A Survey of Indoor Thermal Comfort Performance of Residential Homes Using the Effective Temperature Index in Agbama World Bank Housing Estate. Umuahia, Nigeria.

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ABSTRACT

Residential estates as elite solution to urban accommodation should be energy efficient, and sustainable. This is not the case with Agbama World Bank Housing estate in Abia State, as the estate lacks the integrity of providing acceptable indoor thermal comfort in this estate. Primary data was from measurement of indoor air temperature, relative humidity and air velocity for a year, January to December 2013, with data loggers. Architectural measurements of the study buildings and questionnaires structured with ASHRAE scale for thermal comfort. ASHRAE scale recognizes =3 (hot) to -3 (cold) comfort sensations. The estate was divided into 6 areas 1-6 and 4 areas (1, 2, 4, 6) selected by ballot. In like manner, roads from each of the 4 areas were chosen and 10 buildings each substantially selected from the roads. The study population was 120, buildings representing 10%. The variables were measured between 6.30-7.30am, 2.30-3.30pm and 6.30-7.30pm daily. The questionnaires were 480 Analysis with Effective temperature index, which provides 20-26^{o}C as acceptable indoor environment in warm humid climate revealed that 73.7% of the buildings and 79.3% of the respondents failed. ASHRAE holds that at least 80% of the respondents voted for comfort, only 20.7% did while 26.7% of the buildings did of in hest is the finding that 79.3% who voted discomfort all came from 73.7% buildings that failed the study thus concluded that indoors of majority of homes in Agbama World Bank housing estate Umuahia are thermally uncomfortable and that the case is lack of professional engagement the study thus recommended that for thermal comfort, energy efficiency and sustainability that all future estates originate from professionals.

Keywords: Residential Estates, Residential building, Indoor thermal comfort, Air temperature, Relative humidity and Air velocity.

ISSN 2229-5518

1.1 INTRODUCTION

Buildings and the built environment define every urban settlement, because buildings determine the character and very important landmark in any city (Pinheiro, 2006). Accordingly Pinheiro (2006) believed that buildings and the built environment create a feeling of familiarity and identity which makes cities pleasant places for dwellers and tourists, and provides the suitable environment for dwellers to live and work in. Pinheiro (2006) concluded that the standard of a particular built environment determines the ranking among other urban environment.

Building is essential for human welfare, which includes habitation, and health (Alozie, 2014). Just like building and the built environment are in reference to the identity of the urban environment, so is housing estates an elite sustainable chart, of every civilized society to decently accommodate the residential quest of her populace (Alozie, 2014).

Population the strength and character element of any urban environment, since cities are most rottenly defined by its population. Notably, the economic activity of any city is also a function of its population, since most cities with high number of dwellers are known to have higher level of economic and social dividends, as urban environments have remained the centre of civilization amongst all nations. Urban environment have always exerted strong draining pull on the rural population. The rate at which rural to urban migration have taken place in recent times, especially in Nigeria, if not checked will soon leave the rural environment with a declining population. (Ijioma, 2000). This has been the fate of Umuahia, the capital city of Abia State Nigeria, ever since it became a state capital in 1991.

According to NPC (2015) population approximation, the urban city of Umuahia in the past two decades have witnessed a population surge from 423,000 to 1.2 million people (see page on website), with more than 70% of this increment coming from the rural areas. Umuahia being an administrative and educational city have also attracted people from diverse areas, unfortunately this population increase in Umuahia was not matched with an increase in housing provision, which resulted in the scarcity of accommodation, in the city causing many people to live in squatters. The effect of these squatters on the city and its environment is the gradual but steady slum growth.

The need for decent housing and slum control in Umuahia resulted in the creation of many housing estates by Government, and the private sector. Some of these housing estates are, Ehimiri, Low cost, World Bank 1, Agbama (World Bank), Amaeke, Ohii, Amakama, Ogurube, Aguiyi Ironsi, Umuobia, and Evangel.

