Quality of Thermal Indoor Environment and the Level of Comfort Satisfaction of the Occupants of Middle Income Housing in Uyo metropolis

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Abstract

The study aimed at assessing quality of thermal indoor environment and the level of comfort satisfaction of the occupants of middle-income housing in Uyo metropolis, Akwa Ibom State. Descriptive survey research design was used for the study. The population for the study consisted all middle-income housing in Uyo metropolis. The instruments used for data collection were liquid crystal thermometers, wet and dry bulb hygrometer, anemometer and the CBE Thermal Comfort Tool (a computer model programme). The instrument was face and content validated by expert from test, measurement and evaluation while Crombach Alpha technique was used to determine the reliability of the instrument at 0.84 coefficients. Data obtained were analysed using Pearson Product Moment analysis. The findings of the study revealed that there is significant influence of quality of thermal indoor environment on the level of comfort satisfaction of the occupants. It was recommended that Architects should ensure that in their designs, the presence of feature that will promote high level of quality of indoor thermal environment is available and they should ensure that civil engineers, builders and all allied professionals in the built industry abide by it.

Keywords: Design Strategies, Thermal comfort, residential houses, ventilation

Introduction

Increasing concerns about global warming present the building industry with the challenge to cut its energy consumption. In countries such as the UK and the US, for example, the building sector consumes 40-50% of the total delivered energy (DTI, 2003), (US-EPA 2004). Of this, climate control systems, namely ventilation, cooling and heating can account for as much as 70% of the total energy use. However, this part of the energy consumption can be reduced significantly by employing passive environmental solutions in the tropical environment: for example, a well-designed naturally ventilated building can consume only a third of the energy consumed by an air-conditioned building, while arguably providing a comparable level of comfort (BRESCU, 2000). This is because passive design allows buildings to adapt more appropriately to their local climates and take better advantage of natural energy resources, such as wind and thermal buoyancy, to help condition their interior environment. Furthermore, passive, naturally ventilated buildings have potential to provide more pleasant and healthier environments for the occupants compared to their mechanically ventilated counterparts. A well-designed naturally ventilated building can use just a third of the energy consumed by an air-conditioned building, while seemingly giving an equivalent level of comfort. Indeed, sick building syndrome is almost exclusively observed in the latter (Kumar, Vijyakumar and Sinivason, 2014).

The primary criterion for this design project is based on purpose and functions. That is application of passive design strategies for affordable and sustainable middle-income housing. However, the task in the design of middle-income housing according to Diogu (2004) lies in the correlation of the functional dimensions of the dwelling with the volumetric characteristics of the house types. While the functional dimension is influenced by the lifestyle activities of consumer population, their social demographic and socio- environment contextual situations, the volumetric characteristics are dictated by the need to achieve optimal planning density and economy of urban land. A research finding by Diogu (1990) indicates that a residential density of 250-300 persons per hectare is ideal. He however recommends the provision of open and outdoor living spaces of up to 25% of the gross total residential floor area.

Aim and Objectives of Study

The aim of this research is to design middle-income housing with the view to using passive design strategies for sustainable thermal comfort. The objective of the study is to:

1. Examine the influence of quality of thermal indoor environment on the level of comfort satisfaction of the occupants of middle-income housing in the study area.

Research Hypothesis

To achieve the aim and objectives of the study, the following hypotheses will be tested:

H_O: There is no significant influence of quality of thermal indoor environment on the level of comfort satisfaction of the occupants.

H_1: There is significant influence of quality of thermal indoor environment on the level of comfort satisfaction of the occupants.

Statement of Problem

The problem of energy usage during building operations particularly in the warm-humid climate where so much energy is required for cooling, lighting and ventilation are not properly considered during building creation (Odim and Onyegiri, 2008). According to Diogu (2004), such buildings depend on active means for maintenance of acceptable comfort standards, resulting in high energy utilization and high operational cost. Koenigsberger, Ingersoll, Mayhew and Szokolay (1974) posited that the task of the designer is to create the best possible indoor climate since it is not feasible to regulate outdoor climatic conditions. However, many people do not consider this as they failed to understand that the designer should acknowledge the fact that buildings comfort should come from naturally occurring source. Hence, the study, which is aimed at designing a middle-income housing with the view to using passive design strategies for sustainable thermal comfort.

