THE RELATIONSHIP BETWEEN THERMAL PERFORMANCE, THERMAL COMFORT AND OCCUPANTS. A STUDY OF THERMAL INDOOR ENVIRONMENT IN SELECTED STUDENTS ACCOMMODATION IN UNIVERSITI SAINS MALAYSIA (USM), PENANG.

BY

Sulaiman R S Wafi and Mohd Rodzi Ismail
School of Housing Building and Planning, Universiti Sains Malaysia. Penang, Malaysia.
Email: sulimanw@hotmail.com.

ABSTRACT: Thermal comfort is considered to be a principal requirement that is usually demanded of by occupants of accommodation units. A compatible indoor climate design is actually a modification of the external environmental system and is designed to provide comfort for occupants. There is a reciprocal relationship between climate and man in both indoor and outdoor areas. Thermal comfort plays a significant role in organizing that relationship and in activating it, thus making an area inhabitable and well adapted for daily existence. In this paper, the relationship between the indoor thermal comfort and the external equatorial climate of Malaysia is investigated in student accommodation quarters, in Universiti Sains Malaysia (USM).These accommodation quarters known as “hostel” would be studied for their thermal performance and energy consumption patterns. To accurately determine these aspects, data regarding the building envelope, plan, system, orientation, and operation design would be gathered. This information would be compiled from the various hostels located within the university precincts. Finally, the comfort condition of the hostels would be estimated via comfort surveys and on site measurements.

Keywords: Thermal Comfort, Occupants, Climate, Student Accommodation, USM.

1. INTRODUCTION

Humans, since the dawn of time, have designed places of abode that have afforded them protection from the natural elements. Most of these efforts have attempted to create internal environments that are conducive for living and the optimal performance of daily activities. In order to develop these internal environments, man has developed and utilized a range of sophisticated tools and scientific methods to gain an understanding of his surrounding climatic conditions. With this knowledge, he has endeavored to design building materials that are capable of assisting him to create an appropriate climate in indoor space that will alleviate the effects of the external environment on personal comfort.

Due to climatic differences, various methods have been devised to deal with hot, cold and humid environmental conditions. Besides this, cultural differences and traditions have also influenced the development and usage of building materials apart dictating architectural design and landscaping.

In the last decade, there has been growing public awareness on thermal comfort in Malaysia. In a country with a hot and humid climate, a large number of the buildings are served by air-conditioning and other mechanical ventilation systems that are designed to maintain a thermally comfortable indoor environment.

One of the significant objectives of designing buildings is to ensure the thermal comfort to occupants. This is because most people generally spend 85-90% of their time indoors and thus providing a comfortable and healthy environment is imperative. Thermal comfort is defined as: ‘that condition of mind which expresses satisfaction with the thermal environment’ (ISO 7730). Thermal comfort refers to a condition of mind that is satisfied with its thermal environment while the term ‘thermal environment’ refers to the surrounding environment within which the subject operates or lives in. Nicol (2007), noted that a proper and precise delineation of the interior climate is essential in determining the efficacy of a building because it will not only ensure the comfort of its occupants but will also impact upon energy consumption and its sustainability. In terms of bodily sensations, thermal comfort refers to the sensations of warmth and cold which an occupant experience. It should be noted that thermal comfort identification processes are difficult to be precisely quantified as there are both psychological and environmental factors that directly or indirectly influence the attainment of optimum thermal comfort.

In order to achieve an environmentally appropriate indoor space for thermal comfort, there is a need to identify the climatic area where an individual lives or works in and characteristics analysis and take advantages what it has, and avoid what it has imperfections.

2. METHODOLOGY.

Aim. To reach thermal comfort in the student house in (USM).

⇩

Objective. Study the thermal performance in the student house in (USM).

⇩

Identify Variable. To identify variables, definitions, parameters and criteria's that related to performance thermal comfort.

⇩

Hypothesis. Building materials and design affect of thermal comfort inside the building .

Data Collection. Detailed investigation and variable factor related of thermal comfort.

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Data Analysis.

⇩

Discussion. On the suitability of thermal comfort factors.

⇩

Expected Results.

⇩

Conclusion.

3. ENERGY EFFICIENT COMFORT.

Early, thermal comforts is to a large extent obtained through the use of machines that cools or warms interiors as well as provide ventilation. This results in the widespread consumption of energy. Nevertheless, a reduction in energy consumption patterns can be accomplished by decreasing the amount of energy required, by rational energy use, by reacquirement heat and cold and by using energy from the surrounding air. Generally, the building sector is an energy intensive sector as huge amounts of energy need to generated in order to maintain artificial indoor climates that provide thermal comfort for its occupants that would allow them to conduct various activities in a conducive environment.

