SHADING EFFECTS ON THE PHYSICAL PARAMETER RELATED TO THERMAL COMFORT IN A HOSTEL ROOM AND RESIDENTIAL HOUSE.

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ABSTRAK

Sistem peneduhan luaran telah digunakan secara meluas di kebanyakan bangunan tropika untuk meminimumkan kuantiti radiasi matahari yang memasuki struktur. Tambahan pula, dengan mengehadkan jumlah tahap cahaya yang memasuki bangunan, sistem teduhan meningkatkan prestasi pencahayaan siang hari secara dramatik. Kesannya lebih tinggi pada hari-hari yang lebih panas, walaupun lapisan teduhan mungkin meningkatkan penghasilan haba melalui tingkap. Bayangan luaran dan bayangan dalaman adalah dua jenis bayangan yang boleh digunakan. Selain itu, bayangan dalaman digunakan untuk mengkaji parameter fizikal keselesaan termal terhadap kesan bayangan di dalam sebuah ruangan. Beberapa parameter diukur, iaitu parameter fizikal Suhu (T) dan Kelembapan Relatif (RH) dan juga bahan cemar kimia Sebatian Organik Berat Total (TVOC) dan Bahan Partikulat (PM_{10}) Kualiti Udara Dalam Ruangan. Data persampelan kajian ini dikumpulkan di dua lokasi di bilik asrama di Kampus Kejuruteraan USM dan bilik rumah kediaman di Bukit Mertajam, Pulau Pinang. Kajian ini menunjukkan bahawa kepekatan parameter fizikal (T dan RH) di bilik asrama dan rumah kediaman di Bukit Mertajam (dipantau pada waktu pagi, petang dan malam), RH masih dalam had garis panduan yang boleh diterima yang disyorkan oleh ICOP ketika berada dalam keadaan luar ruang bilik daripada keadaan dalam ruang bilik. Walau bagaimanapun, suhu semasa keadaan dalaman dan luaran melebihi had garis panduan yang dibenarkan dari 23°C hingga 26°C. Secara keseluruhan, penemuan menunjukkan bahawa keselesaan haba yang lebih baik berlaku di asrama daripada di rumah kediaman di Bukit Mertajam. Keadaan sensasi termal yang bermula dari 'Neutral' hingga 'sedikit hangat' dan 'sedikit hangat' hingga 'hangat'. Menyediakan pengudaraan dan pelindung tingkap yang mencukupi adalah kaedah untuk mengekalkan keadaan termal yang baik di dalam bilik.

ABSTRACT

External shading systems have been used widely in most tropical buildings to minimise the quantity of solar radiation that enters the structure. Furthermore, by limiting the amount of light levels entering buildings, shading systems dramatically increased daylighting performance. The impact was higher on hotter days, although the shading layers might increase heat generation through the windows. External shading and internal shading are the two types of shading that may be applied. In addition, the internal shading was used to study the physical parameter of thermal comfort toward the shading effect in a room. Several parameters were measured, which is the physical parameters Temperature (T) and Relative Humidity (RH) and also the chemical contaminants Total Volatile Organic Compounds (TVOC) and Particulate Matter (PM_{10}) of Indoor Air Quality. The sampling data of this study were collected in two locations in a hostel room at USM Engineering Campus and a room of a residential house at Bukit Mertajam, Penang. This study showed that the concentrations of the physical parameter (T and RH) in hostel room and residential home in Bukit Mertajam (monitored during the morning, evening and night time), RH was still within the acceptable guideline limit recommended by ICOP when it is in outdoor condition rather than indoor condition. However, the temperature during indoor and outdoor conditions exceeded the permissible guideline limit of 23°C to 26°C. Overall, findings indicated that better thermal comfort occurred at the hostel than at the residential house in Bukit Mertajam. The thermal sensation conditions in the former ranging from ‘Neutral’ to ‘slightly warm’ and ‘slightly warm’ to ‘warm’. Providing adequate ventilation and window shading is a means to maintain good thermal conditions in a room.

