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An Assessment of Thermal Comfort in Hot and Dry Season (A Case Study of 4 Theaters at Bayero University Kano)

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Abstract

In hot and dry seasons, thermal discomfort is a major problem to the occupants of many lecture theatres of Bayero University Kano, especially where a theatre is not fitted with a recommended air conditioning system. This research work investigated the level of thermal comfort in the lecture theatres of the University permanent site. While conducting this study, measuring instruments were used to record five different thermal comfort parameters, namely; indoor air temperature, outdoor air temperature, indoor relative humidity, outdoor relative humidity and indoor air velocity. All the Data were collected during the month of March and April of the year 2013. In addition to thermal comfort measurements, a questionnaire survey was employed during the study. Data collected by field measurement and survey were analyzed and found that, the indoor air temperature of the theaters is in the range of 31.8℃ to 36.2℃, and the indoor relative humidity is in the range of 36.5% to 50.6%, while the air velocity is between 0.29m/s and 0.05m/s. The ASHRAE guidelines recommend 22.2℃ to 26.7℃ in the summer and also its recommend a relative humidity (RH) of 30 to 60 percent. Comparatively, these conditions found in the theaters are outside the comfort zone as specified by ASHRAE which is "UNACCEPTABLE". The questionnaire survey shows that 66% of the total respondents rated the thermal comfort level in the theatres as "NOT ACCEPTABLE". This condition can be changed with installation of up to capacity cooling unit in the theaters by considering the size of the theaters, climate of the theaters, energy efficiency and lastly the number of the occupants in the theaters.

Keywords: *Thermal comfort, Lectures Theaters, hot and dry season, thermal comfort parameters*

1. Introduction

The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) is a society that focuses on building systems, energy efficiency, indoor air quality, refrigeration and sustainability within the industry. The society defines thermal comfort as that condition of the mind, which expresses satisfaction with the thermal environment [1]. Thermal comfort is a key component for quality of indoor environments. Environmental elements such as heat from electrical lighting, lack of adequate ventilation, high humidity levels, and poorly performing building envelopes can contribute to health problems at workplaces. Thermal discomfort in school buildings can create unsatisfactory conditions for both lecturers and students. This can be distracting and irritating for the occupants and is likely to reduce their productivity and performance in academic activities. The challenge is to come out with self-sustaining buildings, which will facilitate learning and overcome the state of discomfort with minimum energy utilization.

The most commonly used indicator of thermal comfort is air temperature because it is easy to use and most people can relate to it. But although it is an important indicator to take into account, air temperature alone is neither a valid nor an accurate indicator of thermal comfort or thermal stress. Air temperature should always be considered in relation to other environmental and personal factors. Air temperature is often taken as the main design parameter for thermal comfort. The research conducted by [2] to investigate the thermal comfort for classrooms (mechanically ventilated by fans) in Singapore found that the temperature range in the classroom is outside the acceptable range of ASHRAE Standard 55. Similar research by [3] studied the thermal comfort conditions in classrooms in Hawaii (naturally ventilated and air conditioned types). Neutral temperatures (temperature at which majority of people felt neither too warm nor too cold) for the two types of classrooms were 26.8°C and 27.4°C respectively. As important as these studies are, their findings have not yet emerged into comprehensive and widely accepted guidelines for tropical naturally ventilated buildings [4].

In Nigeria, the Northern part of the country is characterized by high temperature and low humidity

during dry season, this climatic condition makes the residents to be uncomfortable. This was verified by studies conducted by [5] which conduct a field survey on comfort study at Bauchi, North eastern part of Nigeria. 206 subjects were used for the questionnaire survey and field measurement. Results showed that the thermal sensation vote exceeded acceptable thermal condition set by ASHRAE even though 80% of the respondent found the thermal condition to be acceptable. The unacceptable thermal condition mostly found in buildings are also attributed to building design and constructions materials used. In addition to building design and materials, story building may experience some differences in thermal comfort conditions from one floor to another floor as verified by [6] they draw up conclusion that the ground floor experienced lower temperature while the first floor had a higher temperature with difference of 2℃.

