Journal of Environment and Earth Science
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol. 3, No.12, 2013

Bioclimatic Design Principle a Solution to Thermal Discomfort in Minna Residences, Niger State Nigeria

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Abstract
Residential buildings are places where people find themselves to be for a better part of their day. For a lot of individuals, this should serve as a comfort zone but is being defeated by a number of factors that range from construction materials choices, inappropriate design concept to suite building location, lack of consideration of existing site features, micro climate of the building location and improper orientation of building. From the simple random sampling in Niger State Nigeria drawn from Dutsen Kura, Tunga and Chanchaga in Minna, it was deduced from the study by administering 25 questionnaires in Dutsen Kura, 14 in Chanchaga and 15 in Tunga that 49% of residents are uncomfortable in their homes during the day, while the rest 26% find it to be fair while 24% say it is good. The aim of this paper is to determine ways in which thermal comfort can be achieved in houses within Minna. The methodology adopted was both structured survey and observation. It was deduced that bioclimatic design through the use of readily available materials can reduce the effect of heat gain into the building, incorporation of natural landscape, and micro climate of the environment will be considered. It is recommended that individuals in their various capacities adopt such design principles in order to have a serene, energy efficient and less polluted environment.
Keywords: Bioclimatic Design, Local Materials, Thermal Comfort.

1. Introduction

In every locality around the world, buildings are erected on daily basis as there is always a need for one form of structure or the other. Amongst the various building types which range from industrial, commercial, educational, institutional, office structures, the most dominant of them all is the residential building. For any building to be effective and serve the occupant adequately, a number of basic amenities will have to be in place such as electricity, pipe borne water, cooling and heating systems and other amenities that makes life more comfortable. Buildings consume a lot of natural resources due to various utilities and fittings used in the building system. The environment is polluted from the waste produced by these utilities. The used up energy determines the amount of waste generated, (Edem, 2010). Sustainable architecture promotes building materials to be reused. It is imperative therefore, to be able to synergize our building designs comfortably with the local environment and the micro climate where they are to be built thereby adopting the bioclimatic design approach.

Bioclimatic consists of two words, 'bio' meaning the natural form of living things and 'climate' the regular pattern of weather conditions of a particular place (Hornby, 2000) Bioclimatic architecture according to Proharam optimizes interactions between building and its environment, thus reduces heating and cooling needs, improving by the same way inhabitant comfort (Proharam, 2008). It is defined by Martinez as the architecture of a place, taking into consideration the specific climatic conditions of the place, using free resources to reduce environmental impacts and energy consumption (Martinez, 2012). Houses are therefore, expected to be in tune with the local climate of the region where they are built, and incorporating the environment into it. Its focus is to integrate buildings into their natural environment considering the climatic factors of the location for a particular design.

A bioclimatic home is a building (individual or communal) designed and built on the basis of local climate and resources (energy and materials). Bioclimatic buildings make efficient use of solar radiation (energy from the sun) and make less use of concrete and aluminum materials that involve lots of energy production, favoring stone, earth and wood materials. (Universcience, 2006). The essence of any bioclimatic design is to be able to attain a degree of thermal comfort within any structure. Thermal comfort according to ANSI/ASHRAE is the cognitive state which determines contentment with the thermal environment and is evaluated by individual assessment (ASHRAE, 2010). It is further defined by British standard BS EN ISO 7730 as "*That condition of mind which expresses satisfaction with the thermal environment*" Thermal comfort is therefore an important aspect of any designs enclosure as this determines the effectiveness of the buildings occupants. The term 'thermal comfort' therefore is determined by the state of mind of an individual whether he or she is hot, cold or simply comfortable in their environment (HSE, 2012).

However, a number of buildings use HVAC (Heating Ventilation Air Conditioning) systems to keep check of their thermal environment. In recent times however, more energy efficient and environmentally friendly methods are used to heat and cool buildings. Natural ventilation reduces or eliminates the amount of mechanical systems required to cool the building if adequately designed. Temperature could either rise to be too hot or too cold depending on season of the year. Therefore, the factors below should be considered when designing to achieve good thermal comfort (Omer, 2008).

- Building orientation
- Cross ventilation
- Construction materials
- Roof, walls and floor insulation
- Window sizes and location
- Additional cooling required during heat periods

The key elements of a building is to protect the occupants and indoor space from drastic weather conditions as excessive sun, wind and rainfall. But when this function is defeated, occupants become thermally uncomfortable and alternative sources of heating and cooling are sort. This can be resolved by adopting climate responsive designs. It has been identified that 75% of buildings in Minna do not conform to the checklist of bioclimatic design indicators. Some of the reasons highlighted being the difference of geographical regions, and varying climate makes a particular design suitable only to the climate of that region. The same problem goes for adapting to other building types that do not fall within the same climatic zone although, within the same country.

