CHAPTER 5.0

Case Study

Field measurement has been conducted in JKR 989 which is the selected former British residence in an urban environment. This is to ascertain whether the indoor thermal comfort conditions are influenced by the window designs and its current microclimate. The field study was conducted for duration of 8½ weeks between 13 May 2010 and 12 July 2010. This period was selected as it matches with the period of constant changes in mean air temperature, mean relative humidity and mean air movement based on the 2004-2008 weather data. This field measurement aims to evaluate the micro climate condition of the study site and its impact on the heat gain pattern of a selected room.

The influence of window designs on heat gain as one of the main factor that affects the indoor thermal comfort were measured on two scenarios, first with windows opened and second with windows closed. This is to determine the amount of heat gained through the windows. All the windows on site are 5mm thick clear glass. HOBO data loggers were used to measure 3 parameters of thermal comfort including air temperature, relative humidity and illuminance factors between 13 May 2010 and 12 July 2010.

The impact of micro climate condition was evaluated based on the measurement result of indoor thermal comfort factors using BABUC climatic data analyzer to represent the occupants. Parameters recorded by BABUC included air temperature, relative humidity, air velocity and daylighting. Outdoor climatic parameters which are air temperature, relative humidity were measured using HOBO data logger. This measurement was conducted between 28 June and 23 July 2010.

The thermal comfort index that has been established for hot humid climate according to Wong (2003), De dear (1991) and Busch (1990) thermal comfort level that has been determined by respondents in Malaysia is in the range of 26°C- 30.7°C and other code of practice as shown in Table 5.1 has been used to determine the impact of micro climate on the indoor thermal comfort and the effectiveness of related window designs in selected room (zone 2).

Table 5.1: Range of thermal comfort parameters compiled
Source: Zain-Ahmed, 2000

Source	Temperature Range $t(^{o}C)$	Relative Air Humidity Range RH(%)	Air Velocity v(m/s)
ASHRAE	23.0 - 25.0	20 – 60	
Abdulmalik	25.5 - 29.5	45 – 90	
Malaysia	22.0 - 26.0	30 – 70	
Abdul Rahman	23.4 - 31.5	54 – 76	$\geq$ 0.20
Zain-Ahmed	24.5 - 28.0	~73	
Singapore	22.5 – 25.5	$\leq$70	~0.25

Figure 5.1: South West facade of JKR 989
Source: Author, 2008

5.1 Case study procedure

Figure 5.2: Floor plan JKR 989

JKR 989 was built in 1928. It was selected for this case study as this building is located in the most critical urban setting and is still well maintained and has the least changes compared to the other selected British Colonial residences. The building shown in Figure 5.2 is a 1 storey bungalow located at No.2 Jalan Stonor, Kuala Lumpur with an approximate floor area of 381.4m². The building is elevated 950mm from ground, has high ceiling and clerestory windows in the main hall and two main rooms. The purpose of the high ceiling is to improve and help to drive natural ventilation to the building using buoyancy from the increased temperature in the hall. The residence is designed to house a 5 person family and servants. The integration of the bio-climatic architectural concepts was the central point during the design stage. Figure 5.3 shows the floor plan layout of the building.

The field measurement covered all spaces in JKR 989. It was divided into 4 different zones. The zonings were determined based on the physical condition of the space and space usage. Spaces with the same physical conditions are categorized under the same zone as stated below:-

Zone 1 – resource centre

Zone 2 – main hall + meeting room + gift shop

Zone 3 – office

Zone 4 – pantry

Figure 5.3: Zoning in JKR 989

5.1.1 Exterior surrounding

The building is shaded by high rise buildings and Figure 5.4(a), figure 5.4(b), figure 5.4(c) & figure 5.4(d) showed the case study building within its context. In front of JKR 989 is an 11 storey high rise building, the Royal Chulan Hotel as shown in Figure 5.4(a), on its left is an 8 storey apartment, No. 1 Stonor as shown in Figure 5.4(b), at the back of it, is a

30 storey new office tower as shown in Figure 5.4(c) and on its right is the upcoming 42 storey apartments as shown in Figure 5.4(d).

Figure 5.4(a): Royal Chulan Hotel in front JKR 989

Figure 5.4(b): Apartment on East JKR 989

Figure 5.4(c): Office tower under construction which behind JKR 989

Figure 5.4(d): Upcoming 42 storey apartments next to JKR 989

5.1.2 Instrumentation

The thermal comfort level of the indoor environment is measured using a measuring physical quantities instrument (HOBO) data logger and BABUC showed in Figure 5.5(a)&(b) that was able to measure air temperature, relative humidity and luminance. All these equipments were calibrated before to ensure reliability and accuracy in the readings taken during the field studies.

Figure 5.5(a): HOBO data logger to measure air temperature, relative humidity and daylighitng

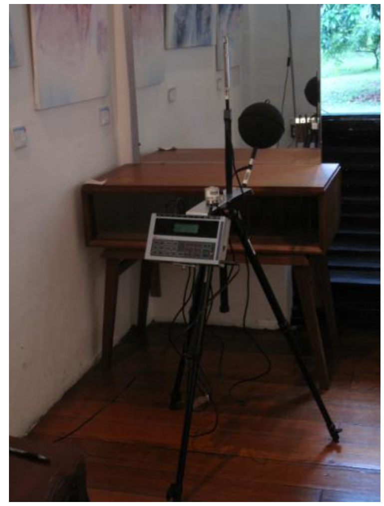


Figure 5.5(b): BABUC used to measure air temperature, wind velocity, relative humidity and daylighting for the internal space

All measurements were taken at a height of 700mm above the floor, which represents the height of the occupant at seated level. The instrument was placed at work plane level in the rooms at 1.2meters from the window.

These measurements were carried out at one point at the corner of the room. There are two recording done for all the rooms. One recording was done with all windows closed which are the normal condition for the users of this house as they depend on mechanical ventilation. The measurement data were recorded in every 30 minutes interval, within a period of two weeks. The other recording was done with windows open which is unusual for current users.

Due to the unwillingness of occupants and for various reasons which will be explained in the next sub-chapter, the recording of environment with the windows open were only carried out for 4 days at 15 minute intervals.

While using Babuc climate analyzer in this study has been set, the metabolic rate 1.2met which is sedentary activities and the Clo value (thermal resistance) is set to be 0.5 where the males were wearing underpants, shirt with short sleeves, light trousers, light socks and shoes. The females were wearing 'baju kurong' which is cotton or silk with light cotton undergarments and a lightweight scarf.

5.2 Measurement process of Indoor Thermal Condition in Zone 1 (Resource Centre) of JKR 989

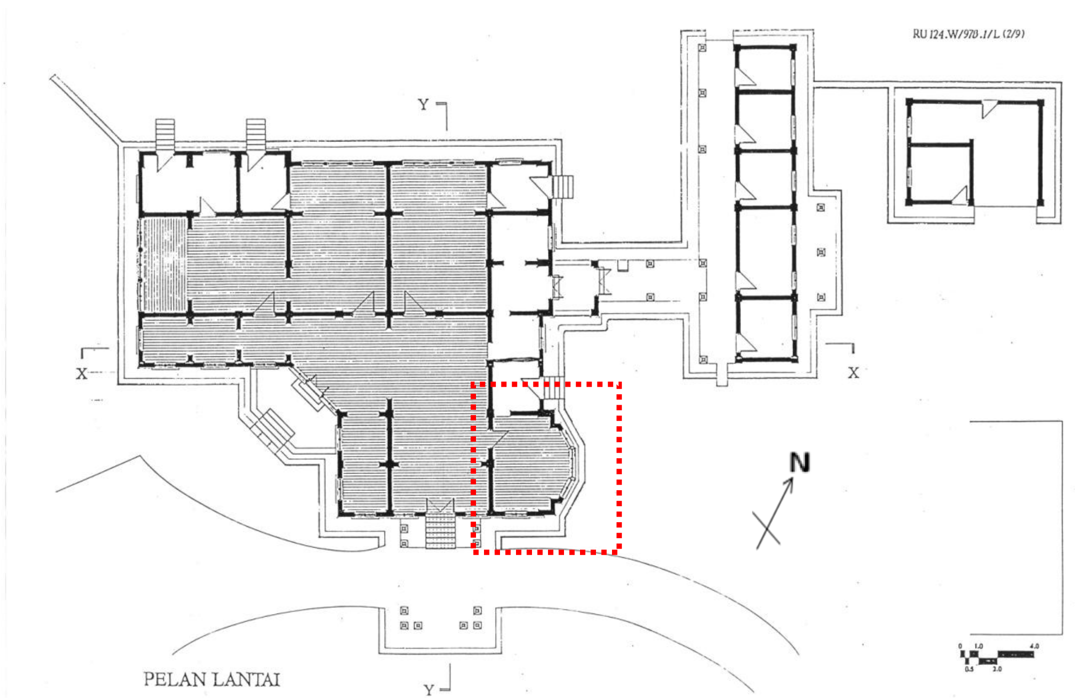


Figure 5.6: Floor plan JKR 989
Source: UTM, 1998

5.2.1 Description of Zone 1 existing features

Table 5.2: Zone 1 existing features

Room form	rectangle + hexagon
Ceiling height	4.2m at peak
Dimension	5.1m (length) x 4.6m (width)
Floor area	23.5m²
Orientation	North East

Type of glass	clear transparent glass (5mm)
Interior walls construction	brick wall (210mm)
Interior walls finishing	plaster (25mm) with white paint
Exterior walls construction	brick wall (210mm)
Roof construction	pitched roof with Marseilles tiles
Ceiling	painted white suspended ceiling
Wall	brick wall painted white
Floor	timber plank
Ventilation	one air condition
Windows	double leaf glass panel casement window with timber louvers on top and bottom and clerestory windows on top
Door	1 double leaf glass panel door with louver on top l
Lighting	2 nos fluorescent lights on ceiling
Fan	1 standing fan
Air condition	1 air condition with 1horse power

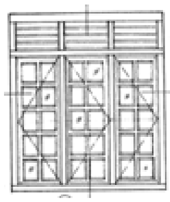
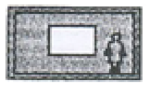
Experimental work was conducted in a resource centre on the ground floor of JKR 989 at No.2 Jalan Stonor which shown in Figure 5.7(a) and Figure 5.7(b). The dimension of room was: 4.6m x 5.1m x 4.2m height. The volume of room was 98.5m^3 and its surface area was 23.5m^2. The room consists of two interior walls, interior timber raised floor, ceiling and two exterior walls with windows area. This room is normally used by researchers (students or professionals) upon appointments with a possibility to have meetings around the square tables with up to eight people taking part. This resource centre is built into the North East. Room was fitted with two window and one door. The dimension of the window area is 2.72m^2.

Figure 5.7(a): Resource Centre with windows closed

Figure 5.7(b) Resource Centre with windows open

The resource centre at the Badan Warisan Malaysia is open from Tuesday till Saturday and close on Sunday and Monday. Researchers will only use this room based on appointment. There will be a librarian (staff of BWM) monitoring students at the work space shown in Figure 5.8(a) to prevent vandalism, photographing, damaging the material provided. Figure 5.8(b) shows the windows types and details at zone 1.

Figure 5.8(a): Librarian working space

 W9	Hardwood frame glass window with fixed louvers on top
	Orientation: North East
	Opening system : swinging
	Opening dim : 1.6m x 1.7m
	Glass type: clear glass
	WWR : 0.22
	Nos: 1
	Window – height on wall  A 400mm B 800mm

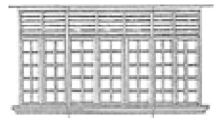
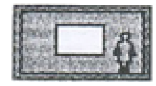
 W9	Hardwood frame glass window with fixed louvers on top
	Orientation: East
	Opening system : swinging
	Opening dim : 1.6m x 1.7m
	Glass type: clear glass
	WWR : 0.22
	Nos: 1
	Window – height on wall  A 400mm B 800mm

Figure 5.8(b): Summary of window types in Resource centre

Result of indoor thermal condition in Zone 1

5.2.2 Air Temperature

The temperature profiles of the resource centre for a period of two weeks (windows closed) and for a period of 4 days (windows opened) were recorded. The windows in the Resource centre were not opened as the current users depended on mechanical cooling. Besides that, they wished to reduce noise and dust pollution from existing buildings. As this room was used as reading room, noise pollution from nearby traffic will cause discomfort for users. In addition, there are construction work going on at nearby lot which is a 41 storey height SOHO building, lots of dust enter the building everyday which is a risk especially for those who have asthma. When the air conditioned is not turned on, natural ventilation enters the room through louvers which are on top of each window. There are the relationship between these users' behaviour and indoor temperatures. Satisfied thermal comfort range that has been determined by respondents in Malaysia is 26°C- 30.7°C (Wong, 2003, De dear, 1991 and Busch, 1990).

Windows closed

Malaysia comfort standard (Wong, 2003, De dear, 1991, Busch, 1990)
Temperature 26-30.7ºC; humidity 30-70%; daylighting 350lux

Figure 5.9(a): Graph shows air temperature zone 1 with windows close from 13 May 2010 till 31 May 2010

The result in Figure 5.9(a) clearly showed that air temperature in the morning, which is before working hour is more constant and much cooler than the rest of the day. During working hour, air temperature increases and unstable and between 25.5°C and 34°C causing thermal discomfort. Mean indoor air temperature is 29.8°C. Average external min air temperature during that period of time is 29°C. Clearly, indoor temperature is higher than external temperature during daytime. This is due to the thermal capacity of thick walls, which is brick released heat storage. At night time after working hour, the room temperature drop to the range of 28 - 31°C. Based on the graph, the air temperature on 15th May has a sudden drop to comfort zone due to air condition was on for researchers. Thus, result on 15 May 2010 had been superceded. According to Window to wall ratio, this windows allowed 0.22 which is poor ventilation and daylighting into the room. The difference in the measurement with the calculation indicate that the air temperature of the room is not only based on the heat gain through windows or door but occupancy, orientation of the room and existing features at surrounding, artificial lighting and electrical equipment.

Figure 5.9(a) demonstrated that thick wall contributed in controlling the heat penetrated inside the room when windows are not opened.

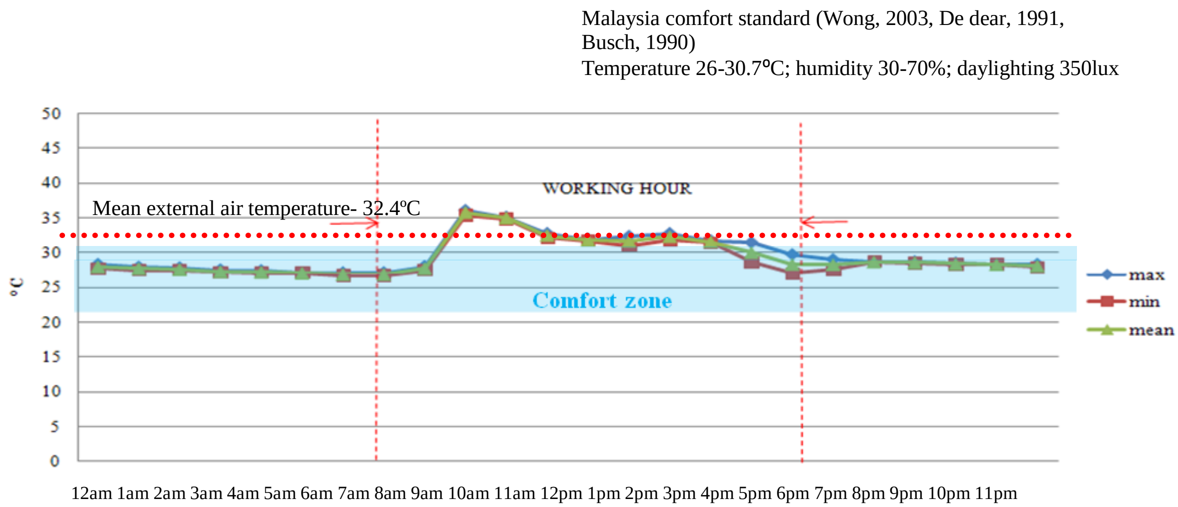


Figure 5.9(b): Graph shows zone 1 temperature with windows opened from 12 July 2010 till 15 July 2010

Windows opened

Windows were opened from 12th July – 15th July 10 during working hour, from 8am till 4.30pm. Figure 5.2.2(b) showed that before working hour, it was noted that the air temperature of the room was constant, which was 27-28°C. When windows were opened, the air temperature increased tremendously from 28°C to 36°C. This means that windows when opened, not only allow natural ventilation into the room but also gain heat at the same time. During 10.00am, the temperature of 36°C is higher than external temperature- overheating in the room due to orientation of this room is facing to North East. Consequently, as a norm, users of the room will request air condition to be turned on and windows were closed. After 12pm, air temperature dropped to normal, which is 27°C-33°C. Data on 13th July 2010 is obsolete due to air condition was turned on as a result requested by users and the result was removed from graph. As a result, it is proved that windows allowed a lot of heat gain in the room which caused thermal discomfort. Besides, too much daylighting penetrating inside the room caused glare and difficult for users to read.

5.2.3 Relative Humidity

Relative humidity is the ratio between the actual amount of water vapour in the air and the maximum amount of water vapour that the air can hold at that air temperature. Malaysia is hot and humid throughout the year. High humidity environments have a lot of vapour in the air, which prevents the evaporation of sweat from the skin. In hot environments, humidity is important because less sweat evaporates when humidity is high (80%+). The evaporation of sweat is the main method of heat loss in humans.

Windows closed

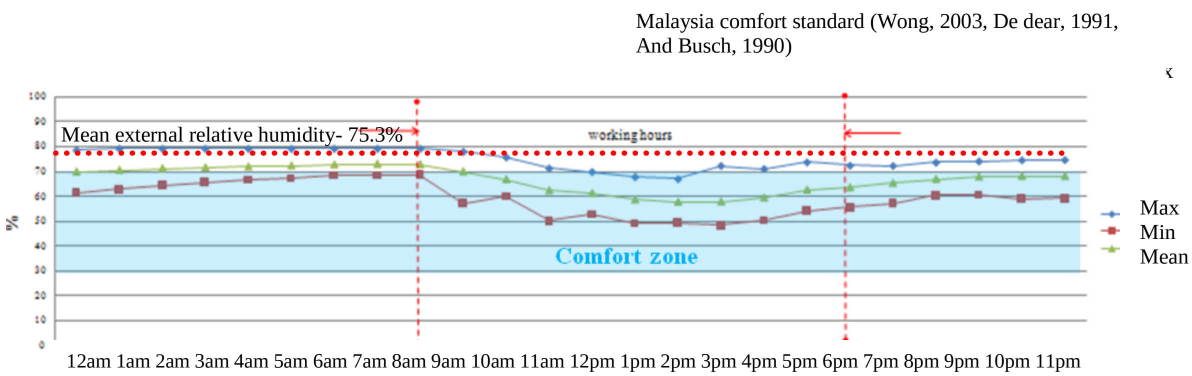


Figure 5.10(a): Graph shows RH for zone 1 with windows closed from 12 July 2010 till 15 July 2010

Figure 5.10(a) shows the relative humidity profiles of resource centre. The relative humidity was constant in the morning. During working hour, it varied widely was from 50% - 75% which is lower than mean external relative humidity which is 75.3% (microclimate). This is due to the thermal capacity and the moisture adsorbed and desorbed performance of thick wall in brick building. Graph shows relative humidity is unstable during working hour. This is due to air condition was turned on when there were researchers conducting research in that room. Researchers used the resource centre only for 1 or 2 hour within the working hours.