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LIST OF SYMBOLS

%	Per cent
m	Metre
m^2	Square-metre
m^3	Cubic-metre
m/s	Metre per second
mg	Mili-gram
ppm	Parts per million
ppb	Parts per billion
°C	Degree Celcius
sec	Second

LIST OF ABBREVIATIONS

ASHRAE	American Society of Heating, Air conditioning & Building-Related Illness
CO	Carbon Monoxide
CO_2	Carbon Dioxide
DOSH	Department of Occupational Safety and Health
HVAC	Heating, Ventilating, and Air-Conditioning
IAQ	Indoor Air Quality
PMV	Predicted Mean Vote
PPD	Predicted Percentage Dissatisfied
PPM	Parts per million
RH	Relative Humidity
T	Temperature
TVOC	Total Volatile Organic Compounds
PM_{10}	Particulate Matter with a diameter of less than ten micrometre
$PM_{2.5}$	Particulate Matter with a diameter of less than 2.5 micrometre
USM	Universiti Sains Malaysia
WHO	World Health Organization
ICOP	Industry Codes of Practices

CHAPTER 1

INTRODUCTION

1.1 Background

The pandemic has forced most people to work from home and students with their online learning at home. Some of the university's students will continue their online education in the hostel during the COVID-19 pandemic. A hostel means simply sharing accommodation rather than staying in private rooms, where students share space with others. According to Arifin & Denan, (2015), it states that tropical country such as Malaysia has different thermal comfort range because of hot and humid weather.

In Malaysia, public awareness of thermal comfort has grown over the last decade. Many hot and humid countries have air conditioning and other mechanical ventilation systems to maintain indoor thermal comfort. According to (Ismail 2008), most people usually spend their time indoors about 85-90%, so it is imperative to provide a comfortable and healthy environment. The appropriate temperature and relative humidity in the office building with shading devices under hot and humid weather in Malaysia. Furthermore, most office buildings in Malaysia are facing the problem of how to prevent direct entrainment of sunlight, especially from the side east and west. Shading devices invented, vertical shading, horizontal shading, egg-crate shading and pattern shading designed according to preference designers and client Arifin & Denan (2015).

Malaysia is located in a hot and humid climate. Air conditioning is usually required in countries such as Malaysia. Still, in residential buildings such as university hostels where the mechanical ventilation and air conditioning (MVAC) is not installed in the room and the thermal comfort of the window, shading can be minimised. This study was conducted on hostel buildings at Universiti Sains Malaysia (USM)

Engineering Campus, Pulau Pinang. Besides, the hostel residents in the university and residential housing area are less comfortable with the environment because of the high-temperature ventilation and the poor shading effect of the windows in the building. The problem mainly occurs at noon because the highest temperature will appear in the afternoon. Students, indeed, will become less comfortable when staying for a long time in a room.

1.2 Problem statement

Thermal comfort is essential to the health, productivity, and work quality of Malaysian students who stay in hostels and other campus accommodations. USM Engineering Campus, as a university that values student comfort and education, must address the thermal comfort conditions in its dormitories. Moreover, their thermal comfort in such a space of room must be determined since the shading effect of the window on their room space affects their comfort. According to Ismail (2008), most people usually spend 85% to 90% of their time indoors, so a comfortable and healthy environment must be provided. In addition, Malaysia has a tropical rainforest environment with hot temperatures and plenty of rain all year. Humidity and rain are prevalent in Malaysia, and nights are relatively cool. During the day, temperatures can range from 28°C (82°F) to 32°C (89°F) throughout the year based on (Climate and average weather in Malaysia, 2021). Therefore, due to the high temperature in the ventilation of the building, residents are less comfortable with the environment in the building where they live, and the window shading effect is less effective.

This research was carried out in order to conclude the compliance parameter to the recommended standard value on indoor thermal comfort based on Industry Codes of Practice on Indoor Air Quality ICOP (2010). In addition, this research also identifies the impact of window shadings on the occupant in a room based on the parameter measured. Finally, this study correlates the indoor thermal shading effect for the condition of an open and closed curtain in a room with human comfort and health.

1.3 Objective

The research's primary purpose is to study the indoor air temperature and relative humidity in a hostel room and residential house with a different type of shading based on the industry's guideline limit Codes of Practice on Indoor Air Quality (ICOP) 2010. This can be achieved by implementing the following objective as below:

1. To compare the indoor temperature and relative humidity with the standard guideline of Industry Codes of Practice on Indoor Air Quality (ICOP) 2010.
2. To identify the impact of window shadings on the occupant in a room based on the parameter measured.
3. To determine the thermal comfort for indoor of the hostel and residential room with a different condition of window shading (open and close curtain).

1.4 Scopes of this research

This study was conducted in a room hostel on the first floor and a residential house. The hostel is located in the USM area, and the campus covers about 4047m².

