BUILDING FORMS AND VENTILATION AS DETERMINANTS OF THERMAL COMFORT IN HOSTEL ROOMS IN UNIVERSITY OF PORT HARCOURT.

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ABSTRACT

This study assessed building forms and ventilation as determinants of thermal comfort in hostel rooms in University of Port Harcourt. Two specific research objectives were formulated to guide the study. The researchers adopted a descriptive survey design. 3 hostels from Abuja campus of the University of Port Harcourt were randomly selected for the study. The instruments used in collecting data were Gun bellani, Max/min thermometer, Dry/wet bulb thermometer (hygrometer) and Anemometer. The findings made from the study revealed that there is significant relationship between ventilation of students hostel and occupants thermal comfort level. The result also proved that there is significant influence of building form (L – shape coupled with inverted L – shape as form 1, I - shape as form 2 and Rectangular shape as form 3) on the thermal comfort level of student hostels, meaning that the mean value (27.20) of the level of occupants' thermal comfort derived from building forms of hostel 3 was significantly higher than that of hostel 1 (22.59) which was higher than that of hostel 2 (21.59). One of the recommendations was that architectural building form that incorporates double windows as found in the building of hostel number 3 being Rectangular shape of the case study should be adopted in all other student hostels and residential areas in order to enhance thermal comfort of the occupants.

Key words: Building forms, ventilation, thermal comfort, hostel rooms, University of Port Harcourt.

Introduction

Man has over the years been successful in creating environment that is conducive for all kinds of activities. One of the basic requirements of this environment is to maintain thermal conditions comfortable for occupants as this has a direct effect on health, productivity and morale of the occupants (Budaiwa, 2006). We live in an age of machines and great transformations. Manual labour is being superseded by steam power and electrical power. Most homes, offices, educational institutions are equipped with electrical appliances and computer machines of all kinds; and hostels in the universities cannot be an exception. This is to enhance the comfort of the students and facilitate the learning process. A good hostel is the students' paradise. Here, he is completely free; he has no restraint excepting that of his own sense; no interference, excepting of his conscience that calls him to class. In between classes, he finds here recreation and relaxation. In fact, he is a master of his fate and he can very well take care of himself. The hostel refreshes his tired mind; it lifts the head from his weary brain. Modern education is a strenuous affair, and students have often been required to spend long hours in the lecture room, libraries and hostels. They need good and appealing dwelling rooms/environment which can keep the body and brain fit for work.

According to Thompson (2010), the history of the University of Port Harcourt (UNIPORT) is a very rich one. The University of Port Harcourt, Unique UNIPORT as it is popularly known by her students, staff and alumni is an institution of higher learning owned by the Federal republic of Nigeria. It is pertinent to state that, when designing students' hostels, cognizance be given to factors that will enhance the attainment of thermal comfort. Factors like environmental parameters (temperature, thermal radiation, humidity and air speed); building forms and materials (building thermodynamics – i.e, conduction, convection, radiation and evaporation) and personal parameters (personal activity and condition – personal metabolic rate as influenced by food, drink habits and clothing insulation), should form the bases to achieving thermal comfort. Invariably, the time for authorities and agencies charged with university education matters to act is now.

Statement of the Problem

In recent years, climate change has had adverse effect on the tropical climate and the effect of global warming due to ozone layer depletion is becoming conspicuous. It is pertinent to state that majority of hostels existing in Nigerian universities are not so thermally conducive for students to study. This thermal discomfort decreases productivity and poses a serious threat to the well-being of students: a situation faced by students residing in the hostels of the University of Port Harcourt.

The occupants of these hostels experience excessive heat resulting from the penetration of sunrays into the rooms, which may hinder their productivity and performance. This was confirmed when few students were interviewed and they complained bitterly how heated the rooms are, especially during the day. This forces the students to stay outside the hostels most hours of the day. It is pertinent to note that, the hostel design concept or building form also hinders thermal comfort to be attained in the hostels. The heat dissipated by students resident in the hostels and expelled gases, carbondioxide (CO_2) released into the rooms can impede concentration; reduce sound sleep and relaxation which may affect students' health and academic performance negatively. In such hostels, the used air is not correspondingly expelled from the space as a result of low headroom experienced in the rooms that cannot allow for proper air flow/circulation within the space.

