COMPLIANCE OF THERMAL COMFORT PARAMETERS WITHIN STUDENTS' DORMITORY, RESIDENTAL AND PUSAT ISLAM ENGINEERING CAMPUS, USM BASED ON INDUSTRY CODE OF PRACTICE ON INDOOR AIR QUALITY (ICOP) 2010

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by

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I hereby declare that all corrections and comments made by the supervisor(s) and examiner have been taken into consideration and rectified accordingly.

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ABSTRAK

Kajian ini dilakukan untuk menilai kepuasan penghuni terhadap keadaan suhu sekitarnya. Kajian ini dilakukan di tiga tempat iaitu asrama pelajar, kediaman dan ruang solat, Pusat Islam Kampus Kejuruteraan, USM. Kajian ini melibatkan kepatuhan parameter keselesaan terma; suhu, kelembapan relatif dan pergerakan udara. Parameter kemudian digunakan sebagai input dalam *"Center for the Built Environment (CBE) Thermal Comfort Tool"* untuk mendapatkan Nilai Purata Ramalan dan Peratus Ramalan Tidak Puas untuk *"ASHRAE Standard-55"*. Pemantauan untuk kajian ini dilakukan selama tiga jam dalam tiga slot yang berbeza; 6 A.M. – 9 A.M. , 11 A.M. – 2 P.M. dan 5 P.M. – 8 P.M. untuk asrama pelajar dan kediaman rumah. Untuk pemantauan di Pusat Islam, ia dilakukan dalam dua slot; 11 A.M. – 2 P.M. dan 6 P.M. – 10 P.M., dan dijalankan pada bulan Ramadhan, di mana umat Islam menunaikan solat Teraweh. Secara keseluruhan, penemuan menunjukkan bahawa kebiasaannya, parameter keselesaan terma tidak mematuhi had ICOP. Ini disebabkan oleh reka bentuk asrama pelajar yang tidak bagus di mana reka bentuk itu sendiri tidak mendorong pengudaraan silang menyebabkan ketidakselesaan terhadap penghuni.

ABSTRACT

This study was conducted to assess occupants' satisfaction with their surrounding temperature conditions. The study was carried out at three places which are students' dormitory, residential and prayer hall of Pusat Islam Engineering Campus, USM. It entailed determining the compliance of thermal comfort parameters; temperature, relative humidity and air movement. The parameters are then used as input in the Center for the Built Environment (CBE) Thermal Comfort Tool to obtain Predicted Mean Value and Predicted Percentage Dissatisfied for ASHRAE Standard-55. The monitoring for this study was conducted for three hours in a three-time period; 6 A.M. - 9 A.M., 11 A.M. - 2 P.M. and 5 P.M. - 8 P.M. for students' dormitory and residential. For monitoring at Pusat Islam, it was conducted in two slots; 11 A.M. - 2 P.M. and 6 P.M. - 10 P.M., and it was assessed during Ramadan, where the Muslims perform Teraweh prayer. Overall, the finding indicates that most of the time, the thermal comfort parameters do not comply with the ICOP limit. This is due to the poor design of students' dormitory where the plan itself does not promote cross-ventilation, causing discomfort towards the occupants.

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LIST OF ABBREVIATIONS

AM	Air Movement
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
CBE	Center for the Built Environment
IAQ	Indoor Air Quality
ICOP	Industry Code Of Practice On Indoor Air Quality 2010
IEQ	Indoor Environment Quality
PMV	Predicted Mean Value
PPD	Predicted Percentage Dissatisfied
RH	Relative Humidity
T	Temperature
USM	Universiti Sains Malaysia

CHAPTER 1

INTRODUCTION

1.1 Background

Thermal comfort is a state of mind in which a person is satisfied with their thermal surroundings. A person's sense of thermal comfort is primarily due to the body's heat exchange with the environment. Four parameters influence this condition; air temperature, radiant temperature, humidity and airspeed that constitute the thermal environment. Two personal parameters; clothing and activity level or metabolic rate. (Olesen & Brager, 2004)

According to Wafi & Ismail (2010), thermal comfort, which is highly associated with climatic and human factors, is crucial for hostel occupants regarding students' physical and psychological wellbeing. The factors like solar radiation, surface reflection from walls and orientation of buildings are highly associated. One of the ways that contribute to better comfort is by improving ventilation. Sound ventilation system not only provides thermal comfort by controlling temperature and humidity, but they also distribute sufficient amounts of air to occupants and eliminate contaminants.