Furthermore, the residential home is located in Bukit Mertajam, Pulau Pinang. However, monitoring works involves only two of the selected location, which is in the hostel room and residential house, to measure indoor air temperature and relative humidity and the effect of shading toward the occupant. Passive ventilation (windows and doors), active ventilation (fans), and interior window shading are used to ventilate the designated hostel rooms and residential house, which is a window curtain. Only two parameters were measured for thermal comfort, which is temperature and relative humidity. However, there is an additional parameter analysed in this study which is the chemical contaminants Total Volatile Organic Compounds (TVOC) and Particulate Matter (PM_{10}).

1.5 Thesis layout

The organisation of this thesis consists of 5 chapters that have been divided as follows:

i. Chapter 1: The fundamental framework for this thesis is discussed in this chapter. It contains the study's background, problem statement, objectives, and scope of the study.

ii. Chapter 2: This chapter discusses the literature review on thermal comfort of shading effect and parameter measured details. Besides, the adverse impact of poor window shadings installation, and the type of window shading which will also decrease occupant productivity, is also described.

iii. Chapter 3: Introduced basic research framework concepts, research completion methods, and research use methods. This chapter also includes detailed research procedures as well as selected analytical practices.

iv. Chapter 4: The result obtained from the field work-study is analysed and discussed in this chapter.

v. Chapter 5: This section analyses the study's conclusion while keeping the study's key ideas and objectives in view.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Thermal comfort is crucial for productivity as well as health and well-being. Building occupants are stressed due to a lack of thermal comfort. People might become fatigued if they are too hot, and if they are too cold, they will become restless and distracted based on (Creating a sustainable future, 2021). This situation can be evaluated by objective investigations in which the human body is treated as a thermodynamic device that exchanges heat with the external physical world, according to (Roaf et al., 2010). Our bodies will feel thermal warmth when we are relaxed from a physiological standpoint. The skin temperature is between 32°C and 33°C, and the core temperature is about 37°C. Aside from the temperature of an area, the composition of the air has a role in comfort and health. When the air is odorous or stale, for example, people become uneasy. Poor air quality and temperature conditions can cause occupant discontent and discomfort, as well as a decrease in productivity and an increase in absenteeism.

Thermal comfort and occupant comfort are crucial factors in determining the efficiency of architectural designs. Furthermore, the composition of the air affects the environment's thermal conditions, comfort, and health. For example, people will feel uneasy if there is a strange smell or staleness in the air. Poor air quality and high-temperature conditions may cause dissatisfaction and discomfort among occupants, their performance will be reduced, and absenteeism is higher. It can also affect the health of the occupants in severe cases, causing physical symptoms such as nose, throat, headache, eye and skin irritation, nausea, and drowsiness.

Thermal comfort and indoor air quality are two essential aspects of indoor environmental quality (IAQ). It concerned many disciplines, including architecture, engineering, medicine, physiology, geography, and climatology. International and regional standards specify conditions aimed at creating a livable environment for the occupants.

2.2 Energy-efficient comfort

The condition of indoor air often influences the comfort of building residents. According to the Code of Practice for Indoor Air Quality (IAQ), good indoor air quality is critical for a safe indoor working climate (2010). Poor indoor air quality can cause several short- and long-term health problems. Allergies, breathing difficulties, eye inflammation, sinusitis, bronchitis, and respiratory disease are serious health issues linked to inadequate indoor air quality. The most efficient indoor air quality involves using systematic methods, specifically source protection, filtration, and ventilation techniques, to eliminate and control contaminants.

While certain buildings share some familiar sources, renewable energy buildings may have unique sources that need special consideration. The method of supplying filtered air to the inhabitants of a room is known as ventilation. Indoor air quality is characterised as the air free of contaminants that cause irritation, pain, or ill-health.

2.3 Parameters of thermal comfort

Thermal comfort is impossible to measure because it is a state of mind that reflects pleasure with the thermal atmosphere. It's impossible to please everyone in a room because people's physiology and psychology vary too much. The ambient factors that are needed for comfort do not seem to be the same for everyone. Furthermore, it has long been known that human thermal comfort is related to five other less apparent parameters, including mean radiant temperature, activity level, relative humidity, relative air velocity, and thermal resistance of clothing.

2.3.1 Factor affecting thermal comfort

People's attention has been drawn to the field of thermal comfort research in recent years. Many researchers' concern in the world has prioritised climate change research due to the growing public discussion of the issue (Ricardo et al., 2015). Physical parameters do not entirely determine overall thermal comfort and indoor environmental quality. The physiological and psychological reactions of the human body to their surroundings are complex, involving a variety of physical phenomena (light, noise, friction, temperature, humidity, and so on) that interfere with space (Parsons, 2000). Several factors influence thermal comfort, including environmental factors (relative humidity, air movement, and air temperature) and individual factors such as human activity and clothing.