Apart from temperatures, Indoor Air Quality also plays a vital role in ensuring comfort for building occupants. According to the Code of Practice on Indoor Air Quality (IAQ),(2005), good indoor air quality is necessary for a healthy indoor working environment. This is because poor indoor air quality can cause a variety of short-term and long-term health problems. Health problems commonly related to poor IAQ include allergic reactions, respiratory problems, eye irritation, sinusitis, bronchitis and pneumonia. The attainment of best indoor air quality depends on an integrated approach dedicated to the removal and control of pollutants using techniques such as source control, filtration, and ventilation. Martin (1996), Irrespective of the method adopted, good indoor air quality need to possess both effective source control and ventilation. While there are sources common to several types of buildings, buildings that focus on renewable energy may have some special sources and, thus, may need particular attention. Ventilation can be defined as the process by which clean air is supplied to an occupant within an enclosed space. Good indoor air quality may be defined as air, which is free of pollutants that reason annoyance, discomfort or sick health to resident.

According to ASHRAE (55-1992), airflow can be an energy efficient means to achieve indoor thermal comfort. Airflow does not create sensible cooling of air that can be measured on a thermometer; it conducts heat from our skin. According to Sekhar (2004), one of the major factors affecting indoor quality is the ventilation system, which is associated with the distribution and dilution of indoor pollutants. It also serves to provide an acceptable level of thermal comfort.

3.1 INDOOR AIR ENVIRONMENT.

Indoor air environments must be appropriate the condition of thermal comfort and indoor air quality. Thermal comfort is influenced by several factors, which principally contain air temperature, air humidity, air velocity, mean radiant temperature, human clothing, and activity levels. According to Niu (2004), the great use of air conditioning helps to get better thermal comfort, but health problems accompanied with poor indoor air quality. According to Gao (2002), several specialist in this domain trust that indoor air quality may be the most important and relatively overlooked environmental issue of our time. Its indoor pollutants that lead to poor indoor air quality.

3.2 RELATIONSHIP BETWEEN CLIMATE, BUILDING AND OCCUPANT.

The climate sensitive in architecture, strategies are adopted to fulfill occupants requirements, taking into account local solar radiation, temperature, wind and other climatic conditions. Different strategies are required for the various seasons. According to Abdeen Mustafa Omer (2008), these strategies can themselves be subdivided into a certain number of concepts, which represent action.

The heating strategy includes four concepts:

i. Solar collection: gathering of the sun is heat through the building envelope.
ii. Heat storage: storage of the heat in the mass of the walls and floors.
iii. Heat distribution: distribution of gathered heat to the different spaces, which require heating.
iv. Heat conservation: retention of heat within the building.

The cooling strategy includes five concepts:

i. Solar control: protection of the building from direct solar radiation.
ii. Ventilation: expelling and replacing unwanted hot air.
iii. Internal gain minimization: reducing heat from occupants, equipments an artificial lighting.
iv. External gains avoidance: protection from unwanted heat by infiltration or conduction through the envelope.
v. Natural cooling: improving natural ventilation by acting on the external air.

The day lighting strategy includes four concepts.

i. Penetration: collection of natural light inside the building.
ii. Distribution: homogeneous spreading of light into the spaces or focusing.
iii. Protect: decreasing by external shading apparatus the sun's rays infiltration into the building.
iv. Comfort: control light penetration by movable screens to avoid discomfort.

Ventilation is necessary for ensuring a good indoor air quality, but, also, can have a prevailing impact on energy consumption in buildings.

3.3 INDOOR ENVIRONMENTAL QUALITY.

The indoor environmental quality impacts not only health and comfort, but also the occupants, productivity, as it strongly affects working and learning competency, with affect on production and social costs (Clements et al, 2001). In particular, student quarters are a type of buildings in which a high level of environmental quality may yield improved levels of individual concentration, learning, and performances. A lot of studies, in the last years, have been concentrated on finding relationship between the indoor environment and occupants performance and productivity in quarters building and working environments. Some of them are concentrated on the analysis of the of the various impact of the single aspects of the indoor air quality, such as acoustical, thermal, indoor air and visual quality on the overall quality estimation. Thermal comfort is an significant factor for the indoor air quality and it's also one of the main sources of energy consumption in quarters.

According to Corgnati (2008), the environmental parameters impacting thermal comfort were measured while, at the same time, the subjective judgements of the people about the thermal environment were expressed. Significant tendency and correlation were found out.