Objectives of the Study

The aim of this study is to assess thermal comfort level in students' hostels in University of Port Harcourt with the view to proposing a thermally conducive hostel through design.

1. To assess the level of ventilation in the selected hostel buildings and their relationship with the occupants thermal comfort level.
2. To compare the level of thermal comfort achieved in rooms based on the hostel building forms (L-shape coupled with inverted L-shape, I-shape and Rectangular shape) as applicable to hostel buildings in University of Port Harcourt.

Research Hypotheses

The following hypotheses will be tested:

1. There is no significant relationship between ventilation of student hostels and the thermal comfort level.
2. There is no significant influence of building form (L – shape coupled with inverted L-shape, I-shape and Rectangular shape) on the thermal comfort level of student hostels.

Ventilation and Occupants Thermal Comfort

According to Heiselberg (2006), the primary objective of ventilation in occupied space is to supply fresh air and remove contaminants in order to assure thermal comfort. Fanger (1970) in Toftum, (2004) defines thermal comfort as the condition of the mind which expresses satisfaction with the thermal environment. Thermal comfort is said to be achieved in a building when the highest possible percentage of all occupants are thermally comfortable. People have always been in pursuit of creating comfort in their environment through natural ventilation due to its low cost. It is still one of the most important matters taken into account in the building design process. According to Hazim, (2010), natural ventilation is where the airflow in a building is as a result of wind and buoyancy through openings or cracks within the building envelop. It can also be defined as:

1. **Single-sided ventilation:** where the ventilation rate is limited to zones close to the openings. Wind turbulence and thermal buoyance are the main driving forces. On comparison with other principles, lower ventilation rates are registered with single-sided ventilation.
2. **Cross ventilation:** where two or more openings on opposite walls of a building cover a zone. The openings are usually windows or vents. Effect of cross ventilation is dependent on wind pressure and opening size.
3. **Stack ventilation:** It relies on two principles which take the advantage of air density. That is, as it warms, it rises to the exit and the warm air is replaced by cool air hence, the space is ventilated. Here ventilation openings are at both high and low levels.

Wang and Wong (2006), states that with the global emergence of energy shortages, climatic changes and sick building syndromes associated with the common usage of air-conditioning, authorities worldwide have recognized the necessity in finding strategies that can cultivate a more sustainable design with satisfactory indoor thermal comfort. This has led to the growing interest in low energy cooling strategies that take advantage of natural ventilation which has the potential to reduce first costs and operating costs for commercial buildings while maintaining ventilation rates consistent with acceptable indoor air quality. It has been demonstrated that naturally ventilated buildings in some climates can operate for the entire cooling season within adaptive comfort constrains without mechanical cooling. According to Cai and Wai, (2010), natural ventilation efficiency and building thermal comfort are affected by both internal and external factors (Cai and Wai, 2010). Internal factors are majorly dependent on openings control setup and building designs and can be varied or engineered for the desired conditions while external factors include building orientation, location and prevailing weather conditions. These are usually natural and constrained.

Manual window control

Adoption of manual control of windows is to have the window opening and closure left to the occupants. Windows in this strategy are opened by the occupants. This usually happens whether or not the outside temperature is above the inside temperature. Though considering the lowest cost option, a challenge in this strategy is that at times, occupants neglect or forget to open and close the windows when the outdoor conditions vary in unpredictable manner hence, leading to thermal comfort problems