According to ICOP-IAQ (2010), ventilation is defined as supplying air or removing air from space to control air contaminants levels, humidity or temperature within the area. The indication of inadequate ventilation is when the ventilation performance indicator, carbon dioxide, CO_2 exceeding the ceiling limit based on ICOP 2010. Therefore, improving ventilation is recommended.

Adequate ventilation is crucial as people spend more than 90% of their time indoors (Lee & Chang, 2000). The same goes for the students, as they also spend most of their time indoors. Therefore an excellent indoor air quality is necessary for their well-being.

A student dormitory is a common form of a residential building in Malaysian colleges. The number of students enrolled in colleges has risen dramatically in recent years, with most of them living in campus dorms. The majority of Malaysian dormitories have similar indoor layouts, furniture, and construction materials. In comparison to residential homes, student dormitories are often furnished more simply and have fewer electrical appliances. Each dormitory usually contains three or four students and has three or four single beds at each corner. The most common ventilation form in dormitories is natural ventilation through the windows.

The thermal comfort in the dormitory, residential and prayer hall is crucial as it is closely related to comfort and functional performance. Hence, knowing the compliance of thermal comfort parameters in students' dormitory, residential and prayer hall can ensure their comfort and working performance.

1.2 Problem Statement

The weather in Malaysia is not consistent and changes throughout the year due to the hot and humid weather. The occupants would be uncomfortable if the temperature and humidity are high.

This study investigates the compliance of thermal comfort of a naturally ventilated student's dormitory, residential and prayer hall in Engineering Campus, University Science Malaysia (USM). One of the sampling locations is the prayer hall of Pusat Islam Engineering Campus, USM. Pusat Islam is a massive structure used by Muslims to perform their communal religious activities and congregational prayers. As a result, thermal comfort inside the prayer hall must ensure that the occupants are comfortable executing their duties. In most cases, the discomfort is caused by insufficient ventilation for the building's occupants, Thus, determining the compliance of thermal comfort parameters within the dormitory, residential and prayer hall can ensure the occupants' comfort.

1.3 Objectives

This study's primary purpose is to determine thermal comfort compliance in a dormitory, residential and prayer halls based on ICOP 2010. In achieving the goal above, the following objectives are developed:

1. To determine physical parameters; air temperature, relative humidity and air movement in the dormitory, residential and prayer hall.
2. To compare the physical comfort parameters in the dormitory, residential and prayer hall with Industry Code Of Practice On Indoor Air Quality 2010.
3. To determine thermal comfort compliance in the dormitory, residential and prayer hall based on ICOP 2010.

1.4 Scope Of Study

The following are the scope and limitations to achieve the main objectives of this study:

1. The sampling for this study was conducted at the student dormitory, residential and prayer hall of Pusat Islam Engineering Campus, USM. The sample's location is made after considering the current situation of COVID-19, and it is a safe place to do the sampling.
2. The parameters monitored during the sampling include physical parameters; air temperature, relative humidity and air movement.
3. The sampling results are then compared with the acceptable limit based on ICOP 2010 to determine the thermal comfort compliance in the dormitory, residential and prayer hall.

1.5 Thesis Layout

The dissertation of this study has been divided into five chapters to make it easy to follow.

Chapter 1 is the overview of this study. This section consists of information about the study's background as well as the dissertation's context, which assist the reader in comprehending the study's intent.

Chapter 2 is the literature review. This chapter describes the details of this study based on previous research and journal. This section consists of a detailed understanding of thermal comfort parameters and the method used to indicate occupants comfort in the indoor environment.

Chapter 3 describe the methodology to conduct this study. This chapter is to describe the activities involve throughout this study and the data collection. The primary activity in this study is the field monitoring at the site and data collection. The Center for the Built Environment (CBE) Thermal Comfort Tool was used in order to calculate Predicted Mean Vote (PMV) and Predicted Percentage Dissatisfied (PPD) and described in detail in this chapter.

Chapter 4, the results of thermal comfort parameters obtained from monitoring for dormitory, residential and prayer hall are discussed in this section.

Chapter 5, where possible conclusions are made. Based on the results of the study, recommendations can be made, and changes can be prepared for future studies.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

To assess thermal comfort, it is necessary to determine the parameters such as air temperature, radiant temperature, relative humidity and airspeed of the air in the building. The following literature review analyses the current study or research in work by referring to the articles, journals and other information sources.