3.4 INDOOR AIR QUALITY STANDARD.

Indoor air quality is the nature of air that affects the health and well being of occupants indoor. Indoor air quality is usually due to inadequate ventilation. Indoor air quality will effect in terms of comfort, acute health and chronic health. Effects of indoor air quality contain six categories, respiratory cancer, pulmonary disease, infectious diseases, immunological disorder, irritations, and odor. Indoor air quality will lower productivity and morale of occupants due to. Some of the symptoms are, eye, nose or throat irritation, headaches, fatigue and dizziness, difficulty in concentration, nausea, nose bleeds, nasal congestion, rashes, dry skin or lips, and difficulty in breathing. Indoor air quality has consolidated the many different standards, guidelines, reports and study recommendations. Table 1 below shows the recommended indoor air quality from various organizations.

Parameter	Air Quality Standard	Organization	Health Hazards
Temperature	22°C - 24°C	ASHRAE	discomfort, difficulty in concentration, fatigue, sleepiness
	22.5°C - 25.5°C	SIAQG	
Relative Humidity	40% - 60%	ASHRAE	discomfort, stuffy, headache, dry throat, skin discomfort, eye discomfort (contact lens wearer)
	70%	SIAQG	
Air Movement	0.25m/s	WHO SIAQG	physical discomfort, stuffy, headache

Table 1. Indoor air quality standard. (source: www. Cmteknologi.com/iaq.html),(20/09/2008).

3.5 THE ENERGY INFLUENCE OF VENTILATION.

Evaluation on the energy influence of ventilation relies on knowledge about air alteration rates and differences between the entering and exiting air streams. In practice, this is a difficult exercise to undertake since there is much uncertainty about the value of these parameters. As a result, a suitable data from which strategic planning for improving the energy efficiency of ventilation can be developed has proved difficult to establish. Good indoor air quality may be defined as air which is free of pollutants that cause irritation, discomfort or ill health to occupants. Since much time is spent inside buildings, considerable effort has focused on methods to achieve an optimum indoor environment. An almost limitless number of pollutants may be present in a space, of which many are at virtually immeasurably low concentrations and have largely unknown toxicological effects. According to Liddament (1996), ventilation is necessary for ensuring a good indoor environment but it can have a prevailing affect on energy consumption in building. Air quality problems are greater probably to happen if air supply is limited.

4. COMFORT ZONE.

Effective temperature (ET) is the uniform temperature of a radiantly black enclosure at 50% relative humidity, in which an occupant would experience the same comfort, physiological strain and heat exchange as in the actual environment with the same air motion.

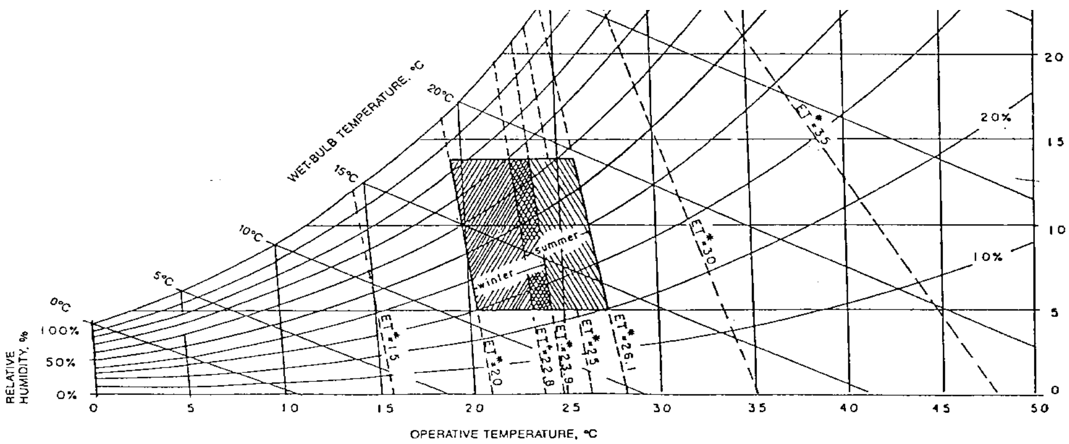


Figure 1. Standard Effective Temperature and ASHRAE Comfort Zones

The comfort zone is, 22.8 ^{o}C < ET < 26.1 ^{o}C for summer, 20.0 ^{o}C < ET < 23.9 ^{o}C for winter. The comfort zones are intended to provide an acceptable thermal environment for occupants wearing typical indoor clothing and near sedentary activity. Acceptable thermal environment is an environment which at least 80% of the occupants would find thermally acceptable.(Look at table 1).