2.3.1(a) Environment factors

Relative humidity, air velocity, air temperature, and radiant temperature are all environmental variables that influence thermal comforts, such as the floor, windows and walls.

2.3.1(a)(i) Relative humidity

The relative humidity is defined as the ratio of the partial pressure (or density) of water vapour in the air to the saturation pressure (or density) of water vapour at the same temperature and total pressure (RH). Sweating is an excellent way to lose heat, and it depends on the evaporation of sweat from the skin. Higher relative humidity, on the other hand, brings the air closer to its optimum water vapour potential, which reduces evaporation and heat loss.

The relative humidity in a workplace without air conditioning, or where outside weather conditions can affect the indoor thermal climate, can exceed 70%. The humidity level in the indoor environment varies greatly, and it may be influenced by the use of a steam-emitting drying process (paper mills, laundry rooms, etc.). Humidity is essential in a hot atmosphere because sweat evaporates less when the humidity is high (80% or higher). The most natural way to cool off is by sweat evaporation.

Humidity affects thermal comfort as a temperature-related parameter by affecting the human body's capacity to shed body heat by perspiration. Furthermore, high humidity encourages the growth of mildew and other fungi on the furniture and furnishings of buildings. Dryness in the eyes, noses, and throats caused by low relative humidity can cause pain, inflammation, and infection susceptibility. Static energy, which is unpleasant for inhabitants and can interrupt system activity, can be caused by very low humidity. According to the Malaysian Department of Health (DOSH) 2010, the prescribed indoor relative humidity ranged from 40% to 70%.

2.3.1(a)(ii) Air velocity

A certain amount of air movement or air velocity across the human body is required for both thermal comfort and the dispersion of contaminants in the air. The air's temperature and humidity determine the necessary amount of airflow. Increased air circulation, for example, can contribute to a more relaxed atmosphere during the hot and humid summer months. Ventilation and convection currents, which are induced by hot air rising and cold air failing, affect airflow in a building (The Government of The Hongkong Special Administrative Region Indoor Air Quality Management Group, 2003). Blocked or unbalanced ventilation systems, as well as too low-pressure levels in ventilation ducts, may limit airflow, resulting in a "stuffy" condition that makes occupants uncomfortable. Furthermore, a comfort of indoor air velocity in the range of 0.15m/s to 0.5m/s will be achieved (DOSH Malaysia, 2010).

Air velocity is an essential factor affecting thermal comfort, such as:

- Physical activity causes an increase in air movement, and air velocity can be adjusted to reflect a person's level of activity.
- People can feel stuffy in an artificially heated indoor atmosphere if the air is still or stagnant. It could also lead to odour build-up.
- Moving air in a hot or humid environment increases heat loss by convection, although the air temperature remains unchanged.

2.3.1(a)(iii) Air temperature

Indoor temperature is regarded as an indoor environmental factor that influences human comfort and wellbeing, and it has emerged as the most pressing concern for ordinary people (Huang et al., 2012). Indoor temperature is determined by factors such as air conditioning temperature control, solar heat gain, and other indoor heat sources such as lighting, electrical appliances, humidity, machines, and water heaters, according to research undertaken by the Hong

Kong Special Administrative Region Government's Indoor Air Quality Management Group (2003). Variations of temperature in a space served by a single thermostat must also be taken into account. Broad window areas or large vertical surfaces may create temperature variations between rooms or between different locations within a room. Besides, the indoor temperature would be more comfortable in the range of 23°C to 26°C (DOSH Malaysia, 2010).

2.3.1(b) Individual factor

Two individual factors have a strong correlation with thermal comfort, which is activity and clothing.

2.3.1(b)(i) Activity

The activity level is evaluated in terms of metabolic rate, referred to as "met.". According to (Olesen & Parsons, 2002) it states that laboratory testing, in which the output of heat or oxygen is calculated for participants performing a specific task, is the most precise way to calculate the metabolic rate. The rate at which chemical energy is transformed into heat and mechanical function in an organism by metabolic activities is specified by the ASHRAE 55-2010 standard and is usually expressed as a unit area of the entire body surface. Mets are used to calculate the metabolic rate, with one met equal to 58.2 W/m2 (the energy emitted per unit surface area of an average person sitting at rest). The typical citizen has a surface area of $1.8m^2$. Table 2.1 shows examples of metabolic speeds for common behaviours. A table of metabolic rates for different activities is given in ASHRAE Standard 55 (2010). The time-weighted average metabolic rate is allowed for intermittent activities if the activity is performed in one hour or less. Still, different metabolic rates must be considered for more extended periods, according to this standard.