Automated window control

In automated window control, an automatic window control device is installed on the window. This device has a temperature sensor set to a set point temperature that opens the windows when the inside temperature is higher than the outside temperature and closes the window when the inside temperature is lower than the outside temperature (Carrilho et al, 2003). Here windows can be opened to a variable width depending on the change in inside temperature. In hot and humid climates, elevated indoor air velocity increases the indoor temperature that building occupants find most comfortable. Nevertheless, the distribution of air velocities measured during these field studies was skewed towards rather low values. Many previous studies have attempted to define when and where air movement is either desirable or not desirable (i.e. draft) (Mallick, 1996). Thermal comfort research literature indicates that indoor air speed in hot climates should be set between 0.2 - 1.50 m/s, yet 0.2 m/s has been deemed in ASHRAE Standard 55 to be the threshold upper limit of draft perception allowed inside air-conditioned buildings where occupants have no direct control over their environment (de Dear, 2002). The new standard 55 is based on Fanger's (1988) draft risk formula, which has an even lower limit in practice than 0.2 m/s. None of the previous research explicitly addressed air movement acceptability, instead focusing mostly on overall thermal sensation and comfort (Toftum, 2004).

Building Forms and Thermal Comfort

According to Budaiwa (2006), thermal comfort is attained when a thermal balance is achieved: a situation in which no heat storage occurs in the body. Although this can be achieved over a wide range of thermal environment conditions, thermal comfort is associated with conditions to which the body can readily adjust. ASHRAE standard 55 defined thermal comfort "as the state of the mind that expresses satisfaction with the surrounding environment". Standards such as ASHRAE standard 55 and 150 standard 7730 are the basis in the determination of thermal comfort by most practitioners and researchers (Charles, 2003). Nonetheless, people in different climatic zone feel comfortable at different indoor air temperatures: a situation which can vary considerably from that of the world standards.

The factors affecting thermal comfort depend on four environmental (that is dry bulb temperature, mean radiant temperature, relative and air velocity) and two personal (Clothing insulation and physical activity) parameters (Szokolay, 2004). The thermal comfort standard prescribed by 1507730 was the first to have been used on a world-wide basis, based on Fanger's work in climate chamber experiments using young Danish Students and eventually the PMV model. Architecturally, the hot and humid regions are the hardest climates to improve through design: due to high outdoor thermal condition (humidity and temperature) that result in soaring indoor temperatures exceeding the ASHRAE summertime comfort upper limit of 26^{o}C. A temperature limit should at least get 90% of occupants feeling thermally comfortable for most part of the year. The overall thermal comfort field studies according to Humphery and Nicol (2002) and de Dear (1993), the PMV model does not always accurately predict the actual thermal sensation of occupants. Measuring of the physical variables with reliable instrument, clothing insulation, activity levels, individual differences, building differences, outdoor climate, behavioural and psychological adaptation are all factors that have been mentioned by thermal comfort researchers as factors contributing to the bias nature of the PMV model (De Dear and Brager, 2002). This model has been found by most researchers as a better predictor in mechanically ventilated buildings (Brager, 1998). In the case of naturally ventilated buildings, differences have been observed between the thermal comfort. Hence, it is essential for occupants' well-being, productivity and efficiency.

Adebamowo (2010) and Heidari (2002) suggested that air temperature alone is a good indicator of thermal comfort. The effects of other environmental parameters on thermal comfort like heat gain through the exterior window accounts for 25% - 28% of the total heat gain. Moreover, the thermal capacities of various materials respond differently on incident solar radiation. Orientation and spatial organization also affect the ability of a building to ventilate and receive solar radiation Jones (2012). To minimize solar heat gain and maximize ventilation, buildings should be orientated with their longer sides intercepting prevailing winds and the shorter sides facing the direction of the strongest solar radiation. The positive effects of shading on thermal comfort have been stated by Jones (2012), Sumanon (2004), and Chenvidyakaran (2007).