Literature Review

Concept of Thermal Comfort and Thermal Indoor Environment

One of the main goals of building design is to provide a comfortable space for living. This was the reason of creation for a new field in science called "Thermal Comfort". Thermal comfort is a psychological phenomenon defined by the American society of heating refrigerating and air-conditioning engineers (ASHRAE) as "the state of mind which expresses satisfaction with the thermal environment". This psychological phenomenon is often taken to be a response to the physical environment and the psychological state of the body, but is almost certainly affected by the attitude of the person to their surroundings as their experience of thermal environment as well as it current state. Adebamowo (2007) defines it as "a state of thermal rest, devoid of heat or cold stress".

Thermal comfort is maintained when the heat generated by human metabolism is allowed to dissipate, thus maintaining thermal equilibrium with the surroundings. It is one of the basic physical and biological needs of human. Thermal comfort basically has to do with the temperature that the resident considers as comfortable to stay in. Indoor thermal comfort is achieved when occupants are able to pursue without any hindrance, activities for which the building is intended. Hence, indoor thermal comfort is essential for occupants' well being, productivity and efficiency (Akande and Adebamowo, 2010).Good indoor thermal condition will create comfortable (without heat stressor thermal strain for the occupants) and healthy environment to sustain occupants' living quality.

In designing comfortable room condition, there are many factors needed to be considered. These factors are microclimate condition such as air temperatures, humidity, radiant temperature, air movement, and human physiological aspects like body metabolic rate, level of activity and clothing of the occupants (Jamaludin , Khamidi,Wahab and Klufallah, 2014). Other researchers such as Olgyay (1963), Fanger (1970), Nicol (2000), Arizon (2002) and Adebamowo (2007) has long recognized and agreed with Jamaludin, *et al*(2014)that the sensation of feeling hot or cold is not just dependent on air temperature alone, but by these other microclimate factors. The indoor thermal environment is much affected by local climate, and air movement through the building is necessary to decrease indoor discomfort due to overheating conditions in tropical climate (Rajapaksha, Nagai and Okumiya,2002). External air movement therefore becomes necessary to assist in controlling the indoor environment.

Research Methodology

Design of the study

The study adopted a descriptive survey research method.

Study Area

The study area is Uyo, the Capital City of Akwa Ibom State.

Population of the Study

The population of the study consisted of all middle-income housing in Uyo Metropolis.

Sample and Sampling Technique

The respondents in the study consisted of 200 household heads that was selected randomly from all the households in Uyo metropolis, using simple random sampling method. The sample size was determined using sample fraction from Ibanga (1992)

Instrumentation -validation of the instrument and reliability of the instrument

The following instrument were used to measure physical comfort variables, liquid crystal thermometers, Wet and dry bulb hygrometer, and anemometer for collecting data of the indoor thermal environment.

The CBE Thermal Comfort Tool (a computer model programme) (Tyler *et al.,* 2013) was used as one of the tools to ascertain the prevalent comfort situation based on field measurements made.

Validity of Instrument
The instrument was face and contents validated done by one expert from test, measurement and evaluation.