2.2 Thermal Comfort

According to Olesen & Brager (2004), thermal comfort is defined as the condition where is a state of mind where a person expresses satisfaction with the thermal environment. A person’s sense of thermal comfort is primarily due to the body’s heat exchange with the environment. Four parameters influence this condition; air temperature, radiant temperature, relative humidity and airspeed that constitute the thermal environment. Two additional personal parameters are; clothing and activity level or metabolic rate. In this study, the parameters that will be monitored are air temperature, relative humidity and airspeed. Thermal comfort is not only about the temperature. It only can be achieved when the air movement, air temperature, radiant temperature and humidity of the air are balanced with each other. The temperature preference varies significantly among individuals, a person’s thermal comfort is not the same as others, and it is impossible to satisfy everyone.

Indoor air quality and thermal comfort are two critical aspects of indoor environmental quality that many disciplines, including climatology, geography, medicine, physiology, engineering and architecture, pay close attention to. International and regional guidelines specify requirements that are meant to create livable environments for occupants.

2.3 Thermal Comfort Parameters

Since thermal comfort is highly subjective, it is difficult to measure. For a long time, it has been acknowledged that a human's thermal comfort a not only determined by air temperature but also other less obvious parameters such as relative humidity, air movement, activity level and clothing thermal resistance.

2.3.1 Factors Influencing Thermal Comfort

Many researchers worldwide have been attracted to the field of thermal comfort research in recent years, probably due to the increased public discussion about climate change (Richardo et al., 2015). The measurement of indoor environmental quality and overall thermal comfort is not purely dependent on physical parameters. The physiological and psychological responses of the human body to the environment are dynamic, including various physical phenomena that associate with space, such as vibration, light, noise, humidity, temperature, etc. (Parsons, 2000). According to (Humphreys & Fergus Nicol, 2002), the physiological variables of metabolism are divided into two groups; clothing's thermal resistance and effect of activities and climate variables (airspeed, relative humidity, air temperature and radiant temperature). In contrast, psychological variables include the expectations and experience of the indoor environment (Humphreys & Hancock, 2007). In short, physiological are referring to the studies of the body, and psychology is the studies of the mind.

2.3.1(a) Environmental Factors

The environmental factors contributing to thermal comfort are air temperature, relative humidity, air movement and radiant temperature.

2.3.1(a)(i) Air Temperature

Air temperature is the air temperature surrounding the body and is usually given in degrees Celsius (ºC). Based on the study conducted previously by Wafi & Ismail (2010), it is found that the comfort temperature for Malaysian students is 28.5 ºC. The regression of mean thermal sensation scale response produces a typical value of regression coefficient, which confirmed that the sensitivity of Malaysian students towards thermal environment. Therefore, it is suggested that they adapt themselves in the indoor condition by using a fan, opening the door and clothing modification.

2.3.1(a)(ii) Relative Humidity

Relative humidity (RH) is defined as the ratio of water vapour to the amount of water vapour that the air could retain at a given temperature and pressure. Sweating is an effective way to lose heat because it depends on evaporation from the skin. However, at high RH, the air has condensed to the maximum amount of water vapour it can retain, reducing evaporation and heat loss. On top of that, RH < 20-30% indicate that arid environments result in discomfort because of their effect on the mucous membrane. (Balaras, 2006; Wolhoff & kjaergaard, 2007). Based on Malaysia's ICOP 2010, the recommended acceptable range for relative humidity is in the field of 40-70%.

Relative humidity may be higher than 70% in non-air-conditioned workplaces or where the weather condition outside may affect the indoor thermal climate. Humidity in indoor environments varies a lot, and it can be influenced by whether or not there is any drying process (laundry, paper mills, etc.) that emit steam. Humidity is crucial in hot environments as sweat evaporates less when humidity is high (80%+). Sweat evaporation is the primary means of heat reduction.

2.3.1(a)(iii) Air Movement

Based on ASHRAE Standard (2004), air movement is defined as the average speed of the air to which the body is exposed, concerning distance and time. Air movement is the most difficult parameter to measure accurately and need precise equipment as it is a highly variable parameter and can have more than one direction.

2.3.1(a)(iv) Radiant Temperature

Radiant temperature is the heat that radiates from a warm object, and it is present when there are heat sources in the environment. Examples of radiant heat sources are the sun, hot surfaces, fire, dryers and others. The radiant temperature is related to the amount of heat transmitted from the surface and is determined by the material's emissivity or ability to absorb or emit heat.

