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THERMAL COMFORT SCALES IN THE EQUATORIAL FULLY HUMID CLIMATE OF MALAYSIA

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Abstract- The aim of the study is to investigate the desired ASHRAE thermal sensation versus the ASHRAE sensation scale in the humid tropics of Malaysia. This study was carried out in university classrooms by means of both objective and subjective approaches. The field study was conducted in the Faculty of Engineering, University Malaysia Sabah. This study discussed some of the issues in using different scales for predicting comfort temperature and the preferred temperature. The results showed that the desired thermal sensation was lower than the neutral sensation by about one unit.

Keywords- Thermal Comfort, ASHRAE scale, Desired ASHRAE Scale, Humid tropics, Malaysia.

I. INTRODUCTION

Thermal comfort studies have been carried out in many locations in the word [1]. Probably field investigations are dominant due to several factors; among them, the complexity of the issue, the simplicity of the investigation compared to laboratory studies and the relatively low cost equipment (s) used for the analysis. However several issues on thermal comfort remain unknown or unresolved. For instance little has been published about the validity of the scales used in predicting comfort temperature. Though most of recent studies used ASHRAE thermal sensation scale for the prediction of the indoor comfort (neutral) temperature. The ASHRAE thermal sensation scale is shown in table 1.

The ASHRAE scale appears to be very well balanced scale; however, there are few observations that require further clarifications. The first observation is related to the question that might be used by the researchers to investigate the subject thermal perception toward the indoor thermal environment at the moment of the survey. For instance one may ask: How do you feel about the indoor air temperature at this moment. Another investigator may use: How do you feel just now [2]. A third investigator may ask the question differently: How do you perceive the temperature in this space at this moment. A fourth investigator may use: Now, how do you feel the air temperature [3]. The implication of each question on subjects' votes has not been investigated yet. Another issue that has been well documented by Rijal et al. [3] is the cultural implication in using ASHRAE scale. For instance the words "warm" or "cool" imply comfort in Japanese. Therefore SHASE scale was suggested by the Society of Heating, Air-Conditioning and Sanitary Engineers of Japan to overcome this limitation. The scale is shown in Table 2. Thus, it has been used by Rijal et al. [3] in their field investigation.

Additionally, further clarification relevant to climate and ASHRAE scale may require further discussion. This is about how a population living in the humid tropics will describe the indoor thermal environment compared to a population subjects mostly to cold thermal environment. This may lead to the following question: Is ASHRAE scale is a universal scale? Should the scale be adjusted according to the population under investigation? Which is the best methodology to approach this issue? For instance when it is better to increase the number of scale points? Admittedly the author has no precise answer to the questions.

Table 3 and 4 show the bedford scale used by many investigators in the past such the case study in reference [4] and the subjective scale of warmth sensation used by webb [5]. It is clear that the word "comfortable" was replaced in recent studies by "neutral". Additionally, it is apparent that the scales at the extreme range are different. Recent thermal comfort field studies added to "neutral" the words "neither cool nor warm" [3].

II. PREFERRED TEMPERATURE VERSUS COMFORT (NEUTRAL) TEMPERATURE

The mostly widely used thermal preference scale is McIntyre scale. The McIntyre scale is shown in table 5. Several studies showed that people may feel comfortable at a particular indoor operative temperature but may still prefer to feel cooler or warmer. They prefer to feel cooler under warm environment and warmer under cool environment.

Apparently the subjective scale of warmth sensation shown in table 4 seems to be more reflective to both situations feeling comfortable and feeling comfortably cool or comfortably warm. However, the main limitation is that it has 9-points scale. Therefore, it requires more data collections for an accurate prediction due to the wide range. One may also modify the McIntyre preference scale as shown in Table 6. Then the investigator may use the subjective scale of warmth sensation and the suggested preferred scale for better interpretation of results. Further improvement is needed. It requires careful observation and investigation. It is necessary to mention that ASHRAE thermal sensation scale is the most widely recognised scale by both ASHRAE 55 and ISO standards [6, 7]. Therefore, it is necessary to be used for comparison among studies and scales.

Humphreys and Hancock [2] selected the ASHRAE scale for comparing between subjects thermal sensation versus subject preference at the time of the survey. The selection of ASHRAE scale was for the purpose to quantify how much cooler or warmer their subjects would have liked to felt when exploring the variation of the desired thermal sensation on the

ASHRAE scale. The authors reported that the preference scale has implication for the estimation of energy use in buildings. Recent study by Rijal, Humphreys and Nicol [3] used a different thermal preference scale. This is provided in table 7. Unfortunately, there is no explanation on why different thermal preference scale was used instead of the ASHREA Scale.

III. METHODOLOGY

This study is all about exploring the desired thermal sensation on the ASHRAE scale. This study was carried out in Malaysia, Sabah state and precisely in University Malaysia Sabah, in Faculty of Engineering. The location of University Malaysia Sabah is shown in Figure 1

The subjective assessment-questionnaire survey and the objective indoor environmental data monitoring has been conducted simultaneously. Only few classrooms are selected. The examined classrooms are located in each floor from the ground floor to the 3rd floor. Questionnaires were used to investigate the desired thermal sensation on ASHRAE scale. They are delivered and filled by the students in the classrooms. The measurement period take at least 15 minutes in each classroom. In the evaluation of thermal comfort the metabolic rate was assumed 1.2 met (sedentary activity). All the selected subjects for this study are UMS student.