According to Jones (2012), buildings can be designed to interact with the external environment in order to benefit from the natural energy of the sun and wind. The building form and fabric can be used to control solar gains in summer to avoid overheating. The wind could also be used to provide ventilation and cooling. The fabric of the building can be used to insulate against heat loss or gain, and to stabilize the internal environment against extremes of temperature (hot or cold). The form, mass, orientation and construction of the building need to be designed in response to the climate and specific location. This is often termed "passive design" (Jones, 2012.and Simons 2014). They also agree that, lightweight buildings will respond quickly to heat gains, from either internal sources (people, lights, machines) or external sources (solar radiation, high external air temperatures). The internal air will therefore warm up quickly as the mass of the building will have a relatively low capacity to absorb internal heat. They are more likely to overheat during warm weather and be cool during colder weather. They therefore require a more responsive heating/cooling system and are more suited to intermittent occupancy. Heavyweight buildings are slower to respond to changes of temperatures, and therefore have the potential to maintain a more stable internal environment. Buildings constructed of heavy weight materials will have a high thermal capacity. They will be slow to heat up as the building will absorb heat from the space. However, they will also be slow to cool down and are able to retain relatively high internal air temperatures between heating periods. Heavy weight buildings can maintain relatively cooler internal environment in warmer weather by absorbing packs in heat gains. Typical cooling effects may be up to 3^{o}-5^{o}C (Szokolay, 2004).

Methods

Research Design

This study adopted a descriptive survey research method. The adoption of the descriptive survey is because of the nature of the research. The phenomena that surround the study also informed the utilization of the design. It describes the extent of thermal comfort of the buildings.

Study Area

The study area is Port Harcourt which is the capital of Rivers State, southern Nigeria. It lies along the Bonny River (an eastern distributaries of the Niger River) 41 miles (66 km).

Population of the Study

The population of the study consisted of all students' hostels and occupants in the three campuses of University of Port Harcourt. There are 21 hostels and 20,160 students.

Sample and Sampling Technique

The 3 hostels used in the study were selected from the 21 hostels obtained from the 3 campuses of the University of Port Harcourt. The hostels were selected from three campuses, using simple random sampling technique. These 3 hostels formed 14.29% of the population of 21 hostels.

Data Collection /Instrument

The main instruments used for data collection are as follows with their usefulness and picture:

1) Gun bellani -------- solar radiation
2) Max/min thermometer -------- temperature
   Dry/wet bulb thermometer (hygrometer) -------- humidity
3) Anemometer -------- air velocity

Stevenson screen is the case that shields max/min thermometer, dry/wet bulb thermometer from direct sunlight.

Method of Analysis

To ascertain climatic change, mythological reports of the research area were obtained along with other academic researchers. The collected data were calculated based on Fanger's approach (the heat-balance approach) to obtain the thermal comfort index (PMV) in relation to PPD (Predicted Mean Vote – PMV and Predicted Percentage Dissatisfied – PPD). After the laboratory test was conducted on the data, all the hypotheses were stated in the null form, and were tested at 0.05 level of significance with appropriate statistical tool as follows:

Data Analysis and Results

Hypothesis One

The null hypothesis states that there is no significant relationship between ventilation of students hostel and occupants thermal comfort level. In order to test the hypothesis, two variables were identified such as:-

1. Ventilation of students' hostel as the independent variable
2. Occupants thermal comfort level as dependent variable

The two variables were subjected to regression analysis in order to generate R and R^2 values (See Table 1).

TABLE 1

Model Summary of the Relationship between Ventilation of Students' Hostel and Occupants' Thermal Comfort Level.

Model	R	R-Square	Adjusted Square	Std. Error of the Estimate
	0.98*	0.96	0. 86	2.45

***Significant at 0.05 level; df =4; critical R-value = 0.95**

The above calculated R-value (0.98) was greater than the critical R-value of (0.96) at 0.05 alpha level with 5 degree of freedom. The R-square value of (0.98) predicts (98%) influence of indoor and outdoor temperature of students hostel on occupants thermal comfort level, while the remaining 2 % of thermal comfort is contributed by others factors not mentioned here. The rate of percentage (98%) is highly positive and therefore implies that there is significant relationship between ventilation of students hostel and occupants thermal comfort level.

Hypothesis Two

The null hypothesis states that there is no significant influence of building form (L – shape coupled with inverted L - shape, I - shape and Rectangular shape) on the thermal comfort level of student hostels. In order to test the hypothesis, two variables were identified as follows:-

1. Building form of students' hostel as the independent variable
2. Occupants' thermal comfort level as the dependent variable.