Windows open

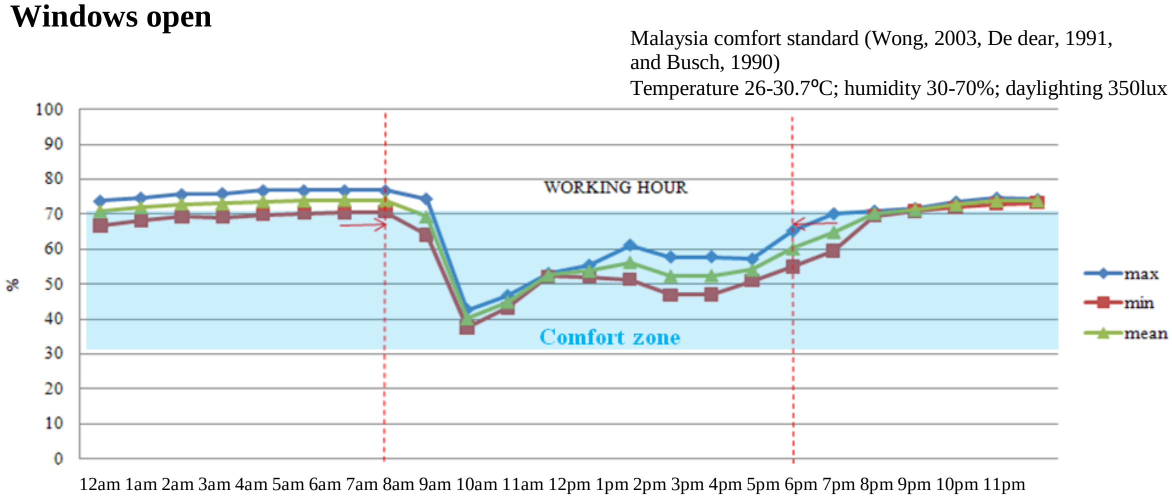


Figure 5.10(b): Graph) shows RH for zone 1 with windows opened from 12 July 2010 till 15 July 2010

Graph 5.10(b) shows that when the windows were opened, the relative humidity dropped tremendously from 75% to 37% which is within the comfort zone. Relative humidity between 37-77% does not have major impact on thermal comfort. In this room, relative humidity is usually kept between 40-60% because of books kept in this room. This room is used as resource centre for academic researchers. High relative humidity can cause damage, especially to leather bindings. If there is too much relative humidity in the air, it is an invitation to mould and insects. Thus, windows are kept closed most of the time because of the fluctuations in relative humidity and temperature. During these 5 days of recording, windows were opened from 8am till 4.30pm. Data on 13 July 2010 was obsolete due to air condition was turned on. It was noted that after the windows closed after working hour, relative humidity increased. The factor of having an increase of relative humidity is due to when windows are closed, air temperature increased as hot air unable to drive out. Hot air is less humid compared to cold air. This is proven from graph in Figure 5.9(a) showing the increase of air temperature when windows are closed. At higher air temperature, more water that kept in air will evaporate. For a while, the rate of evaporation will exceed the rate of condensation, which increases relative humidity.

5.2.4 Daylight

Table 5.3: List of illuminance requirement of a house
(Source : CIBSE, 2004)

Location	Illuminance/Lux
Living room	**50**
Dining	**150**
Reading room	**350**
Study	**300**
Kitchen	**300**
Bedroom	**50**
Hall / landing	**150**

The use of natural light, or daylighting, has traditionally been a desirable building feature and a hallmark of good design. When skilfully introduced, daylighting creates an ambience of quiet contemplation and visual comfort. This room was originally used as a dining area in the 1950s and refer to table 5.3, the daylight requirement is 150lux. However, this room is currently used as a reading room. Thus the requirement is now 350lux. Proper lighting is crucial to the overall success of a resource centre. Although all the rooms in JKR 989 were design for daylighting, the function of each spaces has changed. Different function or activity in a room requires different amount of daylight. For example, the dining room will not necessary need a lot of daylight compared to a reading room. Thus, two fluorescent lights were installed to lit up the room.

Refer to CIBSE (2004), *"the first requirement for library lighting is to provide enough light to accomplish a visual task such as reading. For daylight, this means tuning the aperture designs to minimize solar heat gain while achieving the lighting levels required* *for visual acuity. The second requirement is that the contrast brightness of other objects within the field of view must not be excessive, such that the resource centre user can view the task comfortably and not become visually fatigued over time."* In daylight design, glare conditions (i.e., when the brightness ratios of surfaces exceed visual comfort conditions) are avoided through aperture design, exterior sun control components and the placement of adjacent surfaces to balance the nearby surface brightness level. It is rare that lighting in this resource centre were turned on during the day. The amount of daylight and its direction at the windows vary during a typical day as the sun moves, and seasonally as the sun's predominant position in the sky changes. Daylight direction on cloudy days is still variable, though the light is more diffuse than on a clear day. On overcast days, the daylight is uniform, though varying in absolute brightness somewhat from sunrise to sunset. It is important in resource centre to maintain a relatively constant light level for visual tasks so that short term variability does not become distracting or inadequate. This is accomplished by using fluorescent lamps for what they do well in providing a constant level of comfortable light, in coordination with the light available from daylight. As the resource centre is opened from 10am till 4pm, most of the time the light fixtures were not turned on except on cloudy days. Furniture becoming dried out by the sun occurred in the past when sunlight was allowed to enter the building directly, or too much daylight was admitted in an uncontrolled manner. Current users added blinds to reduce this problem.

The daylight of resource centre was tested under real sky conditions in Malaysia. The daylight was determined by measuring the absolute illuminance of interior. The minimum lighting requirement that provides visual comfort is set at 350 lux. Therefore, the illuminance levels obtained are rather low. There is difference in recorded data when measurements were taken either windows are open or closed. This is due to this room's windows applied 5mm thk clear glass which reduce the amount of lighting penetrated into the room.

Window closed

Malaysia comfort standard (Wong, 2003, De dear, 1991, Busch, 1990)
Temperature 26-30.7°C; humidity 30-70%; daylighting 350lux

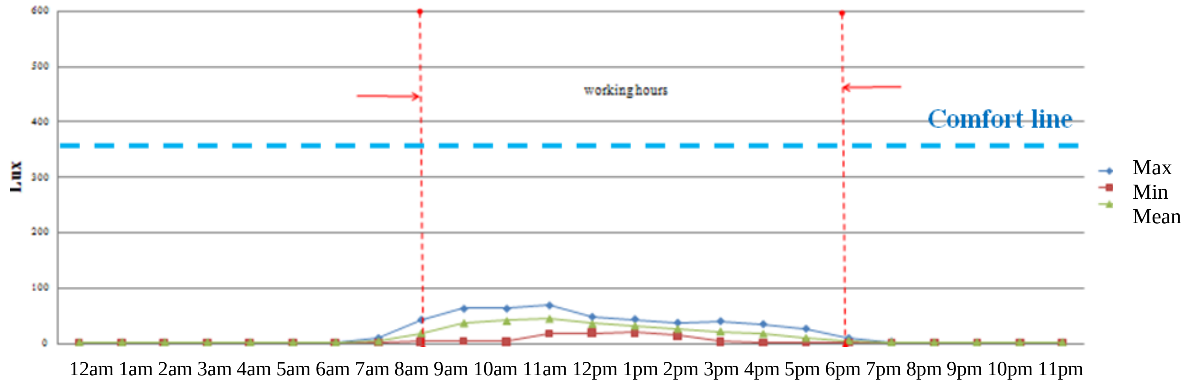


Figure 5.11 (a): Graph of Illuminance zone 1 with windows closed from 13 May 2010 till 31 May 2010

It is noted that the measurement of the internal illuminance were done without diffuser attached to the system. That explains why the light distribution is not very well distributed. There are days when the room was too bright which cause glare and discomfort. According to Window to wall ratio, daylight in this room is sufficient. From the graph showed in Figure 5.11(a), it can be concluded that using WWR to predict the performance of the daylight is reliable. The precision of the estimated daylighting performance would strongly depend on the orientation of the building and existing structure at surrounding. From the measurement, resource centre has the highest daylighting at 11.00am. The results also showed that the interior illuminance for this room was rather low in the afternoon and would not be sufficient for visual comfort. Additional lighting is required to ensure sufficient lighting.

Window opened

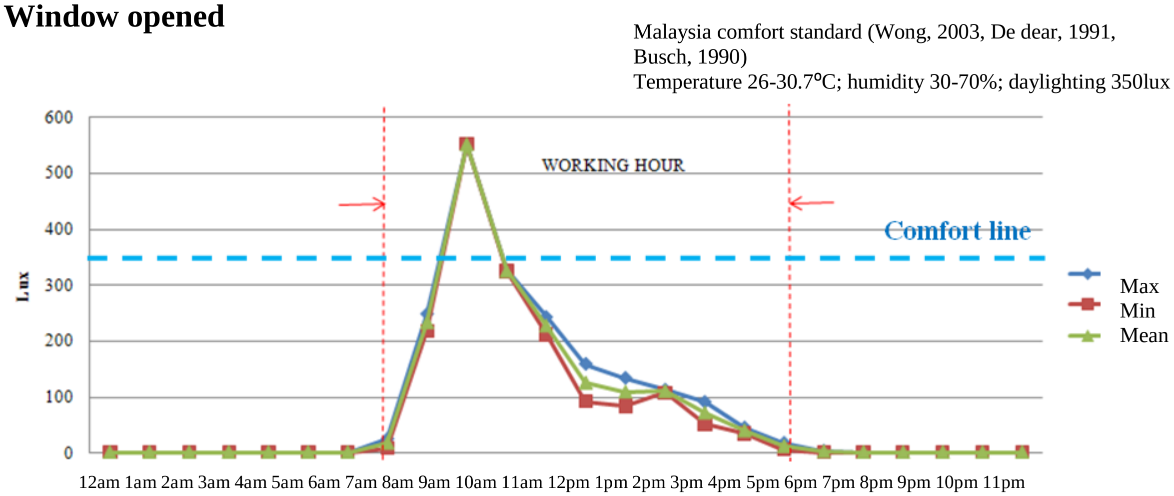


Figure 5.11(b): Illuminance Data zone 1 with window opened from 12 July 2010 till 15 July 2010

Refer to Figure 5.11(b), resource centre had the highest illuminance during 10am. This was when the sun ray penetrate into the window at an angle. As Resource centre was oriented facing North East, it was the morning sun light that penetrated into the room. Due to the daylighting reached 550lux which considered too much lighting, it created glare. Thus, blinds were added in the room to reduce the amount of daylighting into the room. The perfect lighting requirement for reading is 350lux.

5.3 Measurement process of Indoor Thermal Condition in Zone 2 (Meeting Room) of JKR 989

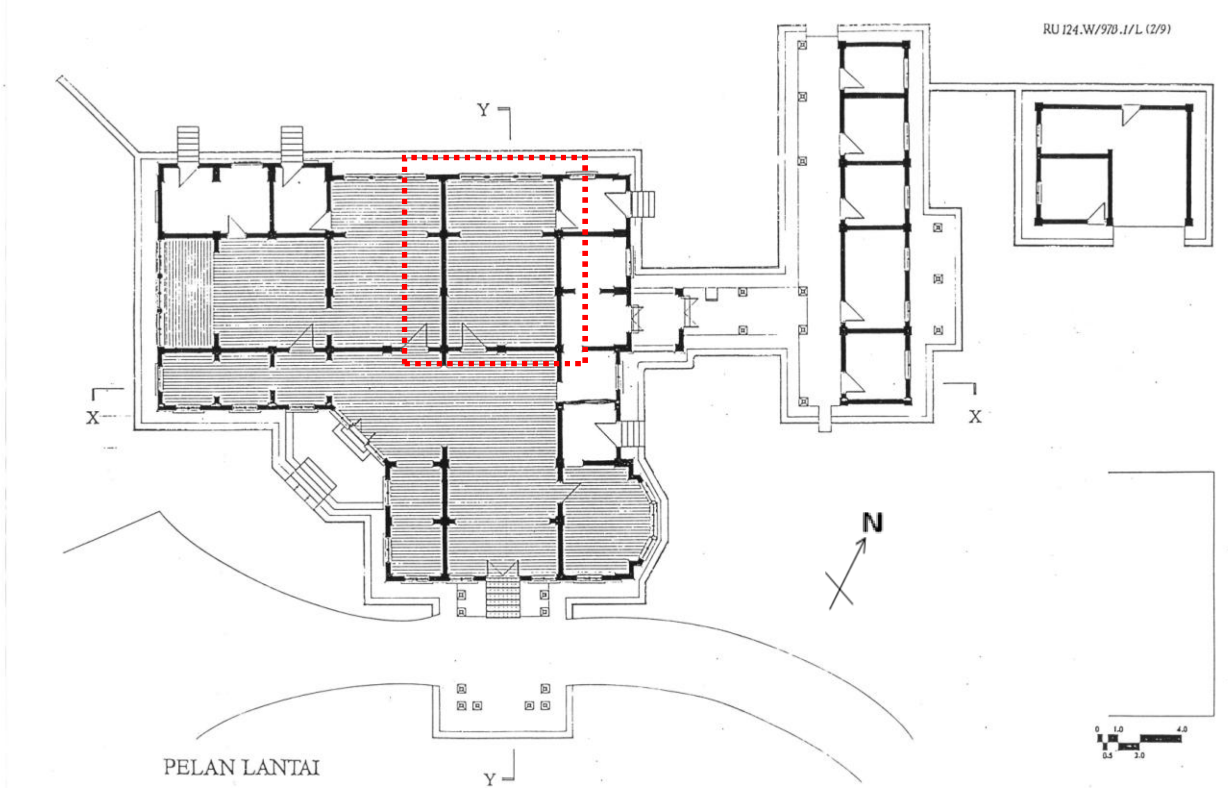


Figure 5.12: Floor plan JKR 989
Source: UTM, 1998

5.3.1 Description of Investigated room

Table 5.4: Zone 2 existing features

Room form	Rectangular
Ceiling height	8m
Dimension	8.1m (length) x 5.2m (width)
Floor area	42.12m²
Orientation	North West
Type of glass	Clear transparent glass (5mm)
Interior walls construction	brick wall (210mm)
Interior walls finishing	plaster (25mm) with white paint
Exterior walls construction	brick wall (210mm)
Roof construction	pitched roof with Marseilles tiles
Ceiling	painted white suspended ceiling
Wall	brick wall painted white
Floor	timber plank
Ventilation	one ceiling fan with 3 air condition

Windows	double leaf glass panel casement window with timber louvers on top and bottom and clerestory windows on top
Door	1 double leaf glass panel door with louver on top leads to the meeting room and one flush door to the store room attached
Lighting	track line with spotlight hanging and wall mounted down light

Experimental work was conducted in a meeting room on the ground floor of JKR 989 at No.2 Jalan Stonor. Location of measurement being taken is shown in Figure 5.13(c). The dimension of room is: 8.1m x 5.2m x 8m height. The volume of room was 337m³ and its surface area was 42.1m². The room shown in Figure 5.13(b) consists of two interior walls, interior timber raised floor, ceiling and one exterior wall with windows area. There is an internal door shown in Figure 5.13(a) that leads to zone 2. This room is normally used by council members or BWM members to have council meetings or AGM, seminar/ talk, art exhibition or even bazaar and can accommodate up to 30 people. This meeting room is facing to the North West.

Figure 5.13(a): Door to meeting room

Figure 5.13(b): Meeting room with windows closed and windows opened

Room was fitted with windows on the North West. The dimension of the window area is 9.75m². The meeting room is open from Mondays till Saturdays and close on Sundays and public holidays. Members will use this room on appointment basis if the room is not used for meeting.

Figure 5.13(c): Location of measurement equipments in meeting room

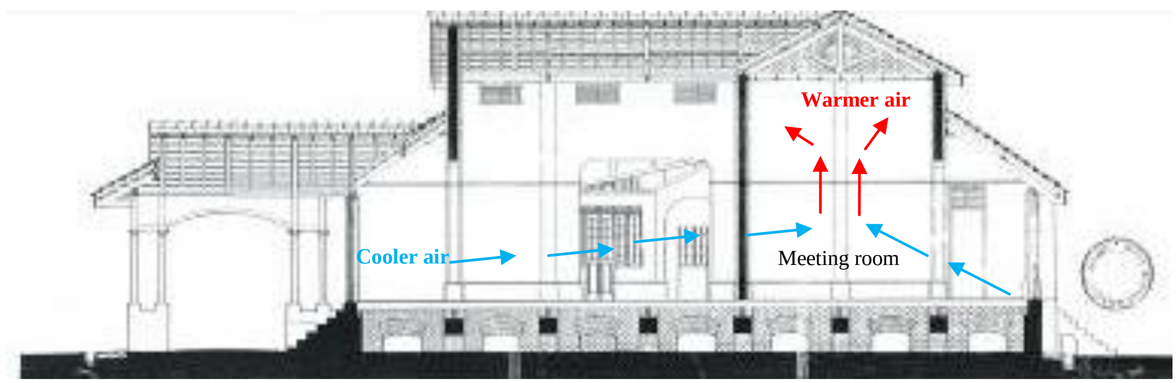


Figure 5.13(d): Section of Meeting room
Source: UTM, 1998

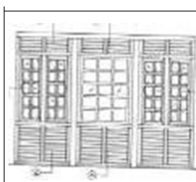
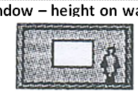
 W2	Hardwood frame casement window with louver on top and bottom
	Orientation: North West
	Opening system : swinging
	Opening dim : 2.5m x 3.9m
	Glass type: clear glass
	WWR : 0.5
	Nos: 2
	Window – height on wall  A 2200mm B 800mm

Figure 5.13(e): Summary of window types in Meeting Room

The meeting room has windows which are full length as shown in Figure 5.13(e). The top and bottom part of the windows are timber louver which allow for ventilation. The middle panel of the window is fixed window while both sides of this fixed window is swing windows. Users of this room only open the windows during daytime and close at night time for security purpose. As the window area for the wall is large, therefore, WWR for this window is 0.5 which will cause overheating to the room. Internal blinds are installed at these windows to reduce heat gain in the room.