Reliability of the Instrument

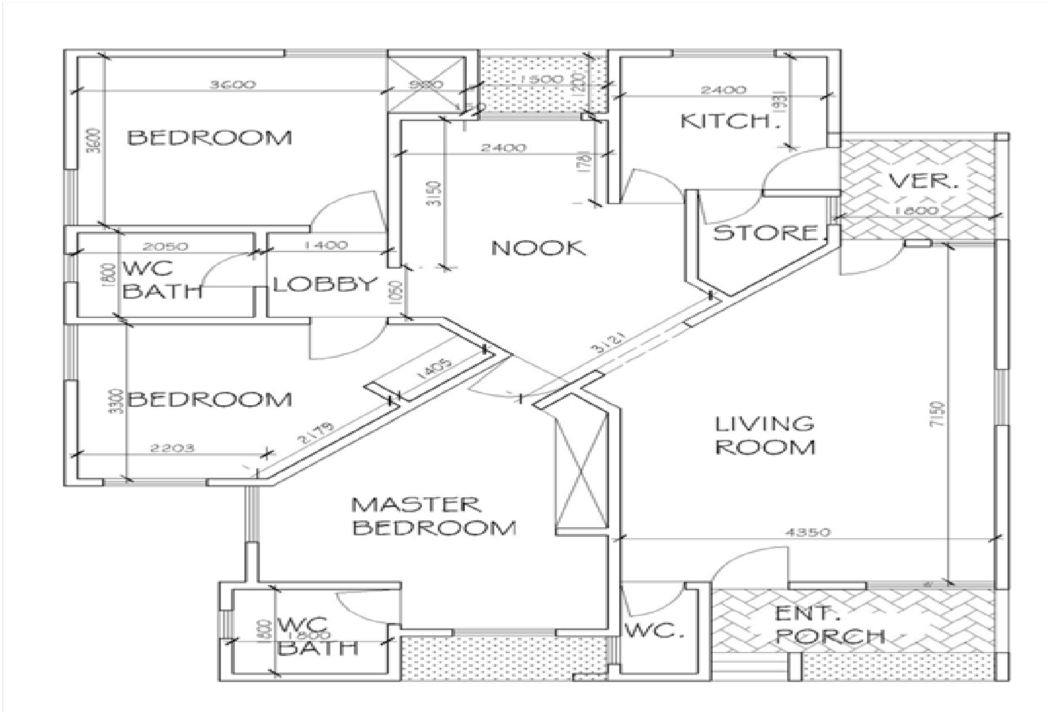
Crombach Alpha technique was used to determine the reliability of the questionnaire used in the study with a reliability coefficient of 0.84 to 0.94.

Sources of Data
The principal source of data used was from both the primary and secondary sources.

Methods of Analysis
Hypothesis was stated in the null form, and was tested using Regression Analysis at 0.05 level of significance.

Case Study
CASE STUDY 1: 3- BEDROOM BUNGALOW AT PLOT K12, ALISON ATTAH DRIVE, SHELTER AFRIQUE ESTATE, UYO.

Plate I: Plot K12 on Google Earth map
Source: Author’s Work (2015)



GROUND FLOOR PLAN

Figure 3.4: 3- Bedroom Detached Bungalow at Plot K12, Alison Attah Drive (designed by Novone Consult)

Source: APICO (2015)

Plate II: Front view of 3- Bedroom Detached Bungalow, Plot K12,
Source: Author's Field Work (2015)

DATA PRESENTATION AND ANALYSIS

Hypothesis One

The null hypothesis states that there is no significant influence of quality of thermal indoor environment on the level of comfort satisfaction of occupants. In order to test the hypothesis regression analysis was performed on the data, (see table 1).

TABLE 1: Regression Analysis Result of the influence of quality of thermal indoor environment on the level of comfort satisfaction of occupants.

Model	R	R-Square	Adjusted R Square	Std. error of the Estimate	R Square Change
1	0.98[a]	0.96	0.96	0.21	0.96

***Significant at 0.05 level; df= 198; N= 200; critical R-value = 0.139**
Source: Authors Field Work (2016)

The table shows that the calculated R-value 0.98 was greater than the critical R-value of 0.139 at 0.05 alpha levels with 198 degree of freedom. The R-Square value of 0.96 predicts 96% of the influence of quality of thermal indoor environment on the level of comfort satisfaction of occupants. This rate of percentage is highly positive and therefore means that there is significant influence of quality of thermal indoor environment on the level of comfort satisfaction of occupants. It was also deemed necessary to find out the extent of the variance of each case of the independent variable (quality of thermal indoor environment) as responded by each respondent (see table 2).

