior, diminish structural load, and improve the aesthetic appeal of edifices (Datta, 2001; Al-Saadi, 2006). An appropriate choice of glass area and the implementation of a natural ventilation system can mitigate the adverse impact of solar radiation on interior air temperature (Al-Tamimi

and Fadzil, 2010). Consequently, despite the numerous advantages that glazed windows provide to both inhabitants and designers, they can present issues if not appropriately chosen.

Thermal comfort and human performance

Humans engage in diverse activities within architectural structures. These actions can be optimally executed only under favourable environmental conditions. Individuals within a building experience either beneficial or detrimental effects due to physiological reactions and psychological responses to the temperature environment.

Thermal comfort significantly influences human performance both mentally and physically. The performance level of assigned tasks would reflect the degree of influence exerted by the impulses generated by diverse environmental factors. Markus & Morris (1980) assert that temperature circumstances influence arousal, vigilance, exhaustion, attention, and boredom levels. Wyon (2000) demonstrated that two states of equivalent thermal comfort were attained through various combinations of clothing and temperature, resulting in no disparity in the performance of a diverse array of cognitive activities. This implies that various methods of attaining the same comfort level do not yield differing performance outcomes. It is proven that an elevated metabolic rate results in increased body heat generation and a rise in body temperature during physical exertion. This will lead to either heat discomfort or an increased necessity for more frequent rest breaks. Typically, the work rate is intentionally or subconsciously modified in the opposite direction to achieve a reduced metabolic rate, resulting in diminished performance (Markus & Morris, 1980).

MATERIALS AND METHODS

The study area

This research focuses on Maiduguri, the capital of Borno State, established in 1907 by colonial powers. The region possesses a semi-arid climate, characterised by predominantly hot and dry weather for most of the year, with a wet season lasting approximately three months. The average annual precipitation in the region is 570mm for the years 1960 to 2001 (Daura, 2001). The temperature fluctuates between 25°C and 45°C throughout the year. The annual average of sunshine is 305.7 hours, with monthly averages fluctuating between 176.8 hours and 323.2 hours. It shares boundaries with three sovereign nations: Niger, Chad, and Cameroon. It is situated in the Sahel transition zone at a latitude of 11°52'N and a longitude of 130°06'E, encompassing a land area of 550 km². The Umarari and Bolori communities were chosen in Maiduguri for this investigation. Umarari is situated at coordinates 110° 52' 11.1"N to 110° 52' 29.2"N and 130° 07' 50.80"E to 130° 07' 58.80"E. Conversely, Bolori is situated at coordinates 110° 51' 30.9"N to 110° 51' 50.3"N and 130° 07' 53.90"E to 130° 07' 58.80"E. The mean elevation of the research sites is 320.6 meters above sea level for Umarari and 318.8 meters above sea level for Bolori (Digma, 2012).

Means of obtaining data

Information regarding the environmental and domestic attributes of residential structures was collected, based on their performance relative to climatic circumstances, from respondents via questionnaire administration. Umarari has a total population of 2,532, whereas Bolori has 1,175. A systematic sampling method was employed to collect data with a 5% sample size. The outcome was 126 dwellings for Umarari and 59 homes for Bolori, culminating in a total of 185 houses. Data regarding the correlation between houses and fences, landscape coverage within households, dimensions of access streets, window quantity and placement, building setbacks, exterior painting, building orientation, floor area ratio, and active energy utilisation levels—considering types, quantities, and wattage of electric bulbs alongside other heat-generating appliances—were collected via questionnaires and physical inspections.

Data analysis

The data was gathered from the study region according to the respondents' replies. The data was additionally shown in tables and analysed utilising percentages. Multiple conclusions were derived from the participants' responses. These analyses were employed to render a judgment regarding the comfort attainment within the study area's context. Issues were so discovered.

Results and discussions

The collected data was revised and analysed. Table 1 presents the respondents' feedback regarding the relationship between houses and fences, considering factors such as attachment, landscaping presence, the width of streets for sufficient ventilation, the positioning of windows and doors, painting, utilisation of heat-generating appliances, and the proximity of windows to fences. Sixty-six per cent of respondents, constituting the majority, concur that their dwellings are contiguous to the barrier. 57% of the participants reported insufficient landscaping. 52% of respondents concurred that the roadways are exceedingly narrow. 92% of respondents concurred that the windows and walls of their rooms are situated on one side of the wall. The participants concurred that 61% of the residences are unpainted. 94% of respondents concur on the optimal utilisation of heat-generating devices. The responders concur that 74% of the houses are in proximity to the walls.

Table 2 presents a summary of the respondents' feedback concerning the number of windows in each particular room. According to the response, 74% of the dwellings possess a single window per room, whilst just 17% have two windows. This is more proficient in Bolori than in Umarari. Nine per cent are entirely devoid of windows.

