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A Study on Thermal Comfort of Office Employees in the Philippines

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Abstract: The Philippines has been following the ASHRAE standard in the area of thermal comfort however, other studies suggest that this standard is not fit for countries that have different climate from America. Thermal comfort, according to ASHRAE 55, is the state of mind that expresses satisfaction with the surrounding environment The aim of this study is to determine the thermal comfort of office employees and compare them with the ASHRAE standards. This study was conducted in three office buildings in the Philippines and a total of 64 respondents participated. The participants were given a survey that asked them how they feel about the thermal conditions at the moment and what would they like it to be. Thermal parameters were measured around the office simultaneously while the survey was happening. The data were tabulated and analyzed and the neutral and preferred temperatures were obtained for each building through a regression analysis. It was observed that the neutral temperatures for each building did not fit the ASHRAE standard of 25° C. The preferred temperatures were also lower compared to the neutral temperatures which showed that the respondents do prefer and were satisfied with a cooler temperature even if they feel a neutral sensation. The study also showed that in terms of thermal acceptability, there is a lesser percentage dissatisfaction among the respondents. This means that at lower temperatures, most of the respondents feel satisfied and these temperatures are acceptable to them.

Key Words: ASHRAE standard, thermal comfort, cooling, neutral temperature

1. INTRODUCTION

Thermal comfort, according to ASHRAE 55, is the state of mind that expresses satisfaction with the surrounding environment. It is also defined in ISO 7730 standard as that condition of mind which expresses satisfaction with the thermal environment. In as much as men wanted to create a thermally comfortable environment, the development of guidelines were set through laboratory – based thermal comfort research in temperate countries. This was done through a survey that asked the respondents how they feel about the thermal conditions at the moment and what would they like it to be. The Predictive Mean Vote (PMV) sensation scale was utilized by the respondents to answer the survey. It consists of a seven – point ASHRAE scale wherein a person can rate his / her thermal preference at the moment. The following correspond to the numerical scale used: -3 (cold), -2 (cool), 1 (slightly cool), 0 (neutral), 1 (slightly warm), 2 (warm), and 3 (hot). Numerous researches have been done worldwide to evaluate the acceptability of these standards, however, only a few studies related to this have been done in the Philippines.

The objective of this study is to provide baseline data to aid future researchers who are interested on the thermal comfort of office employees in the Philippines. Since, high percentage of energy consumed in buildings is attributed to air – conditioning systems, knowing the thermal comfort of the occupants will allow control of the temperature in a certain area, thus reducing energy consumption. Although thermal comfort affects the health and productivity of the employees in an office, this is not part of the scope of this study.

2. METHODOLOGY

Three buildings were selected from different locations in the Philippines and there was a total of 64 respondents that participated in the survey. Before the actual survey was done, the participants were given an orientation with regard to the activities that are allowed to be performed inside the office. Limitation of the study did not allow the participants to do dynamic activities to avoid increase in heart rate and perspiration as it would affect the thermal parameters in the target area. Dynamic activities performed by the participants will change the metabolic rates and this will have an immediate change on their thermal sensation. They were also oriented as to how the survey questionnaire will be filled out. Considering that the respondents were working in the area for a huge span of time, the survey was answered every hour during the experiments by the respondents as the thermal parameters, specifically the temperatures, within the area were varied every 2 hours. The following thermal parameters were measured during the experiment: dry bulb - temperature, wet - bulb temperature, relative humidity, and carbon dioxide content of the air. These parameters were measured from specific points within the area. The results of the survey were used to determine the neutral and preferred temperatures of the respondents. These results were also compared to the other studies on thermal comfort in tropical countries.

3. RESULTS AND DISCUSSION

The three buildings that participated in the survey were located in Malate, Manila; Pasig City and Urdaneta, Pangasinan.

3.1 PMV vs. Preference

Table 1 shows the total votes of the respondents in building 1 with regard to what they were feeling at the moment and what their preference would be. Majority of the respondents voted for -2. Most of the respondents that voted for -2, voted for either warmer (15 votes) or no change (13 votes). The respondents voted most on no change on the thermal sensation vote of -2 and -1 where 13 votes and 10 votes were gathered, respectively. The preference that obtained the highest amount of votes is cooler which indicates that most of the respondents desired a temperature lower than the measured temperatures in their respective area.