5. THERMAL TRANSITION BETWEEN THE EXTERNAL ENVIRONMENT AND INTERNAL SPACE OF THE BUILDING.

When the fall of the quantity of solar radiation on the wall is part of that radiation is reflected back to the surrounding atmosphere, while absorbing the other part, which turns into energy increasing surface temperature of the outer wall first, and then the remainder joining to indoor air of the building. And take the heat and transferring it to the building in three forms which are radiation, conduction and convection. (Henery et. al, 1980).(Look at figure 2).

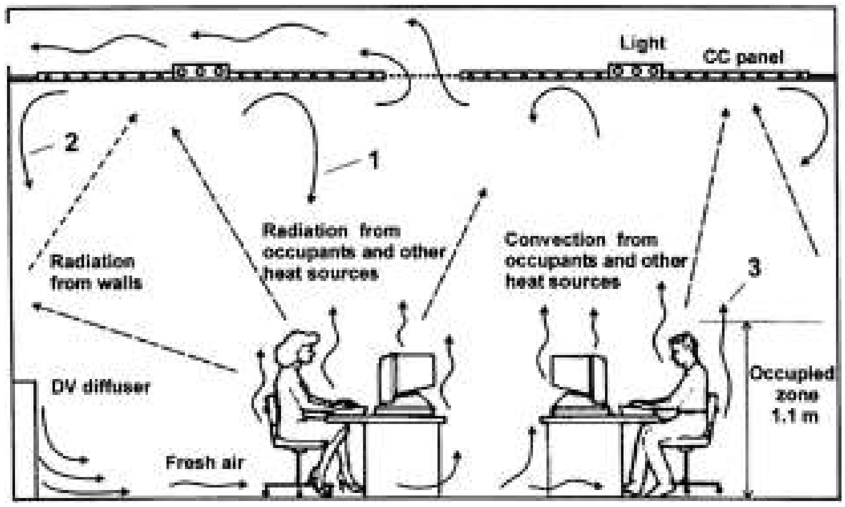


Figure 2. Heat transfer and thermal energy balance in a space.
Typical insulation values for clothing ensembles (ASHRAE STANDARD – 55-1992).

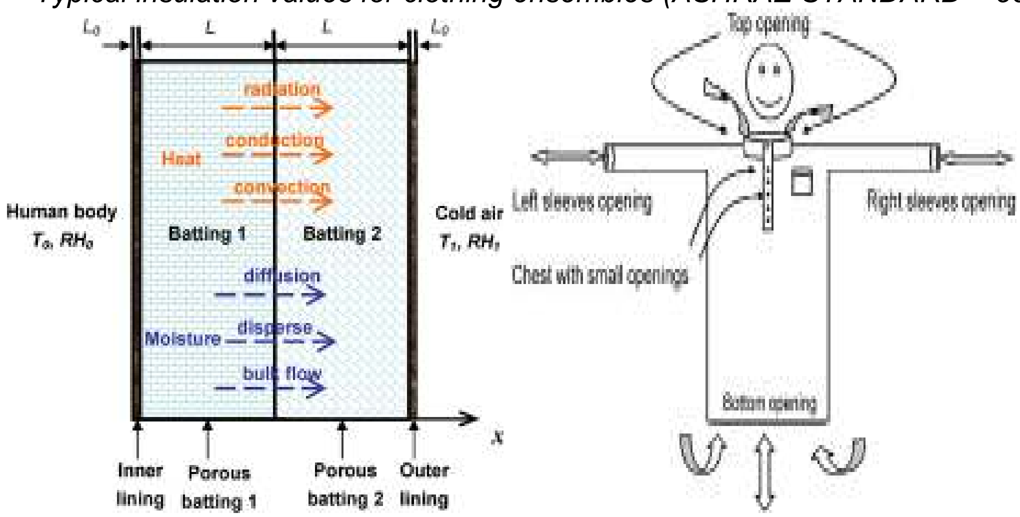


Figure 3. *Schematic diagram of the clothing assembly system.*

5.1 HEAT RADIATION.

Solar is gained from external sources and internally processed. Radiant heat refers to the heat that transfers through a vacuum through electromagnetic waves.

5.2 HEAT CONVECTION.

Heat convection refers to heat exchange between building and exterior air as well as with occupant, lights and equipment. The effect of internal sources of heat is minimized by having high internal inertia.(Look at figure 3).

5.3 HEAT CONDUCTION.

Heat conduction is the heat flow through material molecules from molecule has larger thermal energy to the molecule have least thermal energy. Nearly all of the heat exchange by conduction is between the building frame and the ground and this becomes appreciable in very cold climates.(look at figure 3).