Investigation by [7], the thermal efficiency of a new mosque building in Baghdad and optimization of comfort level for occupants for five prayer times by considering the design and construction materials used. The research was carried out by collecting data from 50 new mosques which represent 65% of the total new mosque build in 2008. Their results suggest that the indoor thermal condition is not within thermal comfort level and the materials used are not thermally efficient in protecting the indoor environment from climatic fluctuation. Another research by [8] assessed thermal performance of residential buildings in Ibadan in which they consider four different building with different system design, based on their analysis, the result indicates strong relationship between building design and ambient temperature. This shows that adequate consideration must be given to building design and construction materials not HVAC system alone.

In Nigeria, very few studies have been conducted in this field. In view of this, there is the need to add up to the growing knowledge of thermal comfort in buildings. Under the present circumstances, this research on comfort in university buildings is to investigate the occupants' perception of the accepted level of indoor thermal comfort of four academic Theaters in Bayero University Kano, Nigeria. Validation of the level of acceptability of the findings with ASHRAE Standard 55 will be done.

2. Methodology

The research was conducted in an academic environment of Bayero University Kano, new site campus, in which four Theaters was chosen as study areas. The building was chosen because of the large population of students who are using the theaters.

The four Theaters are A21 Lecture Theater, B09 Engineering Lecture Theater, Yahaya Gusau Lecture Theater and Electrical Engineering Lecture Theater. The figure 2.1, 2.2, 2.3 and 2.4 shows the interior of the Theaters.

Figure 2.1 Interior of A21 Theater

Figure 2.2 Interior of B09 Theater

Figure 2.3 Interior of Yahaya Gusau

Figure 2.4 Interior of Electrical Eng'g Theater

The field measurement focuses on measuring four thermal comfort parameters: namely: indoor air temperature, outdoor air temperature, indoor relative humidity, outdoor relative humidity, and air velocity. Air temperature and relative humidity was recorded using a digital thermo-hygrometer, while air velocity was measured using anemometer. All the readings were taken at a height of 1.3 m above floor level, which represents the approximate height of students at seated level. The theaters usually operate between 8am to 4pm. The instrument were calibrated and tested before the usage and then the readings were taken from 8am to 4pm daily. The data were recorded at every one hour interval, alternately repeated for all the four theaters for a total period of two months.

In addition to field measurement, questionnaire survey was conducted in the four theaters. The Theaters were occupied by approximately 1000 students daily. Most of the students are not willing to participate in this study, sometimes, the students complain of not having time to responds to the questionnaire because of tight schedule of academic activities. In light of the above constraints, a 20% sample size (i.e. n=200) was deemed to adequately reflect the population size (N=1000). The survey was conducted at the four theaters, the respondents were free to decide if they wanted to participate in the study or not. A total of 200 successful questionnaire interviews were completed.

The questionnaire survey covered 2 sections, section A and section B. Section A focuses on respondent's demographic information such as name, age, gender, and status (student or lecturer). The second section deals with respondents' perceptions of thermal comfort in the four different theaters. Based on a different scale, the respondents were asked to describe the general conditions of the four theaters in terms of thermal comfort parameters. The measures include air temperature (ranging from very warm to very cold), wind velocity (ranging from very windy to no wind), humidity (ranging from very damp to very dry) and the kind of cloth the respondent normally wear during hot and dry season. Prior to the actual survey, a pilot study was conducted to examine the respondents' understanding of the terms used to gauge thermal comfort. It was found that the respondents understood the terms used. This is probably attributed to the fact that majority of the building occupants are either undergraduate or postgraduate students.

3. Results and Discussion

The thermal comfort parameters were measured using digital thermo-hygrometer and anemometer in the months of March and April of the year 2013. The readings were taking at an interval of one-hour from 8am to 4pm, Monday to Thursday, excluding Fridays. Using statistical tool (Microsoft excel) the data was analyzed and presented below in table 3.1, 3.2, 3.3 and 3.4 for the four theaters.

