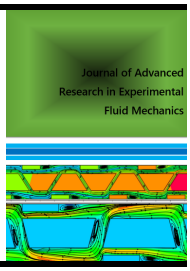
Journal of Advanced Research in Experimental Fluid Mechanics and Heat Transfer

Journal homepage: https://akademiabaru.com/submit/index.php/arefmht/index
ISSN: 2756-8202



Experimental Study of Indoor Air Temperature in the Laboratory

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ARTICLE INFO

Keywords:
Experimental Work; Thermal Comfort; Air Temperature; Classroom University; Indoor Air Quality; Tropical Climate

ABSTRACT

In the university, the laboratory is one of the most important facilities for science-based students. The student will spend their time in laboratories during a session of experiments. Thus, the laboratory indoor air temperature has a huge effect on students' performance. A comfortable indoor air temperature is more conducive to improve the learning efficiency of the students. The purpose of this present work is to experimental study the evaluation of the performance of indoor air temperature in the selected laboratories of the Faculty of Mechanical Engineering (FME), University Technology Mara, Pulau Pinang with a centralized air-conditioning system in a tropical climate. To carry out this study, indoor air temperature was collected at three zones inside the laboratory. The indoor air temperature values are compared to the limits stated in the Malaysia Standard regarding thermal comfort. The factor that affects indoor air temperature has also been identified in this study. The equipment used to determine indoor air temperature which is Humidity + thermometer + barometer LUTRON MHB-382SD. These results indicate that data collected in the FME laboratories do not comply with the standards that have been standardized by Malaysia Standard. In conclusion, the FME laboratories were declared as poor thermal comfort and some improvement needs to be done.

1. Introduction

A suitable indoor air temperature for laboratories in colleges and universities impacts thermal comfort, learning performance, and building energy consumption. Students spend a lot of time in the classroom, and studies have shown the significance of thermal comfort in student achievement [1]. Thermal comfort is well-known as a personal perception of the thermal environment [2] and it is considered as the neutral sensation experienced by the individual in relation to a given thermal environment, avoiding sweat [3]. Expectations of thermal comfort depend on the location of the person and the climatic conditions that exist inside and outside the area [4].

The effects of the thermal environment in educational buildings where unpleasant thermal sensations have been widely investigated. The findings report that an uncomfortable indoor environment affects the learning process and motivation of students in academic activities, as well

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as difficulty to concentrate, learn, memorize, and thinking until completing a test. According to Jiang et al. [1], the discomfort concerned with feeling hot or cold has a negative effect on the well-being of a person. However, the well-being of a person decreases more noticeable when environments are colder. In a randomized controlled study of thermal comfort by Zomorodian et al. [5] and Singh et al. [6] conducted in educational settings highlighted that students' thermal preferences were not in the comfort zone ascribed in the standards. Students were highly dissatisfied with the prevailing indoor thermal environment at each educational level.

The air-conditioning and mechanical ventilation systems are used to maintain a thermally comfortable indoor environment by introducing and distributing fresh outside air in suitable quantities to maintain an adequate supply of fresh air. In 2014, Rackes et al. published a paper in which they described ventilation plays a crucial role in promoting comfort and health to the building occupants [7]. Good ventilation systems control temperature and humidity, provide thermal comfort, distribute adequate amounts of air, and remove pollutants. The typical system that is recommended in tropical climate regions is natural ventilation [8]. However, it is not capable of providing a sufficient level of thermal comfort in all areas, due to the inconsistent wind speed and different climate characteristics.