2.3.1(b) Individual Factors

Clothing and activity level or metabolic rate are the two individual factors that affect thermal comfort.

2.3.1(b)(i) Clothing

The thermal comfort of the occupant is also affected by the insulating effect of their clothing. The person will feel warm or hot if wearing too much clothing even the environment is not warm or hot.

2.3.1(b)(ii) Activity Level or Metabolic Rate

The impact of metabolic rate on thermal comfort is essential as the more one's do physical work, the more heat will be produced and need to be lost so that they don't overheat. It is also essential to consider the person physical characteristics such as size and weight, fitness level and age when considering their thermal comfort even if the air temperature, humidity and airspeed are all constant.

2.4 Ventilation

Based on Malaysia's ICOP, ventilation is defined as supplying air or removing air from space to control air contaminants levels, humidity or temperature within the area. The indication of inadequate ventilation is when the ventilation performance indicator, carbon dioxide, CO_2 exceeding the ceiling limit based on ICOP 2010. Natural ventilation is the flow of outdoor air through an enclosure under the effect of wind and heat pressures through adjustable openings. It is instrumental for controlling the temperature in hot and humid climates. When mechanical air-conditioning is unavailable, temperature control by natural ventilation is frequently the sole option for cooling.

From a previous study conducted by (Hashemi n.d.) on *"Effects Of Natural Ventilation On Thermal Comfort In Low-Income Tropical Housing",* it is found that the effect of natural ventilation strategies has improved the condition, and these improvements were sufficient to pass the assessment criteria. To further enhance thermal comfort, natural ventilation should be considered with other techniques such as solar shading. Based on this study, to evaluate the effects of natural ventilation in conjunction with solar shading and refurbishment strategies in low-income housing, further research is required.

2.5 ASHRAE Standard 55-2004

For this study, there were two standards used in this study, which is ICOP 2010 and ASHRAE Standard 55-2004. ICOP 2010 is used to determine the acceptable limit of physical parameters of thermal comfort; air temperature, relative humidity and airspeed. Meanwhile, ASHRAE Standard 55-2004 is used to determine whether the PMV and PPD values are within are acceptable limit or not. Both PMV and PPD values are vital as they indicate the occupants' comfort of their indoor environment.

According to Olesen & Brager (2004), ASHRAE Standard 55-2004 sets acceptable conditions for the indoor thermal environment for occupants. It is designed to help with the design, commissioning, and testing of buildings and other occupied spaces, as well as the evaluation of existing thermal environments. An analytical method based on the PMV-PPD indices and the inclusion of the idea of adaptation with a separate procedure for naturally conditioned buildings is the two most significant contributions to this new standard.

This standard is solely concerned with thermal comfort in the indoor environment. There are no restrictions on the type of building that can be used, and it may be used for existing or new construction and for commercial or residential buildings. It can even be applied to occupied spaces, such as public transit. Therefore, this standard is used since it is applied to all types of buildings.

2.6 PMV and PPD Method

PMV and PPD are included in determining the comfort zone. The value of Predicted Mean Vote (PMV) indicates the quality of the indoor environment as a mean value of the votes of a large group of people based on ASHRAE seven-point thermal sensation scale; +3 hot, +2 warm, +1 slightly warm, 0 neutral, -1 slightly cool, -2 cool and -3 cold. On top of that, the acceptable limit of PMV should be within +0.5 to -0.5 which indicates the quality of the indoor environment.

Predicted Percentage Dissatisfied (PPD) is directly determined from PMV, and it indicates the thermal comfort level as a percentage of dissatisfied people. Based on the standard, the permissible limit for PPD is 10%.

Section 5.2.1 in the ASHRAE Standard specifies two methods that can be used to determine the level of indoor comfort, which is the Graphical Method and Computer Method. To use either of these methods, the parameters for clothing insulation levels and occupants' metabolic rates need to assume and the assumption of the values used for this study are based on previous studies.

For the graphical method, it is limited to the situation where the air speed is less than 0.20m/s and metabolic rates ranging from 1.0 to 1.3 met. While for the computer method, it is applicable when the metabolic rates are between 1.0 to 2.0 met and the clothing insulation is less than 1.5 clo.