TABLE 2: Analysis of Variance Result of the influence of quality of thermal indoor environment on the level of comfort satisfaction of occupants.

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	194.74	1	194.74	4388.99	.000[b]
Residual	8.79	198	0.04		
Total	**203.52**	**199**			

Source: Authors Field Work (2016)

The above table presents the calculated F-value as (4388.99) and the P-value as (000). Being that the P-value (000) is below the probability level of 0.05, the result therefore means that there is significant relationship between the level of comfort satisfaction of occupant and the quality of indoor environment.

Furthermore, it was deemed necessary to be more objective about the comfort satisfaction of occupants by conducting a two seasons (rainy and dry) field survey using physical instruments to measure thermal comfort in and around the premises. A computer simulation of the field survey indicates the comfort sensation of the occupants in each of the case studies (see table 3).

Table 3 **Standard Effective Temperature, Comfort Sensation, Cooling Effect, Based on Summary of Results of Physical measurement by Case Study**

Case Study	Mean Temp. (℃)	Mean Rel. Humidity (%)	Mean Air Velocity (m/s)	Mean Radiant Temp (℃)	Set (℃)	Cooling Effect (℃)	Sensation
Case Study 1	27.20	81.10	0.42	28.20	26.80	2.3	Neutral
Case Study 2a	27.50	81.40	0.42	28.40	27.20	2.2	SlightlyWarm
Case Study 2b	27.20	82.40	0.43	28.10	26.7	2.3	Neutral
Case Study 3	27.60	80.40	0.37	28.30	27.5	2.0	SlightlyWarm
Case Study 4	27.50	79.60	0.37	28.30	27.4	2.1	SlightlyWarm
Case Study 5	27.50	81.40	0.42	28.80	27.4	2.3	Slightlywarm

Source: Authors Field Work/Computer Simulation of the Field Survey (2016)

It should be noted that the Sensation in table 3 was determined using the CBE Thermal Comfort Tool (ASHRAE Standard 55-2013) with metabolic rate value of 1.2 met and Clothing level of 0.5 Clo. The metabolic rate of 1.2 met is for a light activities standing, while the Clothing level of 0.5 Clo is clothing ensembles and garments of knee length skirt, short sleeved shirt, panty hose, and sandals (See figures 1, & 2).