Several studies have been carried out to determine the thermal comfort status preferred by students at schools, colleges, and universities. Previous research has indicated to achieve the optimal cooling temperature set point, and thermal environments that are comfortable and acceptable, field studies should be carried out under actual conditions [9]. Experimental studies in air-conditioned classrooms have been investigated, such as the carried out in Malaysia and Japan by Sheikh Ahmad Zaki et al. [10], in 2017, applying the ASHRAE methodology, field studies were carried out with mechanical cooling and free-running operative modes and surveying 1428 responses obtaining an acceptable temperature value. In Japan temperature was found to be 25.1^{o}C, while in Malaysia it was 25.6^{o}C. In Brazil, Buonocore and co-worker [11] point out leads to a reflection on the excessive use of air conditioning systems, normally found in university classrooms, causing an over-cooling of indoor environments. Instead of providing thermal comfort to students, these systems cause discomfort and unnecessary energy costs. The experimental study carried out in [11] is applied in a tropical climate, in 16 university classrooms, and with 1030 surveys done, obtaining that the best thermal conditions in the air-conditioned classrooms were between 23 ◦C and 24 ◦C. In the classroom, students experience a transient thermal condition for the first 10-15 minutes in a class and when ASHRAE 55 and Malaysia Standard MS 1525: 2014 [12] which generally deal with steady-state conditions are applied to evaluate the classrooms thermal environment, the deviation reported by many studies seems obvious [13,14].

The present work is part of a research project at the laboratories of the Faculty of Mechanical Engineering (FME), University Technology MARA (UiTM) Pulau Pinang. In this paper, we present an evaluation of indoor air temperature in selected laboratories at the University Technology Mara, located in Pulau Pinang, Malaysia, which is characterized by a tropical climate and the use of air conditioning systems is required to provide thermal comfort conditions. At first, the case study and methodology applied for this study are shown. Indoor air temperature value was measured inside the laboratory, as well as the data collected from the temperature sensation device are shown. The data collected are compared to the limits stated in the Malaysia Standard regarding thermal comfort. The factor that affects indoor air temperature has also been identified in this study. It is expected that a good suggestion can be made to improve the indoor air temperature performance to create a comfortable learning environment for students.

2. Methodology

2.1 Description of Selected FME Laboratory

University Technology MARA (UiTM) Pulau pinang consist of several FME laboratory and this investigation will be carried out at a laboratory that is actively used by students and staff. The laboratories that are frequently used by students and staff that are chosen in this investigation are Thermodynamics Laboratory, Fluid Mechanics Laboratory, and Mechanical Workshop. These 3 laboratories are in the FME building as shown in Figure 1 and utilized by both diploma and degree students which become a suitable choice for this investigation.

(a) (b)

(c)

Fig. 1. Selected FME Laboratory (a) Thermodynamics laboratory layout (b) Fluid Mechanics laboratory layout (c) Mechanical Workshop layout

FME laboratory had installed the Centralized Cooling System as the main type of air conditioning system. To meet most of its cooling demand among occupants in several laboratories, FME laboratory used the Water-Cooled Chiller System. The system includes a cooling tower, a condenser pump, a chiller, a chilled water pump, an air handling unit, a supply duct, and an exhaust fan. The air handling unit (AHU) systems were placed on each of the floors of the FME building.

2.2 Measuring Instrument

The equipment used to conduct the field measurement is Humidity + thermometer + barometer LUTRON MHB-382SD used to determine the air temperature in the laboratory as shown in Figure 2. This measurement device can measure humidity, temperature, and barometer. The temperature range is from 0°C until 50°C while the resolution for temperature reading is 0.1 degree.

Fig. 2. Air temperature measure device, Humidity + thermometer + barometer LUTRON MHB-382SD

2.3 Experimental Procedure

The measurement is taken in a situation in which the laboratory with no occupants. Measurements were taken at three zones in the laboratory. Zone selection to take measurements is by choosing an area that is always occupied by students to do discussion or conduct experiments as shown in Figure 3.

(a)

(b)

(c)

Fig. 3. The three zones for taking measurements in the laboratory (a) Thermodynamics laboratory (b) Fluid Mechanics laboratory (c) Mechanical Workshop

The measuring instruments will be placed at the same level as the students sitting or standing about 1.1 meters from the floor at their table discussing and doing their experiment. The indoor air temperature data was taken automatically using Humidity + thermometer + barometer LUTRON MHB-382SD every 30 seconds for 1 hour.

