IMPACT OF AIR TEMPERATURE IN THERMAL COMFORT OF INDOORS OF RESIDENTIAL BUILDINGS IN UMUAHIA URBAN ABIA STATE, NIGERIA.

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Abstract

Achieving indoor thermal comfort in residential buildings, is very essential, because little we do take place outside. Most residences in Umuahia urban of Abia State Nigeria are cells of unhappiness because their indoors are thermally uncomfortable, thus the aim of this study was to evaluate the impact of air temperature in thermal comfort of residential buildings in Umauhia urban. This was achieved by carrying out air temperature measurement and questionnaire survey of some randomly selected residences in the area to determine the thermal perception of inmates, also evaluate thermal performances of the same residences in response to air temperature. The experiment took place in rainy and dry seasons of 2012, 108 respondents were obtained from twenty seven (27) residences. Data loggers, digital thermometers and measuring tapes were major instruments used, while thermal comfort parameters measured were air temperature, relative humidity and air velocity. The result revealed that 70.3% of the residences did not achieve acceptable indoor thermal comfort, while 69.1% of the respondents voted discomfort. Analysis of respondents also revealed that the inhabitants of the residents with unacceptable temperature, also voted discomfort, thus agreeing with the study index. It was discovered that the residences failed, due to their designs. The study recommended that all building designs originate from the architect.

Keywords: Thermal comfort, Residential buildings, Air temperature, Humidity.

1. INTRODUCTION

Buildings function mainly to adapt to the prevailing climates and to provide internal and external environment which will be comfortable and conducive for its inhabitants (Akande and Adebamowo 2010). The need for buildings to perform this all important function must be remarked, especially in this era of global warming and climate change. It also becomes essential due to the facts that architects and others in the built environment face a task of developing buildings that will be thermally comfortable and energy efficient (Alozie 2014). Thermal comfort is a necessary feature when considering the functional adequacy of any building space and the suitability of the built environment (Adunola 2015). In further opinion Adunola (2015) believe that in whatever location, that buildings are meant to provide the requisite thermal environment indoors, so that human activities may be carried out conveniently. He further stated that people are affected either positively or negatively inside the building because of their innate physiological responses to their indoor thermal environment. It is obvious then that there is a significant role, thermal comfort plays in human performance at both mental and physiological levels. This makes it necessary then to investigate how residential buildings in Umuahia, a warm humid climate urban environment of Abia State, Nigeria have fared in providing indoor thermal comfort, with particular regard to air temperature.

American Society for Heating Refrigerating and Air Conditioning Engineers. ASHRAE, defined thermal comfort as the express satisfaction within the thermal environment, in which at least 80% of sedentary or slightly active

persons find their environment thermally acceptable. (ASHRAE 2004). Among other definitions of thermal comfort is that presented by Odim (2006) who defined thermal comfort as the condition human beings find themselves when they are satisfied with their environment.

The need for the home maker to be thermally accommodated in his environment is seen in Adebayo, Ayuba and Oyetola (2013) assertion of thermal comfort being essential for the wellbeing, productivity and efficiency of occupants Adebayo(2013) then concluded that the preservation of thermal comfort should be defined as an imperative issue. The inability to meet this imperative issue of preservation of this state of mind defined as thermal comfort is described by Cheividyankarn (2007) as the cause of sick building syndrome, resulting from poor indoor air quality. According to Cheividyankarn (2007), because thermal comfort depends on weather and on the environment, therefore the design of the building contributes 75% role to its comfort level.

This paper therefore examines the degree to which building designs have affected indoor air temperature, a major determinant of thermal comfort in Umuahia urban environment of Abia State. The study has become necessary because most residences in Umuahia urban environment are known cells of unhappiness, due to the major reason that their architecture does not support them providing thermal comfort naturally (Alozie, 2014).

Many field studies carried out in humid climates did not consider the nature of Umuahia climate (warm humid). In warm humid climates temperature and

relative humidity are high, sometimes above 32^oC and 80% respectively. Air velocity is at 1m/s. The high humidity leaves damp and sticky feeling effect on people which causes discomfort. Studies by Auliciem(1985). Auliciem and de Dear (1986, 1986b); Busch (1990) and de Dear and Fountain (1994) were all in hot humid climates, only little thermal studies exist in warm humid climates, and no major studies exist on Umuahia urban environment.