Table 3.1 Statistical analysis for A21 Theater

S/N	Parameters	AVE.	MAX	MIN
1	Indoor air temperature (℃)	34.0	36.5	31.8
2	Outdoor air temperature (℃)	35.4	37.8	33.1
3	Indoor relative humidity (%)	44.5	50.6	34.0
4	Outdoor relative humidity (%)	34.4	42.3	25.8
5	Indoor air velocity m/s	0.13	0.24	0.05

Table 3.2 Statistical analysis for B09 Engineering Theater

S/N	Parameters	AVE.	MAX	MIN
1	Indoor air temperature (℃)	33.9	36.4	31.9
2	Outdoor air temperature (℃)	35.5	37.5	33.0
3	Indoor relative humidity (%)	44.9	50.2	36.5
4	Outdoor relative humidity (%)	34.4	42.3	25.7
5	Indoor air velocity m/s	0.12	0.22	0.05

Table 3.3 Statistical analysis for Yahaya Gusau Theater

S/N	Parameters	AVE.	MAX	MIN
1	Indoor air temperature (℃)	34.1	36.6	31.8
2	Outdoor air temperature (℃)	35.8	37.9	33.5
3	Indoor relative humidity (%)	44.3	49.3	36.0
4	Outdoor relative humidity (%)	32.2	40.8	24.0
5	Indoor air velocity m/s	0.13	0.29	0.06

Table 3.4 Statistical analysis for Electrical Engineering Theater

S/N	Parameters	AVE.	MAX	MIN
1	Indoor air temperature (℃)	34.0	36.2	32.1
2	Outdoor air temperature (℃)	35.7	37.8	33.2
3	Indoor relative humidity (%)	43.9	49.0	35.5
4	Outdoor relative humidity (%)	32.8	40.9	24.4
5	Indoor air velocity m/s	0.13	0.21	0.08

As earlier discussed, the measurement basically captured five parameters mainly indoor and outdoor air temperature, indoor and outdoor relative humidity and air velocity, which are required for computing the indices for thermal comfort. Looking at the statistical results, the indoor air temperatures in the theaters were found to be between 31 and 36℃ with indoor relative humidity 35 and 48%. These results show that the temperature and

relative humidity exceeded the standard [9] during hot and dry season. The temperature specified by the standard should be between 20°C and 26°C and relative humidity should be between 30% and 70%. The average air velocity was 0.13 m/s for all the theaters which was within the threshold of < 0.2 m/s.

The highest values for relative humidity were recorded in the morning and the least in the afternoon. It should be noted that even though high humidity levels result in inefficient evaporative cooling of the skin which leads to also discomfort, likewise low level of humidity may develop sign of a dry and irritated skin. Based on these result the relative humidity is on the average side which can balance the two effect of either high or low relative humidity in the theaters.

Analysis of the questionnaire results shows that the respondents of the questionnaire prefer rainy season among all seasons we have in Nigeria. The result was shown in figure 3.1 which indicate 48% of the respondents prefer rainy season while 34% prefer harmattan, on the contrary only 18% prefer hot and dry season. This indicates that most of the respondents are not comfortable during hot and dry season.

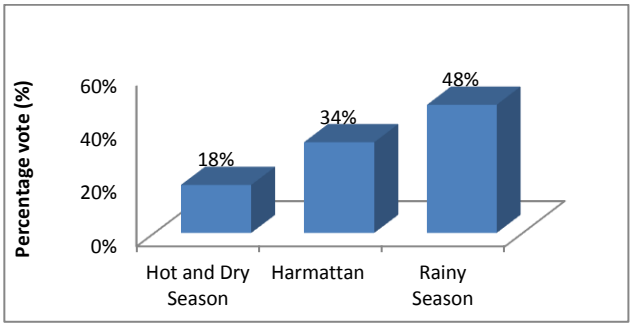

Figure 3.1 Season Preference vote by the occupants

The results of thermal sensation by respondents are presented in figure 3.2 below.