As the meeting room has high ceiling and clerestory windows which showed in Figure 5.13(d), cooler air tend to enter from both the bottom of openings (windows) and internal door into the room. Warmer air which is lighter will drive out through all these clerestory windows which mostly are timber louvered windows.

5.3.2 Air Temperature

Windows closed

Malaysia comfort standard (Wong, 2003, De dear, 1991, Busch, 1990)
Temperature 26-30.7ºC; humidity 30-70%; daylighting 350lux

Figure 5.14 (a): Graph shows air Temperature zone 2 with windows closed from 31 May 2010 till 14 June 2010

Figure 5.14(a) shows the air temperature profiles of meeting room for a period of two weeks. Occupants of the room sometimes opened windows for getting ventilation during day time and closed them during night time. Days of opened window depend on the user of the centre which means users only open windows during working days from Monday to Saturday. There are the relationship between these users' behavior and indoor temperatures. Satisfied thermal comfort range that has been determined by respondents in Malaysia is 26°C- 30.7°C (Wong, 2003, De dear, 1991 and Busch, 1990). The result clearly showed that temperature in the morning, which is before working hour is much cooler than the rest of the day. During working hour, temperature increases and varied from 25°C to 33°C causing thermal discomfort. Average microclimate during that period of time is 24°C to 33°C. Internal temperature is within the range of microclimate. At night time, the room temperature drop to the range of 25 - 30°C. The Window to wall ratio of the windows all is 0.5 which caused overheating to the room as it allowed too much heat inside the room. This is proven by measurement where temperature for most of the days is far higher than comfort standard. Although there is shading to the windows and mechanical ventilation, the ceiling fan was turned on throughout the working hour, the air temperature of this room is considered warm. Users of meeting room often found that this room hot and stuffy. Often, the air conditioner is turned on whenever there is meeting. There are 2 days where the temperature suddenly dropped into comfort zone which is on 9th June 2010 and 10th June 2010. This is due to air condition is turned on for that 2 days for meeting purpose which affect the temperature of the room. Data for air temperature which air conditioner is turned on is obsolete.

Windows opened

Malaysia comfort standard (Wong, 2003, De dear, 1991, Busch, 1990)
Temperature 26-30.7°C; humidity 30-70%; daylighting 350lux

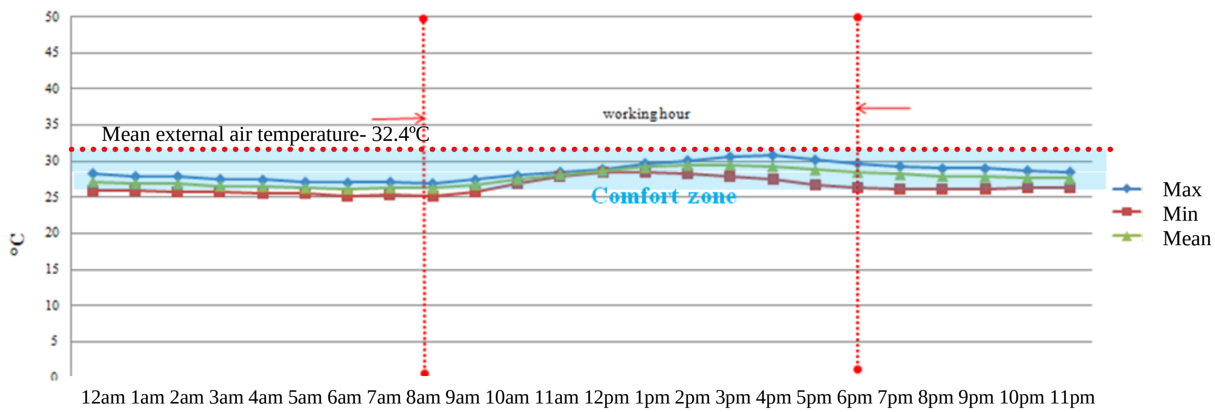


Figure 5.14(b): Graph shows air temperature zone 2 with windows opened from 15 July 2010 till 20 July 2010

Refer to Figure 5.14(b) shows air temperature when windows are opened from 15th July – 20th July 10 at 8am till 4.30pm during the recording period. On normal days, the windows in this room are closed to reduce the noise pollution from nearby construction site. Before the windows were opened, the room air temperatures were constant between 25 and 28°C. The room air temperature increased by 6°C when the windows were opened. After 3 or 4pm, the room air temperatures dropped to 28-30°C before windows were closed. All the data in Figure 5.14(b) was below the outdoor temperature range. The data on 18th July 2010 was considered obsolete as no windows were opened during weekend. During the measurement period, no air conditioner was turned on to prevent variable in data. It is noted that when the windows were opened, the indoor air temperature were lower than when the windows were closed. This is due to when windows are opened; they allowed cooler air to enter and warmer air to escape through louvers and clerestory windows. Circulation of air encourages lower indoor temperature.

5.3.3 Relative Humidity

Windows closed

Malaysia comfort standard (Wong, 2003, De dear, 1991, Busch, 1990)
Temperature 26-30.7°C; humidity 30-70%; daylighting 350lux

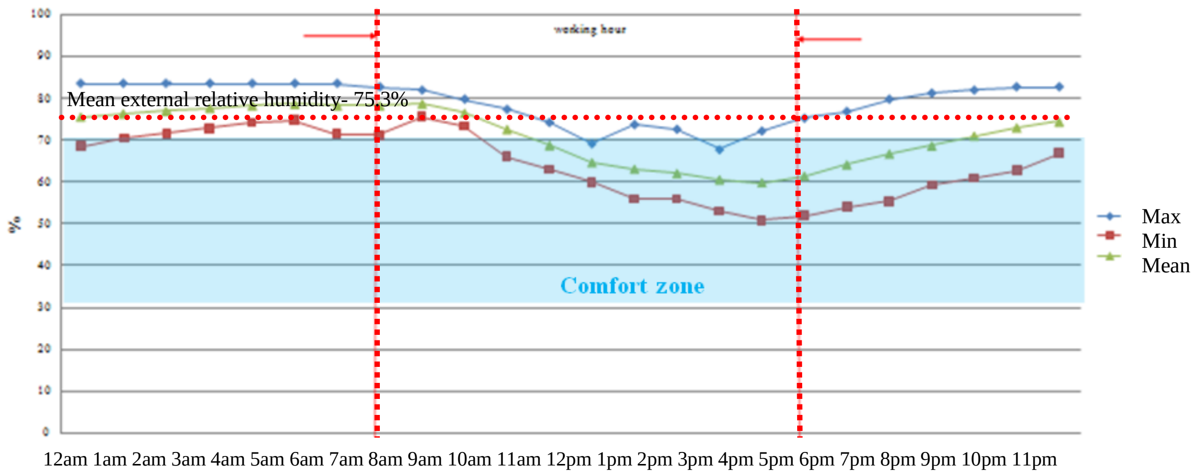


Figure 5.15(a): Graph shows relative humidity graph zone 2 with windows closed from 31 May 2010 till 14 June 2010

Figure 5.15(a) shows the relative humidity profiles of the meeting room. The relative humidity was constant in the early morning. During working hour, its percentage dropped momentarily from 50% - 83% which is lower than external relative humidity which is 59% - 100% (microclimate). This is due to the thermal capacity and the moisture adsorbed and desorbed performance of thick wall in brick building. There is critical drop of relative humidity on 31st May 2010 due to air condition is turned for meeting purpose. According to thermal comfort level proposed by Zain-Ahmed (2000), comfort level for relative humidity is 30-70%. It was noted that before working hour, relative humidity was high, >70% and above comfort level. This was due to air was accumulated in the room, plus windows were not opened, condensation occurred and consequently created high relative humidity. High relative humidity can be especially dangerous as it disrupts the body's ability to cool itself, which may lead to heat stroke. Exceptionally high relative humidity can also trigger asthma symptoms. Another unpleasant effect of high relative humidity is the appearance of mold. High relative humidity makes it easier to molds to reproduce, and they can appear virtually anywhere, damaging whatever they grow upon. It was fortunate that there is none any trace of mold found in meeting room JKR 989. For normal days, this room was used as TV room for Rumah Penghulu's visitors to watch video before going for the tour. The video is15mins in length. Thus, visitors spent a short amount of time in this room compared to BWM staffs.

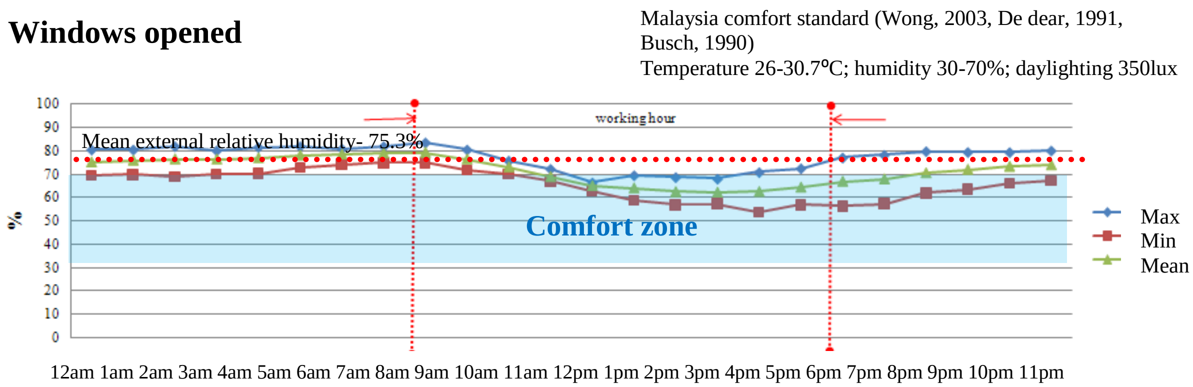


Figure 5.15(b): Graph shows humidity graph zone 2 with windows opened from 15 July 2010 till 20 July 2010

Figure 5.15(b) shows that when windows were not opened before working hour, relative humidity was at the range of 70-84% which is uncomfortable for users. When windows were opened, the relative humidity of the room dropped tremendously of 30% into the comfort level. This was the result of when windows were opened; they allowed air into the room. When there was a circulation of air, there will be evaporation occurred. This was proven by the increased of air temperature (heat gain through windows). After working hour, windows were closed for security reason, air temperature decrease and relative humidity increase. Data on 17thand 18th July were obsolete due to windows were not opened on that weekend for security reason.

5.3.4 Daylight

Table 5.5: List of illuminance requirement of a house
(Source : CIBSE, 2004)

Location	Illuminance/Lux
Living room	50
Dining	150
Reading room	350
Study	300
Kitchen	300
Bedroom	50
Hall / landing	150

Table 5.6: List of illuminance requirement
(Source : MS 1525:2007)

GENERAL BUILDING AREAS	IES STANDARDS ILLUMINATION LEVEL	MS 1525 RECOMMENDATION	PANDUAN TEKNIK JKR	NOTES
Fine bench and machine work fine sanding, finishing	750		400	
OFFICE				
General office with mainly clerical task and typing office	500	300-400	500	
Deep plan general offices	750	300-400	300	
Business machine and typing	750	300-400	300	
Filling room	300	200	300	
Conference rooms	750	300-400	300	
OFFICES AND SHOPS				
Executive office	500	300-400	300	
Computer rooms	500	300-400	500	
Punch card rooms	750	300-400	600	

The daylight was determined by measuring the absolute illuminance of interior. Previously zone 2 was used as a bedroom which refers to Table 5.5, the daylight requirement only 50lux. However, currently when this bedroom converted into a conference room, refer to Table 5.6, the minimum lighting requirement at provides visual comfort is set at 300 lux-400lux.

Windows closed

Malaysia comfort standard (Wong, 2003, De dear, 1991, Busch, 1990)
Temperature 26-30.7°C; humidity 30-70%; daylighting 350lux

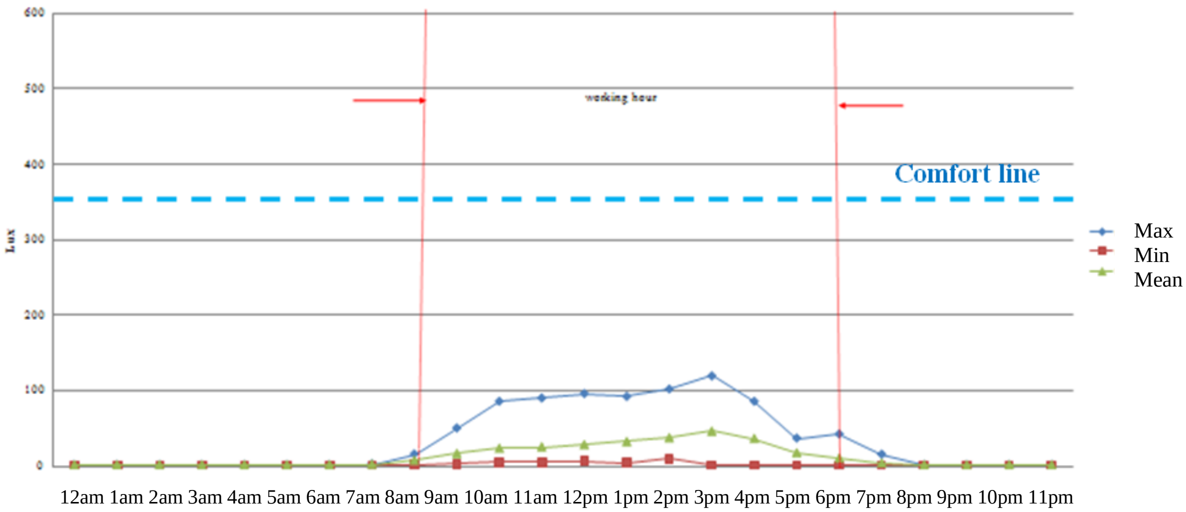


Figure 5.16(a): Graph shows Illuminance zone 2 with windows closed from 31 May 2010 till 14 June 2010

Refer to Figure 5.16(a), the illuminance levels obtained are rather low. It is noted that the measurement of the internal illuminance were done without diffuser attached to the system.

That explains why the light distribution is not very well distributed. There are days when the room was too bright which caused glare and discomfort. From the measurement, the meeting room has the highest daylighting at 11am on the 31st May 10. According to Window to wall ratio, daylight in this room is very sufficient. Thus, results from the calculation of WWR contradict with the result from measurement. This is due to additional internal shading added to windows which affect the reading. Additional artificial lighting is required to ensure sufficient lighting. There is critical increase of lighting on 31st June and 1st June due to artificial lighting which were turned on for meeting.

Windows opened

Malaysia comfort standard (Wong, 2003, De dear, 1991, Busch, 1990)
Temperature 26-30.7°C; humidity 30-70%; daylighting 350lux

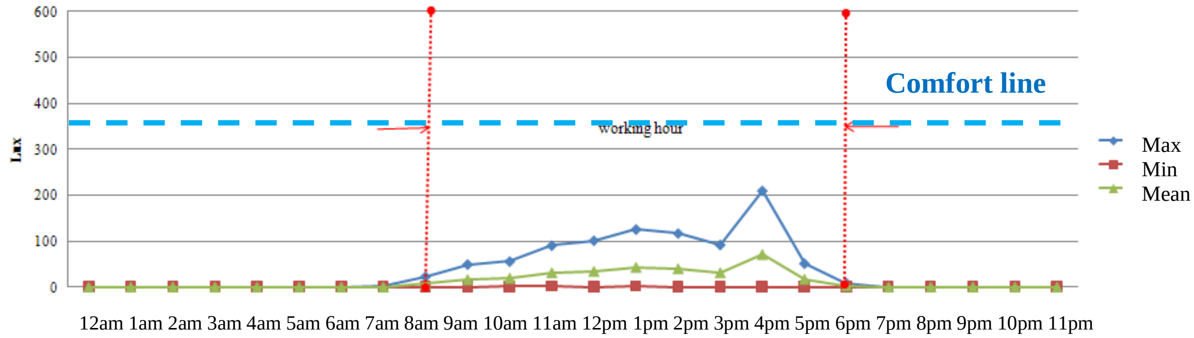


Figure 5.16(b): Graph shows illuminance zone 2 with windows opened from 15 July 2010 till 20 July 2010

Refer to Figure 5.16(b), it was noted that the illuminance level for the recorded days were very low, <100 lux. This was due to all the windows were shaded by internal blinds in order to make preparation for a talk which was conducted on 17th July 2010. The talk was conducted using screen and project screens. Thus, only data on 19th July was available and can be used for analysis purpose. This room had the highest illuminance of 210lux at 3.30pm on 19th July 10. However, this level of illuminance is considered not adequate for meeting purpose. Additional lighting are needed to be switched on when there are visitors or meeting. There is not enough natural lighting for this room due to its high ceiling, which is 8m. The amount of light penetrated into the room is insufficient to lid up the whole room. In addition, there is no light shelf install to help reflect the light. Therefore, this room was considered 'dark' when visitors enter.