One-way analysis of variance was used to analyze the data in order to determine the influence of architectural building forms of the hostel and occupants' thermal comfort level (see Table 2).

TABLE 2

One-Way Analysis of Variance of Influence of Building Forms on the Students' Hostel and Occupants' Thermal Comfort Level.

Groups	**N**	**$\overline{X}$**	**SD**
L – shape coupled with inverted L - shape as in hostel 1	2	22.59	0.17
I - shape as in hostel 2	2	21.59	0.24
Rectangular shape as in hostel 3	2	27.20	0.63
Total	**6**	**23.80**	**2.69**

Source of variance	**Sum of Square**	**Df**	**Mean square**	**F**
Between group	35.78	2	17.89	
Within group	0.48	3	0.160	111.79*

Total	**36.26**	**5**		

***significant at 0.05 level; df = 2 & 3, Critical F-value = 9.55**

Table 2 Shows that the calculated F-value of (111.79) was obtained after testing for significance at 0.05 alpha level with 2 & 3 degrees of freedom. The calculated F-value (111.79) was greater than the table F-value (9.55). Hence, the result was significant, and this means that architectural building forms of the students' hostel has significant influence on the occupants' thermal comfort level, meaning that the mean value (27.20) of the level of occupants' thermal comfort derived from building forms of hostel is significantly higher than that of hostel 1 (22.59) which is higher than that of hostel 2 (21.59).

Discussion of the Findings

The result of the data analysis in table 1 was significant due to the fact that the calculated R-value (0.89) was greater than the critical R-value of (0.95) at 0.05 level with 4 degree of freedom. The result implies that there is significant relationship between ventilation in students' hostel and occupants thermal comfort level.The result was in agreement with the findings of Adebamowo (2010) and Heidari (2002), who suggested that air temperature alone is a good indicator of thermal comfort and that the effects of other environmental parameters on thermal comfort like heat gain through the exterior window accounts for 25% - 28% of the total heat gain. He added that moreover, the thermal capacities of various materials respond differently on incident solar radiation.

The result of the data analysis in table 2 was significant due to the fact that the calculated F-value (111.79) was greater than the critical F-value of (9.55) at 0.05 level with 4 degree of freedom. The significant difference here exists due to the fact that *Berlloni's Principle* applies to building form of the hostel number III. This is true because stack effect is achieved in an open courtyard building –- where cold/fresh air flows into the rooms through fenestrations to ventilate the space; and subsequently, the hot/used air is sent out through high level windows into the courtyard; consequently, the hot/used air is expelled from the building through the open space over the courtyard and the process is repeated. The result implies that there is significant influence of building form on the thermal comfort level of students' hostel on the occupants. The result was in agreement with the findings of Jones (2012), who stated that buildings can be designed to interact with the external environment in order to benefit from the natural energy of the sun and wind and that the development of the building can be used to "filter" or "modify" the external climate to provide internal comfort conditions for much of the year without the use of fuel. Besides, he stated that, building form and fabric which can be used to control solar gains in summer to avoid overheating.

Conclusion

Based on the findings of the research work, the researcher deemed that most hostels in University of Port Harcourt are not conducive as a result of inadequate thermal comfort in them. The indoor temperature in these hostels which are mostly below or above the acceptable comfort level standard of 23°C - 26°C as well as the inability of the humidity level in the rooms to fall within the acceptable standard of 30-60% during most hours of the days made the hostels not conducive. It can also be deduced that there is significant relationship between ventilation and occupants thermal comfort level. It could also be concluded that there is significant influence of building form of the students' hostel on occupants' thermal comfort level.

Recommendations

In assessing thermal comfort level in student hostels in University of Port Harcourt, the followings are recommended:

1. An open courtyard form of architectural building with double windows as found in the building of hostel number 3 of the case study should be adopted in all other student hostels in order to enhance thermal comfort.
2. The hostel should be built to accommodate adequate windows and the windows should be positioned to enhance cross ventilation.
3. The hostel should have high level of windows to allow escape of hot air.

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