(#88) Thermal Satisfaction of Students in Indoor Spaces at Academic Institutions

K.A.B. Weerasinghe[1], A.G.D.T.N. Nanayakkara[2]

[1]Division of Civil Engineering Technology, Institute of Technology, University of Moratuwa.
[2]Division of Civil Engineering Technology, Institute of Technology, University of Moratuwa

Abstract

This paper discusses a study conducted to identify the critical factors influencing the thermal comfort of learners within a classroom. The Fanger Model is used to predict the critical factors, and a result of a questionnaire survey has also been used.

Keywords: *Thermal satisfaction, Fanger model, Temperature, Humidity, Indoor environment*

Introduction

Thermal comfort is critical to the teaching and learning nature of an academic institution [1]. Thermal comfort in a learning environment is determined by essential characteristics which include temperature, humidity, airspeed, sunlight, as well as most significantly, the location of the institution [8]. The thermal comfort of a learning environment may be improved to various degrees by including natural and mechanical ventilation techniques. Despite the fact that there are more information technology resources available nowadays, most pupils decided to have a physical education.

As a result, the academic institution's premises must be built with improved thermal comfort in accordance with international standards such as ASHRAE 55 [2] and the ISO 7730 rule for "Ergonomic Principles on Environmental Thermal Satisfaction" specifies and investigates thermal convenience statistically [4].

This study focused on identifying the thermal comfort levels in occupied classrooms with different ventilation systems according to the Fanger model calculations which are PMV (Predicted Men Vote) and PPD (Predicted Percentage Dissatisfied) with respect to international standards.

Literature Review

As per the results of a study done by Kwok [11] within academic institutions in Japan, during the summer the thermally comfortable temperature in naturally ventilated classrooms was in the range of 26.9 ^{0}C and 27.1 ^{0}C, whereas that of air-conditioned classrooms was 24.0 ^{0}C and 24.2 ^{0}C. Further, it was found that the comfortable relative humidity for occupants in a naturally ventilated learning environment was 72.8% and for an air-conditioned space this value was 50.7%. There was a significant different between the air speeds in naturally ventilated learning environment and an air-conditioned environment and those measured values were 0.27 m/s and 0.08 m/s respectively.

It was noted that the findings presented by Knok [11] are compatible with the ASHRAE 55 standard parameters. In China, the favorable temperature range was recorded as 23.5 - 27.4 ^{0}C at a relative humidity of 70% with an airspeed of 0.44 m/s, clothing insulation of 0.43, and a metabolic rate of 1.0 met [9]. A study conducted to identify the most effective ventilation types for the classrooms based on thermal satisfaction revealed that the most cost effective and thermally satisfied are the hybrid ventilated classrooms in an education institute [6].

Methodology

Thermal comfort inside a classroom is heavily influenced by the internal architectural layout and the air circulation techniques employed [5]. A mixed, qualitative, and quantitative approach was adopted in this study in order to acquire more reliable results. The study areas were selected according to the ventilation systems adopted such as AC rooms and HBMS (Hybrid Ventilation with Mechanical Systems) rooms [6] to obtain the results based on the requirement of the Fanger model.

Both indoor and outdoor temperatures, humidity, and air speeds required for the Fanger model were measured simultaneously. A questionnaire survey was conducted to obtain the thermal satisfaction level of the occupants.

The questionnaire survey was conducted on 500 students by collecting their gender, thermal preferences, thermal satisfaction level during the questionnaire survey, stress levels, the immediate past activity performed, and their clothing habits. Table I shows the specifications and accuracies of the instruments used to collect data.

Table I: Specifications of Measuring Instruments

Instrument	Parameter	Resolution	Range	Accuracy
OEM HTC-2 Hydrometer	Temperature	0.1 ^{0}C	-50 ^{0}C – 70 ^{0}C	±1.0 ^{0}C
	Humidity	1 % RH	10% - 99% RH	±5% RH
UT363 mini wind speed and temperature meter	Wind Speed	0.01 m/s	0- 30 m/s	±0.02 m/s

Results and Discussion

The main objective of the study is to identify appropriate thermal parameters for the thermal comfortability of students in an academic institute in Sri Lanka. With the outcome of the questionnaire survey, clothing insulation (Iclo) and the metabolic rate (MET) were calculated as per the Fanger model [3]. The calculated clothing insulation was 0.61 since most of the students were wearing light clothes due to the hot humid environment in Sri Lanka. The metabolic rate was also calculated according to the Fanger model, and the magnitude was 60.0 W/m2. The activities engaged by the students were taken as sitting and writing in the calculation of the rate of metabolic.

According to the equations of the Fanger model [10], the PMV and PPD percentages, thermal preferences, and stress levels were calculated by incorporating the collected data. Tables II and III show the results summary of the study.

Table II: Summary of Indoor and outdoor thermal parameters

Classroom	Session	Classroom & Type	Indoor parameters			Outdoor Parameters		
			Temp ^{0}C	RH %	Wind speed(m/s)	Temp ^{0}C	RH %	Wind speed (m/s)
U1 114	Morning	HBMS	28.89	81.3	0.05	27	86	0.15
U1 733	Morning	AC	24.08	61.8	0.15	28.5	85	0.45
U3 517	Evening	HBMS	31.23	68.6	0.1	31.2	65	0.6
Z0 725	Evening	AC	23.82	63.3	0.05	27.2	86	0.15

Table III: Summary of Results

Classroom	Session	Type	Fanger model		Thermal preferences (%)			Learning stress (%)		
			PMV	PPD %	Cold	No change	Warm	Relaxed	Neutral	Stressed
U1 733	Morning	AC	-0.41	8.49	20	70	10	17	53	30
U1 114	Morning	HBMS	5.89	100	59	32	9	15	37	47
U3 517	Evening	HBMS	3.78	100	89	7	4	4	45	51
Z0 725	Evening	AC	0.38	7.37	7	77	17	13	63	23

As per the results, it can be concluded that indoor thermal comfort mainly depends on the classroom ventilation type. It was noted that the PMV and PPD were within the acceptable range of the Fanger model [-0.5 < PMV < +0.5 and PPD < 10%] when classrooms were air-conditioned. Further, the results of the questionnaire survey are compatible with the results of the Fanger model, since students prefer a learning environment with PMV and PPD is within the acceptable range of the Fanger model.

Conclusion

Based on the results of the study, it can be concluded that the best temperature for thermal comfort in a classroom should be in the range of 23.0 0C to 25.0 0C and relative humidity in the range of 60% to 65%. When considering the AC classrooms, have fulfilled the acceptable parameter range, while HBMS classrooms need some improvements in ventilation techniques to meet the acceptable parameters [9].

It was also noted that the HBMS classrooms could easily be converted to a satisfactory level if students were wearing clothing with low insulation. This will drastically reduce the operation cost [7] of the institute by reducing the number of AC rooms.

Future Work

Following future works may be suggested,

- Further study is required to identify possible natural ventilation systems to enhance HBMS classrooms to appropriate temperature and humidity ranges specified in the Fanger model.
- Develop local standards to evaluate appropriate thermal parameters to achieve the required thermal comfortability levels.
- To develop a relationship between thermal satisfaction level with the student's residence places, since thermal comfortability may vary based on their previous lifestyle and habits.

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