6. LOCATION OF UNIVERSITI SAINS MALAYSIA.

Figure 4. Map of Malaysia

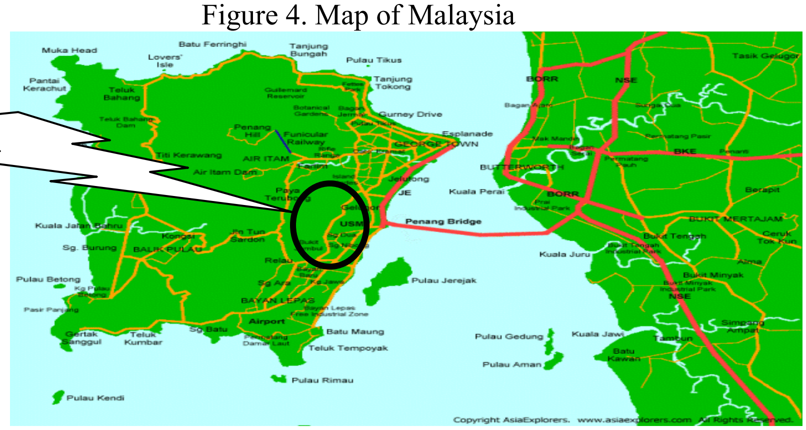


Figure 5. Penang Island Map

Penang is the second smallest and one of the 13 states of Peninsular Malaysia. It is situated at the northeastern coast and constituted by two geographically different entities - an island (area: 293 km^2) called Penang Island (or “Pulau Pinang” in Malay Language) and a portion of mainland called Butterworth (area 738 km^2), connected, besides a regular ferry service, through a 13.5 km long Bridge. The island is located between latitudes 5° 8’ N and 5° 35’ N and longitudes 100° 8’E and 100° 32’ E.

The climate is tropical with the average mean daily temperature of about 27^{o}C and mean daily maximum and minimum temperature ranging between 31.4^{o}C and 23.5^{o}C respectively. However, the individual extremes are 35.7^{o}C and 23.5^{o}C respectively. The mean daily humidity varies between 60.9% and 96.8%. The average annual rainfall is about 267cm and can be as high as 624cm. The two rainy seasons are southwest monsoons from April to October and north-east monsoons from October to February. The terrain consists of coastal plains, hills and mountains. The population is mainly concentrated on the eastern side of the Island, probably due to its close proximity with the mainland. Figure 4 and Figure 5 show the map of Malaysia, and the map of Penang island respectively.

6.1 HOSTELS IN USM.

USM campuses in Malaysia are located with a tropical island of Penang, Malaysia. Besides the main campus in Minden, USM has two other campuses; one at Kubang Kerian in Kelantan known as health campus and the other at Seri Ampangan, Nibong Tebal in mainland Penang known as engineering campus. USM in Penang island has many hostels, these hostel call, Aman Damai, Bakti Permai, Cahaya Gemilang, Fajar Harapan, Indah kembara, Jaya, Lembaran, Murni Nurani, Restu, Saujana, Tekun, International house. (www.usm.my./en/ptj.asp?s=6.).(25/09/2008).
(Look at figure 6, 7, and 11).