Table 2-1 Metabolic rates for a typical task (ASHRAE, 2010)

Activity	met	W/m^2	W(av)
Sleeping	0.7	40	70
Reclining, lying in bed	0.8	46	80
Seated, at rest	1.0	58	100
Standing, sedentary work	1.2	70	120
Very light work (shopping, cooking, light industry)	1.6	93	160
Medium-light work (house, machine tool)	2.0	116	200
Steady medium work (jackhammer, social dancing)	3.0	175	300
Heavy work (sawing, planning by hand, tennis)	6.0	350	600
Cumbersome work (squash, furnace work)	7.0	410	700

2.3.1(b)(ii) Clothes

The amount of thermal insulation worn by a person significantly impacts thermal comfort because it affects heat loss, affecting heat balance. The insulation layer can support or hurt the human body by preventing heat loss and causing overheating. According to (Papadopoulos 2014), they reported that one clo is the insulation value of a standard suite with cotton underwear. Shorts with a short-sleeved sweater are approximately 0.25 clo, a winter suit with a heavy coat is about two clo, and the heaviest Arctic clothing is approximately 4.5 clo. The majority of the students dress in western-style clothing, including a mix of skirts, T-shirts, and pants/jeans. Five typical ensembles (as shown in Table 2.2) were listed, and the subjects' clo values were assigned to the most appropriate ensemble. The clo values in Table 2.2 take into account undergarment insulation and footwear.

Table 2-2 Clothing ensemblers (Mishra & Ramgopal, 2014)

Ensemble	Clo value
T-shirt, thick trousers	0.39
Half-shirt, thin trousers	0.50
Half-shirt, thick trousers	0.59
Full-shirt, thin trousers	0.56
Full-shirt, thick trousers	0.65

2.4 Indoor Air Quality

2.4.1 Understanding Indoor Air Quality

According to Bluyssen (2009), they divided IAQ into two categories while defining it. From the human perspective, the IAQ is a space. It is the physical consequence of individuals being exposed to the indoor air of the place they are visiting or occupying, as perceived by those individuals. IAQ can be expressed in an odorous unit at a certain point in time, and IAQ over time can be linked to the number of persons suffering particular illnesses. In addition, from the Indoor Air Quality (IAQ) perspective, it is frequently stated in terms of ventilation rates (in L/s per person and/or L/s per m^2 floor space) or concentrations of certain substances in the indoor environment. The source, whether within or outside the room, has an impact on these concentrations, such as outdoor sources and sources present in the HVAC system or surrounding spaces.

According to (Syazwan et al., 2009), they conducted a study on IAQ and sick building syndrome (SBS) in Malaysian buildings to evaluate the relationship between SBS and indoor air pollutants in two distinct buildings (new & old). Relative Humidity (RH), temperature, carbon dioxide (CO_2), Carbon Monoxide (CO), ventilation rate, TVOC, Particulate Matter (PM), and air velocity are the IAQ factors evaluated. Their study's findings suggested that CO_2 concentration at a specific level was a key factor contributing to SBS complaints among office employees. Following that, Norhidayah et al. (2013) investigated IAQ and SBS in three Malaysian buildings to identify the relationship between IAQ characteristics and SBS symptoms. The IAQ parameters are air velocity, temperature, relative humidity, CO_2, CO, fungi, and PM. According to the findings, ventilation and the accumulation of potential pollutants within the indoor environment are vital predictors of SBS.

According to the discussion above, the most commonly used IAQ parameters are temperature, relative humidity, air velocity, Particulate Matter (PM), and Carbon Dioxide (CO_2). As a result of poor IAQ, various adverse effects such as Sick Building Syndrome (SBS), occupant dissatisfaction, and decreased employee productivity will occur. According to (Syazwan et al., 2009) finding, lowering the SBS may be accomplished either by raising the ventilation rate or by implementing source control of pollutants, which may identify point sources of contaminants and is more cost-effective. Furthermore, SBS is caused by CO_2 and Ultra-Fine Particle (UFP) exposure, but it is also caused by a combination of CO_2, UFP, and other indoor pollutants that might cause SBS symptoms.

2.4.2 Factor affecting indoor air quality

Several factors affect indoor air quality, which is temperature (T), relative humidity (RH), air velocity, carbon dioxide (CO_2), formaldehyde, Total Volatile Organic Compounds (TVOC) respirable particulate matter and radon. From this study, only a specific parameter will be highlight which is TVOC and particulate matter PM_{10}.