Findings from the study will enable architects, engineers and other environmental designers develop buildings that will be environmentally friendly (sustainable and energy efficient). Buildings that will require little or no mechanical enhancement to function, and provide the desired thermal comfort level indoors.

2   LOCATION AND CLIMATE OF STUDY AREA

Umuahia the urban capital city of Abia State is in South Eastern, Nigeria, and located on latitude $51° 25^IN$ and longitude $7^0 10^IE$. (Ijioma 2000). Umuahia falls in the tropical rainforest vegetation belt and has an elevation of 250meters above sea height, and falls within the warm humid climate zone. In the warm humid zone, there is very high solar radiation and humidity but with relatively low wind speed (Hyde 2000). The climate data for Umuahia showed that the climate contex combined high temperature (mean max -32^{0}C), high humidity (mean max -85%) and low air velocity (mean max -1.55m/s). the maximum

temperatures were above 30^0C for all months with exception of August and September. The sequence of weather conditions in any place in Nigeria and other West African countries during the cost of a given year, actually depends on the location of the place in relation to the fluctuating surface reaction of the Inter Tropical Discontinuity (ITD). The ITD movements and effects on various locations in West Africa are discussed in Ojo (1977).

3. METHODOLOGY

3.1 FIELD STUDY

The field study was conducted in Umuahia urban environment in the central senatoral area of Abia State. It was carried out with questionnaire survey and field measurements on indoor air temperature character and the nature of residential thermal environment, during the rainy and dry seasons of 2012. This was carried out to get a variation measurement in terms of the indoor and outdoor temperature, relative humidity and air velocity.

The field study asked questions based on thermal sensations and were based on the Seven point (ASHRAE Scale -3 to +3), which represented the respondents comfort votes. At the same time, the following thermal variables were measured, indoor air temperature, relative humidity and air velocity.

The aim of the field measurement was to match the responses from the questionnaire to the air temperature measurement from the twenty seven residences whose indoor thermal measurements were captured. This matching is

used to substantiate the Effective Temperature (ET) index thermal comfort range of (20-26^{0}C) provided by Fagner (1970) as acceptable thermal comfort temperature range for warm humid climate.

The effective temperature index can be defined as the temperature of still, saturated atmosphere which would in the absence of radiation, produce the same effect as the atmosphere in question (Koenigsberg et al, 1973). The ET scale was first developed by Houghton and Maglou in 1923, with subsequent revisions, integrates the effect of these fundamental environmental variables relevant to thermal comfort in any contex, these are air temperature, relative humidity and air movement.

The effective temperature has been an internationally accepted thermal comfort scale which has been of wide applicability. However, with recent findings disqualifying the general applicability of thermal indices, it has become pertinent to use field survey results to examine index locally. According to Humphery (1975), field studies of thermal comfort are with two purposes, first is to find a way of describing the thermal environment which correlates well with human response, thus enabling reliable predictions to be made and secondly to define the range of conditions found to be pleasant or tolerable by the population concerned.

This contextual study of Umuahia urban environment sought to assess indoor air temperature in residential buildings and compare them with that allowed by studies from Fanger (1970) as comfort limits in warm humid climates. The

study also includes the physical measurement and analysis of the architecture of the case study buildings, again this became necessary in order to find out the degree to which architectural designs contributed to variations in thermal comfort perception of indoor residential buildings in the study area.

The study which considered the local climate characteristics was carried out during two extreme periods of dry and rainy seasons of 2012, while the questionnaire and its application were raised in accordance to 1S0,7730 and 10551 (1994) standards. The questionnaires were distributed and retrieved after a month in each of the seasons, this enabled the respondents assess without bias their perception.

3.2 POPULATION SIZE

The research adopted Akande (2010) sampling technique for measurement of indoor thermal comfort in residential buildings in Bauchi due to similarities in both study, but limited to its own sample population.

A sample size of 108 in (27) naturally ventilated residential buildings in the study location were collected in both dry and rainy seasons of (2012). Table 1 shows the summary of the subjects of residential occupants in the study area. The population for the study was made up of 52 females (48.1%) and 56 males (51.9%). The percentages of residence with and without mechanical ventilation system (i.e. those using windows only and those not using windows only) were

21% and 79% respectively. The average age of respondents lie between 30-50

years.