IV. RESULTS AND DISCUSSION

There were over 400 records collected from this investigation which spanned over three weeks. However, only 127 records were used in this study for several reasons. Therefore, it has been decided to carry on a preliminary data analysis using the 127 records judged to be more reliable. Description of the collected data is listed in table 8.

The mean indoor temperature recorded during the time of the survey was about 28.93^0C. Detailed descriptive statistics is shown in Table 9. .The minimum and maximum record of air-temperature varies from 26 to 31^0C having a range of 6^0C. It is necessary to mention that despite that air-conditioning was available in most classrooms, however in few cases the air-conditioning was not performing properly.

The descriptive statistic listed in tables 10 and 11 showed that the mean votes when using ASHRAE scale was 0.55 whereas the desired mean votes is –0.81 which is almost close to one scale unit. This indicates that overall, students may have preferred lower indoor temperature below neutrality when subjected to a mean temperature value of 28.9^0C.

Similar observation was reported earlier by Humphreys and Hancock for their case study carried out in the UK. They reported that the desired thermal sensation could on occasion lead to up to one scale unit in their estimate how much warmer or cooler people would like to feel. They found that the desired sensation yielded different distributions of thermal comfort. This certainly will affect the energy consumption as reported by the same authors. This is because, it requires reducing further the indoor air temperature below the comfort temperature.

It is necessary to mention this study used a continuous ASHRAE scale following Humphreys and Hancock case study. Statistically, it is highly recommended method for better predictions. However, the collected data showed that people have tendencies to select a specific category instead of selecting any value between two categories. However, some students selected the mid interval between categories. Still few selected their thermal sensation at any value between categories. One of the limitations in using continuous scale is for the case when the author may have interest in comparing between thermal sensation and the desired thermal sensation at various ASHRAE thermal sensation scale. The investigator may need to round off the value for more precision comparison at different thermal sensation. This was not the objective of this investigation due to the limited data collection; therefore, it will not be discussed in this paper.

V. CONCLUSIONS

This study discussed some of the issues in using different scales for predicting comfort temperature and the preferred temperature in the humid tropics of Malaysia. The usage of ASHRAE scale for investigating the desired comfort temperature versus comfort ‘’neutral temperature’’ showed that the desired thermal sensation was lower than the neutral sensation by about one unit ASHRAE scale for the mean indoor air temperature of about 28.9C. Validation of the results is necessary due to the limited data collections reflected by the wide range of the confidence interval.

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Fig. 1: Map of Sabah That Zooms In the Location of UMS.

Table 1: ASHRAE Scale

Cold	Cool	Slightly Cool	Neutral	Slightly warm	Warm	Hot

Table 2 SHASE Scale

SHASE scale: How do you feel air temperature?						
Very cold	Cold	Slightly Cold	Neutral (neither cold not hot)	Slightly hot	Hot	Very hot

Table 3 Bedford Scale

Much too cool	Too cool	Slightly cool	Comfortable	Slightly warm	Too warm	Much too warm

Table 4 Subjective Scale of Warmth Sensation

Excessively cold	Cold	cool	Comfortably cool	Comfortable and neither cool nor warm	Comfortably warm	Warm	Hot	Excessively Hot

Table 5: McIntyre Preference Scale

McIntyre: Preference Scale		
Warmer	No change	Cooler

Table 6: Adjusted McIntyre Preference Scale

Preference Scale			
Comfortably cool	comfortable (neither cool nor warm)	Comfortably warm	Others, please specify

Table 7: Five-point Preference Scale

Much warmer	A bit warmer	No change	A bit cooler	Much cooler

Table 8 Description of the collected data

Date	Month	Time	Survey location	Type of Building	Air Conditioning	NO OF STUDENTS
7	5	15:45	BT9	CLASSROOM	ON	24
7	5	19:45	BT5	CLASSROOM	ON	26
7	5	21:30	BT9	CLASSROOM	OFF	28
8	5	8:50	BT18	CLASSROOM	ON	25
8	5	10:48	BT14	CLASSROOM	ON	10
8	5	14:45	BT23	CLASSROOM	OFF	21
8	5	19:50	BT4	CLASSROOM	ON	22

Table 9 Descriptive statistic of air temperature

		Statistic	Std. Error
Mean		28.93	.169
95% Confidence Interval for Mean	Lower Bound	28.60	
	Upper Bound	29.27	
5% Trimmed Mean		28.96	
Median		27.90	
Std. Deviation		1.909	
Minimum		26	
Maximum		31	
Skewness		-.168	.215
Kurtosis		-1.291	.427

Table 10 Descriptive statistic of thermal sensation (ASHRAE scale)

		Statistic	Std. Error
Mean		.55	.130
95% Confidence Interval for Mean	Lower Bound	.29	
	Upper Bound	.80	
5% Trimmed Mean		.57	
Median		.00	
Std. Deviation		1.468	
Minimum		-3	
Maximum		3	
Skewness		.225	.215
Kurtosis		-.493	.427

Table 11 Descriptive statistic of the desired thermal sensation (ASHRAE scale)

		Statistic	Std. Error
Mean		-.81	.095
95% Confidence Interval for Mean	Lower Bound	-1.00	
	Upper Bound	-.62	
5% Trimmed Mean		-.81	
Median		-1.00	
Std. Deviation		1.070	
Minimum		-3	
Maximum		3	
Skewness		-.030	.215
Kurtosis		-.154	.427