(i) Carbon dioxide (CO_2)

Carbon dioxide (CO_2) is a relatively easy-to-measure surrogate for human-emitted indoor pollutants, and it correlates with human metabolic activity. Carbon dioxide levels that are exceptionally high inside may cause people to get sleepy, experience headaches, or perform at a reduced level of activity. Outdoor CO_2 levels are typically 350–450 ppm, but the maximum allowable indoor CO_2 level is 1000 ppm. In most buildings, humans are the primary generator of carbon dioxide. Indoor CO_2 levels are a good measure of how well outdoor air ventilation is working in relation to occupant density and metabolic activity.

Carbon dioxide is often used to assess the effectiveness of ventilation systems. All buildings, whether summer and winter, require ventilation when the windows and doors are closed. In most houses, this ventilation is given by naturally existing leaks and gaps around windows and doors. Most leaks in energy-efficient homes have been removed, although some sort of ventilation system may be required. The needed ventilation in commercial buildings is generally provided via a fresh air input to the heating and cooling system. Unfortunately, in order to save electricity, many businesses have stopped the fresh air intake. A large number of other systems were installed without fresh air intake. Because human respiration produces carbon dioxide, the amount of carbon dioxide may readily be utilised as an indication of the sufficiency of fresh air ventilation in occupied buildings. Outdoor values are at 300 ppm. According to the ASHRAE guideline, sufficient fresh air must be given to maintain the level below 1,000 ppm.

Buildings with poor ventilation will have levels ranging from 1,000 ppm to 2,000 ppm. The levels are frequently low in the morning and rise when the building is occupied. In buildings that are occupied during the day, the reading should be obtained in the mid-afternoon, when CO_2 levels are at their peak. Lastly, excessive amounts of carbon dioxide are frequently indicative of insufficient ventilation. People who work in buildings with high CO_2 levels may have burning eyes, fatigue, and headaches. These symptoms can be induced by a combination of carbon dioxide and several other contaminants found in a poorly ventilated environment.

(ii) Temperature

Indoor temperature is characterized as an indoor environmental element that influences human comfort and health, and it has emerged as the most pressing problem (Huang et al., 2012). Indoor temperature is affected by air-conditioning temperature control, solar heat gain, and other indoor heat sources such as lighting, electrical equipment, computers, and water heaters, as well as humidity, according to the Hong Kong Special Administrative Region Government's Indoor Air Quality Management Team (2003). Temperature variations in the room serviced by a single thermostat should also be taken into account. The temperature may fluctuate across rooms or inside the room due to the wide window area or the big vertical surface. Furthermore, a suitable indoor temperature in the temperature range of 20°C to 26°C will be obtained (DOSH Malaysia, 2010).

(iii) Humidity

Humidity influences heat comfort as a temperature-related parameter by affecting the body's capacity to disperse heat through sweat. Heat is more challenging to disperse under humid circumstances. Thus the impact is the same as raising the temperature, making individuals feel "sticky." Mould and other fungi can develop on construction materials and furniture when the humidity is high. Dry eyes, noses, and throats can result from low relative humidity, causing pain, irritation, and increased susceptibility to infection. Extremely low humidity creates static electricity, which makes occupants uncomfortable and interferes with computer performance. The ideal indoor relative humidity ranges from 30% to 60%. (DOSH Malaysia, 2010).

(iv) Air velocity

A certain level of air movement around the human body is necessary for thermal comfort as well as the dispersal of contaminants in the air. The needed airflow level is determined by the temperature and humidity of the air. Greater air flow, for example, helps to create a more pleasant environment during the hot and humid summer. The rising of hot air and the weakening of cold air in the room impact airflow, which is governed by ventilation and convection (Hong Kong Special Administrative Region Government Indoor Air Quality Management Group, 2003).

Blocked or imbalanced ventilation systems, as well as low-pressure levels in ventilation ducts, can restrict air movement and produce an unpleasant "stuffy" atmosphere for occupants.

(v) Formaldehyde

Formaldehyde is a prevalent VOC contaminant, as well as one of the most well-known indoor air pollutants. An overview of formaldehyde sources that might lead to higher indoor concentrations are wood-based materials, flooring materials, insulation materials, coatings, indoor chemistry, indoor combustion and other indoor related sources (Tunga Salthammer et al., 2010).