2.7 Previous Studies

The orientation of a building is a crucial design concern, especially in terms of solar radiation and wind. Buildings should be oriented to reduce solar gain and promote natural ventilation in generally hot, humid countries like Malaysia, which receives sunlight all year. According to M. Al-Tamimi et al. (2011), during the months of May, June, July, and August, the north façade faces the sun radiation, while the south façade faces it during the months of November, December, January, and February. Every morning and evening, the east and west façades are exposed to direct sun radiation. Thus, the building orientation, especially in tropical areas, should be thoroughly considered in relation to solar radiation and wind direction.

Based on a previous study done by Givoni (1981), he reported that the supply of appropriate cross ventilation under the local wind direction is the crucial aspect that may impact the building orientation in hot, humid locations. Air flow inside a building is influenced by a variety of factors, including not only the external wind speed but also the design features such as the type and location of the windows.

Nowadays, sometimes the building is designed based on the client's requirements which do not take much concern on the local climate. This shows that people are ignoring the environment as a design determinant in the building design process, resulting in poor indoor thermal performance of a building.

Since the outbreak of COVID-19 in early 2020, people spend most of their time at home. It is crucial to ensure the indoor thermal comfort are within the acceptable limit because there is evidence that COVID-19 propagated more quickly in places with high temperatures and humidity, which were optimal for airborne transmission. Knowing this, poor thermal comfort in housing that puts people in danger must be addressed for their health as well as their comfort and well-being. According to a study of social housing buildings in Toronto, residents who live in buildings with the most external glazing report higher thermal discomfort (Vakalis et al., 2019). In addition, according to a review of studies on occupant comfort in apartment housing, thermal conditions and IAQ are the essential aspects in maintaining occupant comfort (Andargie et al., 2019).

Another factor to consider is that, in the context of COVID-19, nature and thermal comfort have all become status symbols. Due to the virus's highly contagious nature, COVID-19 has compelled people to acknowledge the challenges of structural inequity. Re-evaluate all living environments to ensure that everyone has a home that supports a good atmosphere. Many residences surpassed healthy CO_2 levels, according to an Australian study assessing energy use, indoor thermal comfort, and health in social housing; 32% of individuals had allergies, 54% had health concerns and 42% of households had mould (Haddad et al., 2019). Therefore, significant changes need to be taken in order to decrease the number of people of low socioeconomic status to develop chronic disease.

Natural ventilation and adjustable windows could be simple passive solutions for improving the comfort and health of the indoor environment. In buildings with less operable windows, an overreliance on active heating and cooling systems has resulted in a high reliance on dynamic building systems. The concentration of CO_2 was found to be the strongest predictor of window opening behaviour in residential window research. By ensuring excellent IAQ, thermal comfort, and ventilation, operable windows are crucial to establishing occupants' trust in their houses.

Based on the previous study, it is suggested that indoor air quality and thermal comfort are essential aspects that need to be taken into consideration since people spend most of their time indoors, and they even work from home and do online learning.

According to (Andargie et al., 2019), the study identified occupants’ indoor comfort that is influenced by different parameters and the main parameters are grouped under IEQ; occupants characteristics, building characteristics and outdoor environment. The most commonly studied element of comfort is thermal comfort. As a result, the majority of research has looked at the link between thermal comfort and indoor thermal variables such as temperature, relative humidity, and air speed. Many studies have defined the ideal temperature range for optimal thermal comfort. Neutral temperatures, according to (de Dear & Brager, 1998), are significantly dependent on and tend to be closer in value to mean indoor temperatures due to occupant adaptations to indoor conditions. Nevertheless, the literature survey done suggests that the outside climate may have a more significant impact.

People relate their indoor comfort with outdoor conditions instead of indoor levels (Fanger, 1995). One of the significant influences on occupants' perceptions of thermal comfort is the outside climate. This is supported by a previous study that shows long-term exposure to a particular outside temperature causes physiological changes that influence occupants' preferences and responses to their inside thermal environment. This adaptation to climate, along with other physiological, behavioural, and psychological adjustments, has led to the development of the adaptive thermal comfort model. On top of that, for outdoor climate, outdoor infrastructure has also been recognised as a critical outdoor component that influences occupants' indoor comfort.

The outdoor environment can have a direct impact on indoor temperature conditions in naturally ventilated. As a result, residents' levels of comfort can vary according to the season and time of day. In hot climes, occupants are more uncomfortable in the afternoons than in the mornings and evenings due to higher temperatures (Dahlan et al., 2009).