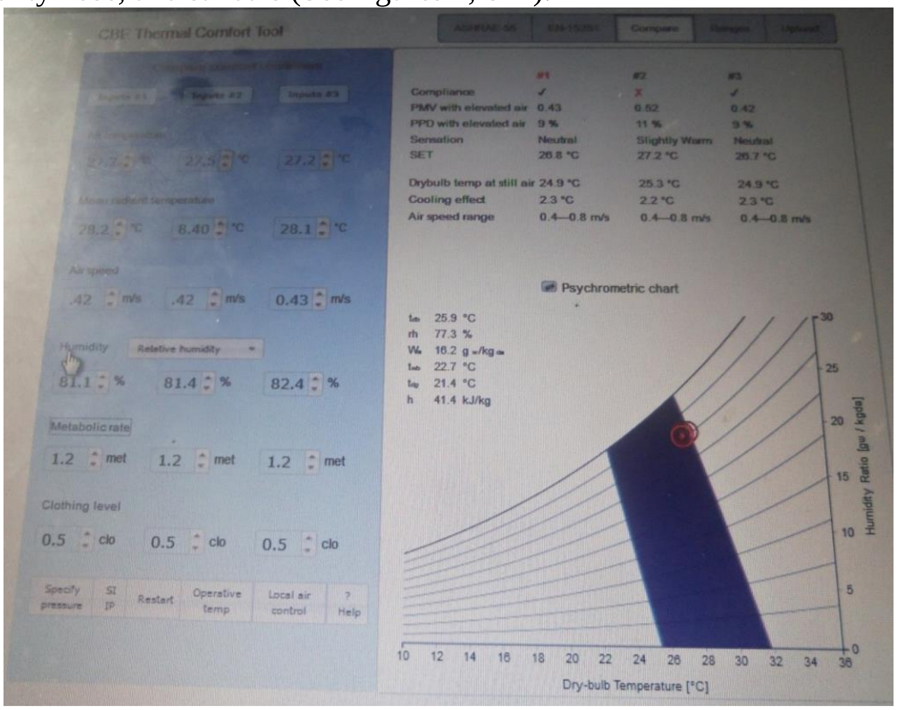


Fig. 1: Psychometrics Chart Comparing thermal Sensation in Case Study 1, 2A, & 2B

Source: Author’s Computer Simulation of the Field Survey (2016)

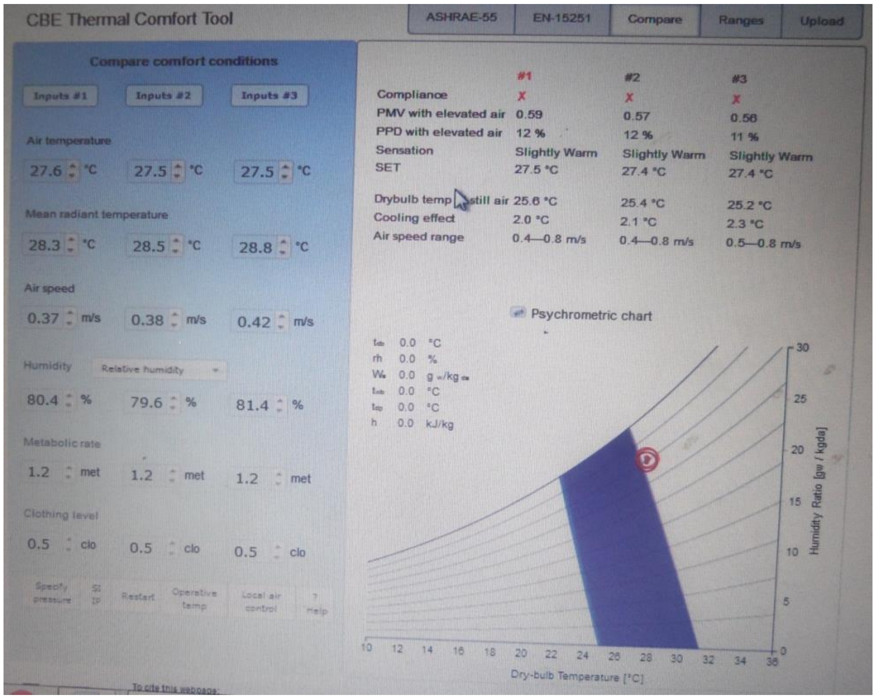


Fig. 2: Psychometrics Chart Comparing Thermal Sensation in Case Study 3, 4 &5
Source: Author's Computer Simulation of the Field Survey (2016)

The results of the analysis in table 3presents the indoor mean air temperature and humidity ranges between 27.2 °C-27.6 °C and 79.6% - 81.4% above ASHRAE Standard 55 ranges of 23.5 °C -26 °C and 25% -60%.It has also been found from the research work that the standard rate of ventilation which is ≥ 0. 2m/s has been exceeded by the range of 0.37-0.43m/s. These values are good for creation of adequate indoor velocities.

Further test was carried using Psychrometrics Chart to compare thermal Sensation in Case Study 1, 2A, & 2B, (see figure 1); Thermal Sensation in Case Study 3, 4 &5 (see figure 2); Effect of air speed on thermal comfort of Case Study 1 building at assumed 0.1m/s, (see figure 3); Effect of air speed on thermal comfort of Case Study 1 building at 0.42m/s, (see figure 4); Effect of air speed on thermal comfort of Case Study 2B building at assumed 0.1m/s, (see figure 5) and finally, Effect of air speed on thermal comfort of Case Study 2B building at 0.43m/s, (see figure 6). It should be noted that in the chart, the shaded portion is the acceptable comfort zone while the red circular pointer indicates plotted point of comfort of surveyed buildings.