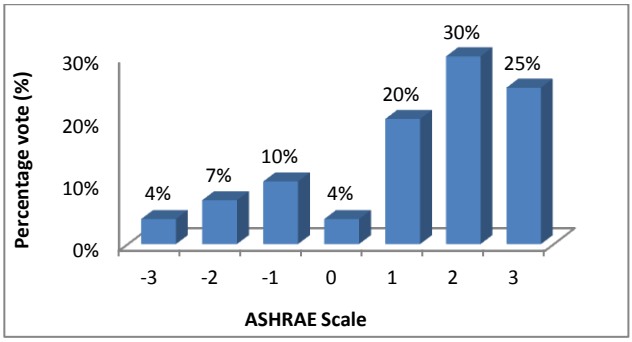

Figure 3.2 Thermal sensation vote by the occupants

The results was obtain using 7-point thermal sensation subjective scale (-3 cool, -2 moderate cool, -1 slightly cool, 0 neutral, +1 slightly warm, +2 moderate warm, +3 warm). Analysis of the results show that the majority of the respondents voted for slightly warm, moderate warm and warm sensation. The ASHRAE standard 55 specified that an acceptable thermal environment should have 80% of the respondents vote for the central categories i.e. -1 (slightly cool), 0 (neutral) and +1 (slightly warm). In this research, only 34% out of the total number of the respondents voted within the central three categories, showing that the students and lectures were not comfortable in these four theaters.

Figure 3.3 shows the results of the air movement in the theaters with 51% saying the air is slightly still, 38% saying the air movement is just right, while only 11% said the air is breezy. Analogy to the previous paragraph can be concluding that the environment is not thermally comfort because 51% of the respondents said the air movement is slightly still.

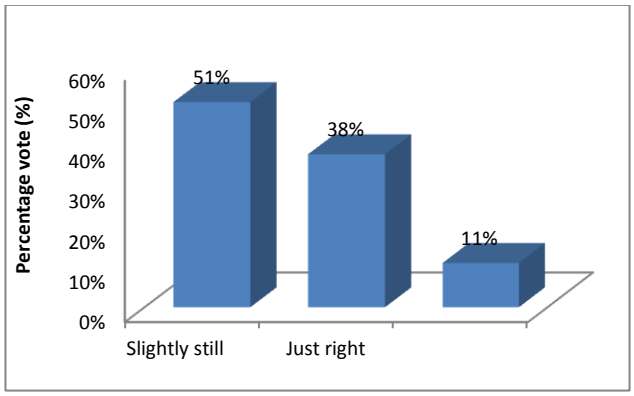

Figure 3.3 Occupant vote on air movement

The results of subjective responses to air temperature are presented in figure 3.4. The results show that the majority of the respondents voted neutral sensation, warm sensation and very warm sensation. The ASHRAE standard [10] specified that an acceptable thermal environment should have 80% of occupants vote for the central categories (-1, 0, +1). In this research, only 45% out of the respondents voted for central a category which is far below the ASHRAE standard, this shows that the students and lecturers were not in thermal acceptable conditions within the four Theaters of the academic building of Bayero University Kano.

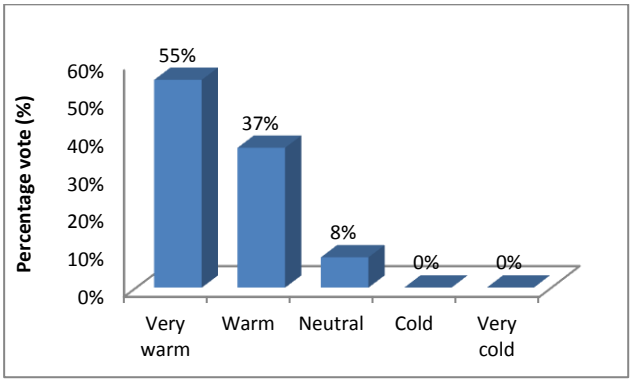

Figure 3.4 Occupant vote on air temperature

The humidity assessment uses the subjective scale of -3 (much too dry), -2 (too dry), -1 (slightly dry), 0 (just right),

+1 (slightly humid), +2 (too humid), and +3 (much too humid). These subjective responses on humidity are presented in figure 3.5 below. It was observed that for the overall votes, the respondents were comfortable with the relative humidity, 77% of the respondents voted within the central categories (-1, 0, +1). Hence the relative humidity was comfortable for most of the respondents; in terms of humidity the theaters are thermally comfort.