Few studies were done by (Xue et al., 2016), (Indraganti & Rao, 2010), (Zalejska-Jonsson and Wilhelmsson, 2013) and (T. K. Lee et al., 2012) reported that, in comparison to younger persons, senior residents are more comfortable with indoor conditions in their homes and have a greater acceptance rate. This could be attributed to older occupants' greater use of adaptive behaviours, such as changing garment levels, to adapt to unpleasant indoor environments than younger occupants, or their reluctance to disclose discomfort when compared to younger occupants.

According to the literature, occupant comfort with thermal and IAQ conditions differs between mechanically and non-mechanically conditioned buildings. Those who live in mechanically conditioned buildings are more comfortable and satisfied with their thermal conditions than those who live in non-conditioned. It also shows that residents in the two types of buildings have different thermal preferences, and the IAQ of the two types of the building also got different levels of satisfaction. Those who live in mechanically ventilated buildings have higher IAQ satisfaction than those who live in naturally ventilated buildings, which is likely owing to higher levels of pollutants due to a lack of adequate ventilation (Zhao et al., 2018). (Ye et al., 2017) stated that in regions where the outside air is heavily polluted, mechanical ventilation systems with filtering devices function better than natural ventilation.

In order to ensure a better indoor environment, architectural components such as windows are the most crucial structure that needs to take into consideration for indoor comfort. According to (Aries et al., 2010) thermal, visual, and acoustic comfort, as well as IAQ satisfaction, are all affected by the type and size of windows in a building. According to studies, windows that are too small can reduce occupant comfort by reducing daylight penetration and obscuring the outside view, whereas windows that are too large can cause thermal discomfort due to increased heat gain and radiant heat transfer, as well as visual pain due to high glare levels and privacy concerns (Amaral et al., 2016). It also reported that to improve the discomfort, occupants tend to increased the use of artificial lighting which will increase the building's energy consumption.

This research project was conducted at 4 storeys of students' dormitory, and one dormitory is chosen for the site, which is located on the ground floor. From literature also shows that occupants' comfort is related to other building-related such as the floor level. Floor level is said to have a significant effect on occupant comfort, with higher floor occupants reporting greater comfort and tolerance of indoor conditions than lower floor occupants. (Wong et al., 2002). Shading component, such as roof overhangs, reduces glare and overheating, resulting in better comfort.

To rank the importance of Indoor Environment Quality (IEQ) factors, several studies conducted survey responses to determine the essential Indoor Environment Quality (IEQ) factor for overall occupants' comfort. The significant aspects for occupants' general comfort, according to most research, are thermal conditions and air quality. Besides, this is consistent with the majority of other building comfort studies.

2.8 Effect of roof tile on indoor temperature

According to (Al-Obaidi et al., 2014), roof-top surfaces are the most exposed surfaces in metropolitan areas to solar radiation. The roof assembly gets hot more than any other building envelope component in residential buildings, which are primarily low-rise since the roof-top surface receives the most solar radiation (Miranville et al., 2003). Residential roofs gain heat mainly by radiation, accounting for 50 per cent to 70 per cent of total heat gain into the interior regions below the ceiling board (Vijaykumar et al., 2007).

Concrete is commonly used as a roof tile material because of its affordable cost and excellent resistance to solar radiation and rainfall, rather than because of its thermal qualities. Yacouby et al. (2011) reported that in Malaysia, red and brown roof tiles are commonly used on modern residential roofs. The survey also looked at the colour preferences of Malaysian potential home buyers, which revealed that the most popular colours are red and brown. The majority of residential roofs in Malaysia are painted red or brown for aesthetic reasons, with the ability of the roof-top surface to reflect or prevent heat transfer not being a rising issue.

According to Yacouby et al. (2011) and Al-Obaidi et al. (2014), even though it is generally acknowledged and has been demonstrated to be able to lower the cooling load significantly for various climatic classes, the use of cool colours for roofs in tropical nations, including Malaysia, is low. Yacouby et al. (2011) compared indoor temperatures of two versions of a test cell with dimensions of 3 m length by 3 m width by 2.5 m height of black and white roof surfaces in Perak, Malaysia. According to the findings, the white roof reflected 700 % more sunlight than the black roof, lowering the peak inside temperature by up to 1.7 °C.

The study by Al-Obaidi et al. (2014) shows that a Building Information Model (BIM) with dimensions of 5.0 m length by 4.0 m width by 3.0 m height was used to compare the effects of roof surface colour area, material, and pitch. The BIM was built in Penang, Malaysia, and featured roof surfaces in black, red, and white. The findings revealed that roof surface colour had a more significant impact on heat gain than roof area, material, or pitch.