According to Alozie (2014), the house remains a major instrument, a machine that allows us to acquire basic indoor thermal comfort. The house is a modifier of our indoor and a must for life sustenance. This is because the house absorbs or repels the beneficial or negative influences of climate affecting our comfort. Most housing estates are made up of residential buildings, and residential buildings are buildings or homes where one lives permanently or for very long time, where one carries out day to day activities, such as sleep, rest, read and answer calls from nature. (Rao, 2007). In light of Rao's definition therefore and since housing estates are conceived to provide residential accommodations for human comfort, they should then be a product of professional planning and construction. One which expresses architectural purity, from specialist in the built up environment, and not a policy to be left in hands of mediocre, as is witnessed in most housing estates in Umuahia.

Housing estates should be sustainable in their design, construction, operation and deconstruction (Mean 2011, Henderson 2012 and Sonnett 2009). Sassi (2006) in support of the above affirmed that the design of sustainable built environment is a professional task which is better left in the shoulders of experts as indoors of homes should express definitely, the integration of strength, cost and beauty, an architectural product which developed accommodes the future, having full aesthetic compliments. Indoor thermal comfort is of great importance to the day to day operation of every home, this should be so if energy is to be conserved, and if housing estates are to remain relevant and sustainable.

Thermal comfort is defined by American society for Heating, Refrigerating and Air Conditioning Engineers, ASHRAE as the express satisfaction within the thermal environment, in which at least 80% sedentary or slightly active persons find their environment thermally acceptable (ASHRAE, 2004).

Akande (2010) believe that indoor thermal comfort is achieved when occupants pursue without hindrance, activities which the building is intended to, while Dagostino (1978) defined thermal comfort as a state of being able to carry out any activities without being either chilly or too hot.

These definitions greatly vary with the state of thermal comfort in Agbama World Bank housing estate, as observations and interactions with the occupants reveals, because a most disgusting attitude observed in the estate is its inhabitants remaining outside the comfort of their homes in the evening times and late at night, fanning themselves with hand fans, especially when there is no electricity. They do this while waiting for the indoor temperature of their homes to fall within acceptable degree. The cause of this attitude may be related also to Adesoye (2011)'s findings. Adesoye (2011) found that mean maximum temperature has been on the increase from 30^{o}C in 1979 to 33.5^{o}C in 2004 in Ibadan, a warm humid environment, the same with Umuahia Abia state.

The level of indoor thermal comfort obtainable in high temperature conditions is of great concern especially with the treat of climate change, as indoor and outdoor air remains dominant climatic factors affecting thermal comfort in the tropics. The afternoon period in the tropics is noted for hot discomfort due to the impact of intense solar radiation which leads to high temperature during the period. This consistent impact of high insulation affects building and detects level of indoor comfort to a high degree. Adunola (2012) underscored the need to establish in principle the need for buildings generally and residential buildings in particular to provide a functionally acceptable thermal environment, because the home environment should provide an atmosphere suitable for its purpose of being a palace of rest. This is true, as buildings should respond to climate.

According to Odim (2008), the architecture of responsive building is one whose design, construction and operation strategies have enabled to take advantage of potentials that will unconditionally create indoor thermal comfort, with little or no energy expenditure. Henderson (2012) described these features as sustainable, while Mean (2011) classified them as green building potentials.

The aim of this study therefore was to determine the indoor thermal performance of residences in Agbama World Bank housing estate using the Effective Temperature Thermal Index and the response of its inhabitants to their thermal environment in order to find out if the residential homes measure up to the definition of comfort required calling it home. This aim however was achieved by ascertaining indoor thermal conditions in the estate through monitored experiments and the analysis of responses thermal of behavior study of inmates of the estate buildings.

It became necessary to conduct a field survey of thermal comfort in the housing estate, because field studies according to Humphreys (1975) are for two purposes, namely to find a way of describing the thermal environment which correlates well with human responses, thereby enabling reliable predictions to be made and secondly to define the range of conditions found to be pleasant or tolerable by the population involved. A thermal comfort field survey was therefore carried out in Agbama World Bank housing estate with a view of matching the indoor comfort conditions of the residences to the perceived individual responses in the estate. The study will help suggest possible methods and solutions to improving indoor thermal comfort of homes in the estate, and the design of new ones in locations of similar climatic conditions.