The data of this experimental study will be compared to the recommended level by Malaysia standard of thermal comfort to disclose whether it complies with the standard or otherwise. The thermal comfort measurement standard adopted in Malaysia is recognized as MS 1525:2014, second edition. The comfort of air temperature for the indoor condition of an air-conditioned building for comfort cooling is 23 – 26 °C.

3. Results

3.1 Indoor Air Temperature of Thermodynamics Laboratory

The maximum and minimum values of the air temperature for zone 1 were 25.1℃ and 22.1℃ respectively. In zone 2, the reading for the maximum and minimum values of the air temperature were 23.3℃ and 22.4℃ respectively. Lastly, the maximum value for zone 3 is 23.1℃ while the minimum value is 22.5℃. Based on Malaysia Standard, the indoor air temperature condition for building is between 23℃-26℃ and the results from the measurement that have been done, it shown that the three minimum air temperature values in the laboratory is not following the Malaysian Standard (too cold), but maximum values for three zones does follow the Malaysia Standard. The graph for the air temperature data was shown in Figure 4.

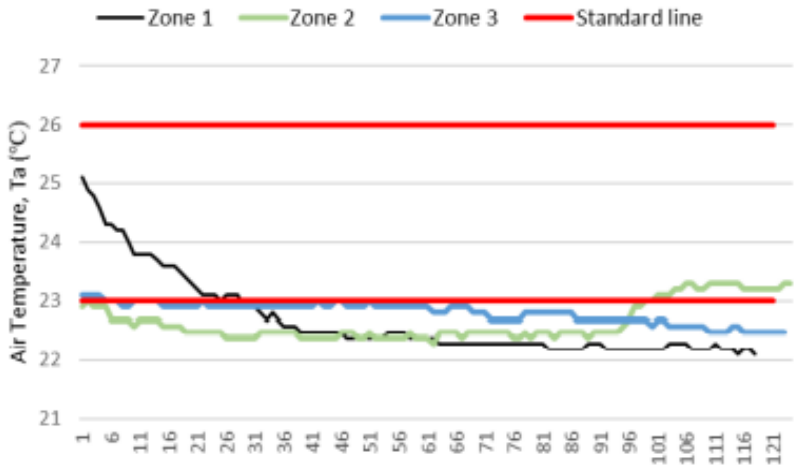

Fig. 4. Air temperature for 3 zones in thermodynamic laboratory

3.2 Indoor Air Temperature of Fluid Mechanics Laboratory

The next data collection process is for the fluid mechanic laboratory with three different zones and at the same time with the thermodynamics laboratory. The data for the air temperature was measured in zone 1, the maximum value was 26.2℃, then the minimum value was 24.8℃. As for zone 2, the maximum and minimum values for the air temperature were 25.1℃ and 24.7℃ respectively. Lastly, the maximum and minimum values of the air temperature for zone 3 were 25.4℃ and 24.9℃ respectively. Based on the Malaysia Standard, all the air temperatures in that three zones were in the standard range and comply with the thermal comfort range which is 23℃-26℃. Figure 5 shows the pattern of the air temperature at zone 1, zone 2, and zone 3 respectively in graph form.