The aim of this paper is to proffer solution to some of the problems of thermal discomfort in residences in Minna by adopting bioclimatic design approach from design to construction and in renovation of houses. This system entails that every construction be adaptive to its location in terms of terrain, climate, locally available building materials, and orientation of building on site, passive design principles and efficient use of eco friendly and renewable energy systems. In order to do this, there is need to:

1. To determine the extent of thermal discomfort of residents in their houses
2. To identify the possible causes of thermal discomfort in houses

1.1 Bioclimatic Design Principle

The term bioclimatic architecture is a term coined in the early 60s by the Olgyay brothers, they brought into existence the bioclimatic chart, which uses the psychrometry chart as a basis to relate climate as strategies to be used to determine thermal comfort of a particular location. The psychrometric chart of Minna as determined by Ajibola (2000) is illustrated in fig 1.

According to Kane Cres (2012), using the micro climate of a region to provide both thermal and visual comfort for occupants with renewable energy (solar) as a means of generating electricity and geothermal system for heating and cooling is an efficient system of eco friendly design. Other parameters as building materials and passive design systems are equally considered. The bioclimatic design principle approaches both interior and exterior aspects of construction. This is achieved by using the essential feature of bioclimatic design to ensure landscape, construction materials and micro climate of a place are integrated actively with the existing environment (Martinez, 2012). Bioclimatic buildings can be achieved by considering the whole building life from design process through to construction. Materials used for construction and the methods used are important aspects of building sustainability, the building orientation, sun shading devices and size of openings must equally be considered in the design process.

Buildings affect the surrounding during their active periods, this is due to their necessity to heat, and cool and also provide lighting needs. During the life span of a building, only about 10% of its impact on the surrounding is corporal to building materials (Earth Architecture, 2012). Energy efficient designs can reduce engaged energy costs by say 75%. The materials used in a building should have less CO_2 discharges on the life cycle of the building (Earth Architecture, 2012). Bioclimatic design measures are centered primarily on the climate of a specific area as thus:

1. **Building envelope and orientation**: The building needs to be protected from heat gain into the structure especially during the hot periods. This can be reduced by the orientation of the building and materials used for construction (Martinez, 2012).
2. **Energy source**: Solar energy should be used as an alternative source of energy and also for lightning up the buildings all through the year. Building orientation towards the south and placement of openings is also to

be considered (Kane Cres, 2012).

3. **Sun shading devices**: Heat gain into the building during periods of high temperature can also be reduced by using sun shading devices and materials and paints that would permit less penetration of the solar rays.
4. **Passive design**: Accumulated heat during the day can also be given out or balanced naturally by night time through the use of large window openings which will allow natural ventilation and appropriate choice of window types.
5. **Indoor air quality**: Through the use of green/living walls, indoor air quality can also be improved as this will capture airborne particles while providing oxygen to liven up spaces. Air locks can also be installed in doors as it reduces the effect of heat on the building envelope (Moon, 2007).
6. **Heating and cooling**: Ensure that materials used for glazing allow minimum solar radiation (glare) and adequate light in the interior spaces.
7. **Landscape**: Planting trees and incorporating artificial water bodies can also improve the micro climate of the environment.

1.1.1 Selected Bioclimatic Houses in other Regions

This section seeks to identify how bioclimatic designs have worked efficiently in other regions of the world and to determine the effectiveness of the designs in achieving thermal comfort considering the micro climate of those regions.

Case Study 1: The Casa Blasco House in Gandia Valencia

Design Location: The house is located in a small lot near the beach of Gandia. It is oriented diagonally on site to face south, this is to enable maximum solar radiation in winter, and less of it in summer.

Plate 1: Approach facade of the Blasco House
Source: Behance.net (2012)

Design Features

- Wide full height openings for maximum heat gain into the building.
- Vertical sun shading devices are used to reduce solar radiation and heat gain during summer
- Mechanical system of cooling is adopted through the use of photovoltaic cells.
- Openings in are only in the south and east walls in order to maximize heat trapped.
- The geothermal and wind systems are used for cooling by means of underground galleries.
- Solar chimney is used to evacuate hot air and mechanical cooling system by evaporation.

Case Study 2: Experimental Urban House

Design Location: The house is located in Granadilla Tenerife Spain. It is built to be a self-sufficient house incorporated in the scenery of the island and blends in with the topography. The inspiration of the design is the basalt stone wall on which a light structure of plywood with galvanized steel walls and glass supports.

Plate 2: Approach facade of the House
Source: DZGN.co (2012)

Plate 3: Interior view of the House
Source: DZGN.co (2012)

Design Features

- **Heat storage**: basalt stone wall connects the sleeping areas to the living room allowing heat gained during the day to disperse in both ways at night
- **Local materials** were used in the construction of the house for energy efficiency as the: basalt wall, wooden floors and the solar glass were used in the living area.
- The use of materials as PVC, VOC, synthetic paints and vanishes were avoided.
- The **building orientation** is inclined in the north-south direction to allow minimum heat penetration and it also integrates the use of solar panels for electricity and hot water allowing zero CO_2 emissions while **geothermal** is used to heat and cool the building.