2.0 LITERATURE REVIEW

A building can be climate responsive, depending on its design and construction. According to Beng (1994), climate is a prime factor in built form, and is the mainspring for all the sensual qualities that add up to a vital tropical architecture. The building envelope is a designed selective filter; excluding unwanted influences like excessive radiation, but admitting the desirable and useful elements like appropriate day lighting. Szokolay and Brisbin (2004) are of the opinion that it should be the designers aim to ensure that the required indoor thermal conditions are met with little or no use of energy, other than from ambient or renewable sources and affirmed that thermal behavior of a building, is a product of the interaction between architecture with climate which has great effect on the energy use and sustainability of the building.

According to Adunola (2015), thermal comfort is an essential feature when considering the functional adequacy of any building space, and the sustainability of any built environment, Adunula (2015) further opined that despite the part of the world or thermal environment one from, buildings shall provide the enclosure for required indoor thermal environment, as individuals are affected positively or negatively inside it due to their innate physiological response to their indoor environment, and believed that there is a significant role thermal comfort plays in human performance at both mental and physical levels.

Tsuzuki et al, (1991); Wyon (2001); and Huizenga et al (2006) in their individual study findings concluded that thermal comfort and air quality can greatly affect productivity in humans. Other prominent studies in thermal comfort that are relevant to this study are Humpherys (1978), Auliciems (1981) and de Dear (1998) whose studies expressed that thermal neutrality is a function of the prevailing climate in a location. Haase and Amato (2009) considered climate conditions as the most important factor in the determination of thermal comfort, while Nicol and Humphery (2010) described how the indoor comfort condition were related to the running mean of the outdoor temperature, and addressed the effect of air movement and humidity. Humphreys (1975) noted further that a far greater part of the variation in response can be attributed to change in temperature than changes in humidity or air movement, and a Humphreys (2007)'s study stated that adaptation in thermal comfort is self regulating while people take actions to attain comfort. A common opinion of all the mentioned authors remains their emphasis on the dependence of indoor environmental condition on the external climatic conditions.

In ways of acquiring thermal comfort in buildings in warm humid climates, Abrams (1986) noted heat avoidance and ventilative cooling to be most effective. Balaras (1996) adding to Abrams (1986) listed shading devices, proper building orientation and use of local vegetation as simple means of reducing heat in buildings.

Further to this, Chandra (1986) in a study revealed that constant air exchange of 15ACH on the average could keep the indoor temperature at 1.4^{o}C lower than the ambient outdoor temperature; and if increased to 30ACH air exchange rate could be maintained at the average ambient outdoor temperature. Implying this to be a product of good ventilation Alozie (2014) in support of this recommended that good ventilation is achieved when functional window types and sizes are installed in buildings and when wind directions are considered during design of the window and the window installation, and in conclusion hinged success of ventilation in buildings on the building design, which he insisted should begin from the design inception and issue that is added as an appendix or after thought.

3.0 LOCATION AND CLIMATE OF THE STUDY AREA

Umuahia the urban capital city of Abia State is in South Eastern Nigeria, and located on latitude 51^{o} 25^{1}N and longitude 7^{o}10^{1}E. (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 a 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^{o}C), high (mean max -85%) and low air velocity (mean max -1.55m/s). the maximum temperatures were above 30^{o}C 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 cause 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).

ISSN 2229-5518

4.0 METHODOLOGY

Agbama housing estate is in Umuahia South Local Government area of Abia State. It remains one of the most rapidly developing housing estates in Umuahia supported by World Bank. The estate comprises of six (6) neighborhoods known as Areas one, to six (1-6). Each of the areas is made up of two hundred (200) units of housing, and one thousand two hundred (1200) in all. The average area of each of the building plots is is 425m^2 and comprising of bungalows and upper floors not exceeding three storeys of tenement buildings. There is no specific architectural style for the estate.