5.4 Measurement Process of Indoor Thermal Condition in Zone 3 (Glass Room) of JKR 989

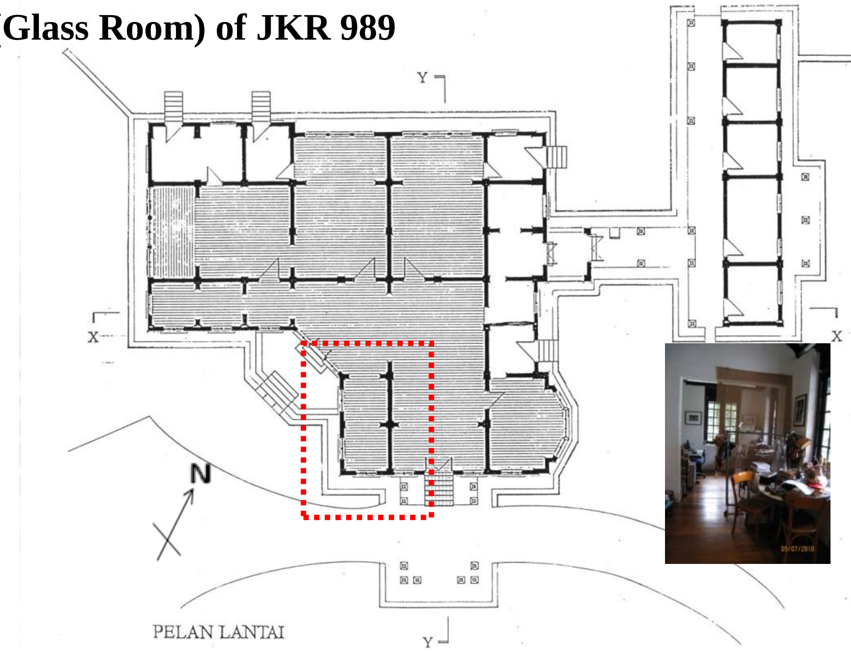


Figure 5.17(a): Floor plan JKR 989
Source: UTM, 1998

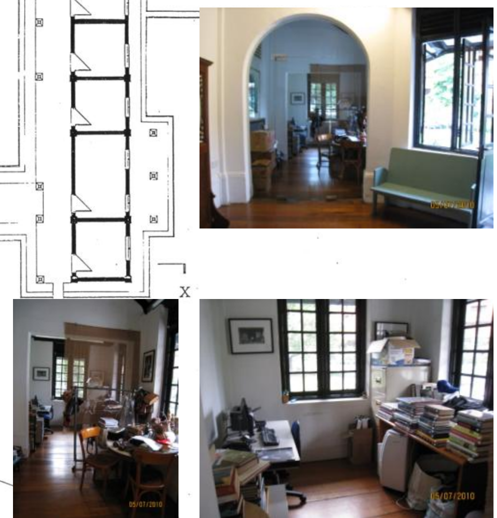


Figure 5.17(b): Exterior and interior view of glass room

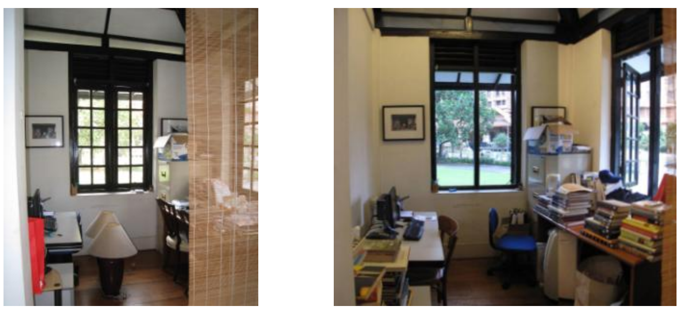


Figure 5.17(c): Location of measurement takes place

5.4.1 Description of Investigated room

Table 5.7: Zone 3 existing features

Room form	Rectangular
Ceiling height	4.2m
Dimension	5.7m (length) x 3m (width)
Floor area	17.1m²
Orientation	South West
Type of glass	clear transparent glass (5mm)
Interior walls construction	brick wall (210mm)
Interior walls finishing	plaster (25mm) with white paint
Exterior walls construction	brick wall (210mm)
Roof construction	pitched roof with Marseilles tiles
Ceiling	painted white suspended ceiling

Wall	brick wall painted white
Floor	timber plank
Ventilation	1 air condition
Windows	2 double leaf glass panel casement window with timber louvers on top and bottom and clerestory windows on top
Door	1 double leaf glass door leads to the hall
Lighting	fluorescent lighting

Experimental work was conducted in a glass room shown in Figure 5.17(a) on the ground floor of JKR 989 at No.2 Jalan Stonor. The dimension of room is: 5.7m x 3m x 4.2m height. The volume of room is 71.82m³ and its surface area is 17.1m². The room consists of interior walls, interior timber raised floor, ceiling and two exterior walls with windows area. The dimension of the window area is 3.6m². The window detail is shown in Figure 5.18. This room showed in Figure 5.17(b) and Figure 5.17(c) is normally used by BWM staff and held small meeting and it can accommodate up to 5 people. This glass room is facing to the South West.

This glass room is used from Monday till Saturday except Sunday and public holiday. The staff used this room every working day from 8am till 6pm. Normal capacity for the room is for 1 person.

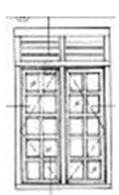
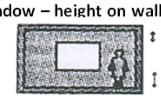
 W6	Hardwood frame double leaf glass window with fixed louvers on top
	Orientation: North East, South, South East, South West
	Opening system : swinging
	Opening dim : 1.5m x 1.2m
	Glass type: clear glass
	WWR : W6 > 0.3
	Nos: 13
	Window – height on wall  A 500mm B 800mm

Figure 5.18: Summary of window types in glass room

5.4.2 Air Temperature

Window closed

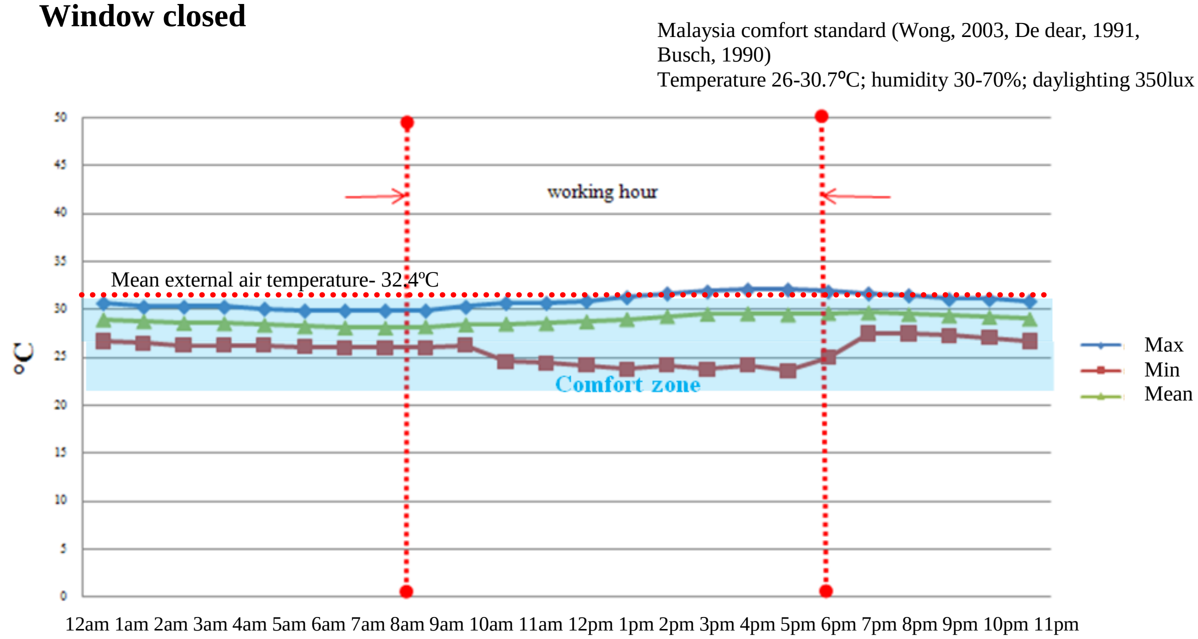


Figure 5.19 (a): Graph shows air Temperature zone 3 with windows closed from 14 June 2010 till 28 June 2010

The graph in Figure 5.19(a) shows the temperature profiles of glass room for a period of two weeks. The user of this room sometimes opened the windows for ventilation during the day time and closed them during night time. There are relationship between these users' behaviour and indoor air temperatures. Satisfied thermal comfort range that has been determined by respondents in Malaysia is 26°C- 30.7°C (Wong, 2003, De dear, 1991, and Busch, 1990).The result clearly showed that the air temperatures in the early morning, which is before working hour was much cooler than the rest of the day. During working hour, air temperature increased and between 25°C and 32°C causing thermal discomfort. Average outdoor microclimate during working hours were between 24°C and 33°C. The internal air temperature were within the range of outdoor microclimate. At night time, the room air temperature dropped within the range of 27 - 31°C. Based on the graph Fig. 5.19(a), there were 3 days in which air temperature dropped tremendously and fell under the comfort zone during the working hour, which is 17th June, 18th June and 22nd June.

Temperature on 18th June is the coolest as there was heavy rain from 4am till 8.30am (data based on microclimate).

The air conditioning was turned on for the other two days for BWM guests. The window to wall ratio for these windows have 0.33 which caused overheating to the room as they allowed too much heat inside the room. This is proven by measurement where temperature for most of the days is higher than comfort standard. Users of glass room often found that this room is hot and stuffy. Often, air conditions are turned on by the users of this room.

Windows opened

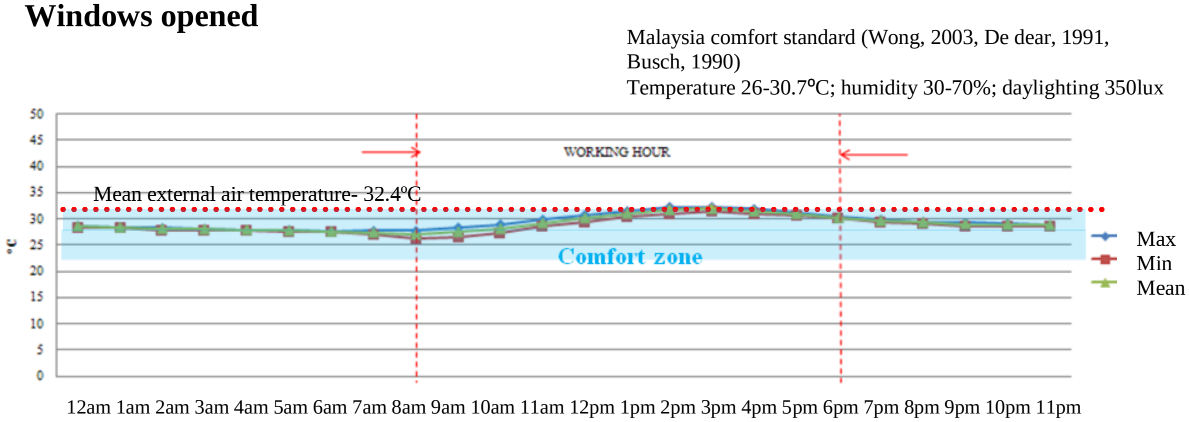


Figure 5.19 (b): Graph shows air temperature zone 3 with windows opened from 20 July 2010 till 22 July 2010

Refer to Figure 5.19(b), shows that the windows were opened between 20th July and 22nd July 2010, from 8am till 5pm. Before the windows were opened, the room temperatures were 26-28.5°C. During working hours, the windows were opened and the room air temperatures increased to a maximum of 32.5°C which can be considered extremely hot by users. This happened at 3pm. After 3pm, the indoor air temperature dropped slowly to 28.5°C at 11pm. This room has windows on South East and South West compared to zone 1 and zone 2 which caused the air temperatures in this room to be higher as more windows contribute more heat into the room. Cross ventilation relies on wind to force cooler exterior air into the building through an inlet and to force warmer interior air out of the building through an outlet. A window’s orientation to the direction of wind movement is critical to the amount of air flowing through an inlet. In inlet is useful for cross ventilation if the direction of wind flow is in the range of -45 to 45 degrees to the surface normal of the window.

As the windows located in this room showed in Figure 5.19(c) located too near to each other facing to the wind direction, cooler wind seldom enter this room. Consequently indoor air temperature increased.

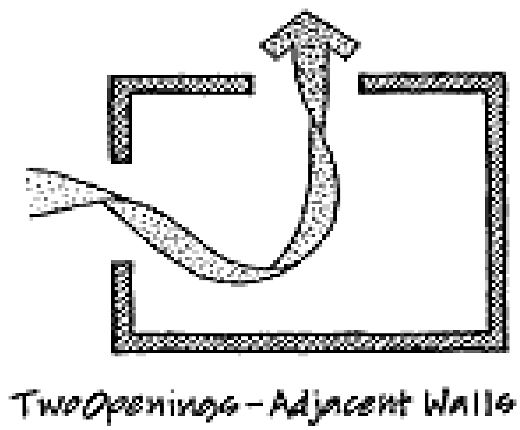


Figure 5.19(c): cross ventilation in glass room

5.4.3 Relative Humidity

Windows closed

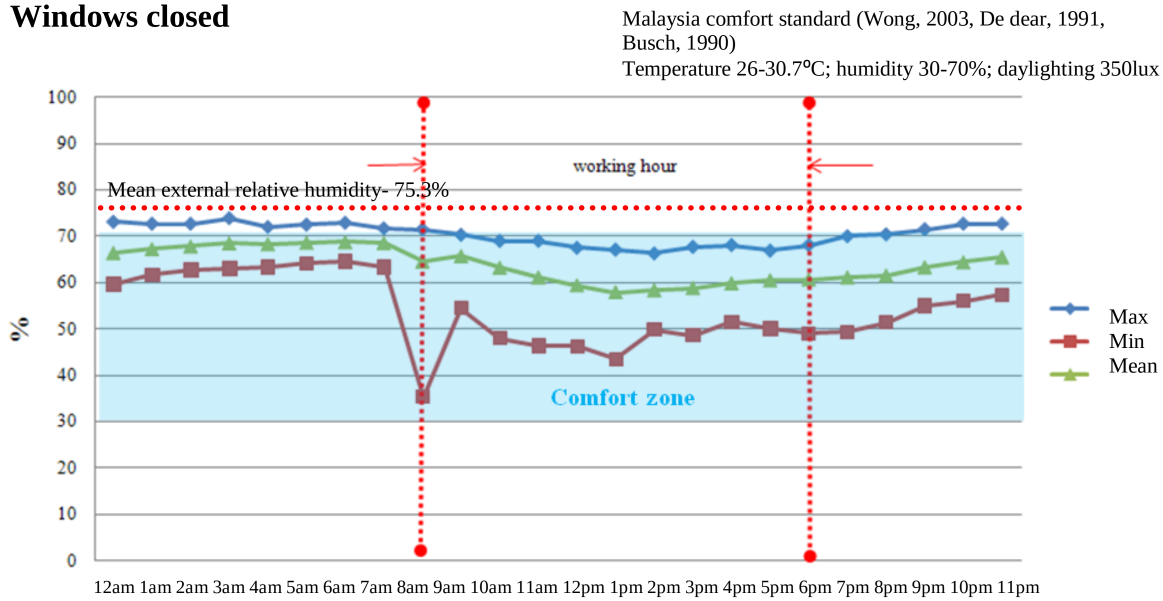


Figure 5.20(a): Graph relative humidity data zone 3 with windows closed from 14 June 2010 till 28 June 2010

Graph in Figure 5.20(a) shows the relative humidity profiles of glass room. The relative humidity was constant in the morning. During working hour, its percentage dropped momentarily from 44% - 70% which is lower than external relative humidity which is 75% (microclimate). It was noted that 22nd June has the lowest relative humidity which was 43% with air temperature of 25°C which fell under the comfort zone when the air conditioning was switched on. It proved that the switching on of air condition will affect the relative humidity of the room.

Windows opened

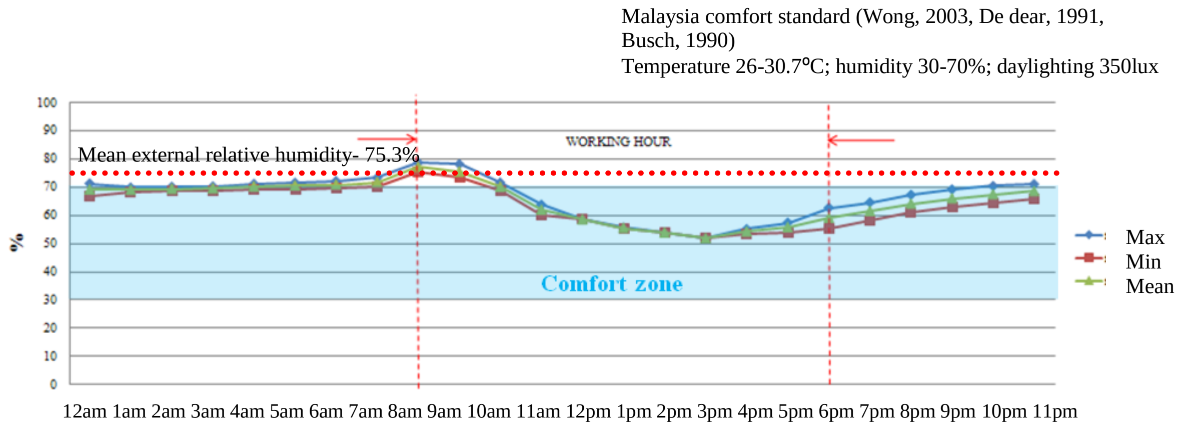


Figure 5.20 (b): Graph shows relative humidity data zone 3with windows opened from 20 July 2010 till 22 July 2010

Graph in Figure 5.20(b) shows that before 8am, the relative humidity in the room increased to 78%. After windows were opened, room relative humidity decreased from 78% to 53% which is the comfort zone. This was due to room temperature increased when windows were opened. Refer to Hanafiah(2005), *"relative humidity is a measure of the amount of water vapor contained in air at a particular temperature. It is basically a comparison between: the amount of water vapor held in the air at any one time and at a particular temperature and the total amount of water vapor which the air can hold at the same temperature, which is the amount of water saturated in the air at that temperature. Relative humidity can be written as an equation:*

RH = water vapor present in the air x 100% / water vapor required to saturate air at that temperature

As the air temperature of air increases, its capacity to contain water vapor increases. This room was used as private study room in 1950s. When Badan Warisan Malaysia takes over this house, this room was converted into an office. Many books are stored in this room. It is fortunate this room has low relative humidity, which is <80%. Incidents such as mold growth, dank smell of mildew, tiny brown spots, curled pages and insects have yet occur. However, it was advisable that the relative humidity to keep at 50% in order to protect the books and documents.

5.4.4 Daylighting

Table 5.8: List of illuminance requirement for a house
(Source : CIBSE, 2004)

Location	Illuminance/Lux
Living room	50
Dining	150
Reading room	350
Study	300
Kitchen	300
Bedroom	50
Hall / landing	150

Table 5.9: List of illuminance requirement
(Source : MS1525:2007)

GENERAL BUILDING AREAS	IES STANDARDS ILLUMINATION LEVEL	MS 1525 RECOMMENDATION	PANDUAN TEKNIK JKR	NOTES
Fine bench and machine work fine sanding, finishing	750		400	
OFFICE				
General office with mainly clerical task and typing office	500	300-400	500	
Deep plan general offices	750	300-400	300	
Business machine and typing	750	300-400	300	
Filling room	300	200	300	
Conference rooms	750	300-400	300	

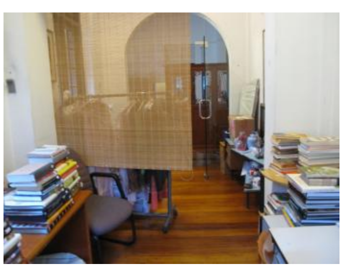


Figure 5.21: Interior of glass room

The daylight was determined by measuring the absolute illuminance of interior. The minimum lighting requirement that provides visual comfort for study room which previously used by occupants in JKR 989 by referring to Table 5.4.4(a) is set at 300 lux. Currently, this zone is used as office which refers to lighting requirement showed in Table 5.4.4 (b) should be 300-400lux.