Figures 1 and 2 further explain that the best thermal comfort level was achieved in Case Study 1 and 2. Figure 3 and 4 however explain that at low wind velocity of 0.1m/s in the same building thermal comfort cannot be achieved.

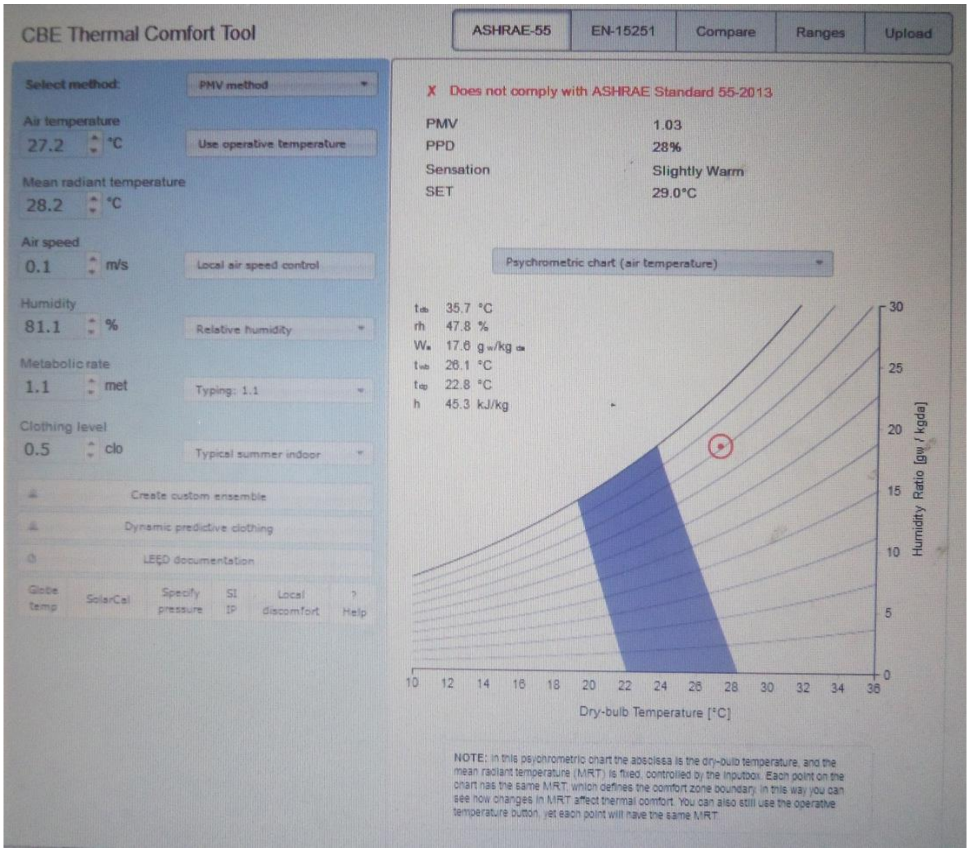


Fig. 3: Effect of air speed on thermal comfort of Case Study 1 building at assumed air velocity of 0.1m/s

Source: Author’s Computer Simulation of the Field Survey(2016)