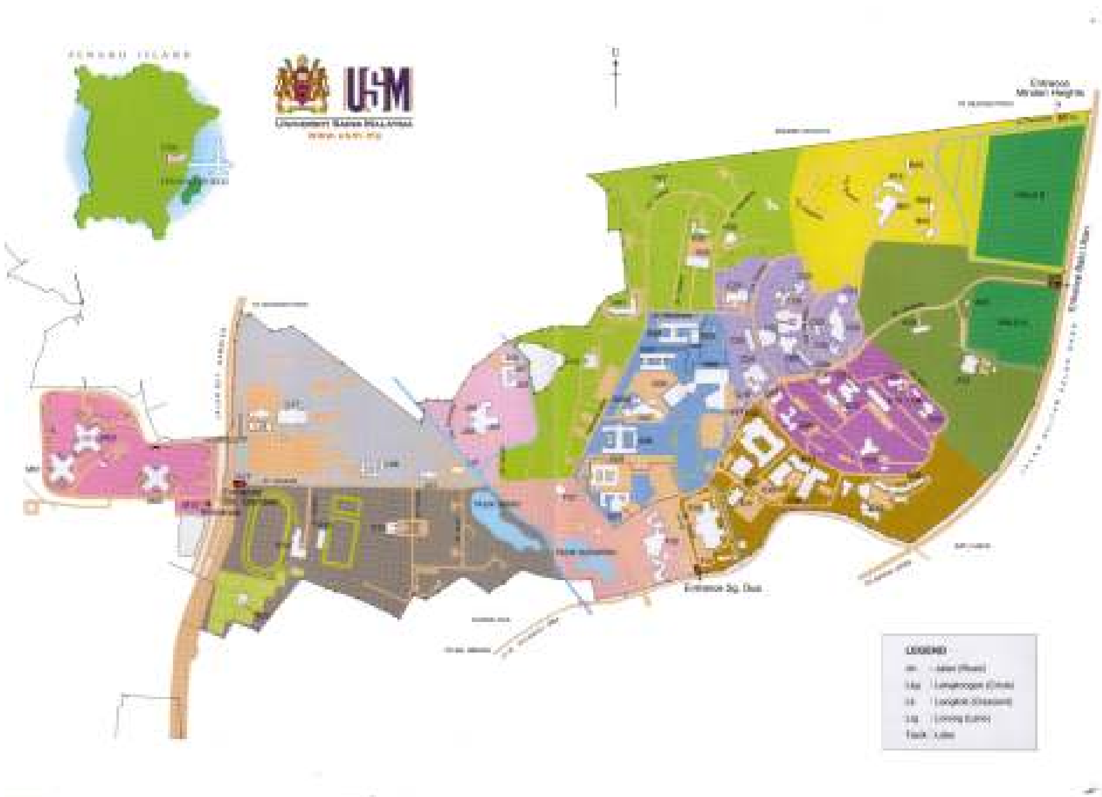


Figure 6. USM Map. Main campus of USM in Penang. (Source, www.usm.my.map.(2008).

Facilitate student housing offered by Malaysian universities for Malaysian students and foreigners alike to overcome the initial difficulties of university students in the long journey. It is also a timely opportunity to identify the Malaysian life and culture closely and create better understanding among people of different race, culture, religion and social back ground. The goal of student hostel is to provide a supportive environment that will enable the student to succeed in the academic endeavors and to make the most of their Malaysian experience. The room system in the building not individual except the international house, each room has two student and every four room has separate two toilets and two showers, and each flour has one room for wash and one room for cooking and each building has meeting room. According to Adel Abdullah Omar Al-Mualm (2007), the room system in the international house individually, each involving rooms in the bathroom and one of the hand and on the other involving every room in the small balcony with other. Figure 7,8 and Figure 9 shows the design detail.

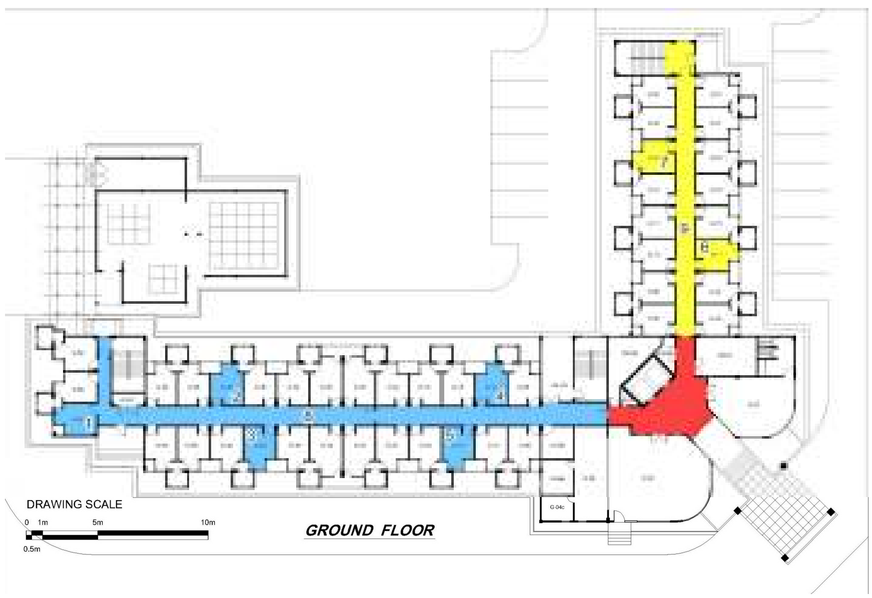
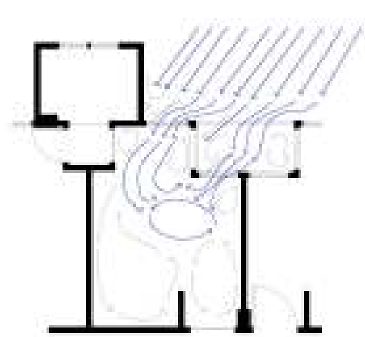


Figure 7. Plan of the hostel.(international house, ground floor).(Source building management office, USM).