In the absence of ozone, formaldehyde emissions from flooring materials such as carpet, parquet, laminate, PVC, and linoleum are of no or very minimal concern (Nicolas et al., 2007). Mineral wool is the recommended insulating material for walls and floors. Although UF foam insulation has been linked to higher emissions, this type of insulation is no longer widely used. In addition, acid curing lacquers composed of modified urea and melamine formaldehyde resins were the most potent formaldehyde sources in liquid coating materials. Indoors, combustion is recognised to be a significant source of formaldehyde. Formaldehyde is one of the primary components released by biomass fuel smoke, along with CO, NOx, SO2, polycyclic aromatic hydrocarbons (PAH), and particulates. Cooking activities in the home have also been recognised as formaldehyde sources (Fortman et al. 2001).

(vi) TVOC

Volatile organic compounds are organic substances that, when it is exposed to air it will turn into a gas. There are thousands of VOCs, and many of them are present at the same time. As a result, the Total VOC is most commonly used and assessing VOCs' total. This is less time consuming and less expensive than measuring individual VOCs. Benzene, Ethylene glycol, Formaldehyde, Methylene chloride, Tetrachloroethylene, and Toluene are examples of VOCs.

Moreover, cleaners and disinfectants, pesticides, air fresheners, paints and solvents, glue, new furniture and carpets, construction materials, electronic equipment, and plywood are sources of VOCs. As a result, certain VOCs may be encountered in everyday life, particularly in cleaning sprays and aerosols.

Furthermore, new buildings and refurbishment may pose considerable health risks. Due to off-gassing, construction materials, as well as new furniture, carpets, and plywood, may increase the indoor concentration of VOCs. Vehicle exhaust and industrial pollution can also contribute to poor interior air quality if dirty air enters the building through open windows or a malfunctioning air conditioner, primarily if the structure is located in a busy or industrial area.

According to the EPA's Total Exposure Assessment Methodology (TEAM) research, levels of a dozen typical organic pollutants are 2 to 5 times greater inside houses than outdoors, regardless of whether the dwellings are in rural or highly industrial locations. Additional TEAM research indicates that when individuals use organic chemical-containing goods, they can expose themselves and others to very high pollutant levels. Higher amounts can remain in the air for a long time after the activity is done. TVOC levels are measured in micrograms per cubic metre (g/m^3) of air (or milligrammes per cubic metre (mg/m^3), parts per million (ppm), or parts per billion (ppb).

(vii) Particulate matter

PM is a common air pollutant made up of solid and liquid particles floating in the air. The mass concentration of particles with a diameter of less than 10 micrometres (PM_{10}) and particles with a diameter of less than 2.5 micrometres ($PM_{2.5}$) are two often used indicators for defining PM that is significant to health ($PM_{2.5}$). PM is a combination having physical and chemical properties that change depending on location. Sulfates, nitrates, ammonium, various inorganic ions such as sodium, potassium, calcium, magnesium, chloride, organic and elemental carbon, crustal material, particle-bound water, metals, and polycyclic aromatic hydrocarbons (PAH) are common chemical components of PM. Particulate matter is a hazardous contaminant. Many researchers have found a direct correlation between PM exposure and harmful health effects. Smaller-diameter particles ($PM_{2.5}$ or smaller) are typically more damaging. In contrast, ultrafine particles (one micron or less in diameter) can permeate tissues and organs, offering a much more significant risk of systemic health effects.

2.4.3 Shading principle

Building surfaces exposed to the sun, such as windows, walls, and roofs in Malaysia, can allow heat from solar radiation, increasing the amount of energy required for cooling. The surfaces on which the sun's rays fall must be shielded to prevent heat intake, whether direct or indirect. The importance of shade devices cannot be overstated because glazed windows are the major components that enable incoming heat to penetrate, increasing the danger of overheating.

Shade device design may be challenging since thermal assessment requires a thorough grasp of the physics of the sun's location and sun path diagrams. Building designers in tropical regions, on the other hand, should keep solar radiation away from the transparent portions of the building's exterior.

Because sunlight reaches each side of a structure from various angles, each face of a structure requires a particular shading treatment. External systems are known to be more effective than internal systems at preventing solar heat gain.

Penang is an island off the west coast of Peninsular Malaysia. It has a latitude of 5.35°N and a longitude of 100.30°E. The area climate is hot–humid tropical, with uniformly high temperatures, high humidity, and heavy rainfall all year. Malaysia has a diurnal temperature range of 23–27°C and a high of 30–34°C, according to the Malaysian Meteorological Department. As a result, there is no distinct hot or cold season. Annual rainfall is evenly distributed throughout the year, while relative humidity ranges from 74% to 86%, with September to November being the wettest months.