Table 1: Summary of the subjects of residential occupants in the study area

Season	Dry season	Rainy season
Sample size (male/female)	108(52/56)	108(52/56)
Gender (% of sample)		
Male	51.9	51.9
Female	48.1	48.1
Mean age (year)		
Mean	30-50	30-50
(Minimum, Maximum)	(14, 72)	(17, 72)
Mean years living in local address		
Mean	10-16	10-16
(Minimum, Maximum)	(1-5, 20)	(1-5,20)
Mean Height (m)		
Mean	1.60	1.65
(Minimum, Maximum)	(1.37, 2.9)	(1.37, 2.01)
Mean weight (kg)		
Mean	60	68
(Minimum, Maximum)	(46, 80)	(46, 80)

The questionnaire covered several areas including demography (name, gender,

age etc), years of living in the present building and individual environmental

measures, taken to achieve comfort. Table 1. The questionnaire also included

the traditional scale of thermal sensation (TSENS) and thermal preference. The

TSENS scale was the ASHRAE seven points scale of cold (-3) cool (-2) slightly

cool (-1) neutral (0), slightly warm (+1) warm (+2) and hot (+3). The three

points thermal preference scale used asked if respondents preferred a change in

their present environment, possible answers were "want warmer, "no change",

want cooler.

3.3 Measurement of indoor climate

Instruments used to carry out the study include, the data logger, which measured air temperature and relative humidity. These parameters referred to as variables formed the primary measured data. Each respondent answered the questionnaire. Questionnaires were given to each of the families based on the number of adults (i.e. between the age of 16years and above), an average of four adults per house-hold. In each building, a data logger hung on the wall at a height of 1.5meters from the finished floor level in the sitting room, while a sensor, was hung in a bedroom, at the same height. The data loggers measure the variable in the sitting room, and those in the bedrooms whose records were registered through the sensors. The data loggers were calibrated to read off measurements every three hours beginning from 6am. This became necessary to help capture the maximum and minimum values of the variables. In every building also a single logger was hung in shaded wall outside for outdoor variables measurement.

3.3.2 Physical Measurements of Case Study Buildings

Architectural details of the buildings used for study were made. The measurement included the site plan(s), floor plan(s), the sections and the elevations. The building's orientations, percentage of plot areas developed, landscaping, set backs from adjoing structures, fencing heights, building materials used, and the building finishings. The research considered also the

location of living spaces (zoning), room sizes and heights, windows (types and sizes), opening locations among other things. This became necessary in order to pin down the extent to which the architecture of the buildings contributed to the thermal performances of the buildings in the study area.

4.0 Results and Discussion

4.1 Environmental Parameter Data

The measurement recorded the essential variables of air temperature, relative humidity and air velocity, necessary to determine the thermal comfort level in residences using thermal indices such as the Effective Temperature (ET), the Predictable Mean Vote (PMV) and the Operative Temperature (T_o). The statistical data on the environment is shown in Table 2 to 3 below. In both seasons the average temperature result of the buildings whose measurement exceeded 26^0C was 32^0C, with an average relative humidity of 80%. While those whose temperature measurement did not exceed the index range of (20-26^0C) was 22^0C, with an average humidity of 78%. The air velocity remained at an average of 0.1m/s which falls within the (ISOEN 773424, 1994) range for sedentary activities.

Table 2: Statistical results of residences with temperature within 20-26°C

Climatic Parameters	Dry Season			Rainy Season		
	Ave	Min	Max	Ave	Min	Max
Indoor air Temperature ^{0}C	22.0	20.4	26	22.4	19.8	25.9
Outdoor air Temperature ^{0}C	26.1	24.0	28.4	26.7	23	27
Indoor Relative Humidity %	78	70	80	78	72	81
Outdoor Relative Humidity %	80	73	78	80	75	80
Indoor air Velocity m/s	0.1	0.`3	00	-	-	-

Table 3: Statistical results of residences with temperature exceeding 26°C

Climatic Parameters	Dry Season			Rainy Season		
	Ave	Min	Max	Ave	Min	Max
Indoor air Temperature ^{0}C	32	30	34	32	29.8	33
Outdoor air Temperature ^{0}C	26.1	25	28	26.0	24	27
Indoor Relative Humidity %	80	77	82	80	79	84
Outdoor Relative Humidity %	78	73	78	78	74	80
Indoor air Velocity m/s	0.1	0.3	00	-	-	-

The result revealed that out of the twenty seven (27) residences used for the thermal comfort test, nineteen (19) or 70.3% of it exceeded the index temperature range of (20-26 ^{0}C) , while eight (8) or 29.7% did not.