Based on a study conducted by Yacouby et al. (2011) and Al-Obaidi et al. (2014), the Malaysian environment is limited to the use of black, red, and white roof tiles and excludes other colours widely used in Malaysia, for concrete roof tile surfaces, such as brown, gold, grey, and orange, based on (Yacouby et al., 2011) findings as well as data from a number of local manufacturers .

According to Farhan et al. (2021), the results of solar reflectance values of roof tiles show that the most common roof tile colour in Malaysia, red, has the third-highest sun reflectance value, while white and black roof tiles have the greatest and lowest solar reflectance values, respectively. White roof tiles reflect a significantly higher amount of heat from solar radiation and thus reduce heat conduction transfer through the roof tiles and into the attic space, the diurnal peak of heat conduction transfer and temperature, as well as the values of heat conduction transfer and temperature throughout the diurnal profiles, are significantly reduced.

Hence, white roof tiles are highly recommended because of their significantly higher solar reflectivity and impact on reducing heat conduction and temperature, resulting in fewer hours of indoor thermal discomfort and less use of air conditioners in indoor spaces.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter is to describe the activities involve throughout this study and the data collection. The schematic flow of the overall methodology in achieving this study's goals is illustrated in Figure 3.1. The primary activity in this study is the field monitoring at the site and data collection.