Table 1: PMV vs. Preference of Occupants in Building 1

	Warmer	No Change	Cooler	Total
-3	7	3	0	10
-2	15	13	1	29
-1	0	10	4	14
0	0	5	7	12
1	0	1	9	10
2	0	1	14	15
3	0	0	3	3
Total	22	33	38	93

Table 2: PMV vs. Preference of Occupants in Building 2

	Warmer	No Change	Cooler	Total
-3	16	1	1	18
-2	16	19	6	41
-1	10	26	10	46
0	2	16	16	34
1	1	0	5	6
2	0	0	1	1
3	0	0	0	0
Total	45	62	39	146

Table 2 shows the total votes of the respondents in building 2 with regard to what they feel at the moment and what their reference would be. Majority of the votes for their preference are the -1, and -2 levels. Employees from this building experience a much cooler environment. The respondents prefer to have a no change of the state of the thermal conditions. The respondents here would prefer a slightly cool environment in their workplace.

Table 3 shows the total votes of the respondents in building 3 with regard to what they feel at the moment and what their reference would be. The largest amount of votes is at the -1 level. Most of the respondents voted for no change when it is at -1, -2 levels. The outdoor conditions were relatively high in both temperature level and humidity, thus making the respondent's vote leaning on “cooler” compared to the no change vote.

Table 3: PMV vs. Preference of Occupants in Building 3

	Warmer	No Change	Cooler	Total
-3	2	0	1	3
-2	4	17	7	28
-1	3	20	20	43
0	0	4	11	15
1	0	1	13	14
2	0	0	10	10
3	0	0	1	1
Total	9	42	63	114

3.2 Neutral Temperature

Figure 1, 2 and 3 show the actual vote regression analysis for building 1, 2 and 3, respectively. The data covers different ranges of temperature based on what was measured throughout the experiment per building. The selected total sensation votes (TSV) by each respondent with respect to the specific dry bulb temperature (DBT) were plotted in the graphs. Variable y represents the TSV and variable x represents the DBT. The neutral temperature was computed by looking for the value of x that would result to a 0 value in y, as 0 represents the neutral level in the TSV.

The measured temperature in building 1 ranges from 20 to 26 degrees Celsius. Within this range, the computed neutral temperature for building 1 is 23.997°C. For building 2, the temperature measured ranges from 22 to 25.5 degrees Celsius and the

