Improvement Of Thermal Comfort In Residential Buildings

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Abstract: Thermal discomfort experience in a built environment is a thing of concern since the quality of man depends on the quality of his indoor environment. This discomfort experience in an occupied space lowers the emotional and physical health of the occupants. This paper attempts to explore the thermal comfort scenario of the residential buildings in Mubi metropolis with the view of proffering measures to improve the comfort of people in their homes. To achieve the desired result, 240 structured questionnaires were distributed to eight wards in the study area. The study reveals that the exacerbation of thermal discomfort in Mubi are attributable to some factors among which are : epileptic power supply, high cost of air conditioning systems, use of good heat conducting materials in buildings, poor building design and use of high heat emitting lighting devices. This however indicates that majority of Mubi residents are thermally uncomfortable in their homes. Based on the findings, effective manipulation of shading devices, micro-climate, ventilation, infiltration, lighting, electric appliances and building design will enhance the realization of the desired thermal comfort in residential buildings in the study area.

Index terms: Thermal comfort, Residential building, Thermal discomfort, Mubi metropolis

1.0 Introduction

The quality of lives of human beings to a very large extent depends on the quality of their indoor environments because people spend most of their time indoors. Human beings partake in various activities within building enclosures and these activities can only be performed best when the environmental conditions are favourable. Inside a building, people are affected either positively or negatively because of the physiological reactions and psychological responses to the environment. Thermal comfort plays a significant role in human performance at both mental and physical levels [1]. Failure of human beings to respond to the environment through thermo-regulatory mechanism causes thermal discomfort. The thermal discomfort experience by occupants of a built environment during hot season causes lower emotional health manifested as psychological distress, depression and anxiety as well as lower physical health manifested as heart disease, insomnia, headache, fatigue, boredom and poor arousal [2][3].

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During hot weather, stroke cardiovascular abnormalities are common. Acute left ventricular failure, right ventricular dilation and subendocardiac hemorrhages can occur (Ogundele, 2005; Petronio, 1988). The basic intention of a building is that they should be planned, designed, built and managed to offer an environment in which occupants can carry out their work and feel well, and to some extent be refreshed by the environment. The building should serve as a modifier of the microclimate [4]; that is a space isolated from environmental temperature and humidity fluctuations, sheltered from prevailing winds and precipitation, and with enhancement of natural light [1]. The creation of microclimate in today's modern buildings is expensive which can be attributed to the modern materials used in building constructions. This however is at variance with the buildings in the past where comfortable microclimate is achieved with minimal artificial energy input [5]. The modern buildings are characterized by high energy requirement for cooling and lighting. With the erratic power supply and high cost of air conditioning systems, achieving thermal comfort through the use of active cooling systems is expensive [6]. This paper is therefore an attempt to study the thermal comfort scenario in residential buildings in Mubi metropolis and suggest ways of improving it.

1.1 Description of the Study Area

Mubi town comprises of some part of Mubi North and Mubi South local government areas of Adamawa State, Nigeria, with an estimated population of 112004 based on the 2006 census [7]. It is situated on latitude $10^0$12'N and longitude $13^0$10'E. The climate consists of seven months of wet season. The average maximum rainfall is 225mm. The annual mean temperature is 32^0C. The hottest months are March, April and May with 36.4^0C and the coldest period fall between December to early February with minimum temperature of 15^0C [8]. The mean monthly maximum and minimum temperatures in Mubi from 1995 to 2003 are shown on Table 1.0.

Table 1: Mean Monthly Maximum and Minimum Temperature of Mubi

Month	Maximum Temperature (^{0}C)	Minimum Temperature (^{0}C)
Jan	32,8	12.7
Feb	34.1	14.3
Mar	36.8	20.6
Apr	37.0	24.7
May	35.6	23.8
Jun	31.9	23.0
Jul	29.7	22.2
Aug	28.9	21.9
Sep	30.2	21.3
Oct	32.3	20.8
Nov	33.5	18.7
Dec	32.7	18.6

Source: [12]

2.0 Methodology

In this study, 240 structured questionnaires were distributed to samples of the target population in eight wards in Mubi town. They are Kolere, Lokuwa, Yelwa, Arahan Kunu, Nasarawo, Shuware, Lamorde and Wuro Patuji. Focused group discussion guide was obtained by discussing with relevant consultants in the industry. The study of physical traces was also adopted in the collection of information, especially where respondents were un-cooperative.