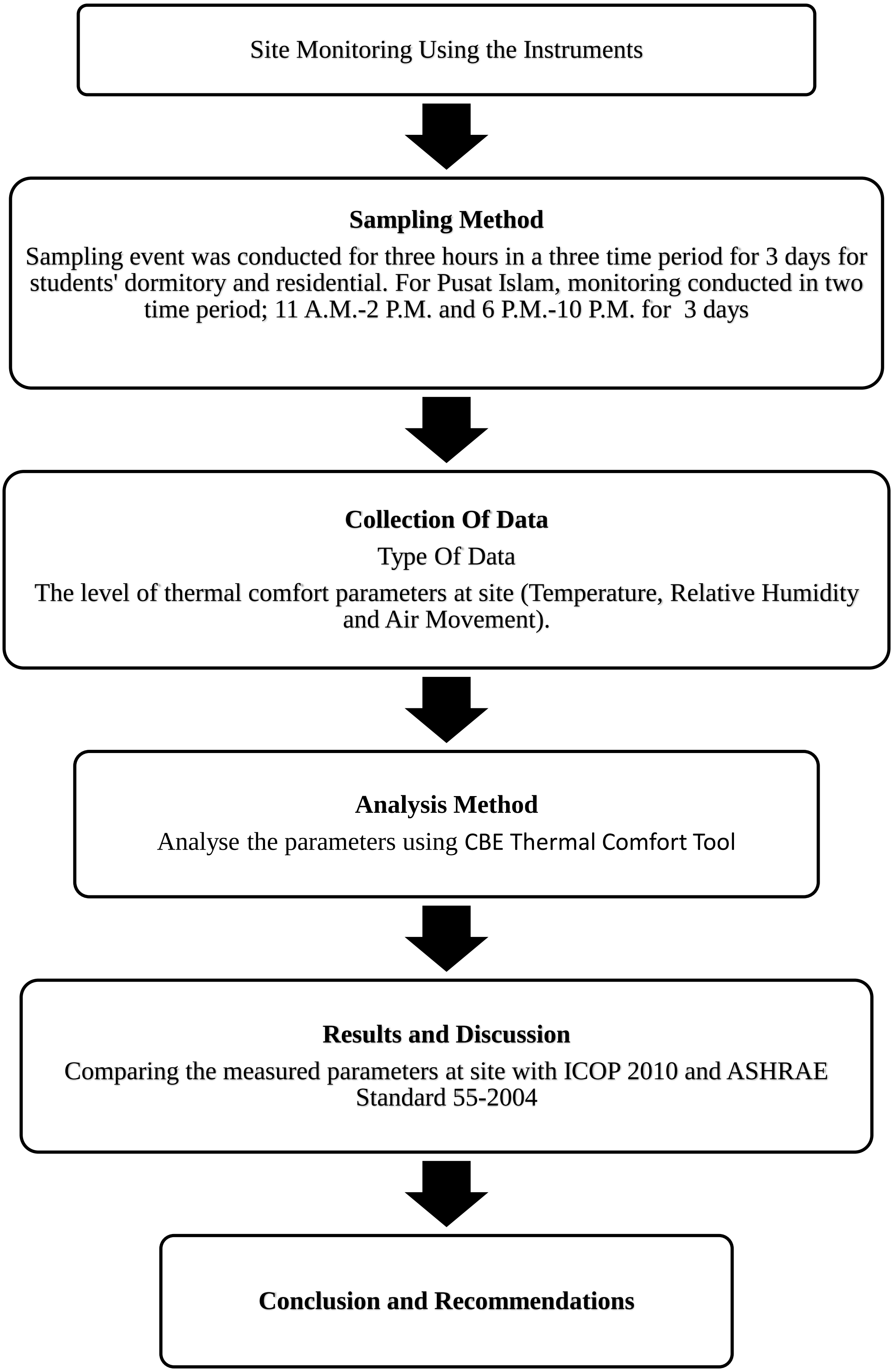

Figure 3.1 The schematic flow of study

3.2 Study Location

University Science Malaysia, USM Engineering Campus Nibong Tebal is located at the south of Seberang Perai and strategically situated amid three small towns of three neighbouring states; Nibong Tebal, Pulau Pinang, Bandar Baharu, Kedah and Parit Buntar, Perak. It was the only higher learning institution in the vicinity. The modern concept of the landscape and the layouts of the building add to its uniqueness and distinctive. This campus is the only higher learning institution in the suburb.

This campus can be assessed via North-South Highway (E1) route and the exit tollway at Jawi Toll (from North) and Bandar Baharu Toll (from South). There are two sampling locations, which is at SH3 Lembaran, students' dormitory and prayer hall at Pusat Islam USM, Engineering Campus.

Each students' dormitory consists of three students and contains three single beds situated at each corner of the room. Natural ventilation through the windows is the common ventilation form in the dormitory. Figure 3.2 until Figure 3.4 shows the students' dormitory location and the arrangement of the furniture. The overview of residential and Pusat Islam are shown in Figure 3.5 and Figure 3.6, respectively.

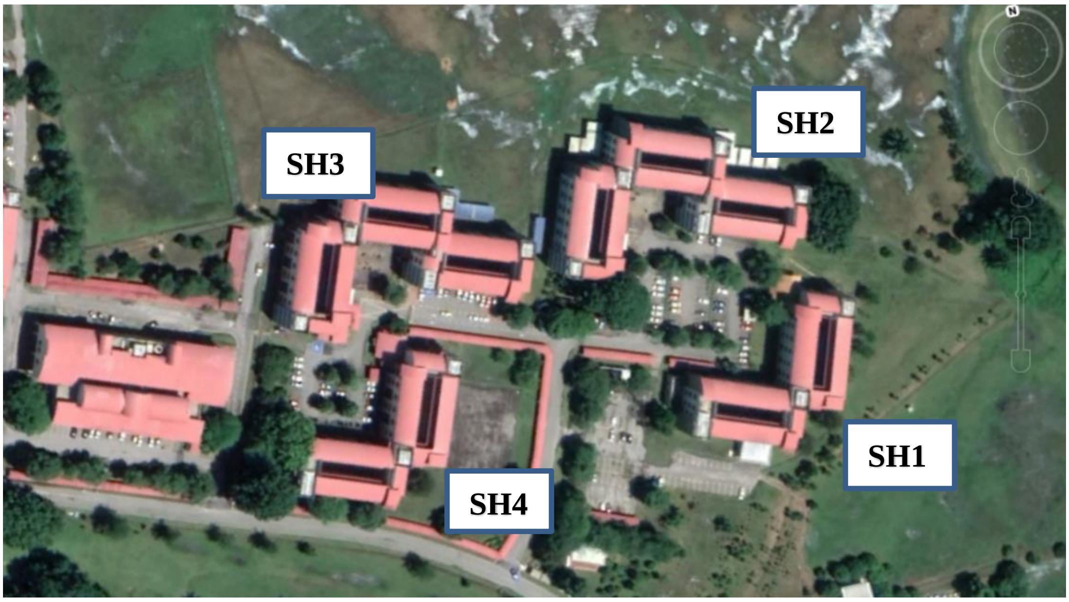

Figure 3.2 The location of students' dormitory SH3 Lembaran

Figure 3.3 The overview of student dormitory

Figure 3.4 The arrangement of furniture in the dormitory

Figure 3.5 The overview of the bedroom where monitoring was done at residential

Figure 3.6 The overview of prayer hall of Pusat Islam, USM Engineering Campus