CHAPTER 6.0

Analysis & Discussion

British Colonial buildings are considered as climatic responsive design buildings. In the early 17th century; this type of buildings was built by the government for the British officers in the Colonial periods. The colonists had adopted their architectural styles in building modified to the climate context and also have combinations of the styles from other cultures such as Indian and Chinese due to migrations. These buildings have high ceiling, large windows, elevated platform which is similar to Malay house concept. The major difference between British Colonial buildings and Malay houses is the earlier is constructed of bricks and the later is constructed of timber. Besides, Malay houses are mostly found in suburban and rural areas where there are more vegetation. British Colonial buildings are located in urban areas. At that period, the difference is temperature between rural and urban area is not as obvious as in modern days.

Experiments on thermal comfort of British Colonial Residences in Kuala Lumpur through different window designs has been conducted by Author using Window to Wall Ratio on five selected British Colonial Residences. Among five of these selected buildings, one building had been selected for field measurement. The effectiveness of windows design of one out of four zones in the selected building was tested using computer simulation.

6.1 Window to wall ratio

Referring to Table 6.1, it is noted that windows in JKR 1331, JKR 1716 and JKR 541 allowed sufficient natural ventilation and daylighting to the building. JKR 1331, JKR 1716 and JKR 541 have higher overheated percentage compared to JKR 511 and JKR 989. Even though JKR 989 has the same floor plan design and same category (which is class 3 government quarter) as JKR 1331 and JKR 1716, the window design for JKR 989 is different compared with those two buildings. There are top hung louvered windows at the bathrooms and utility room which allowed insufficient lighting and ventilation in JKR 989. There is no top hung windows found in JKR 1331 and JKR 1716. As for JKR 511, it has many top hung windows found in JKR 511 which allowed insufficient daylighting and natural ventilation.

Table 6.1: Summary result of natural ventilation and daylighting for 5 calculations

Case study	WWR < 0.24	0.24<WWR<0.30	WWR >0.3
JKR 511	47	7	6
JKR 989	40	1	13
JKR 1331	47	-	2
JKR 1716	41	2	19
JKR 541	15	8	2

From this WWR calculation, JKR 1716 has the most number of windows that caused overheat to the room. JKR 1331 do not have any windows that allow optimum daylight and ventilation into the room. JKR 511 has many windows that are top hung which allowed insufficient ventilation and dayligthing into the room. JKR 541 located at green area in urban area which is considered less critical urban set up compared to JKR 989. Thus, further research has been conducted on JKR 989 that have critical urban setting which gave impact on window performance.

Window to wall ratio at north and south should be maximized as to allow sufficient ventilation and daylight and minimize heat gain. However, WWR on the North did not allow optimum ventilation and daylight located at either north or south. Eventually, the majority of the windows which have optimum WWR are located on East and West facades which also contribute too much daylight into the space and heat gain.

Small windows in JKR 989 allowed insufficient ventilation and dayligthing into the room. Although large windows allow more ventilation into the room, they bring in heat into the room at the same time which causes overheating.

It is inappropriate to use this calculation to determine the thermal comfort level of inhabitants in these houses as window to wall ratio has yet to take microclimate and orientation of the windows as consideration.

6.2 Field measurement

JKR 989 has been chosen for the field measurement using HOBO to measure air temperature, humidity, and daylighting during windows were opened and closed. Four zones in JKR 989 which were zone 1 (resource centre which was originally a dining room), zone 2 (meeting room which originally was bedroom), zone 3 (glass room or manager's room which was originally a bedroom) and zone 4 (kitchen) were measured. Data showed that windows played an important role in contributing ventilation and daylighting. Table 6.2 shows the range of air temperature; relative humidity and daylighting compared with the Malaysian standard.