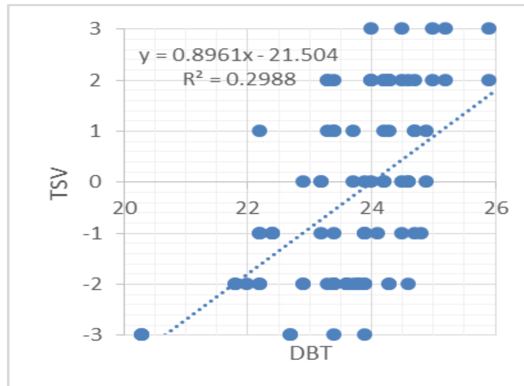

Figure 1: Regression Analysis for Building 1

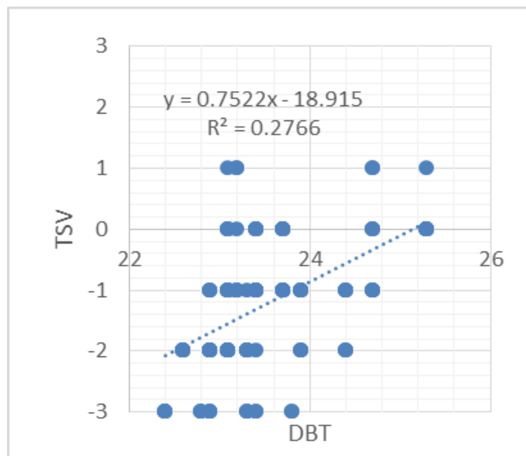

Figure 2: Regression Analysis for Building 2

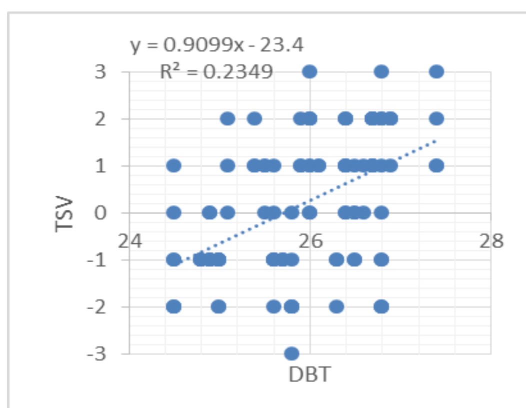

Figure 2: Regression Analysis for Building 3

computed neutral temperature is 25.146°C. For building 3, measured temperature ranges from 24 to

28 degrees Celsius while the computed neutral temperature for the building is 25.717°C.

3.3 Preferred Temperature

The preferred temperatures of the respondents were obtained using two methods. The first method was through the votes of the respondents. The preferred temperature is that temperature where the highest "No Change" votes were obtained. This means that they are already satisfied with the current condition of the air inside the office. The preferred temperatures for the three buildings are 22 to 22.99°C for building 1, between 23.5 to 24.49°C for building 2, and between 24.5 to 25.49°C for building 3.

The second method made use of the linear regression analysis as shown in figures 1, 2, and 3, for which the neutral temperature was obtained. Also the preferred TSV was computed by multiplying the PMV values by the number of No Change votes and getting the average. The results showed that the preferred temperatures for the three buildings are 22.577°C for building 1, 23.709°Cfor building 2 and 24.33°C for building 3. It can be shown that the values of the preferred temperatures are within the range as obtained in method 1. Table 4 summarizes the preferred temperatures obtained both for methods 1 and 2.

Table 4: Preferred Temperature per Building

Office	Preferred Temperature (˚C)	
	Method 1	Method 2
1	22.0 – 22.99	22.577
2	23.5 – 24.49	23.709
3	24.5 – 25.49	24.330

3.4 Thermal Acceptability

The actual votes of the respondents were graphed against the percentage of dissatisfaction to compare it to the theoretical predicted mean votes.

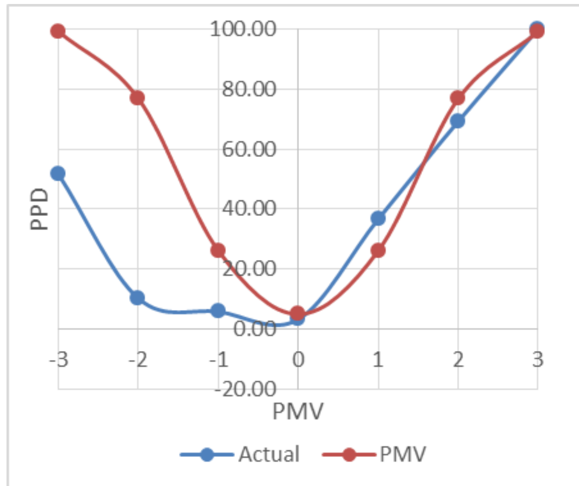

Figure 4 Theoretical Vote vs Actual Vote Percentage of Dissatisfaction

Figure 4 shows the combined votes of all the respondents from the three buildings. At warmer sensation votes, there is an increase in percentage of dissatisfaction and the percentage of dissatisfaction is similar to the theoretical PMV. On the other hand, at cooler sensation votes, there is still an increase in dissatisfaction as the votes move farther from 0 but the percentage of dissatisfaction is not as high as warmer sensation votes. Most respondents that voted for -2 and -1 are not dissatisfied with the thermal conditions at the time and it was acceptable for them. Only 10.2% that voted for -2 and 5.83% that voted for -1 were dissatisfied. This shows that the respondents are still satisfied at lower temperatures.