A thermal comfort study was conducted in Agbama housing estate in 2013, to assess indoor thermal comfort performance of the residences. This took the shape of monitored experiments in the residences to determine the indoor thermal comfort in the buildings and secondly, a questionnaire survey was used to find out thermal experiences of the inhabitants of the estate. One year characterized by average thermal discomfort in the study area was considered sufficient and adequate for all the respondents to experience the same conditions. This is similar to Adunola (2012)'s study of thermal comfort in some estates in Ibadan. Four neighborhoods, namely areas 1, 2, 4 and 6 were chosen by balloting, and in like manner three (3) roads selected from each of the six roads in the neighborhoods. From each road, ten (10) buildings were systematically selected, bringing to total thirty (30) buildings in each area and one hundred and twenty (120) buildings from the study area, representing ten percent (10%) of the building population in the estate.

Questionnaire covering the indoor thermal response at different periods of the day, in morning 7.00-9.00am, afternoon 1.00-3.00pm and evening 5.00-7.00pm specifically, using ASHRAE thermal comfort scale of +3 for (hot) to -3 for (cold) were distributed at an average of four (4) per house hold or a total of four hundred and eighty (480) respondents, made up of 240 males (57.1%) and 180 females (42.9%).

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

Year	2014
Sample size (male/female)	108(52/56)
Gender(%of sample)	
Male	57.1
Female	42.9
Mean age (year)	
Mean	31-49
(Minimum, Maximum)	(16, 70)
Mean years living in local address	
Mean	10-15
(Minimum, Maximum)	(1-5, 20)
Mean Height (m)	
Mean	1.66
(Minimum, Maximum)	(1.37, 2.01)
Mean weight (kg)	
Mean	61
(Minimum, Maximum)	(45, 84)

The questionnaire covered many areas including the demographic (name, sex, age, etc), years of living in the estate and personal environmental control (Table 1) the average age of the respondents lie between 30-50years. The questionnaire also includes the traditional scales of thermal sensation (TSENS) and thermal preference. The three point thermal preference scale used, asked if respondents would like to change their present thermal environment. Possible responses were “want warmer”, “no change”, “and want cooler”.

The major instruments for experiment was data loggers made available by architecture and physics departments of Abia State University Uturu. The data loggers measured the indoor and outdoor air temperatures, relative humidity and air velocities. The data loggers which hung at 1.5meters on the wall were calibrated to take records at between 6.30-7.30am, 2.30-3.30pm and 6.30-7.30pm respectively; this was to capture the maximum and minimum readings of the study variables.

4.2 PHYSICAL MEASUREMENT OF CASE STUDY BUILDINGS

Architectural measurement and details and specification of materials of the study building were taken in order to discover how equipped the buildings are in combating climate challenges. The measurements include the site plan(s), floor plan(s), the sections and the elevations. The buildings orientations, percentage of plot areas developed, landscaping, set backs from adjoining structures, fencing heights, building materials used, and the building finishings. The research considered also the location of living spaces (zoning), room size and heights, windows (types and sizes), opening locations among other things.

This became necessary in order to establish the degree to which architecture of the buildings contribute to their indoor thermal comfort of such homes. The thermal index used to classify the buildings was the Effective Temperature (ET), which admits a temperature range of 20^oC to 26^oC and humidity of 55-80% as comfortable for warm humid climate.

5.0 FINDINGS

Data collected from the study was classified into primary and secondary. Primary data was formed by the measured comfort variables, of air temperature, relative humidity and air velocity. Data from the questionnaires was also considered as primary information. The secondary data used majorly to compare, climate measurement was obtained from Methodological Institute, of National Root Research Umudike.

5.1 PRIMARY DATA

A total of 420 respondents were chosen for the study. Out of this number, 220 (57.1%) were male, while 180 (42.9%) were female. 41.3% were aged 49years and above. It was further discovered that 15.7% of the residents had lived for 1-2years,

ISSN 2229-5518

55.1% had stayed for 3-10years while 27.2% had lived beyond 10years, therefore their value judgment of thermal feeling is reliable.