Deductions

Case study 1: It was deduced from case study one that the diagonal orientation of building on site was to utilize the solar radiation in winter and the vertical shading devices were used o reduce solar radiation and heat gain in summer. PV cells were used to enhance cooling systems in place an also complimented by geothermal and wind systems from the underground galleries.

Case study 2: Stone wall was used to connect the living area to the bedroom thereby storing heat during the day and dispersing at night. In order to achieve energy efficiency, most materials used were locally sourced and do not contain volatile organic compounds.

2.0 Study Area

Residential developments constitute a good percentage of the structures in Minna, and Minna falls within the temperate humid regions of the country. Due to location of Minna in the tropics, it is necessary when designing to reduce the amount of heat gain into the building during the day and maximize evaporative cooling for adequate thermal comfort of occupants. A cross sectional survey was drawn from Tunga, Dutsen Kura and Chanchaga. These areas were chosen strategically based on their axial locations in the town, are well populated and fall among the major areas. They constitute various housing types as different caliber of individuals live in these areas. Tunga is located in the heart of Minna; Chanchaga is located at the major entrance to the town while Dutsen Kura lies along the western bye-pass.

Minna is characterized by various types of housing designed to meet the needs of various individuals. It was observed from survey that the design of residential houses in Minna do not put into consideration the natural setting of the environment but build houses according to intra global trend of construction in Nigeria. Some of the houses studied are shown in plates 5-8 below. Although it was observed that houses at the outskirts of Minna town still conform to using local materials available and build with materials that are favorable of the climatic conditions of the area, a lot of changes are being made as they are also adopting the conventional building materials and modern ways of construction as illustrated in plate 5.

2.1 Research Methodology

Primary data was gathered from observation of residential developments within Tunga, Dutsen Kura and Chanchaga. This enabled both qualitative and quantitative data collation on the perception of the users to assessment of thermal comfort in their houses. Questionnaires were used for the quantitative data, while observation of building states served the qualitative aspect.

Random sampling technique was used in order to get the required information. The population samples for this research were taken from different household types and questionnaires were administered to gain data on the possible causes of discomfort to residents and building units that bring about these problems.

3.0 Discussion of Findings

The survey enabled first hand information to be gathered on the physical form of the buildings. Residential houses in Minna have been identified to pose significant level of thermal discomfort to occupants. The plates 4 and 5 shows the traditional method of which houses were built to be adaptive of the climate through materials used for construction while plates 6 and 7 shows the modern construction materials which do not give the thermal satisfaction required by occupants. Plate 8 shows a building, built with modern building material but used vertical sun shading device to reduce heat gain indoors.

Plate 4: Traditional walling material
Source: Author's fieldwork (2012)

Plate 5: Traditional Gwari settlement in Minna
Source: Author's fieldwork (2012)

Houses at the outskirts of Minna used natural earth with a mixture of sand, stone and water with clay as a binding agent to build their homes. This provided them with a more comfortable indoor temperature during the day while d house was kept warm at night. The traditional houses of the Gwari people were built with compressed earth strengthened with straw to keep it durable over a long period of time. The roofing material is thatch. Earthen buildings have the ability to keep a cool temperature of indoor spaces during the day.

Plate 6: A residential house in tunga
Source: Author's fieldwork (2012)

Plate 7: A residential house
Source: Author's fieldwork (2012)

The residences seen in the plates above are built with zinc as roofing material which allows heat penetration into the buildings, window openings are not wide enough to allow for maximum ventilation and the living area is not cross ventilated. There is also no form of soft landscape to boost the atmosphere to a suitable temperature.

Plate 8: A residential house with sun shading device
Source: Author's fieldwork (2012)

It was observed from survey that the amount of solar radiation that reaches the indoor space is at a minimum due to use of vertical fins as sun shading devices. The indoor and outdoor temperature can be enhanced by planting trees and providing soft landscape as the surroundings lack any form of soft landscape.

3.1 Perception of Respondents on Sources of Thermal Discomfort

The response from occupants identified thermal discomfort to be as a result of heat penetration through the roof, glazing and walls. It is illustrated in table 3. Other factors that bring about heat gain indoors are materials used for construction, the orientation of buildings on the site, the size of openings, the type of window system and the cooling systems adopted. The occupants rating on thermal comfort were also identified as shown in table 3.