3.0 Results and Discussion

In this study, the percentages of the responses from the respondents that required an answer either YES or NO from the questionnaire are presented in Table 2 while the percentages of responses from the respondents with respect to the materials used on buildings are presented in Table 3. Two hundred and forty (240) structured questionnaires were distributed to the eight wards and one hundred and ninety six (196) responded. Table 2 shows the pertinent responses of the respondents from the questionnaires.

Table 2: Percentage Response from Questionnaire

Item	Yes (%)	No (%)
Connected to National Grid	67.8	32.2
Have Ceiling	65.8	34.2
Have Air Conditioner	2.0	92.0
Have Electric Fan	41.8	58.2
Have Electric Heating Appliances	33.0	67.0
Residing in New House	18.8	81.2
Have Vegetation around the House	39.2	60.8
Have Floor/Wall/Roof Insulation	3.0	97.0
Positioned Windows for Cross Ventilation	55.1	44.9
Consult Professional before Erecting Structure	20.8	69.2

Table 3: Percentages of Materials used on Buildings

Roofing Materials	Zinc	Aluminium	Asbestos	Thatch
	85.8	11.2	2.0	1.0
Window Materials	Zinc	Wood	Steel	Glass
	19.8	31.6	4.0	44.6
Door Materials	Zinc	Wood	Steel	Glass
	25.5	37.8	33.6	3.1
Carpet Materials	Rug	Leather	Tiles	Cement Floor
	26.0	65.8	3.0	5.1
Lighting Devices	Incandescent Bulb	Energy Saver	Kerosene Lamp	Candle
	42.3	8.2	48.0	11.5

From Table 2, the responses of the respondents that have direct bearing on thermal discomfort are possession of air conditioner, electric fan and electric heating elements, residing in old houses, have vegetation cover around the house, have floor/wall/roof insulation and positioning of windows for cross ventilation. Air conditioner and electric fan are both power dependent appliances. The high cost of air conditioning system and the epileptic power supply impede the use of these cooling systems to achieve thermal comfort. The electric heating elements generate heat during operation but, the utilization of the heating element is limited because of the insufficient power supply in the study area, despite 67.8% of the people are connected to the grid. About 81.2% of people in the study area are not residing in new houses. This means that during hot weather, there would be an infiltration of warm outdoor air into the building envelope through cracks and unintentional openings which will cause thermal discomfort. 60.8% of people have no vegetation (trees) around their houses. This implies that there will be direct interception of solar radiation by the building envelope which will consequently increase the cooling load of the building. In this study, 97% of people do not have floor/wall/roof insulation. Although some people use rug carpet, lack of proper use of floor insulation causes discomfort known as temperature stratification, by exposing the head and the feet to different temperatures. If the wall of a building is not properly insulated, it causes asymmetric thermal radiation by exposing different sides of a body to different heat gain or loss by radiation. If the roof of a building doesn't have insulation and the space does not have ceiling, the rate of heat gain into the building through the roof will be high. But, the use of ceiling can significantly mitigate the heat gain through a roof without insulation. 44.9% of people in the study area have not positioned the windows in their buildings for cross ventilation. This will affect the air change per hour and by extension, the air quality and the thermal comfort. Table 2 also shows that 68.9% of people did not consult professionals before erecting structures. This practice has an adverse effect on thermal comfort because the non-professionals are oblivious of the parameters involved in building climate responsive structures. Table 3 shows the type of roofing materials used by the people in the study area. 85.8% of the people use zinc and 11.2% use aluminium as roofing materials. Zinc and aluminium are good conductors of heat therefore, during hot season, unless the roof is insulated, the heat intercepted from the sun by these materials can be conducted down the living space thereby creating thermal discomfort. However, the rate of heat conduction into the living space is reduced when the space has a ceiling. Table 3 also shows the type of materials used for windows. 19.8% and 4% of the people used zinc and steel materials for windows. Comparing with other materials, it implies that only few people use these materials (zinc and aluminium) which are good conductors of heat for their windows. It can be seen from Table 3 that 25.5% and 33.6% of people use zinc and steel respectively for their doors. This indicates that heat gain into the building through the doors is significant because these materials are both good conductors of heat. 65.8% of people used leather carpet as shown in Table 3. Leather carpet by its nature is not an insulator. Therefore, temperature stratification in living space that uses leather carpet will be significant. 42.3% and 48% of people used incandescent bulbs and kerosene lamps respectively as shown in Table 3. These lighting devices give off high amount of heat per lux of lighting. Therefore, using these lighting devices tend to increase thermal discomfort in the living space.