Windows closed

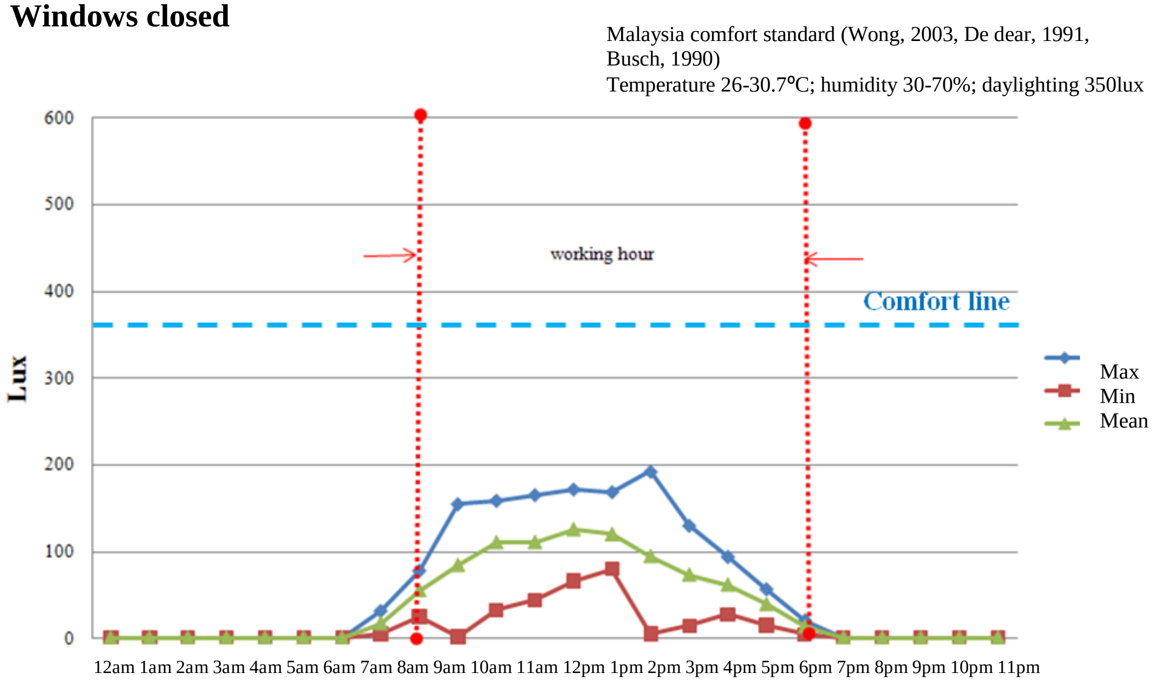


Figure 5.22(a): Graph shows Illuminance zone 3 JKR 989 with windows closed from 14 June 2010 till 28 June 2010

Referring to Figure 5.22(a), it is noted that the measurement of the internal illuminance was done without diffuser attached to the system. That explains why the light distribution was not very well distributed. From the measurement, the glass room has the highest daylighting of 200 lux at 2pm on the 23rd June 10. This is due to artificial lighting is turned on for BWM guests. According to Window to wall ratio, daylight in this room is very sufficient. This is proven true that no additional lighting is required during daytime when BWM staff is working inside the room.

Windows opened

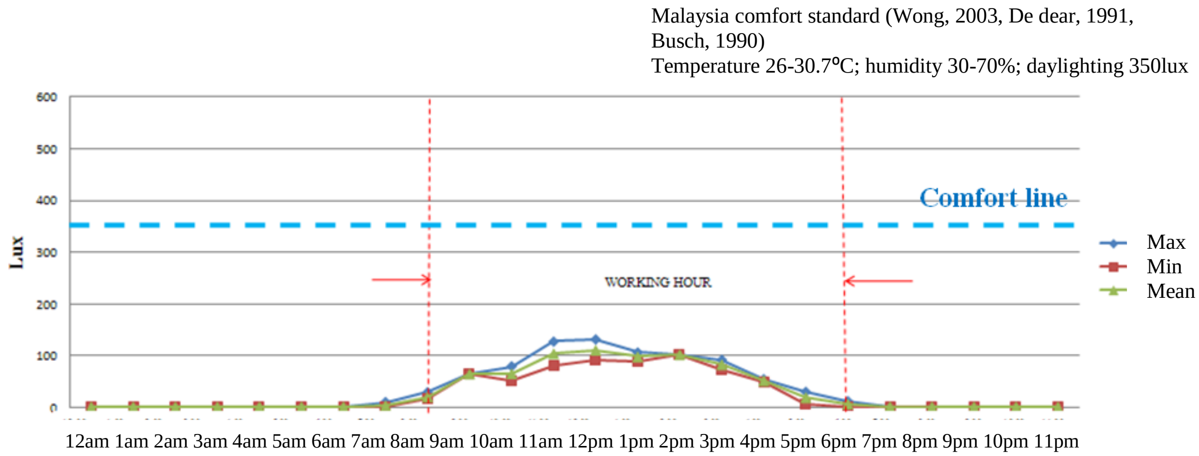


Figure5.22 (b): Graph shows illuminance zone 3 with windows opened from 20 July 2010 till 22 July 2010

Figure 5.22(b) shows that there are no lighting detected before 8am and after 7pm. When windows were opened during working hour, daylight came to a maximum of 130lux at 12pm on 21 July 10. However, it is insufficient for reading purpose. Based on recommendation from MS 1525 and Ander (2003), the ideal lighting for working is 300-400lux. This is due to many goods stored in the room which obstructed the daylight penetration into the room. All these goods were used for the bazaar sale on Oct 2010. Due to limited space in the residence, all these goods were temporary stored here.

5.5 Measurement Process of Indoor Thermal Condition in Zone 4 (Kitchen) of JKR 989

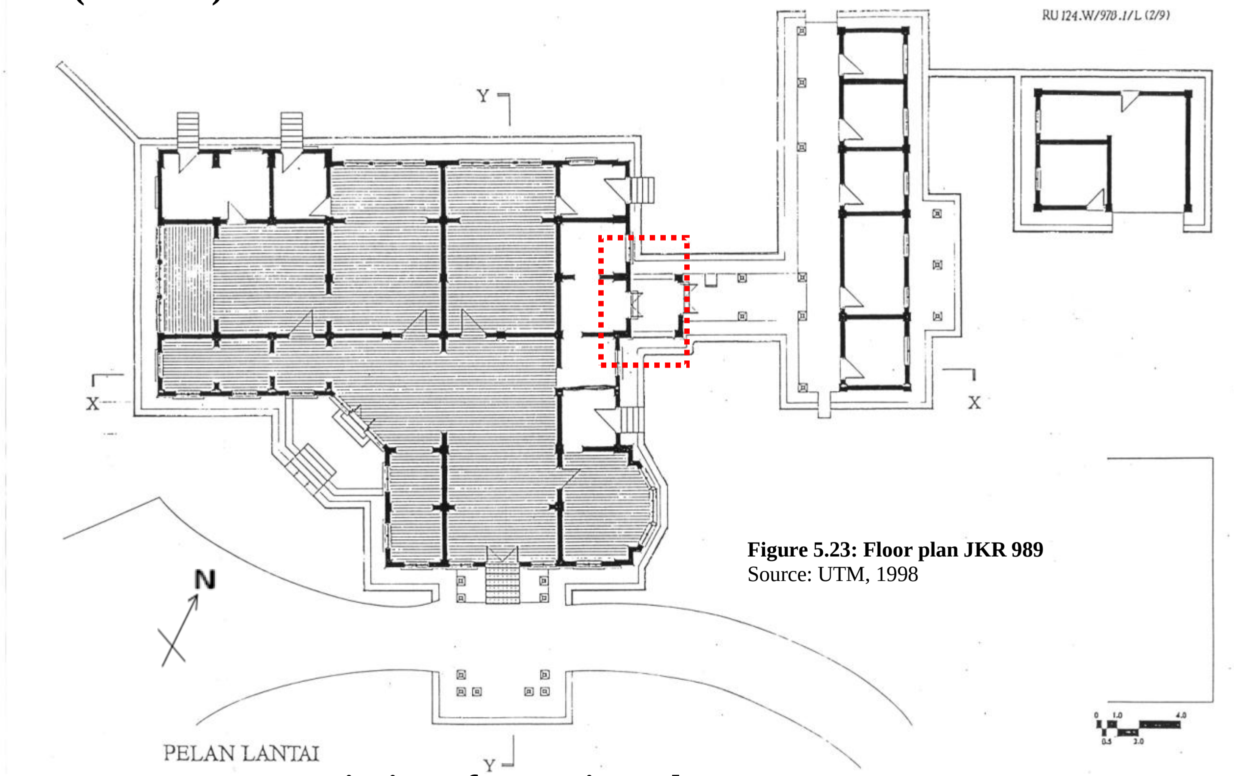


Figure 5.23: Floor plan JKR 989
Source: UTM, 1998

5.5.1 Description of Investigated room

Table 5.10: Zone 4 existing features

Room form	Rectangular
Ceiling height	3m
Dimension	3m (length) x 2.6m (width)
Floor area	$7.8m^2$
Orientation	North East
Type of glass	n/a
Interior walls construction	brick wall (210mm)
Interior walls finishing	plaster (25mm) with white paint
Exterior walls construction	brick wall (150mm)
Roof construction	pitched roof with Marseilles tiles
Ceiling	n/a
Wall	brick wall painted white
Floor	terrazzo floor
Ventilation	natural
Windows	hardwood frame mesh windows
Door	1 double leaf timber door leads to the pantry and 1 double leaf timber door leads to the servant's block
Lighting	fluorescent lighting

The experimental work conducted in the kitchen is shown in Figure 5.23 and Figure 5.24 on the ground floor of JKR 989 at No.2 Jalan Stonor. The dimension of room is: 2.6m x 3m x 3m height. The volume of room is 23.4m³ and its surface area is 7.8m². The room consists of one interior door, one exterior door, interior terrazzo floor, no ceiling exposed under roof tiles and two exterior walls with windows area. The dimension of the window area is 3.6m². Window detail is shown in Figure 5.25.This room is normally used by BWM staff to prepare food and washing purpose and it can accommodate up to 3 people. This kitchen is facing to the North East.

The kitchen is used from Monday till Saturday except Sunday and public holiday. BWM staff used this room every working day from 8am till 6pm. The normal capacity for the room is 1 person.

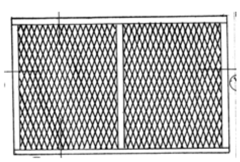
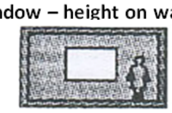
 W5	Hardwood frame mesh window
	Orientation: North West, South East
	Opening system : fixed
	Opening dim : 1.5m x 2.4m
	Glass type: -
	WWR : 0.9
	Nos: 2
	Window – height on wall  A 300mm B 1000mm

Figure 5.25: Summary of window types in kitchen

Figure 5.25 shows hardwood frame mesh window. The mesh was added for security purpose. This kitchen was naturally ventilated all day. This type of window is located both sides of the kitchen with different dimension. Windows on the sink side are lower in height compared to the opposite sides of windows. This is due to the left area (when standing in kitchen looking inward to the pantry) need to accommodate the sink and it act as a working top. Since in the old days, which is in the 1930s has yet any exhaust fan, inhabitants of this house depended on natural ventilation to drive out the smoke caused by cooking. Thus, they have large windows which are 1.5m in length on the opposite side of the sink.

5.5.2 Air Temperature

Windows opened

Malaysia comfort standard (Wong, 2003, De dear, 1991, Busch, 1990)
Temperature 26-30.7ºC; humidity 30-70%; daylighting 350lux

Figure 5.26: Graph air Temperature zone 4 from 28 June 2010 till 12 July 2010

These windows do not have any window leaf. Thus, they allowed natural ventilation into the kitchen 24hours a day. Figure 5.26 shows the air temperature profiles of the kitchen for a period of two weeks. The result clearly showed that air temperature in the early morning, which is before working hour is much cooler than the rest of the day. During working hour, the air temperature increased and varied between 25°C and 35°C causing thermal discomfort. The average external air temperature during that period of time was between 24°C and 33°C. The internal air temperature was more than the range of external air temperature. At night time, the room air temperature dropped to the range of 25 - 30°C. Based on the graph, there were 4 days which the air temperature increased tremendously to 45°C during the working hour, which was 29th June, 30th June, 2nd July and 5th June. Data for these four days should be obsolete as the BWM janitor accidentally placed a hot kettle near the instruments. The night time temperature is slightly higher compared to the early morning air temperature. The window to wall ratio for windows are 0.9 caused overheating to the room as they allowed too much heat inside the room. This is proven by measurement where temperature for most of the days is higher than comfort standard. Users of the kitchen often found that this room hot. Normally, users do not prefer to stay long in the kitchen.

5.5.3 Relative Humidity

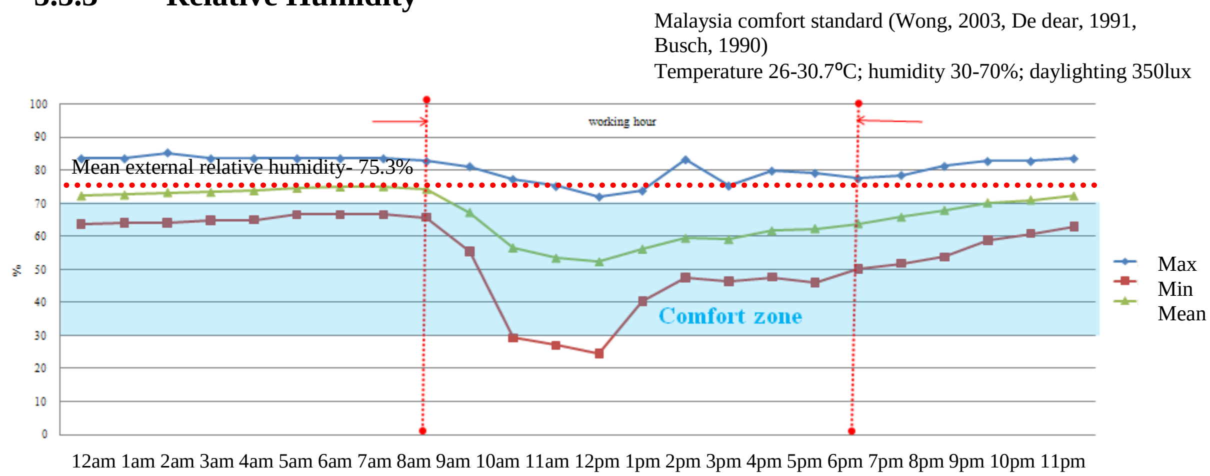


Figure 5.27: Graph humidity of zone 4 from 28 June 2010 till 12 July 2010

Figure 5.27 shows the relative humidity profiles of the kitchen area. The relative humidity was constant in the morning. During working hour, its percentage dropped momentarily from 82% to 28% which is lower than external relative humidity, 75.3% (microclimate). Data on 29th June, 30th June, 2nd July and 5th July are obsolete due to technical error. On 7th July has the highest humidity, 82% due to heavy rain (microclimate).

5.5.4 Daylighting

Table 5.11: List of illuminance requirement of a house
(Source : CIBSE, 2004)

Location	Illuminance/Lux
Living room	**50**
Dining	**150**
Reading room	**350**
Study	**300**

Kitchen	**300**
Bedroom	**50**
Hall / landing	**150**

Table 5.12: List of luminance requirement
(Source : MS 1525:2007)

GENERAL BUILDING AREAS	IES STANDARDS ILLUMINATION LEVEL	MS 1525 RECOMMENDATION	PANDUAN TEKNIK JKR	NOTES
Operating area				
Recovery room and intensive care units	30-50		bedhead	
X-ray department radio-diagnostic and rooms fluoroscopy	500		500	
Dental surgeries				
HOMES				
Living rooms general	50		50	
Casual reading	150		150	
Sewing darningsrudies desk and protuged	300		300	
Bedroom general	50		50	
Bedlead kitchen	150		150	
Kitchen working areas				

The daylight level was determined by measuring the absolute illuminance of interior. The minimum lighting requirement that provides visual comfort shown inTable 5.10 is set at 300 lux and shown in Table 5.11 is set at 150 lux. The illuminance levels obtained were high. From the measurement shown in Figure 5.28, the kitchen has the highest daylighting level of 550 lux from 8.30am – 1pm. According to Window to wall ratio, daylight in this room is very sufficient. This is proven true that no additional lighting is required during the daytime when BWM staff is working at this space. As this kitchen no longer served as a kitchen, it is now used as pantry where users only boiled water, prepare drinks and light food at that area, thus, not much lighting is needed for that area.

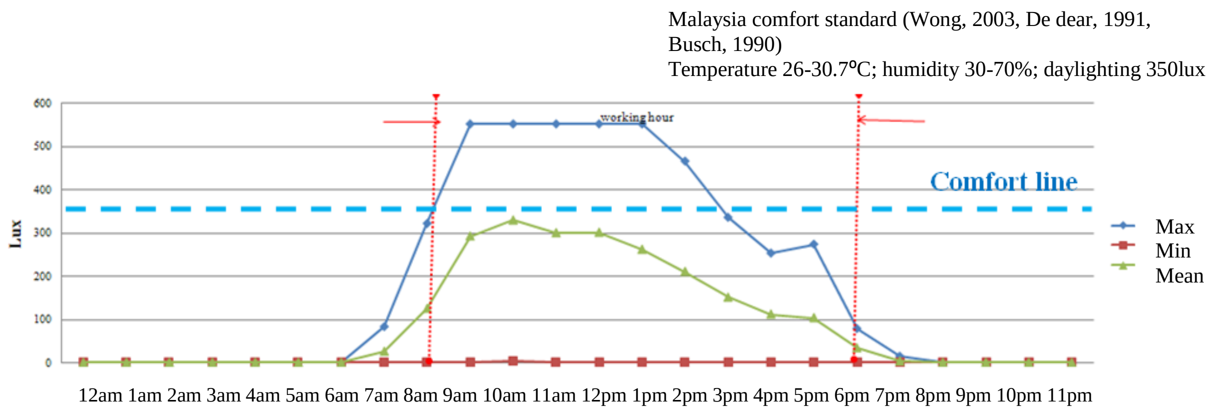


Figure 5.28: Graph daylighting of zone 4 from 28 June 2010 till 12 July 2010

5.6 Summary of field study 1

- Four zones were located at different orientation. Zone 1 was located at North East, zone 2 at North West, zone 3 at South West, zone 4 at North East. Zone 1 and zone 3 had higher air temperatures compared to other zones. Overall result of air temperatures showed zone 1 and zone 3 have gained more heat than other zones.