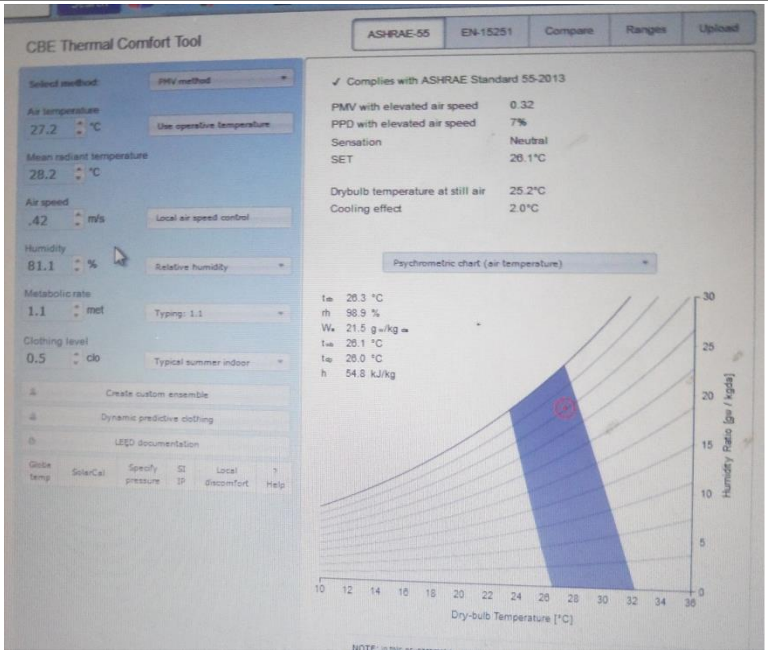


Fig. 4: Effect of air speed on thermal comfort of Case Study 1 building at assumed air velocity of 0.42m/s

Source: Author's Computer Simulation of the Field Survey (2016)

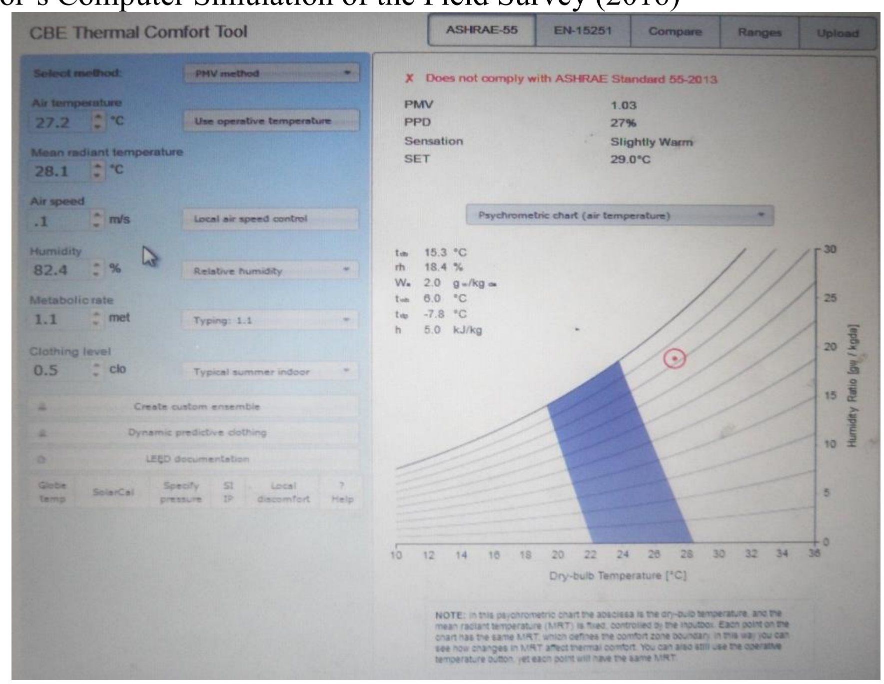


Fig. 5: Effect of air speed on thermal comfort of Case Study 2B building at assumed air velocity of 0.10m/s

Source: Author's Computer Simulation of the Field Survey (2016)