Table 2 statistical results of residences with temperature within (20-26 ^{0}C) representing annual average.

	Max.	Ave.	Min.
Indoor air Temperature ^{0}C	22.9	20.8	26.3
Outdoor air Temperature ^{0}C	26.5	26.0	28.0
Indoor Relative Humidity %	78.3	70.7	80.1
Outdoor Relative Humidity %	80.6	73.5	78.3
Indoor air Velocity m/s	0.1	0.0	0.3

Table 3 statistical results of residences with temperature exceeding 26 ^{0}C representing annual average.

	Max.	Ave.	Min.
Indoor air Temperature ^{0}C	34.6	30.4	34.5
Outdoor air Temperature ^{0}C	26.1	25.3	28.2
Indoor Relative Humidity %	80.7	77.3	82.3
Outdoor Relative Humidity %	78.8	73.8	78.1
Indoor air Velocity m/s	0.1	0.0	0.3

The result revealed that out of the one hundred and twenty (120) homes used for the thermal study, eighty eight (88) or 73.3% exceeded the index temperature range of (20-26 ^{0}C), while thirty two (32) or 26.7% did not.

5.2 ANALYSIS OF VOTES

The results of the questionnaire survey of the thermal perception of home makers in the study 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 Predictable Mean Vote (PMV) index was considered in the analysis. The neutral temperature is the temperature when the PMV=0. The result revealed that majority (79.3%) of the respondents voted for hot sensation while 20.7% voted cool. The rest 5% was shared 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 20.7% of the respondents fell within the ASHRAE standard 55 (2004) category. This therefore confirms that most indoor thermal environment of the study estate were thermally uncomfortable. It was observed that the 79.3% thermal respondents who voted hot sensation (discomfort) all came from 73.3% homes whose experimental results exceeded the Effective Temperature (ET) index thermal comfort range of (20-26%). This thus reveals that at a temperatures exceeding 26^0C indoors of residential homes in Agbama World Bank Housing Estate, Umuahia become thermally uncomfortable. It therefore supports a study by Alozie (2014) on thermal comfort standard of residential buildings in Umuahia Urban, the result also revealed that the average indoor temperature of homes, whose measurement exceed the ET index comfort range of (20-26 ^{0}C) was 34 ^{0}C, while that of those that remained in the comfort range was 22.1 ^{0}C. It was also discovered that the architecture of the buildings used for examination contributed to their performances. It was found that the design construction of all buildings whose thermal measurement exceeded the Effective Temperature (ET) index range of (20-26^oC) 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 choices of windows and locations, use of concrete as major landscape material, absence of vegetation on landscape 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 professional, as all the buildings that did not have acceptable thermal result had no architects. Alozie (2015) 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.

5.3 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 the environmental designers to target essential energy efficient and sustainable architectural products. When buildings are designed to attain thermal comfort naturally or with little mechanical energy, they are classified as energy efficient and are said to be sustainable (Alozie, 2014). The indoor thermal condition of residential buildings therefore can 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 potentials which are also classified as passive design potentials include.

(1) Orienting building properly on site and designing buildings such that its longer sides incline towards the prevailing wind, while avoiding much openings on the west.

(2) The use of thermally friendly materials

(3) Adhering to building codes and regulations such as

(a) Keeping permitting 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 absorption.

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

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

(7) Making good use of colors in outdoor and indoor walls.

(8) Good application of windows; such as

(a) Proper choice of windows type, like the casement and louvered

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

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

5.4 CONCLUSION

There is no doubt that if the architect, and all other partners in the design of the environment implement these recommendations, which is should begin from design inception in the new residential estates they design and the buildings in the existing estates they refurbish, that the product will be thermally responsive, and when building respond thermally to their environment, energy is saved while green and sustainable environment emerges and then architectural products will lives from cradle to cradle and not cradle to grave. Sonnett (2009).

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