- It is noted that from window to wall ratio calculation, windows in zone 1 had the closest match to the optimum ASHRAE standard compared to other zones which are overheated (>0.3). This finding had been strengthened by the field measurement result that showed on the air temperature feedback pattern.

- Air Temperature :

  a. Results showed that when windows were opened, Zone 1 located at North East and zone 4 at North East were overheated as the internal temperature recorded exceeded average outdoor air temperature range and thermal comfort range.

  b. When windows were closed, it is noted that zone 1 located at North East also had the highest temperature while zone 3 oriented at South West had the lowest temperature.

c. There is slight difference of air temperature when windows were opened and closed. When windows were opened, the air temperature recorded showed higher reading. This situation happened at all the zones except zone 2 where the internal air temperatures were higher when windows were closed.

- Relative Humidity

  a. Measurement result while windows opened showed zone 3 had the highest relative humidity while zone 4 had the lowest relative humidity.

  b. When windows were closed, zone 2 had the highest relative humidity while zone 3 had the lowest relative humidity.

  c. There is difference in result on relative humidity measurement with windows opened and closed. When windows were opened, the air temperature increased and the relative humidity should decrease. This situation applied to zone 1 and zone 4 but not in zone 2 and zone 3. Relative humidity increased when windows were opened compared when windows were closed. This is as the internal heat gain was higher for zone 2. As for zone 3, it is oriented facing to a water feature at neighbor's building. The openable of windows at zone 3 will invite the relative humidity into the room.

- Daylighting

  a. When windows were opened, zone 1 and 4 had the highest amount of daylighting compared to zone 3 which had the lowest amount of dayligthing penetrated into the room

  b. When windows were closed, zone 3 had the highest amount of daylighting and zone 1 had the lowest amount of daylighting

c. There is a different amount of daylighting penetrated into the room when windows were closed and opened. It is noted that when windows were closed, alot of daylighting were reduced by 5mm thick clear glass except for windows in zone 3. This shows that dayligthing at zone 3 is not solely from the windows but from the internal space of living as there is no partition between this room with the living area.

5.7 The evaluation of micro climate impact on indoor thermal comfort

The location of measurements zone was showed in Figure 5.7. BABUC was used to measure the indoor environment of zone 2. Indoor parameters that were measured by BABUC included temperature, relative humidity, air velocity and dayligthing. In addition, BABUC also provided measurement of Predicted Mean Vote (PMV) and Predicted Percentage Dissatisfied (PPD) of occupants in zone 2, JKR 989 based on ASHRAE thermal sensation scale. HOBO data logger was used to measure the external condition of JKR 989 (microclimate). External parameters that were measured by HOBO data logger included air temperature and relative humidity. Indoor environmental conditions were measured at a height of 1m above floor level at centre part of the room. All data were recorded at intervals of 5 minutes.

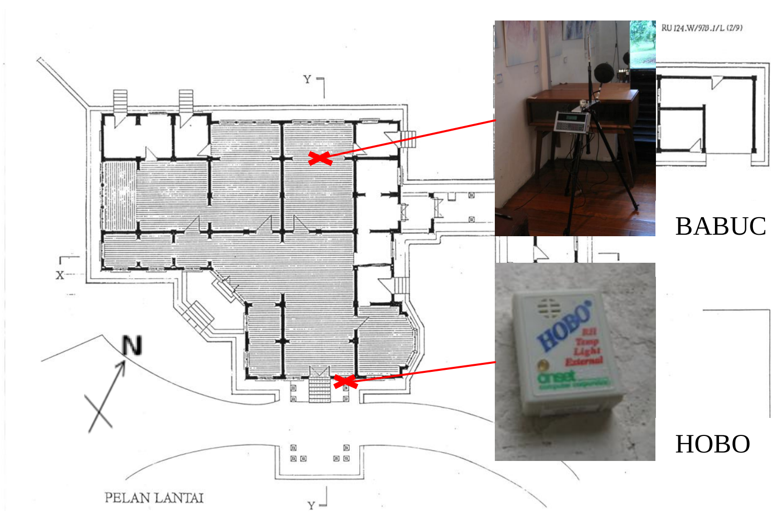


Figure 5.29: Floor plan of JKR 989

5.7.1 Measurement result of micro climate data of JKR 989

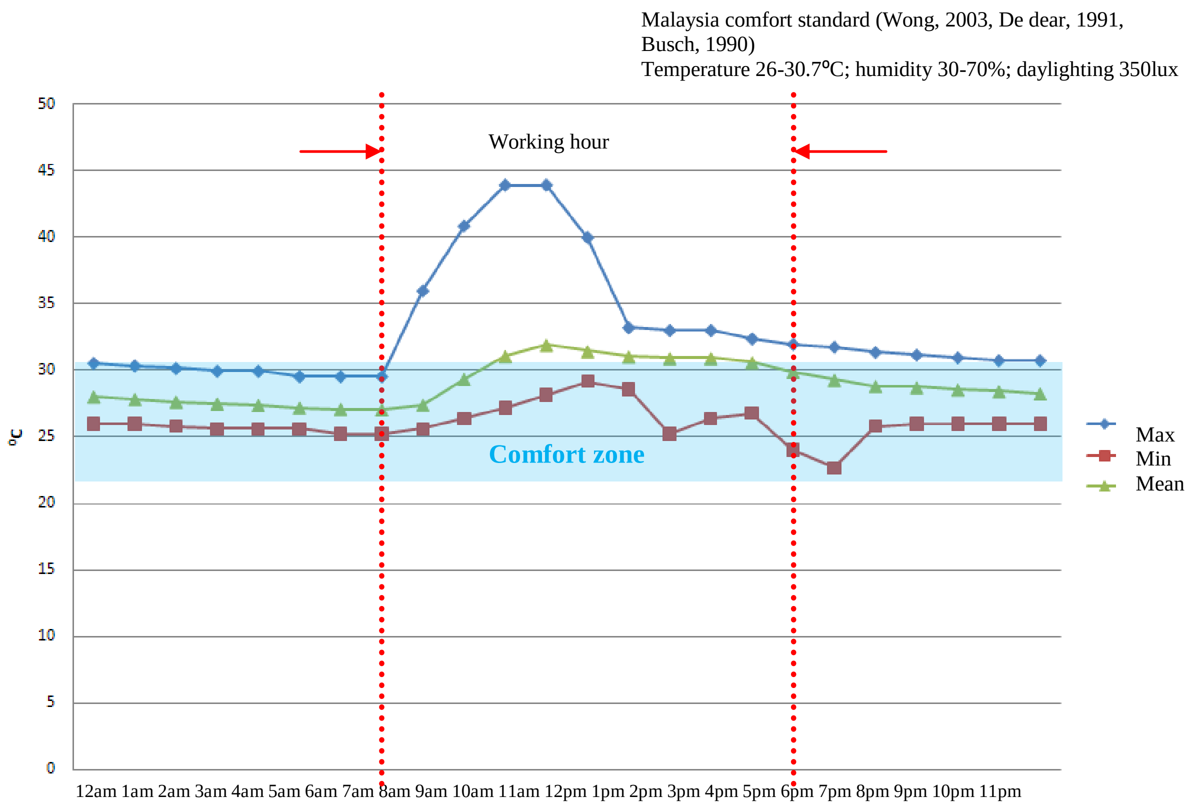


Figure 5.30(a): Graph of microclimate- air temperature of JKR 989 from 28 June 2010 till 23 July 2010

Graph of Figure 5.30(a) shows microclimate of JKR 989 on 28th June 2010 till 23rd July 2010. It shows that temperature is constant at 25-30°C before working hour. Data from 28th June till 2nd July showed there is a tremendous increase of temperature to 42°C. When compared the microclimate data with macroclimate data of Kuala Lumpur obtained from Meteorology Department Malaysia which is shown in Table 5.13, it shows that microclimate air temperature and relative humidity is higher compared to overall climate in Kuala Lumpur. This is due to JKR 989 is surrounded by high rise buildings which created heat island effect at the surrounding.

Table 5.13: Detail of climate

Condition	Lowest Macroclimate	Lowest Microclimate	Highest Macroclimate	Highest Microclimate
Temperature	23°C	22.7°C	32°C	42°C
Relative Humidity	59%	60.5%	100%	90%

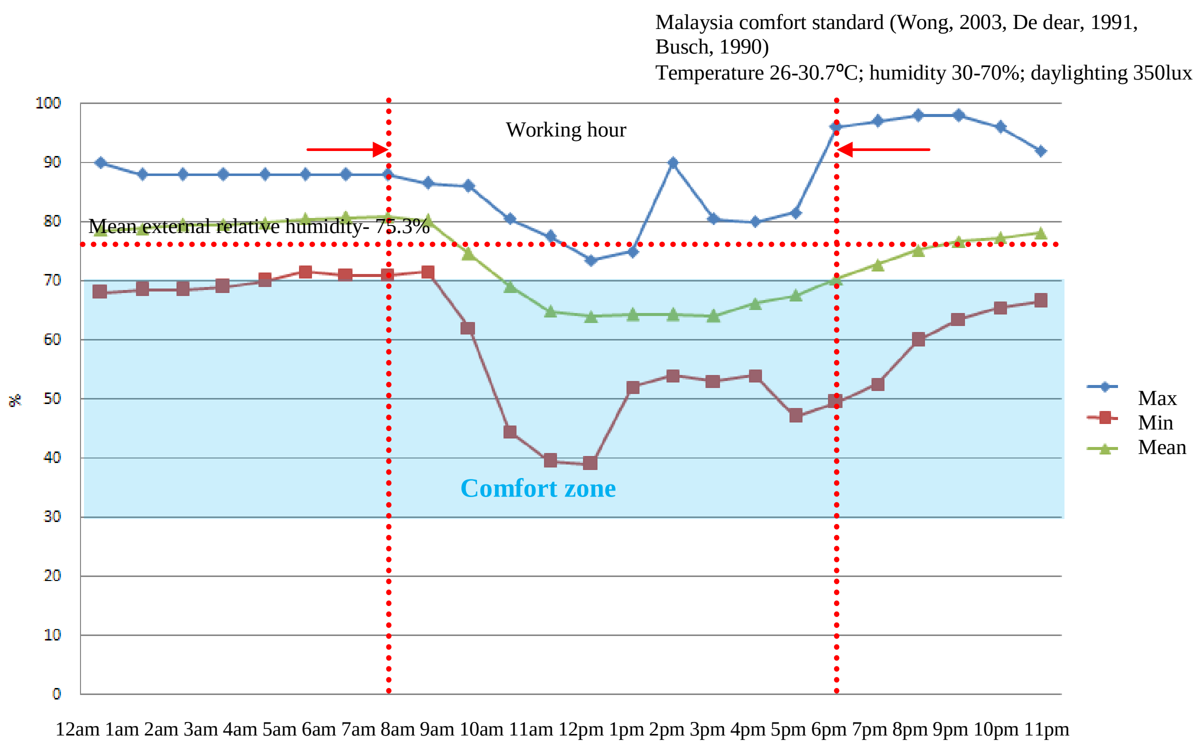


Figure 5.30(b): Graph of microclimate- relative humidity of JKR 989

Graph of Figure 5.30(b) shows the humidity profiles of meeting room. The relative humidity was constant in the morning. During working hour, its percentage dropped momentarily from 60% - 75% which is lower than external humidity which is 59% - 100% (Climatology Department Malaysia). This is due to the thermal capacity and the moisture adsorbed and desorbed performance of thick wall in brick building. There is critical increase of relative humidity on 7th July 2010 due to air condition is turned for meeting purpose and this data had been superceded. According to thermal comfort level proposed by Zain-Ahmed (2000), comfort level for humidity is 30-70%.

5.7.2 Measurement result of average maximum, mean and minimum indoor thermal comfort factors of temperature, air velocity and relative humidity

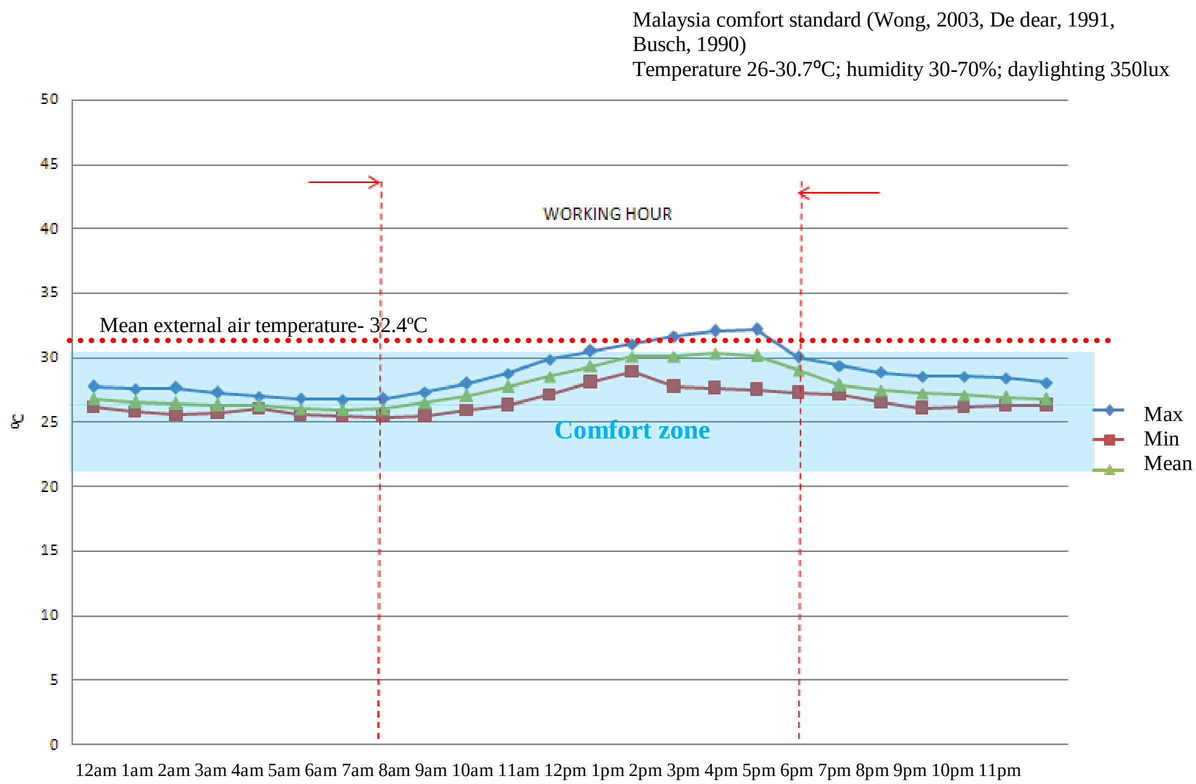


Figure 5.31 (a): Graph of air temperature for meeting room, JKR 989 from 19 July 2010 till 23 July 2010

Graph of Figure 5.31(a) shows indoor temperature from 19th July 2010 till 23 July 2010 of meeting room. Before working hour, the air temperature was under 28°C. During working hour, the windows were opened and the air temperature increased tremendously from below 28°C to 32°C. No air conditioning was turned on during the evaluation period to prevent variable. However, the indoor air temperature were within the outdoor temperature range. After working hours, the windows were closed and the air temperature dropped to below 29°C. This means that during working hour, the indoor temperature is higher than standard comfort parameter for users. On 20th, 21st and 22nd July, the air temperature dropped significantly due to rain. On 20th July, it rained from 3.30pm till 8.30pm (5hours) heavily. On 21st July, light rain started in the morning from 7.30am till 8.30am (1hour). On 22nd July, it rained heavily from 2.00pm till 6pm (4hours). The rest of the days were sunny.

Users were uncomfortable and were living in a thermal environment below the accepted thermal comfort standard. Consequently, air condition needed to be turned on for every meeting held in the evaluated space.

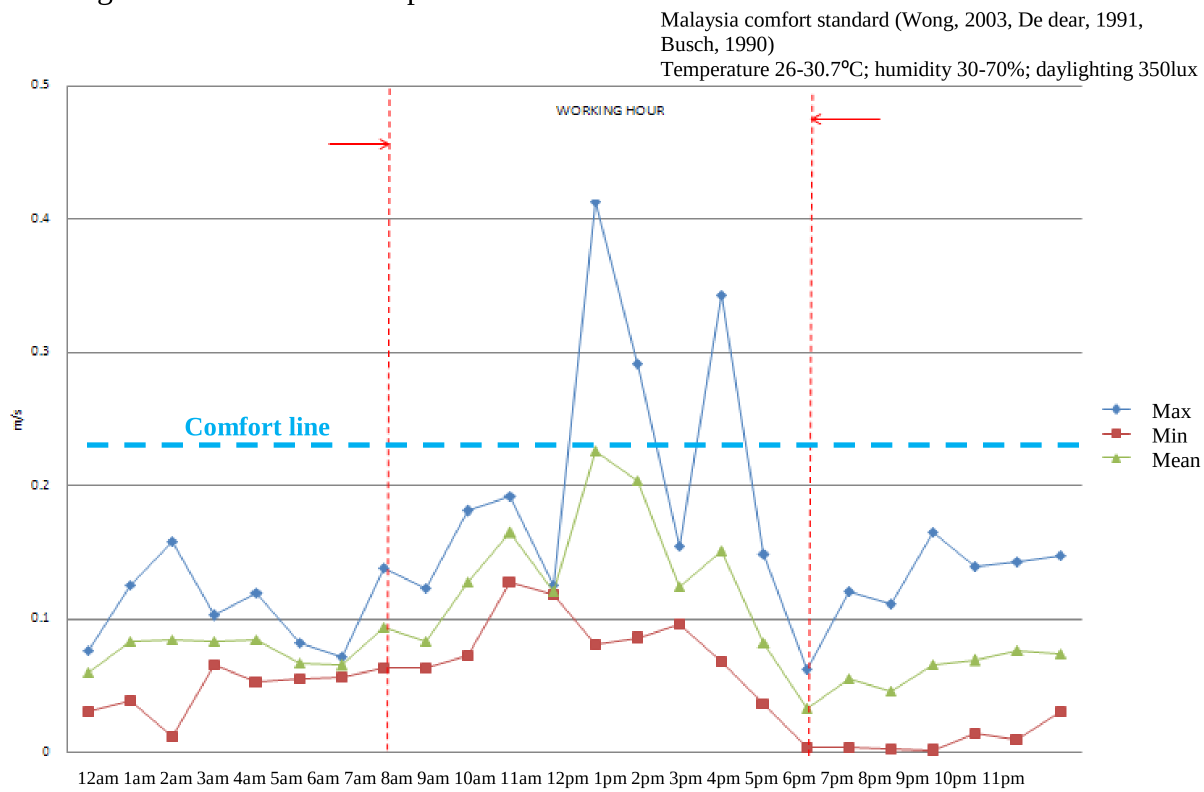


Figure 5.31(b): Graph air velocity of meeting room, JKR 989 from 19 July 2010 till 23 July 2010

Graph in Figure 5.31(b) shows wind speed pattern in the meeting room from 19th July 2010 till 23rd July 2010 captured by BABUC indoor climatic data sensor. Before the working hours, the windows were closed, and the ventilation of the room depended on louvers located at the bottom of the windows. Thus, air velocity was very low, which was below 0.15m/s. when the windows were opened, air speed began to increase to 0.25m/s at 12pm, then dropped to nearly nil at 5pm. After working hour, the windows were closed and wind speed increased to 0.15m/s. this is due to night ventilation. On 23rd July 2010, the wind speed increased to 0.42m/s (which was the peak for that evaluation week). The results show that the most critical problem found in this study was the lack of air movement in the room. The overall wind speed showed during the evaluation days was 0.10m/s. When the room is used, it can cause uncomfortable due to low air movement velocity.