Table 2: Occupants rating of thermal comfort in their houses

Location	Very Poor	Poor	Good	Very Good	Total
Dutsen Kura	10	6	5	2	23
Tunga	6	3	3	0	12
Chanchaga	8	4	1	1	14
Total	24	13	9	3	49
Percentage (%)	49.0	26.5	18.4	6.1	100

Source: Author's fieldwork (2012)

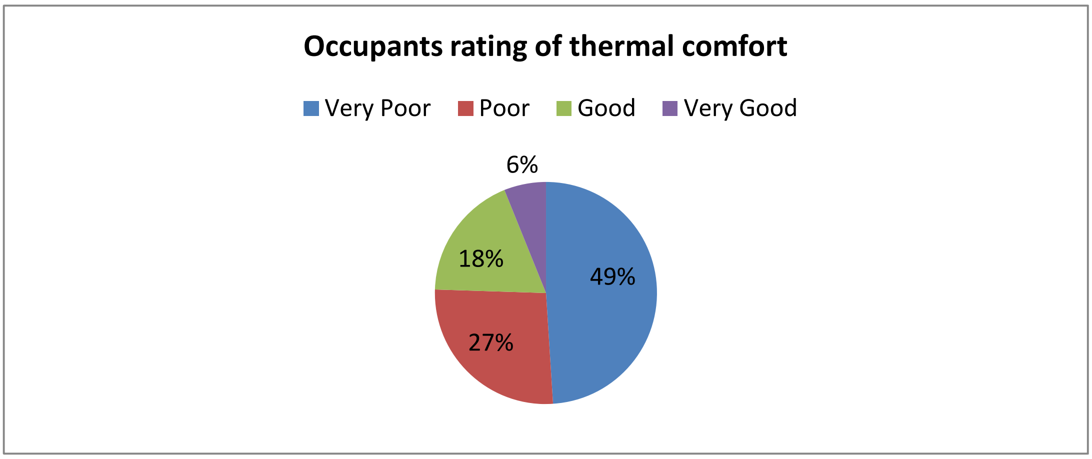

Fig 1: The chart shows occupants rating of thermal comfort in their houses
Source: Author's fieldwork (2012)

Based on the results shown above, it can be seen that in all three zones, 49% of occupants rated thermal comfort within their houses to be poor while 26.5% rated fair, 18.4% said thermal comfort is good while the rest 6.1% said it is very good.

Table 3: Percentage of units that allow heat gain to the house

Heat Gain	Very Low	Low	High	Very high
Glazing	1.85	7.41	22.22	68.52
Roof	22.22	24.08	20.37	33.33
Floor	46.30	18.52	11.11	24.07
Walls	7.41	12.96	20.37	59.26

Source: Author's fieldwork (2012)

It can be seen from fig 2 above that 69% of heat indoor is accumulated from glazing in various houses. It is therefore identified that glazing is a major source of heat gain indoors. Roof is a contributing factor to heat gain indoor as the sun has a direct effect on it from above. The nature of material used can reduce the amount of heat penetration indoors. The floor in the houses also contributes to the amount of heat indoors but minimal as it is 46% poor heat retainer and only 11% good. The type of material used for flooring also determines the amount of heat that is trapped therein. Walls are a major source of heat gain indoor as seen from fig 5 above. 59% of heat gain indoor from the survey was attributed to wall being a very good retainer of heat. This can be reduced by using materials that allow less heat to indoors during the day.

Recommendation

It has been identified from the survey that some units of the house allow more heat penetration indoor than others, it is therefore recommended that for effective design and good thermal achievement in Minna houses, the following factors should be considered:

1) Building orientation: buildings should be inclined on site to face the north-east, south-west approach to allow minimum solar radiation into the buildings
2) Window openings: the openings should be wide enough to allow maximum natural ventilation into the indoor space at a minimum of say 1500mm x 1500mm.
3) Glazing: solar glasses that are double paneled and well laminated that allow light but reduce heat

penetration should be used. And casement window systems allow 100% ventilation rather than sliding which allows only 50% ventilation.

4) Natural materials: should be used for construction such as adobe, compressed earth, and wood as they have better thermal inertia than most conventional building materials.
5) Renewable energy: these energy sources as solar and geothermal energy are more energy efficient and do not contribute to CO_2 emission which pollutes the environment.
6) Landscape: trees should be planted around the houses as they help improve the surrounding air and keeps the environment cool.
7) Cross ventilation: houses should be cross ventilated for effective air flow in and out of the building.

Conclusion

It was established from the survey that 49% of the occupants of houses within Minna do not find their homes to be thermally comfortable. And 26% only think its fair while 18% of the population says it's good. A meager 6% of the occupants live in a comfortable house in Minna, this is an indicator that majority of the houses in Minna do not conform to the design parameters of bioclimatic houses of the environment where they are.

However, if all house builders and owners work towards building houses that are more environmentally friendly, there will be less issues of thermal discomfort and the cost of maintaining houses and the environment will be greatly reduced.

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