Table 3 addresses the respondents' feedback regarding the challenges associated with the dwellings. Forty-seven per cent of respondents choose a front setback of 1-2 meters, whilst thirty-two per cent report having no front setback whatsoever. 26% have a rear setback over 2 meters. However, 60% do not possess a rear setback.

Table 3 presents the answers according to the house elevation oriented towards the dawn. Forty per cent of the responders had their approach elevation oriented towards the sunrise. 21% have their left and back elevations oriented towards the sunrise, whilst 18% have their right elevation oriented towards the sunrise.

Table 5 presents the respondents' feedback according to the floor area ratio of the research area. 42% and 40% of respondents concur that the development within their compound encompasses 71 to 90 per cent of the overall area, whilst 3%, 11%, and 4% account for less than 60 per cent, between 61 to 70 per cent, and 91 to 100 per cent of the entire compound area, respectively.

Table 6 illustrates the types of electric bulbs utilised in the study area. Ninety-five per cent of respondents endorse the utilisation of heat-emitting bulbs. However, merely five per cent abstain from using heat emitters.

Table 7 pertains to the height of the respondents' fences. Six hundred forty-five respondents concur that their fences exceed 3 meters in height. 28% of respondents possess a fence height of 3 meters, whereas merely 8% had a fence shorter than 3 meters.

Table 1: characteristics of houses in relation to surrounding environmental elements.

		Yes	No	Total
House attachment to fence	Variable	123	62	185
	%	66	34	100
Presence of landscaping	Variable	79	106	185
	%	43	57	100
Presence of wide streets	Variable	88	97	185
	%	48	52	100
Window and door on the same wall	Variable	171	14	185
	%	92	8	100
Required painting	Variable	72	113	185
	%	39	61	100
Use of heat-generating appliance	Variable	173	12	185
	%	94	26	100
Closeness of window to fence	Variable	137	48	185
	%	74	26	100

Source: Authors analysis of fieldwork (2021)

Table 2: Number of windows to a room

Number of windows	*variable*	*%*
1	137	74
2	32	17
None	16	19
Total	185	100

Source: Authors analysis of fieldwork (2021)

Table 3: Front and back setbacks

Setback (metres)	*Front*	*%*	*Back*	*%*
0	60	32	112	60
1-2	87	47	26	14
2 & above	38	21	47	26
Total	185	100	185	100

Source: Authors analysis of fieldwork (2021)

Table 4: Elevation facing sunrise

Elevation	*variable*	*%*
Right	33	18
Left	40	21
Front	72	40
Back	40	21
Total	185	100

Source: Authors analysis of fieldwork (2021)

Table 5: Floor Area Ratio (FAR)

Floor area ratio (%)	*variable*	*%*
Below 60	6	3
61-70	21	11
71-80	77	42
81-90	72	40
91-100	9	4
Total	185	100

Source: Authors analysis of fieldwork (2021)

Table 6: Type of electric bulb used

Electric Bulb type	*Variable*	*%*
Heat emitters	176	95
Non-heat emitters	6	5
Total	185	100

Source: Authors analysis of fieldwork (2021)

Table 7: Height of fence

Height of fence	*variable*	*%*
Less than 3metres	14	8
3metres	52	28
More than 3metres	119	64
Total	185	100

Source: Authors analysis of fieldwork (2021)

CONCLUSION

This study reveals that most houses are deficient in ventilation, primarily because they are adjacent to fences with minimal greenery and situated along narrow lanes designated as streets. Certain windows are positioned in proximity to the fences due to inadequate setbacks and the arrangement of windows and doors on one side of the space. Fences are typically rather tall, obstructing unobstructed airflow. The majority of floor area ratios surpass the maximum development limit of 60% for high-density zones. Houses are devoid of paint and sufficient landscaping that could mitigate the impacts of solar radiation and other severe climatic conditions. Crucial factors such as the appropriate alignment of structures, the use of energy-efficient bulbs that do not release heat, and the consideration of heat-producing devices are overlooked.

RECOMMENDATION

1. The development control section of the Borno State Urban Planning and Development Board currently lacks official jurisdiction over all areas in Maiduguri. Given that development control encompasses numerous facets related to ensuring sufficient light, public recreational spaces, appropriate setbacks, aesthetics, landscaping, and ventilation, the Borno State government should empower the unit to fulfil its responsibilities in maintaining a safe living environment.

2. Future layout designs for any area in Maiduguri should consider dawn and sunset to guarantee that the east-west orientation of structures within plots is inherently aligned with the layout.
3. The government should mandate the planting of two trees in every compound to attain cooler environments.
4. The extensive installation of high-albedo concrete tiles in complexes should be actively discouraged by both governmental bodies and people to mitigate the impact of solar radiation.
5. Individuals should utilise energy-efficient bulbs that have minimal power consumption and generate no heat, such as light-emitting diodes (LEDs).
6. Urban rehabilitation initiatives must be devised for impoverished districts that lack sufficiently broad streets for proper ventilation.

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