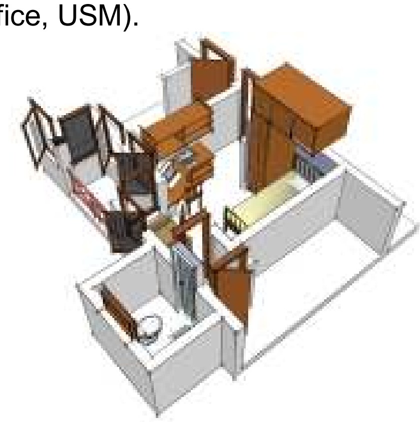


Figure 8.view airflows through only one side window opening. figure 9. 3D perspective view for student room.

6.2 BUILDING MATERIALS.

The categories of building materials create a lot of variation in contributing to the overall thermal comfort in the building. The thermal performance of a brick wall building would behave almost similar to the concrete building. Opposite to, timber absorbs heat readily and release heat readily as well. This accounts for the traditional Malay house being very cool during the early mornings. Most building in Malaysia are built with construction materials which absorbs heat easily from the sun through the daytime. At night time the air outdoor cooled quickly, but the building fabric behaves differently where heat is released from the building mass to the surrounding air indoor and outdoor.(Look at figure 10).

The building envelope comprises all the building components that separate the indoor from the outdoors. Building envelopes consist of the exterior walls, interior walls, roof, floor, windows and doors. The performance of the building envelope is influence by heat, cool, rain, humidity, ventilating equipment and lighting.(Look at figure 7, 8, 9, and 10).

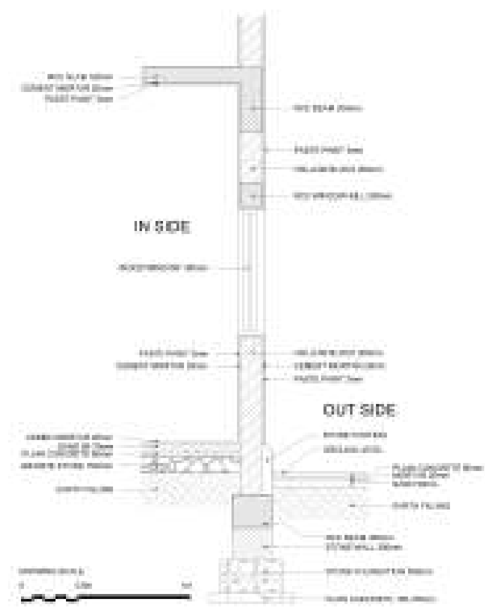


Figure 10. typical details of walls construction and envelope in hostel in Penang.

6.3 REDUCING RADIANT HEAT.

The quantity of solar heat obtained by the surfaces of a building can be minimized for any time of the year through the manipulation of the orientation and shape of the building plan with respect to the sun and also various building heights.(Look at figure 2 and 11).

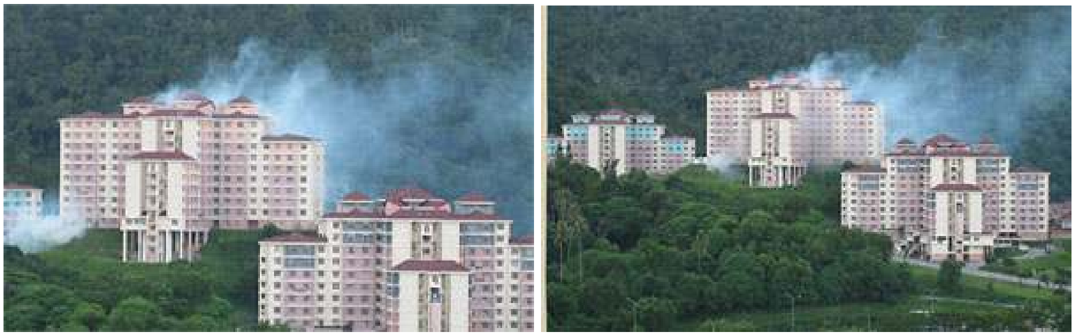


Figure 11. USM hostel. (Source: www.usm.my.campus). (15/09/2008).