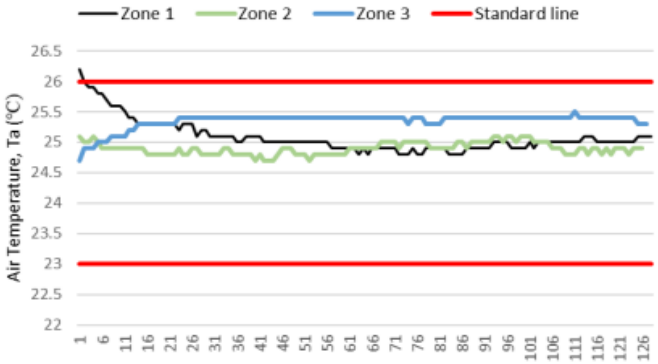

Fig. 5. Air temperature for 3 zones in fluid mechanic laboratory

3.3 Indoor Air Temperature of Mechanical Workshop

The reading for the maximum and minimum values of the air temperature at Zone 1 in the mechanical workshop were 27.1℃ and 26.6℃ respectively. Afterward, in the zone 2 section, the data measured for the maximum and minimum and value of the air temperature were 27.0℃ and 26.8℃ respectively. Finally, the maximum and minimum values of the air temperature at this zone 3 were 28.6℃ and 27.8℃ respectively. In Malaysia Standard (MS 1525: 2014), it was stated that the air temperature condition for thermal comfort level in the building must be between the range 23℃-26℃. So, the results have shown that all three data in zone 1, zone, and zone 3 were beyond the maximum standard range (not comfort). As referred to on the graph given in Figure 6, all of the air temperature data were out of the standard range in every zones, and zone 3 collected the highest value of air temperature among them.

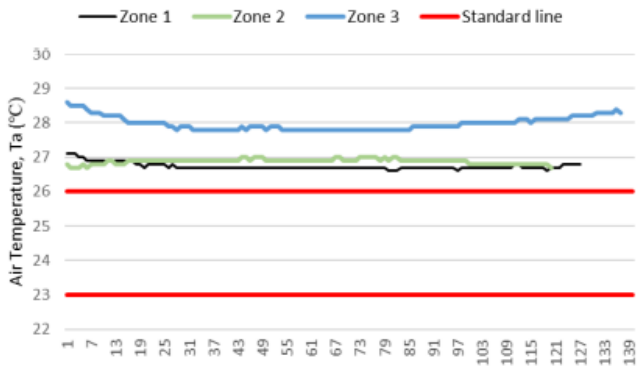

Fig. 6. Air temperature for 3 zones in fluid mechanical workshop

3.4 Data Analysis

There are some factors that may influence the indoor air temperature which can vary the collected data. Throughout this experiment, the air temperature is slightly low for the thermodynamics laboratory, comfortable for the fluid mechanics laboratory, and slightly hot for the mechanical workshop. A high air temperature affects occupants' health. Diseases like headaches and allergic reactions were reported faced by the occupants due to high indoor air temperature [15]. For air temperature, the air conditioning unit is the main factor that can affect thermal comfort. If the performance of the air conditioning is bad, there is a possibility that the data collected will not satisfy the thermal comfort standard. A research review of a total of 93 research articles by Singh has highlighted that the students at each educational stage were highly unhappy with the indoor thermal condition and that the indoor environment of lower temperature is preferable [16]. To improve the indoor air temperature, the facilities manager should ensure that the air conditioning is always in good condition by doing maintenance. The air temperature also can be affected by the weather such as a rainy day or extreme hot day. A rainy day may cause the air temperature to be slightly cold and the extreme hot day makes the air temperature slightly hot from the normal temperature.

4. Conclusions

The purpose of this study was to evaluate the indoor air temperature in the selected laboratories of the FME, UiTM Pulau Pinang is comfort condition or not. This study reveals that the environment of selected FME laboratories had indoor air temperature falling out of the comfort range most of the time as set by Malaysia Standard 1525:2014. The air temperature obtained in the Fluid Mechanics laboratory was the only laboratory that is in the comfort range while for Thermodynamics laboratory and Mechanical workshop indicated that the air temperature was not in the comfort range set by Malaysia Standard. Briefly as stated by Malaysia Standard the environmental condition of FME laboratories does not achieve the requirement for thermal comfort of an air conditioning space. It is recommended that further research be undertaken in the following areas. Further experimental investigations are needed to control the air temperature and protect occupants in enclosed environments, the study of airflow of temperature distribution is important.

Acknowledgement

This research was not funded by a any grant. The authors would like to thank the administration staff at laboratories Faculty Mechanical Engineering as granted us permission to conduct site measurement inside the laboratory and express their appreciation to University Technology MARA Pulau Pinang, Malaysia for giving the opportunity and supporting to do this research study.

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