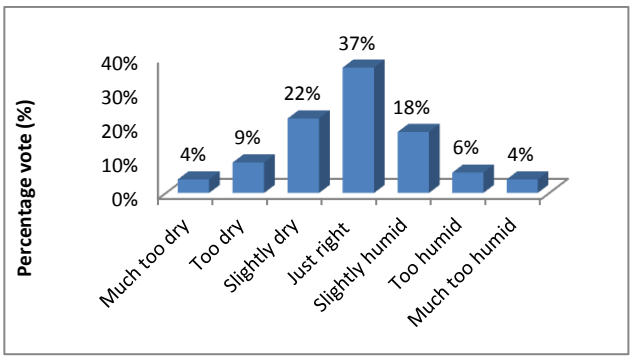

Figure 3.5 Occupant vote on humidity sensation

The distribution of subjective responses on thermal acceptability is presented in figure 3.6. The majority (66%) of the respondents voted not acceptable. These results can be as a result of so many factors that were not considered in the design of the theaters and also HVAC guideline wasn't adhere to.

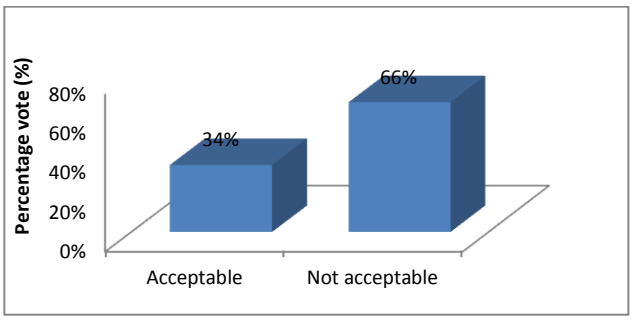

Figure 3.6 Occupant vote on thermal acceptability

Conclusion

The results obtain can be summarize in the following paragraphs:

1. Both the indoor and outdoor temperatures values rises from 32 and 33℃ respectively in the morning to a peak of about 37 and 38℃ respectively in the afternoon and this happen between the hours of 15 and 16. This range of temperatures is outside the limit of ASHRAE standard.
2. Considering the statistical analysis of the data, the temperature specified by the standard should be between 20℃ and 26℃ and relative humidity should be between 30% and 70%. But the statistical analysis reveals that, the values are much higher than the standard. But in the case of air velocity the value obtained was 0.13 m/s for all the Theater which was within the threshold of < 0.2 m/s.
3. The relative humidity results indicate positive results since the majority of the occupants are not too sensitive to humidity and this was also being verified in the questionnaire survey.
4. The questionnaire results conclude that 66% of the respondents will not accept the current thermal comfort of the theaters.

In conclusion, as generally known thermal comfort is determined by theater's temperature, humidity and air speed. In this research, these thermal parameters were analyzed and found that, the indoor air temperature of the theaters is in the range of 31.8℃ to 36.2℃, and the indoor relative humidity is in the range of 36.5% to 50.6%, while the air velocity is between 0.29m/s and 0.05m/s. The American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) provides guidelines that are intended to satisfy the majority of building occupants wearing a normal clothing while working at a desk. The ASHRAE guidelines recommend 20℃ to 23.3℃ in the winter and 22.2℃ to 26.7℃ in the summer and also its recommend a relative humidity (RH) of 30 to 60 percent. Comparatively, these conditions found in the theaters are outside the comfort zone as specified by ASHRAE which is unacceptable.

This condition can be changed with installation of up to capacity cooling unit in the theaters by considering the size of the theaters, climate of the theaters, energy efficiency and lastly the number of the occupants in the theaters.

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