7 DESCRIPTION OF THE MONITORING BUILDING.

Early Malay buildings can be described as raised on timber stilts and made of materials which were easily available from the tropical forests such as timber, bamboo, rattan and leaves. Malay architecture has been modified to adapt with new materials for their durability such as concrete and bricks for walls, metal, concrete and clay tiles for roofing in several types, colours and styles. In fact most of imported building technologies are not thermally suitable under Malaysian climate. A random survey of quarters building in USM in Malaysia showed that quarters are considered too hot by the occupants. The problem of overheating is not restricted only on terrace or windows or vents. To clarify the effect of climatic conditions in relation to building design and comfort conditions, Indoor and outdoor temperatures of quarters were monitored over a period of time to predict and to estimate the indoor comfort temperature of quarters under Malaysian Climate. This study also focuses on possible strategies of improving indoor thermal comfort of quarters.

8 PREDICTIVE METHOD FOR ESTIMATING INDOOR THERMAL COMFORT.

Humphreys proposed the following Equation number 1 for calculating the indoor comfort temperature for free running building based on outdoor monthly mean temperature (Humphreys and Nicol, 1998): $\mathbf{T_c = 11.9 + 0.534T_{mmot.}}$ **................... (1).**

Where, T_c is predicted Indoor comfort temperature (°C), T_{mmot} is monthly mean outdoor temperature (°C). An analysis of the climatic data of Penang with Humphreys model shows that the monthly mean temperature was above the neutral comfort temperature but within the comfort limit which is ±2°C from the neutral temperature. The neutral comfort temperature in Penang varied from 25.5to 28°C. Auliciems (1984) tried to analyze Humphrey's data by including some recent studies and excluding some of incompatible Humphreys data (Auliciems, 1984, Feriadi and Wong, 2004). The

Equation number 2 for Comfort temperature suggested with active and passive climate control. $\mathbf{T_C = 0.48 \times Ti + 0.14 \times T_{mmot.}(2)}$.

Where, T_i is monthly mean indoor temperature (°C), T_{mmot} is monthly mean outdoor temperature (°C). This formula was used to assess the indoor comfort temperature.

9. MOVEMENT AIR.

Supplying fine indoor air quality in air-conditioned building is important for user satisfaction, well-being and performance. It is a main concern issue of public health that poses particular challenges to building design and operation vis-à-vis the climate and external environment in ensuring that the indoor air quality remains acceptable while minimizing the use of energy.

(Look at figure 8 and 12).

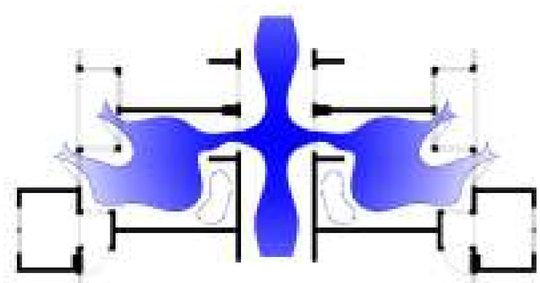


Figure 12. view the air movement through two opposite rooms.

According to Terry (2007), a building is said to have high quality indoor air, when it has no known pollutants at injurious concentrations and when 80 percent of occupants express satisfaction with the air. Bad indoor air quality’s effect on occupants isn’t superficial it can cause many tangible symptoms. Discomfort complaints are commonly related to the temperature, humidity and odours in a building.

10. EXPECTED RESULTS.

This study has brought attention to practical solutions involved in the use of the building material under Malaysia climate. In rural areas which are well surrounded by plants and sufficient number of trees or by a canopy of coconut palms, heat is more readily absorbed or dissipated while this may not be the case in concrete and brick buildings that dominate the urban landscape of Penang. In fact, the difference between tarmac and grass surfaces can easily exceed 3°C - 10°C (Abdul Rahman (2004). In these areas. The absorption and emission of heat from solar insulation is highly dependent on the building cover which prevents any heat build-up in the building. Furthermore, any direct sunlight into the building would defeat the purpose of having a good thermal performance material although such sunlight can be utilized for lighting interiors. Fadzil (2004), good natural ventilation requires locating openings in opposing pressure zones. Solar energy entering the building can be reduced by applying blinds and jalousies or by introducing over hangs, wing walls and other architectural devices that shade a window in a planned way. In addition, the use of natural ventilation mechanisms such as high ceiling height, and indoor water fountains and plants can also assist in heat dissipation and thermal control. Fadzil (2004).

11. CONCLUSION.

In conclusion, any method or technique to generate a more conducive living environment for students must take into account several constraints such design and planning authority, the use of the appropriate building material and the use of natural mechanisms of heat control and dissipation to induce thermal comfort as well as reduce the consumption of artificial energy resources. In hot humid areas near to the equator the disperse radiation has a prevailing contribute to of the overall radiation and the fact that the sharing of the disperse radiation is approximately the same at all orientations, the orientation of the buildings might be more affected by other external sides, like the dominating wind direction.

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