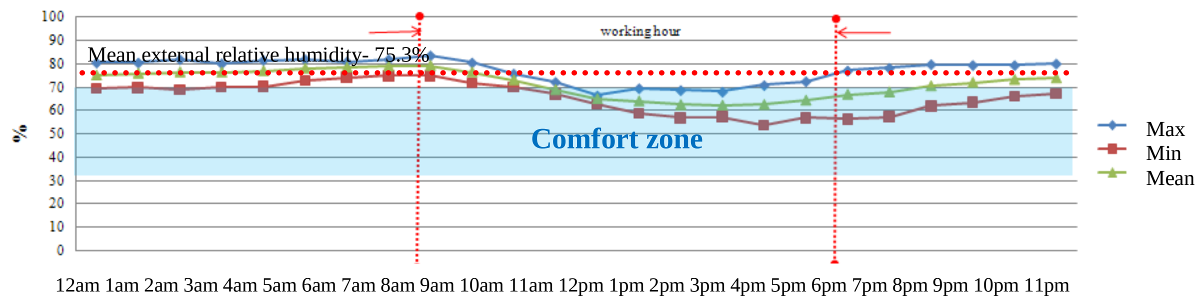


Figure 5.31(c): Graph relative humidity of meeting room, JKR 989 from 19 July 2010 till 23 July 2010

Graph Figure 5.31(c) shows that before working hour, the relative humidity is within the range of 65%- 80%. The windows were not opened before working hours. During working hours, the windows were opened and the relative humidity dropped to comfort zone (which is within 30-70%, Malaysian comfort in relative humidity). When the windows were closed after working hour, the relative humidity range were still within comfort zone.

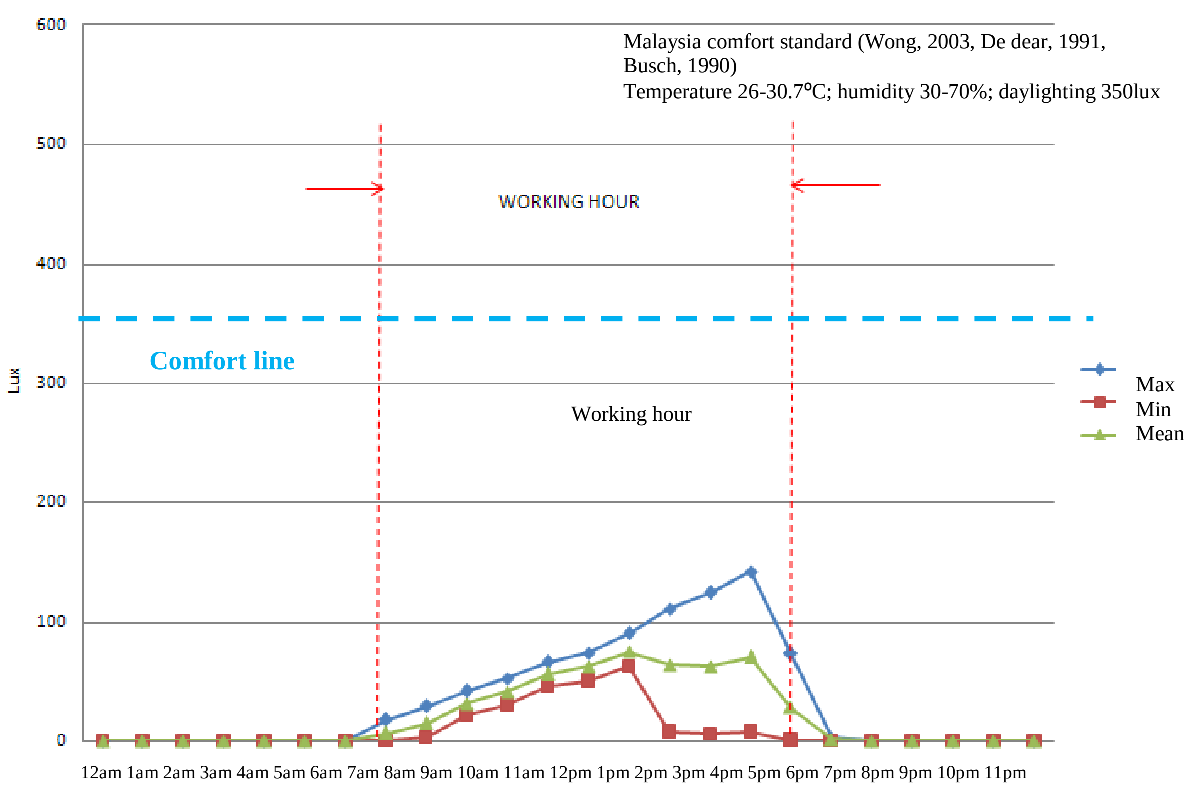


Figure 5.31(d): Daylight meeting room, JKR 989 from 19 July 2010 till 23 July 2010

Refer to study done by Bowyer (1980), *"in large measure, the art and science of proper daylighting design is not how to provide enough daylight to an occupied space, but how to do so without any undesirable side effects. It involves more than just adding windows or skylights to a space. It is the careful balancing of heat gain and loss, glare control, and variations in daylight availability."* For example, successful daylighting designs will invariably pay close attention to the use of shading devices to reduce glare and excess contrast in the space. Additionally, window size and spacing, glass selection, the reflectance of interior finishes and the location of any interior partitions will be evaluated. This meeting room does not have any internal partitions to block the daylight. Only blinds were found to reduce the amount of lighting penetrated into the room. However, refer daylighting showed in Figure 5.31(d), this room has very low illuminance level. This is due to the huge volume of the space and the openings were inadequate to allow sufficient daylight into the room. Before working hour, daylight is almost nil. During working hour, windows were opened; the luminance level was within 60-110 lux (which considered not sufficient for meeting purpose, 300-400lux). Additional lighting is needed to brighten the room. On 23rd July 2010 at 4pm, the openings allowed 140lux of daylight to penetrate into the room. As this room is facing to the North West, the high illuminance usually occurred in the evening. Although there are clerestory windows in this room, these windows do not contribute in daylighting as they are louvered windows which only allow ventilation.

5.7.3 Predicted Mean Value & Predicted Percentage of Dissatisfied

Table 5.14: Results of PMV and PPD

Session	Operative Temp	PMV	PPD
9.00-9.15am	27.3	0.9	22.1
12.00-12.15pm	28.6	1.1	30.5
3.00-3.15pm	29	1.3	40.3

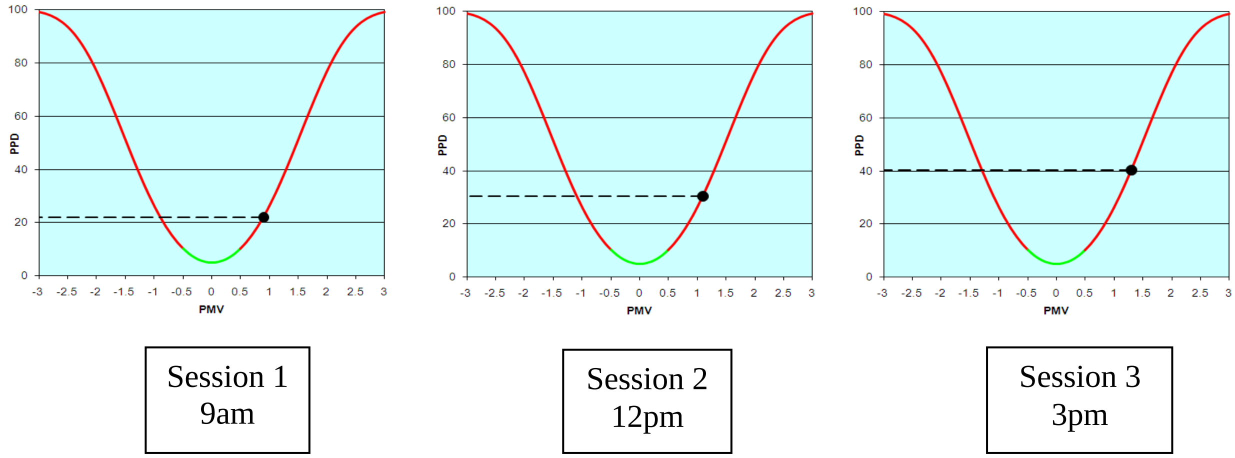


Figure 5.32: Graph Predicted Mean Value – Predicted Percentage of Dissatisfied for different sessions

The thermal comfort of the occupants were assessed using ASHRAE thermal sensation scale using Predicted Mean Vote (PMV) which has been proposed by Fanger (1970). Further Predicted percentage dissatisfied (PPD) was used to estimate the thermal comfort satisfaction of the occupants. Finally, the PPD versus PMV were plotted to present the thermal comfort scenario of occupants in JKR 989 as shown in Figure 5.32. Predicted Mean Vote (PMV) is one way to quantify the comfort level achieved in a space. PPD diagrams clearly show a high ratio of dissatisfied people. The subjective thermal votes of the meeting room under survey are appropriate. Details of the survey will be explained further in chapter 6. The result for sensation vote towards thermal comfort is shown in table 5.14. The thermal comfort assessment which shows from the Predicted Mean Value (PMV) index and Predicted Percentage of Dissatisfied (PPD) in Table 5.14 was not in the comfort zone due to the Predicted Mean Value (PMV) index is at the range of 0.9-1.3. The Predicted Percentage of Dissatisfied (PPD) value were also low from 22.1%-40.3% which means the majority of the occupants were dissatisfied. The Predicted Percentage Dissatisfied (PPD) was calculated from Predicted Mean Value (PMV) which predicts the percentage of people who would likely to be dissatisfied with a given thermal environment.

Thermal comfort standard requires that the PPD to be less than 10% to correspond to Predicted Mean Value (PMV) of between -0.5 and 0.5. However, most of the calculated Predicted Mean Value (PMV) values exceeded the recommended thermal comfort requirements. PMV showed that satisfaction of occupants is at the range of -0.5-0.5. PMV at 9am is 0.9 which indicated occupants dissatisfied; at 12pm PMV is 1.1 and at 3pm PMV is 1.3 which is very dissatisfied compared to the morning session. If PPD is less than 10%, which means the occupants is satisfied with the condition in zone 2. However, results showed that occupants are very dissatisfied especially at 3pm on the heat penetrated into the room.

5.7.4 Summary of evaluation study on micro climate impact on indoor thermal comfort selected zone in JKR 989

Table 5.15: Summary of maximum, minimum and mean indoor and outdoor measurement result

Items	Min		Mean		Max	
	Outdoor	Indoor	Outdoor	Indoor	Outdoor	Indoor
Air Temperature (°c)	22.7	28	32.4	30	42	32
Relative Humidity (%)	60.5	65	75.3	72.5	90	80
Air Velocity (m/s)	-	0.10	-	0.26	-	0.42
Daylighting (lux)	-	60	-	85	-	110

- When the mean indoor air temperature higher than the mean outdoor, overheating may occur. From the measurement result is the minimum air temperature for indoor was higher than external. Minimum air temperature occurred during night time. As JKR 989 has a very thick wall which is 210mm, it can store heat during day time. When at night, the heat stored in the wall released and consequently affected the internal air temperature.

- Table 5.15 shows the min, mean and maximum air temperature in JKR 989 during the month of July- the hottest according to the meteorological records. It can be seen that the mean outdoor air temperatures is above comfort levels which should be at 26-30.7°C.

- The result of indoor and outdoor mean relative humidity are also above the comfort levels which should be between the range of 30-70%.
- The result showed that the mean indoor air temperature is 2.4°C lower than the outdoor mean air temperature.

5.8 Computer simulation

Decision made at the early stage of a building design often has a significant impact on the internal environment of a building. Although many buildings have natural cooling strategies embedded in their conceptual design, it is seldom that these concepts would be fully analysed at the initial design stages. In this study, the zone 2 (meeting room) of JKR 989 is presented as an example to explore an approach, which uses building simulation to evaluate the performance of different window design available in an integrated manner in order to assist the delivery of an effective window design in a residential building.

To be able to achieve this aim, the simulation software AIOLOS is used to conduct a series of sensitivity analysis to find the optimum model, dimension and position with suitable glazing properties on a set of design parameters for a window design available in JKR 989 which have good prospects of influencing the indoor thermal comfort of inhabitants. The parameters include natural ventilation scheme integrated with window type and opening area and how they are positioned. The purpose of this study is to support the previous findings in order to strengthen the research findings. The sequence of the simulation approach, from the selected program, acquiring required data, and analysis criteria are explained below.

AIOLOS was selected to perform this case study as it allowed a thermal model for the assessment of the impact of various natural ventilation strategies on the thermal behaviour of the building. In order to account the airflow rate in natural ventilation application, a sensitivity analysis for the width of windows in the software was used. Comprehensive facilities provided by AIOLOS offer possibility to analyze air flow, air changes and sensitivity of air flow rate per each window aspect in relative short time without reconstruction of the model.

5.8.1 Simulation Inputs and assumption

The simulation was run for a period of 3 days, from 17/7/2010 till 19/7/2010. The measured average inside and outside temperature were taken as boundary conditions, together with wind speed and direction at a height of 1meter, and the following assumptions were made:

- 10 large vertical windows, simulating the casement windows in the facades
- Pressure coefficient from '*Window design for natural ventilation in tropics*'(Source: Chand, 1986)
- Windows open

In zone 2, a mixed mode ventilation strategy was used. In the mixed mode scenarios mechanical ventilation operated between 0730- 1730 when the room is occupied. This operation was used to bypasses the heat exchanger. Then this system operated, it ran at a specific fan power of 2 m/s.

Zone 2 (meeting room) as showed in Figure 5.8.1 was selected to conduct the simulation test due to the following criteria:

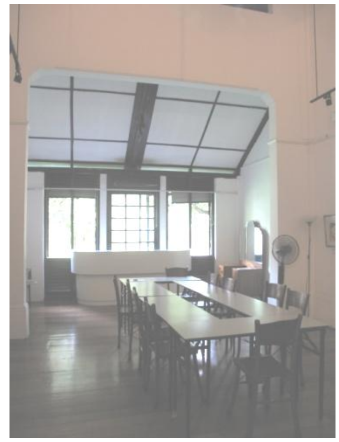


Figure 5.33: Interior of Zone 2

a. High ceiling
b. Clerestory louvered windows
c. Different volume within one space
d. No compartment in-between

All these windows were made of clear glass.

5.8.2 Simulation Procedure

This study proposed 10 window models as showed in Figure 5.32 for the whole residence. First model is window with hardwood frame fixed window with louver on top. Second model is casement window with louver on top and bottom. Third model is timber window with louver on top. Forth model is fixed window with louver on top. Fifth model is mesh window. Sixth model is casement window with louver on top. Seventh model is fixed window with louver on top. Eighth model is fix window. Ninth model is casement window with louver on top. Tenth model is adjustable glass louver window.

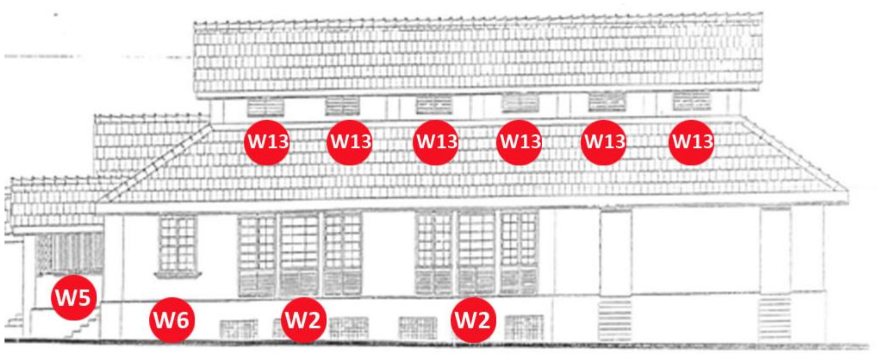
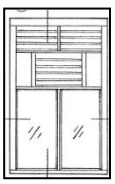
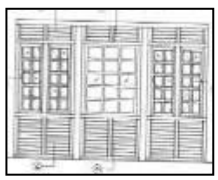
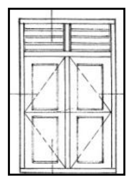
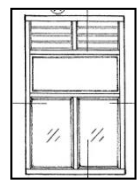
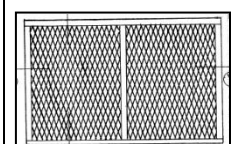
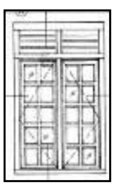
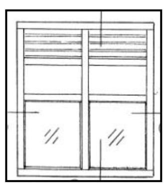
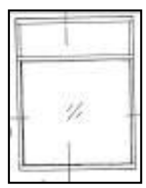
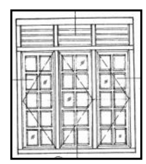


Figure 5.34: Rear elevation of JKR 989

W1 	**W2** 	**W3** 	**W4** 	**W5** 
 **W6**	 **W7**	 **W8**	 **W9**	 **W10**

Above is the window designs available in JKR 989 with W2 is the existing window for zone 2.

5.8.3 Air flow

As the building need to minimize active cooling system, it is important that internal heat gains are controlled to mitigate overheating. The purpose of justifying the airflow rate is to test which zone's windows affect the pattern of air velocity. This simulation test was done on 3 consecutive days with very similar climatic conditions with internal door closed. The ventilation pattern is stack ventilation.