Shading of wall and roof surfaces is critical for reducing summer heat absorption, especially if they are dark in colour and/or heavyweight. The main shading idea is to keep the surface shaded so that direct sunlight does not fall on it, avoiding radiant heat and increasing temperatures. Shading the structure from the noon summer light is simple since the sun is at a greater angle in summer than in winter.

The amount of shade required varies depending on the temperature and the direction of the home. It is critical to have a solid grasp of the sun trajectories at different times of the year to create appropriate shade. There are several advantages to using shade, including protection against warmth and the greenhouse effect. It is a considerable reduction in heat transmission from the outside, and the strain on the active cooling system can be reduced or eliminated. In other words, it can improve comfort where the temperature of the shadowed surface and therefore the room temperature is significantly decreased.

External shading and internal shading are the two types of shading that may be applied. Exterior shade can help to keep the structure cool by preventing sun access. This is accomplished by providing shade overbuilding openings and outdoor spaces, which aids in temperature reduction and energy conservation. There are several instances of exterior shade, and each one must be constructed with the sun's path in mind throughout the year. Eaves, awnings, screens and shutters, louvres, verandahs, pergolas, trees and bushes are examples.

Furthermore, indoor shade is almost usually adjustable or retractable and takes the shape of roller or Venetian blinds or drapes. It is simple to set and maintain, and it may occasionally create nighttime darkness. It is also often less expensive and is incredibly excellent at minimising diffuse and reflected light, which is the primary source of glare. Curtains and blinds can help to reduce brightness, and Venetians and louvres can help to divert light.

2.5 Previous studies on shading effect

The effect of shading devices and their impact on daylight quantity and distribution were investigated according to (Dubois 2001). The previous studies also analysed the energy usage (Datta, 2001), human comfort and the effects of glazing and shading properties based on previous research (Tzempelikos et al., 2010). However, data are scarce on their impact on various indoor air temperatures, especially when natural ventilation conditions are taken into account at different times of the day and night. According to (Corrado et al., 2004), they reported that external shading devices could help monitor the amount of solar radiation that enters a room, lowering the cooling load and improving indoor thermal comfort. Since the sun will shine on each side of the building from various angles, each side will need a different shading treatment. It is common knowledge that external systems are more efficient at preventing solar heat absorption than internal systems.

In Malaysia, Arifin & Denan (2015) investigated the indoor air temperature and relative humidity of various external shading devices. In comparison to the vertical shading device and the horizontal shading device, the egg-crate shading device is found to be the most appropriate. From the perspective of average relative humidity percentage, horizontal shading devices have the highest relative humidity percentage, which is 60%. The study discovered that the egg-crate shading device is the most appropriate to use compared to others. It is the closest to the value of indoor air temperature and relative humidity according to the recommended standard guidelines.

According to research from (Baitul et al., 2020), the research model utilised a table lamp as the light source from the sunlight and a variable per cent of cover filter on the transparent surface perspex. They are using a light metre, and three different dots sizes (13, 19, and 25 mm) are used to evaluate light penetration from three different angles (45 from side 2, 45 from side 4, and 180 from the centre). The aim of this research is to simulate the effects of light penetration on the window surface of a building.

The findings indicate that the larger the dotted filter is, the greater the percentage of light reduction. In addition, when compared to 13mm, 19 mm, and 25mm dotted diameter sizes, shade with a 25 mm dotted diameter size can reduce light penetration at the light source 45° from side 2, 45° from side 4, and 180° from the centre (top) by about 5.44 per cent, 6.48 per cent, and 4.18 per cent, respectively. In a hot and humid country like Malaysia, direct sunlight penetration into the interior space produces significant external daylight, glare, and thermal comfort concern. This issue is a serious danger factor for the occupants' health and comfort.

In Singapore, shading devices' influence on temperature is studied (Wong & Istiadji, 2003). Horizontal shading systems, according to the study, will minimised indoor temperatures by 0.61 to 0.88°C. Another research by Yang and Hwang found that vertical shading systems reduce the temperature by 0.98°C (Yang & Hwang, 1995). These studies were introduced as follows, with the purpose of assessing both passive and active design techniques and their possible use in the Taiwan area for building energy saving. They looked into the impact of outdoor shade on building energy efficiency in Taiwan. According to Yang and Hwang's study, when external shading is appropriately mounted, the air conditioner's reading energy usage decreases by an average of 25%.