4.2 Analysis of Votes

The results of the questionnaire survey of the thermal perception of residential dwellers in the randomly selected residence include thermal sensation and preference. The equation that relates thermal condition to the seven point ASHRAE thermal sensation scale of -3 (cold), -2 (cool), -1 (slightly cool), 0 (neutral), +1 (slightly Warm), +2 (warm), +3 (hot) known as the Predicted Mean Vote (PMV) index was considered in the analysis. The neutral temperature is the temperature when the PMV = 0. The result revealed that majority (69.3%) of the respondents voted for hot sensation while 25.7% voted cool. The rest 5% were distributed among neutral (0), slightly warm (1), cold (-3) and slightly cool.

The ASHRAE Standard 55 (2004) specified that acceptable thermal environment should have 80% of the occupants vote for the centre categories (-1, 0, +1). In this study only 25.7% of the respondents votes fell within the ASHRAE standard 55 (2004) category. This therefore confirms that most indoor thermal environments in the study area were not acceptable or were thermally uncomfortable. It was also observed that the 69.1% thermal respondents who voted hot sensation (discomfort) all came from the 70.3% residences whose experimental results exceeded the Effective Temperature (ET) index range of (20-26^{0}C). This confirms that at temperatures exceeding 26 ^{0}C most indoors of residential buildings in Umuahia urban environment become thermally uncomfortable.

The result revealed that the average indoor temperature of residences, whose thermal measurement exceeded the ET index range of (20-26 ^{0}C) was 32 ^{0}C, while that of those that did not was 22 ^{0}C. It was also discovered that the architecture of the buildings used for examination contributed to their result. It was found that the design and construction of all buildings whose thermal measurements exceeded the Effective Temperature (ET) index range of (20-26^{0}C) i.e those that failed thermal comfort test did not consider the climate in Umuahia, hence, did not imbibe passive potentials needed to improve indoor air quality and thermal comfort in wet humid climates. Such design deficiencies is significant in the orientation of such buildings on site, zoning of living spaces, lack of shading devices. Poor choice of windows and window locations, use of concrete as major landscape material, absence of vegetation, deliberate abuse of building regulations, such as over development of plot areas, inadequate building setbacks, high fence walls etc. The reason for poor indoor air quality, and also abuse of building ethics was found to result from lack of engagement of professionals, as all the buildings that did not have acceptable thermal result had no architects. Cheividyankan (2007) inferred that because thermal comfort depends on the weather and the environment, it therefore becomes necessary for the design of the building to contribute 75% role in its comfort levels.

Recommendations and Conclusion

Since indoor thermal comfort is essential for the well being of the occupant (Akande 2010), it becomes important therefore for the architect and all environmental designers to target essentially energy efficient and sustainable architectural products. When buildings are designed to attain thermal comfort or when buildings need little or no mechanical energy support to do so, they are energy efficient and are sustainable (Alozie, 2014). The indoor thermal condition of residential buildings in Umuahia urban environment could therefore be improved, by adopting and improving on the design potentials of the residences, where thermal assessment remained with the Effective Temperature (ET) index of (20-26 ^{0}C).

Such thermal aids which are passive potentials include.

(1) Orienting building properly on site.

(2) The use of thermally friendly materials.

(3) Adhering to building codes and regulations such as

   (a) Keeping to permitted percentage of development.

   (b) Observing minimum building set backs from adjoining structures.

   (c) Avoiding high fencing walls.

(4) Landscaping; avoiding the covering of the entire site area in concrete. Planting grasses, shrubs and trees as landscape material for shades and to increase air movement, and heat absorbtion.

(5) Zoning spaces in a manner that living areas are separated from the direct sun effect, and directed towards the lee ward direction of the prevailing wind.

(6) Providing plot sizes that are proportionate to the users need.

(7) Making good use of colors.

(8) Good application of windows; such as

    a) Proper choice of windows, eg casement and louvered.

    b) The window opening direction such that adequate air quantity is harvested.

    c) Proper consideration of air inlets and outlets in the building.

CONCLUSION

There is no doubt that if the architect, and his design allies implement the aforementioned recommendations which should begin from design inception, and taken to practical completion of the new buildings they design and the old ones they refurbish, that the new products will provide acceptable indoor temperature. When this happens, energy will be saved, and a green and sustainable environment will emerge. Then product of design would live from cradle to cradle and not cradle to grave.

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