Variable : windows

Invariable : orientation, zone, height, area of the room, volume space

5.8.4 Process simulation

Climatic data stated in software were edited in order to suit our climate. 3 consecutive days from 17th July 2010 till 19th July 2010 climate data: include air temperature, wind direction and wind velocity obtained from Climatology Department Malaysia were used to replace existing list of Climatic Data appeared in software.

For this simulation test, only one room is tested (meeting room). Volume, indoor air temperature and area of the room are constant. Then, the dimension of each window which is tested were inserted into the simulation in order to calculate the airflow and air exchange rate as shown in Figure 5.35.

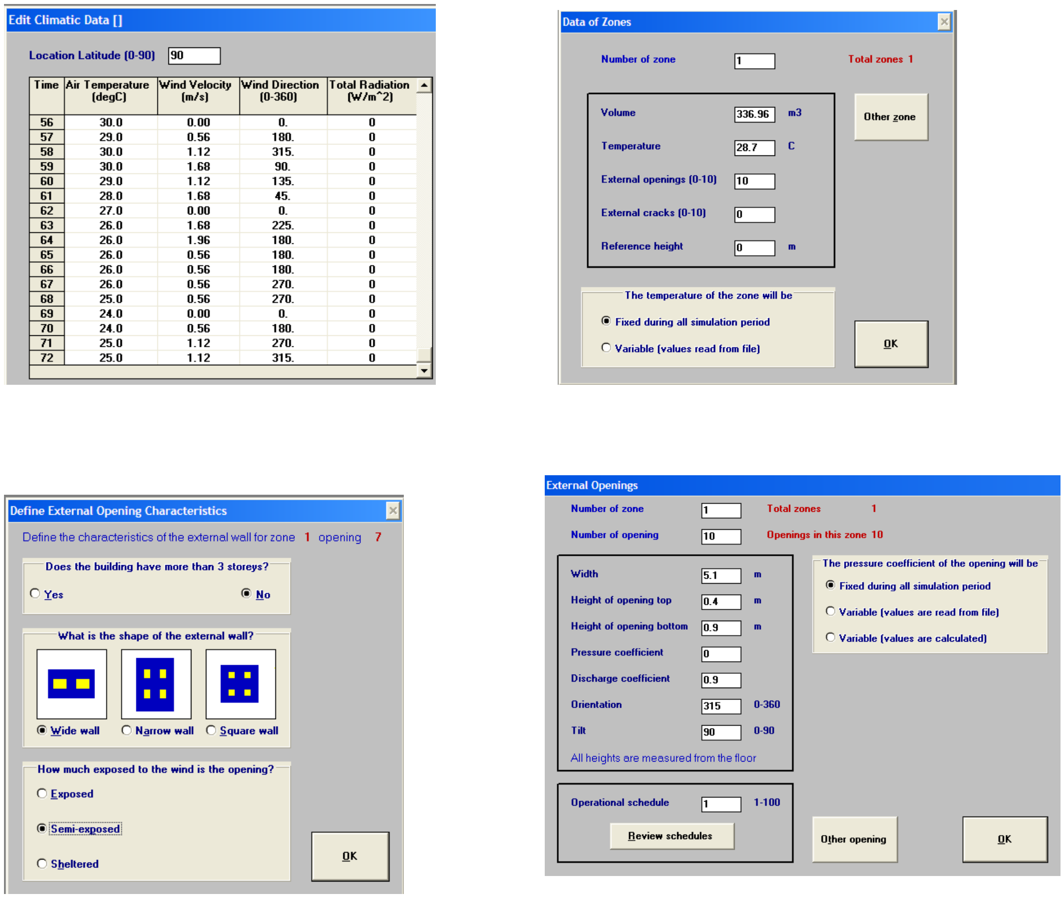


Figure 5.35: information to be inserted in AIOLOS in order to do simulation

5.8.5 Simulation results of microclimate for JKR 989

Average

Table 5.16: Microclimate air temperature

Air temperature	24.8°C
Air velocity	1.85m/s
Wind direction	173

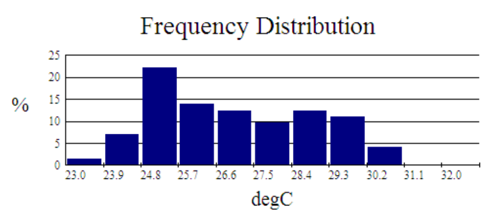


Figure 5.36(a): Microclimate air temperature

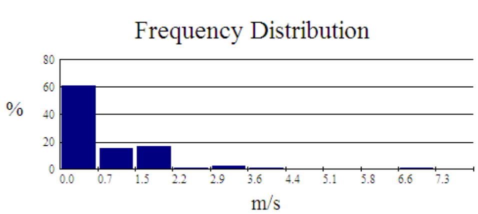


Figure 5.36(b): Microclimate air velocity

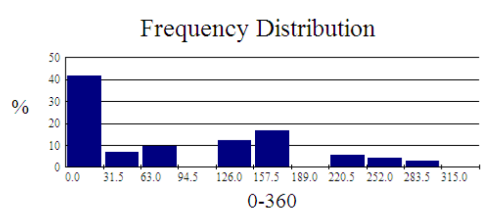


Figure 5.36(c): Microclimate air direction

Table 5.16 showed air temperature of external JKR 989 for the consecutive three days using simulation AIOLOS. Satisfied thermal comfort range that has been determined by respondents in Malaysia is 26°C- 30.7°C (Wong , 2003, De dear, 1991, Busch, 1990). Simulation results of hourly temperature of external JKR 989 (microclimate) shown in Figure 5.36(a) were in 24.8°C in average. This means that in these days, the air temperature of microclimate JKR 989 comply with comfort level of Malaysian codes of practice. Figure 5.36(b) shows the simulation result of these 3 days average wind of external JKR 989 is 1.85m/s. For a hot and humid country like Malaysia, wind is advantage as it encourages perspiration / release heat. Consequently, it will create thermal comfort. Figure 5.36(c) showed air direction for external JKR 989 is 173º.

Air flow & air exchange rates between external and internal area

Air exchange rate is the number of times that the outdoor air replaces the volume of air in a building per unit time, typically expressed as air changes per hour. Simulation result shown in Figure 5.36(d) and Figure 5.36(e) is when the windows have the maximum opening, air flow for meeting room is 18m³/h and the air changes rate is 7.5 air changes /hr.

Table 5.17: Air flow and air exchange rate in zone 2

	AIOLOS Simulation result	Standard (ASHRAE)
Air flow	18m³/h (10.6 cfm)	34m³/h (20 cfm)
Air exchange rate	7.5 air changes /hr	15 air changes /hr

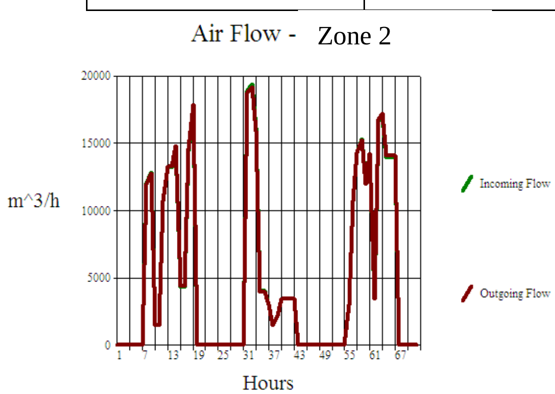


Figure 5.36(d): graph of air changes when all windows design available in JKR 989 are in maximum opening for window

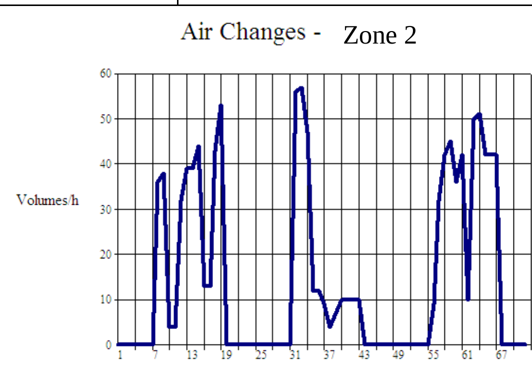
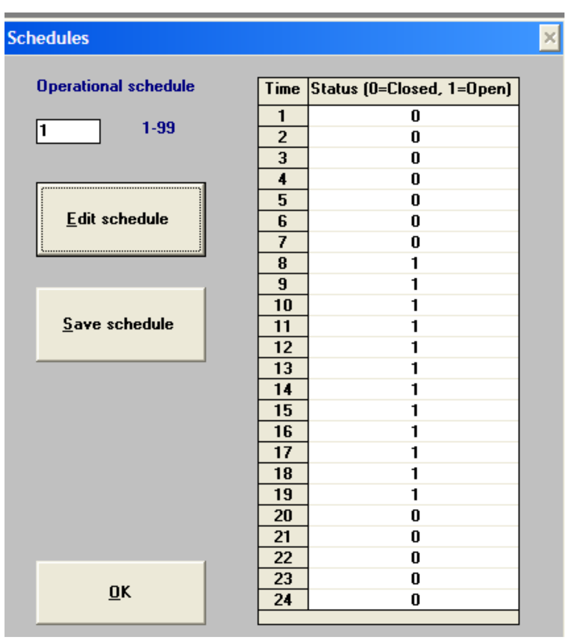


Figure 5.36(e): graph of air flow when all windows design available in JKR 989 are in maximum opening for window

5.8.6 Airflow Result with different window design

Table 5.18 shows the summary result of simulation for the 10 types of windows available in JKR 989. These windows as per discussed in chapter 5.34 were tested in the same zone (zone 2). Refer to table 5.18, there are 3 types of windows design, W1, W4 and W7 which have fixed glass and only depend on louvers on top for ventilation. W8 is the only window which has fixed glass and no louver. This type of window design only allow daylighting but not for ventilation purpose. Thus, there is no air flow graph for zone 2 window 8. Based on the graph shown in Appendix H, W1 has the lowest airflow which is 0.15m³/hr (0.09 cfm) compared to other models. This is due to W1 window is a fixed glass window which only depend on louver on top for ventilation purpose. W2-existing casement windows allowed most air into the building, which is >10 m³/hr (6 cfm). Appendix H showed shaded area in graph represent working hour which is from 8am till 6pm. Based on appendix H, windows are only open during working hour for security purpose. Negative value stated in graph means the wind flow from different direction. Figure 5.37 showed window operable on different time.



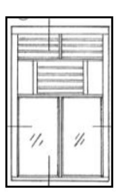
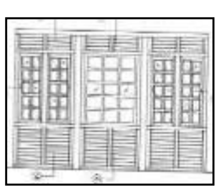
Time	Status (0=Closed, 1=Open)
1	0
2	0
3	0
4	0
5	0
6	0
7	0
8	1
9	1
10	1
11	1
12	1
13	1
14	1
15	1
16	1
17	1
18	1
19	1
20	0
21	0
22	0
23	0
24	0

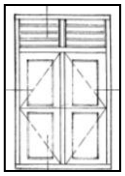
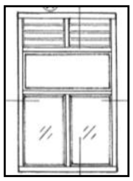
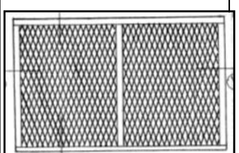
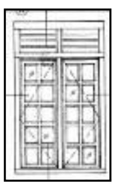
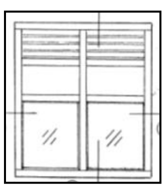
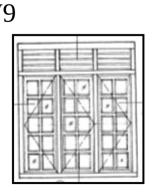
Figure 5.37: schedule of windows

5.8.7 Results of Air Exchange Rate for different types of window design

Sensitivity analysis is used to study the impact of a parameter on the air exchange rate in the simulated zones. Minimum of the window is the existing dimension of the window and maximum dimension will be the width of the sample (meeting room). ASHRAE recommend that minimum ACH is 15 air changes/hr. Ideal ACH (which is normally applied in cleanroom class5 is 100/hr-480/hr). From the simulation, none of the windows designed in zone 2 reached this requirement. Table 5.17 shows that W2, W3, W5 and W9 has highest air changes rate (>6m^3/hr) and lowest for W10 (<10m^3/hr). This is due to W2, W3, W5 and W9 are casement windows with large window. These types of casement window/ mesh window are manageable to open full and allow maximum air into the space. This is different compared with glass louver window. Window for glass louver is limited and the intermediate glass louver panels obstructed wind flow. W1, W4 and W7 are fixed glass non openable window. The only ventilation from these windows depends on louvers which located on top of the windows. Louvers on top however are small compared to the windows. Thus, graph W1, W4 and W7 are obsolete. There is no data for W8 as it is a window purely for daylight purpose.

Table 5.18: Summary air flow rate and air exchange rate for different design of windows in JKR 989

Windows	Orientation	WWR	Width of opening/m	Ideal width /m	Air flow rate (m^3/hour)	Air exchange rate (air changes/hour)
W1 	North West	0.07	1.2	3.01	0.175	5.8
W2 		0.5	3.9	3.92	17	6.4

W3 		0.07	1.1	2.91	1.7	6.4
W4 		0.06	1.1	3.51	0.9	1.0
W5 		0.18	2.4	3.92	4.2	6.2
W6 		0.09	1.2	3.59	0.59	1.0
W7 		0.19	1.4	3.66	0.55	5.9
W8 		0.06	1.2	3.16	-	-
W9 		0.14	1.7	3.76	1.8	6.2

W10 		0.38	5.1	4.0	5.5	0.8

5.8.7.1 Optimization Analysis

Table 5.19: optimization analysis result

Optimization Analysis Results

Zone	Opening	Width (m)	Top (m)	Bottom (m)
1	1	3.01	1.00	0.80
1	2	3.92	1.00	0.80
1	3	2.91	1.00	0.80
1	4	3.51	1.00	0.80
1	5	3.92	1.00	0.80
1	6	3.59	1.00	0.80
1	7	3.66	1.00	0.80
1	8	3.16	1.00	0.80
1	9	3.76	1.00	0.80
1	10	4.00	1.00	0.80

Table 5.19 shows ideal width of the window designs in order to allow for maximum ventilation. The length of all the windows are set to be 2.5m. Referring to Table 5.20, the average width of the windows is 3m<x<4m which many of the existing windows do not exceed, due to limited room size constraints and the width of windows. However, W10 width was suggested to be smaller in order to get the maximum air exchange.

Table 5.20 Summary of window design for optimum ventilation

Windows	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10
Width of window	1.2m	3.9m	1.1m	1.1m	2.4m	1.2m	1.4m	1.2m	1.7m	5.1m
Ideal width	3.01m	3.92m	2.91m	3.51m	3.92m	3.59m	3.66m	3.16m	3.76m	4m
Remarks	+1.81m	+0.02m	+1.81m	+2.41m	+1.52m	+2.39m	+2.26m	+1.96m	+2.06m	- 1.1m
%	150.8%	0.5%	164.5%	219.1%	63.3%	199.2%	161.4%	163.3%	121.2%	- 21.6%

5.8.8 Summary of Simulation test

- This simulation test, of room size- 8.1m(length) x 5.2m (width); orientation North West with 10 window design available in JKR 989, the result showed there is none of the window designs fulfils the minimum standard requirement of air flow which is 34m³/h (20 cfm) and air exchange rate-15 air changes/hr which determined by ASHRAE 1985.

- Out of the 10 designs, there is one window design which had the closest airflow rate to ASHRAE standard which is W2 in zone 2. The simulation result showed it has 17m^3/h air flow rate.

- W2 had the closest match to the ideal width as the difference of existing window width of W2 is only 0.5%.

- The main source of ventilation for zone 2 will be the windows as internal opening was not taken into consideration. Referring to Figure 5.38, the cooler air enters the room from the windows or louvers at the bottom of the windows. Warmer air which is lighter will be drawn out through the clerestory windows or upper louvers on top of windows. Fans are installed by the owner to circulate the air on the upper level due to wind which was obstructed by existing surrounded high rise buildings. Simulation result showed the existing W2 design which is effective in achieving thermal comfort for occupants. Beside almost having an ideal dimension of window width, W2 window design has similar concept with typical traditional window design. Using glass with low visible transmittance on the louver windows can reduce the heat gain and improve horizontal illuminance distribution.

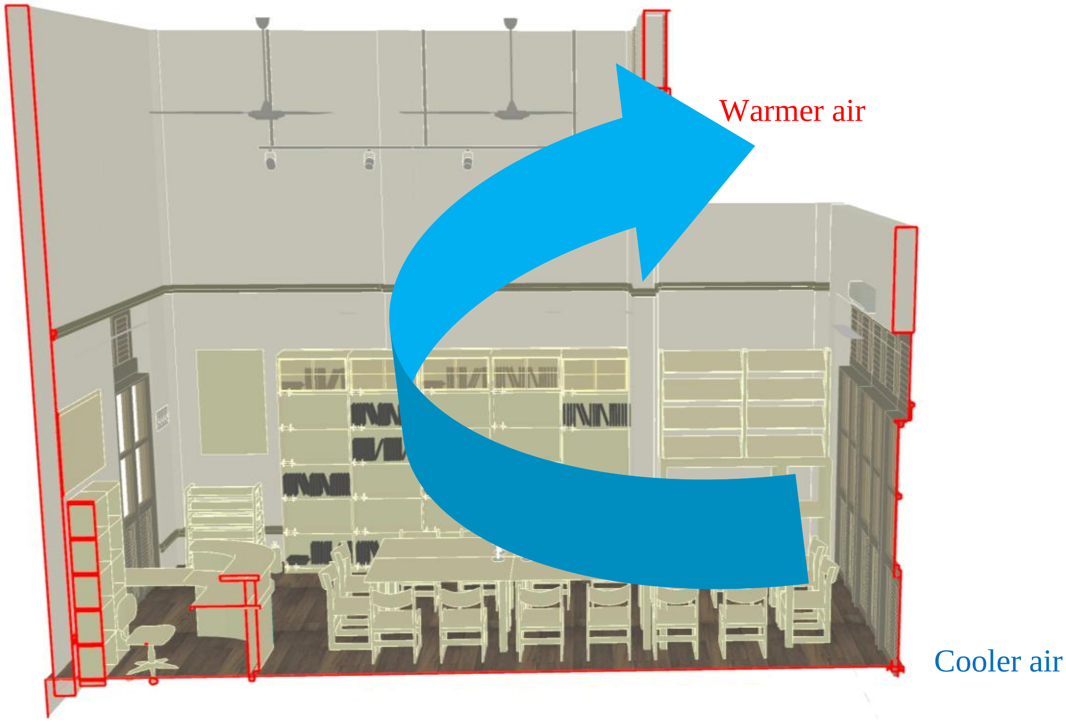


Figure 5.38: Section of meeting room JKR 989