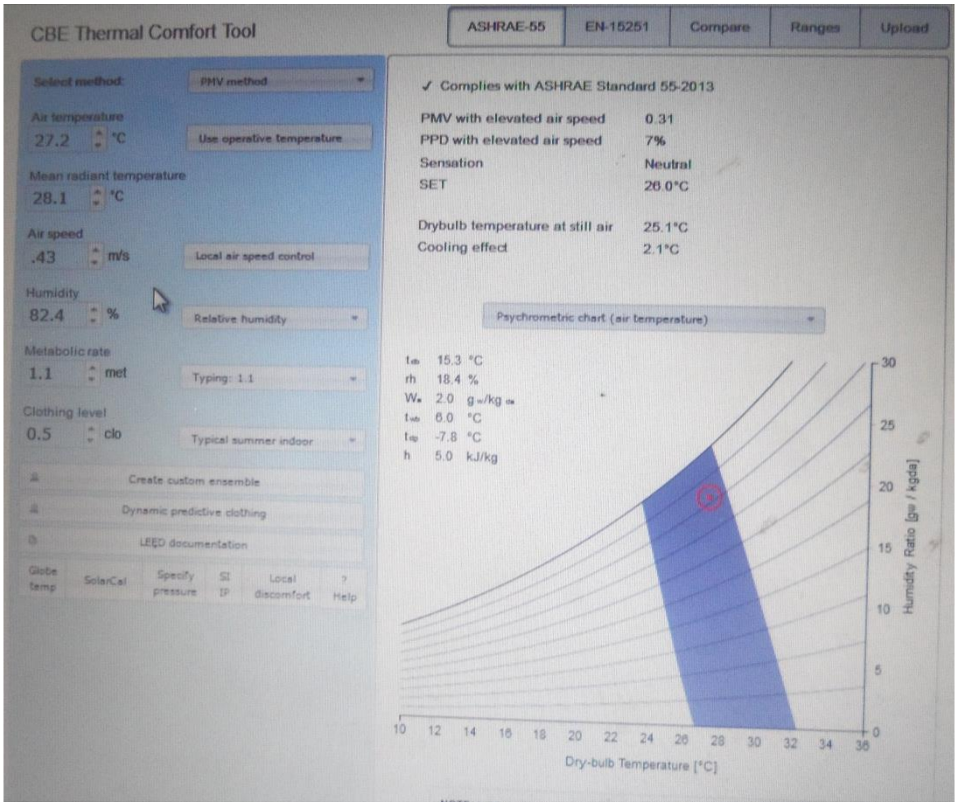


Fig. 6: Effect of air speed on thermal comfort of Case Study 2B building at assumed air velocity of 0.43m/s

Source: Author's Computer Simulation of the Field Survey(2016)

Discussion of Major Findings

The result of the data analysis in table 1 was significant due to the fact that the calculated R-value 0.98 was greater than the critical R-value of 0.139 at 0.05 alpha level with 198 degree of freedom. The result implies that there is significant relationship between the level of comfort satisfaction of occupant and the quality of thermal indoor environment. The result therefore was in agreement with the research findings of Jamaludin *et al*(2014) who founded that microclimate conditions and human physiological aspects is required to create comfortable and healthy indoor environment in order to sustain occupants' living quality. This findings also agree with other researchers like Olgyay(1963), Fanger (1970), Nicol (2000), Arizon (2002) and Adebamowo (2007) who recognized that the sensation of feeling hot or cold is not just dependent on air temperature alone, but by other microclimate factors.

Conclusion

Based on the findings of the work, the researcher concludes quality of thermal indoor environment significantly relates with the level of comfort satisfaction of the occupants of middle-`income housing in Uyo metropolis, Akwa Ibom State.

Recommendations

1. There should be an implementation of accurate passive design strategies by the building owners in order to reduce the thermal stress of the building. These strategies involve provision of adequate windows for sufficient ventilation, elevation of building/rooms above ground level, introduction of water bodies around the building, use of shading devices, use

of louvers or casement sashes windows, use of different height of ventilation openings to create stack effect, use of roof vents, etc.

2. Architects should ensure that in their designs, the presence of feature that will promote high level of quality of indoor thermal environment is available and they should ensure that civil engineers, builders and all allied professionals in the built industry abide by it.

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