4.0 Improving Thermal Comfort in Residential Buildings in Mubi Metropolis

In the context of thermal comfort in residential buildings in Mubi metropolis, passive ways of achieving thermal comfort is the most viable option because of the epileptic power supply and high cost of air conditioning systems. These passive ways are:

- **Proper Orientation of Building**

Proper orientation of buildings to reduce the impact of unfavourable weather conditions like solar radiation, driving rain and thunderstorm. In the house, the rooms should be located in such a way that the ones frequently used should be elongated along the east-west dimensions to mitigate heat gain in summer and also making efficient use of winters sun [9].

- **Proper Ventilation**

By proper positioning the windows and opening them, air movement can be created in the rooms. Walls and vegetation should not be too close to the building in order to avoid diversion of wind away from the openings, thereby reducing air flow within the building. If possible, the rooms should be cross-ventilated.

- **Using Shading Devices**

The most effective way of improving thermal comfort in residential buildings is to shade the windows, walls and roofs of buildings from direct solar radiation. The windows can be externally shaded by using overhangs or a horizontal projection to block off sun's rays completely in summer while letting in most of them in winter. Double pane windows with tinted glass and glass coated with reflective film should be used for windows instead of steels, wood and zincs. External shading can also be provided by growing deciduous trees which block off the sun's rays from reaching the building in summer and in winter, loose their leaves to allow about 60% of solar radiation to pass into the building envelope [9].

The roof of buildings can be shaded effectively by using removable canvass which can be used during the day time and rolled up during the night time to allow radiative cooling. A drapery could be used to internally shade the windows at the same providing privacy and aesthetic effect. A light colour drapery with close or semi-close woven fabric should be used in summer to reflect back the incident solar radiation while a dark coloured drapery with open or semi-open woven fabric should be used in winter to impede the escape of heat from the building.

- **Proper Lighting**

Using day light as much as possible will reduce cooling load because day light contains the least amount of heat per lumen of light. Compact Fluorescent Lamps (CFL) should be used in leau of incandescent bulbs and kerosene lamps because they emit heat into the cooling space. The CFLs have different colour spectrum, used 75% less energy than incandescent bulbs, they are cheap and last 10 times longer than the incandescent bulbs.

- **Creation of Microclimate**

Trees can be planted to create micro-climate that is, small-scale climatic condition at a spot or area or site.

The micro-climate of the adjoining trees can be explored to provide a cool comfortable environment in tropical climate [10]. These living rooms and other areas which are frequently used by inhabitants should be carefully placed for micro-climate so that they are comfortable and more enjoyable, and can be used for a longer length of time.

- **Preventing Infiltration**

Infiltration can be prevented by sealing the sites of air leaks. This can be achieved by caulking, weatherizing, good workmanship, and replacing some aged parts of buildings.

- **Use of Light Colour Paints**

Painting of the walls and roof with light colours will help in the reduction of heat gain. Whitewash which can cheaply be done on walls and roof is an effective way of reducing heat gain [11].

- **Proper use of Electric Appliances**

Electric appliances like heating elements should not be used in living or bedrooms, rather , they should be used in the kitchens. During summer, electric fan should not be used for a long time because the entire energy consumed by the motor of the fan is eventually converted to heat in that room [9].

- **Sensitizing Building Professionals**

Building professionals and other stake holders in the industry should be re-awakened to the realities of the demand for thermal comfort. They should organize seminars, conferences and workshops to educate the public on the problems associated with the activities of the non-professionals in the industry.

5.0 Conclusion

This research work has shown that the thermal discomfort in the study area is aggravated by the epileptic power supply, high cost of air conditioning systems, absence or scanty vegetation around houses, improper positioning of windows for cross ventilation, lack or poor insulation of floors, walls and roofs, activities of non-professionals in the industry, use of good conducting materials on buildings, and the use of incandescent bulbs and kerosene lamps as lighting devices. The thermal comfort can be meliorated by using passive ways such as the use of shading devices, proper orientation of buildings, creation of micro-climate, use of light colour paints on walls, sensitization of building professionals on thermal comfort and proper use of electric appliances, lighting, proper orientation of buildings and as well as adequate ventilation.

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