3.5 Carbon Dioxide Concentration

The average carbon dioxide (CO_2) content of the air in the buildings as measured was above the ASHRAE standard which is 1000 ppm. This would lead to general drowsiness but it would not pose as a health hazard. Improved ventilation is necessary to

Table 5: Carbon Dioxide Content per Building

Building	CO2 Content (ppm)
1	1072.575
2	1363.639
3	1213.317

lower the CO_2 content of the air inside the buildings. Table 5 gives the average CO_2 content of the air in the buildings.

3.6 Comparison of Results with Other Studies

Table 6 shows the results of various studies about thermal comfort in the tropics. The neutral temperatures obtained from these are different from the results of this study. This shows that the value of the neutral temperature will vary depending on various factors and one of those factors is the climate consideration. This also shows that the ASHRAE standard is not really fit for tropical climate countries

Table 6: Results from Other Studies

Title of Studies	Neutral Temperature (°C)
Thermal Preference of Filipino College Students from Selected Universities in Manila by Gatapia, et.al (2008)	26.04
Thermal Preference of Students in Selected Universities in Metro Manila by Ko and Sante (2011)	26 – 26.99
Report on Thermal Comfort and Building Energy Studies in Jakarta, Indonesia by Karyono (1998)	26.7
Large – Scale Survey of Thermal Comfort in Office Premises in Hongkong by Chan, et. Al (1998)	23.5
Thermal Comfort and Building Design in the Tropical Climates by Mallick (1996)	24 – 32
Thermal Comfort in Tropical Humid Climate by Kemajou, et al (2012)	23.28 – 28.13
Thermal Comfort in Lecture Hall in the Tropics byYau, et. al (2011)	25.3
Perceptions and Expectations of Thermal Comfort in the Philippines by Andamon, et. al (2006)	26.4

4. Conclusion

The preferred temperatures of the respondents are lower compared to the neutral temperatures and this shows that most of the respondents would be able to feel a neutral sensation when the temperature is set to the neutral temperature but this does not necessarily mean that this is their ideal temperature. Based on the results of the study, the ideal or preferred temperatures for most of the respondents are lower by 0.5°C - 1.5°C.

The study also showed that in terms of thermal acceptability, there is a lesser percentage of dissatisfaction in the ranges of -3, -2, and -1 thermal sensation votes compared to the ASHRAE standard. This means that at lower temperatures, most of the respondents feel satisfied and these temperatures are acceptable for them.

For future researches, it is recommended to increase the number of buildings involve in the study. It is also important to repeat the same process exposing the same respondents to the preferred temperature that they have chosen and repeat the survey done. This will further validate the results obtained from the study. Another recommendation is to determine the effect of thermal comfort to the health and productivity of workers in the office.

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Appendix: Data Measured in Buildings

Table A.1: For Building 1

Time	Ave. DBT (°C)	Ave. WBT (°C)	Ave. RH (%)	Ave. CO2 content
9:00 am	24.2	17.9	53.6	1166.4
10:00 am	24	17.7	53.7	1240.8
11:00 am	24.5	18.7	57.3	1074.3
12:00 nn	24	18.5	53.3	1057.8
2:00 pm	22.6	17	55.7	973
3:00pm	23.2	17.6	57.2	941

Table A.2: For Building 2

Time	Ave. DBT (°C)	Ave. WBT (°C)	Ave. RH (%)	Ave. CO2 content
10:30 am	23.2	16.7	50	1184
11:30 am	22.9	16.3	49.8	1529
1:30 pm	23.3	17.3	54.7	1336
2:30 pm	22.7	16.6	50.9	1372
3:30 pm	24.1	17.1	48.7	1407
5:00 pm	24.4	17.3.	48.7	1338

Table A.3: For Building 3

Time	Ave. DBT (°C)	Ave. WBT (°C)	Ave. RH (%)	Ave. CO2 content
10:00 am	25.4	18.4	50.5	1100
11:00 am	25.7	17.8	44.8	1285
1:00 pm	26.2	17.4	40.9	1063
2:00 pm	26.4	17.5	40.3	1229
3:00 pm	26.1	17.5	41.9	1398
4:00 pm	25.8	17.6	44	1309