6.2.1 Air temperature

Table 6.2: Summary of measurement for different zones

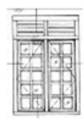
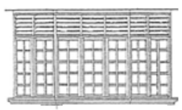
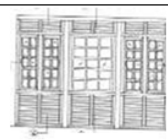
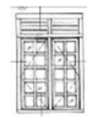
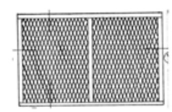
<table>
<tr><td colspan="24">Temperature</td></tr>
<tr><td colspan="6">Zone 1</td><td colspan="6">Zone 2</td><td colspan="6">Zone 3</td><td colspan="6">Zone 4</td></tr>
<tr><td colspan="3">South East</td><td colspan="3">North East</td><td colspan="6">North West</td><td colspan="3">2 nos at South West</td><td colspan="3">1 no at South East</td><td colspan="6">North West, South East</td></tr>
<tr><td colspan="3">1.2m x 1.2m
WWR- 0.3</td><td colspan="3">1.7m x 1.6m
WWR-0.22</td><td colspan="6">3.9m x 2.5m
WWR-0.5</td><td colspan="6">1.2m x 1.2m
WWR-0.4</td><td colspan="6">2.4m x 1.5m
WWR-0.9</td></tr>
<tr><td colspan="3">
W6</td><td colspan="3">
W9</td><td colspan="6">
W2</td><td colspan="6">
W6</td><td colspan="6">
W5</td></tr>
<tr><td colspan="17">Temperature(°c)</td><td colspan="7">Range of thermal comfort air temperature- 26°C- 30.7°C (Nyuk, 2003, De dear, 1991, Busch, 1990</td></tr>
<tr><td colspan="3">Open</td><td colspan="3">Closed</td><td colspan="3">Open</td><td colspan="3">Closed</td><td colspan="3">Open</td><td colspan="3">Closed</td><td colspan="3">Open</td><td colspan="3">Closed</td></tr>
<tr><td>Min</td><td>Mean</td><td>Max</td><td>Min</td><td>Mean</td><td>Max</td><td>Min</td><td>Mean</td><td>Max</td><td>Min</td><td>Mean</td><td>Max</td><td>Min</td><td>Mean</td><td>Max</td><td>Min</td><td>Mean</td><td>Max</td><td>Min</td><td>Mean</td><td>Max</td><td>Min</td><td>Mean</td><td>Max</td></tr>
<tr><td>27</td><td>31.5</td><td>36</td><td>25</td><td>29.5</td><td>34</td><td>25</td><td>28</td><td>31</td><td>25</td><td>29</td><td>33</td><td>26.5</td><td>29.5</td><td>32.5</td><td>23.5</td><td>28</td><td>32</td><td>25</td><td>30</td><td>35</td><td>n/a</td><td>n/a</td><td>n/a</td></tr>
<tr><td colspan="17">Relative Humidity (%)</td><td colspan="7">Range of thermal comfort relative humidity- 30%- 70% (Nyuk, 2003, De dear, 1991, Busch, 1990</td></tr>
<tr><td>Min</td><td>Mean</td><td>Max</td><td>Min</td><td>Mean</td><td>Max</td><td>Min</td><td>Mean</td><td>Max</td><td>Min</td><td>Mean</td><td>Max</td><td>Min</td><td>Mean</td><td>Max</td><td>Min</td><td>Mean</td><td>Max</td><td>Min</td><td>Mean</td><td>Max</td><td>Min</td><td>Mean</td><td>Max</td></tr>
<tr><td>37</td><td>56</td><td>75</td><td>50</td><td>62.5</td><td>75</td><td>54</td><td>69</td><td>84</td><td>50</td><td>67</td><td>84</td><td>53</td><td>65.5</td><td>78</td><td>43</td><td>58</td><td>73</td><td>28</td><td>55</td><td>82</td><td>n/a</td><td>n/a</td><td>n/a</td></tr>
<tr><td colspan="24">Daylighting (lux)</td></tr>
<tr><td>Min</td><td>Mean</td><td>Max</td><td>Min</td><td>Mean</td><td>Max</td><td>Min</td><td>Mean</td><td>Max</td><td>Min</td><td>Mean</td><td>Max</td><td>Min</td><td>Mean</td><td>Max</td><td>Min</td><td>Mean</td><td>Max</td><td>Min</td><td>Mean</td><td>Max</td><td>Min</td><td>Mean</td><td>Max</td></tr>
<tr><td>0</td><td>275</td><td>550</td><td>0</td><td>34</td><td>68</td><td>0</td><td>105</td><td>210</td><td>0</td><td>69</td><td>138</td><td>0</td><td>65</td><td>130</td><td>0</td><td>90</td><td>180</td><td>0</td><td>275</td><td>550</td><td>n/a</td><td>n/a</td><td>n/a</td></tr>
</table>

Table 6.2.1 shows that the air temperatures in room were hotter when the windows were opened except zone 2 and zone 4(windows were opened 24 hour/day). Zone 2 (meeting room) is the coolest room compared to other 3 rooms when windows were opened. Temperature in zone 1 and zone 3 exceed outdoor temperature range. Zone 2 has the closest range to Malaysian thermal comfort standard.

Internal temperature should be cooler when windows are closed as heat from external is blocked by windows and internal heat gain is minimized. However, it was noted that zone 2 temperature increased when windows are closed. This showed that stack effect assist for indoor thermal comfort and this process is obstructed when windows are closed. The different of volume in one space will contribute to better air circulation and stack effect with the addition of clerestory louvered windows on top.

6.2.2 Relative Humidity

Relative humidity of the tested zones was higher than Malaysia standard which is 30-70%. Refer to Table 6.2.1, zone 2 with windows opened had the highest range among the other zones. It is because the air temperature in zone 2 was 3.5ºC lower than other zones.

When the air temperature decreases, the relative humidity should increase. However, zone 3 had different result which showed that the air temperature and relative humidity reduced when the windows were closed. This is due to affected by water feature which located in front of zone 3.

6.2.3 Daylighting

Referring Table 6.2.1, every zone (except zone 1 and 4) had insufficient daylight. Daylight was less influenced by windows which were opened or closed as windows were all clear glass panel casement windows. Although the daylight requirement for different activities will be different, daylight measured in zone 1, 2 and 3 were still unable to achieve the minimum standard of 100lux.

As all the windows in JKR 989 are of clear glass, thus, there should be minimal impact on daylighting when windows opened or closed. It was noted that windows at zone 3 showed that when windows closed, daylight in that zone increased. This is because when windows are closed, there is ceiling at zone 3 which acted as ‘light shelf’ to reflect daylight from windows which are closed.

Although zone 2(meeting room) has high ceiling and clerestory windows, all the clerestory windows are louvered windows. Referring to Malay house concept, there are more windows than wall at external surface of the house with all timber louvered timber windows which assist in higher contribution of dayligthing. For British Colonial house, the timber louvered windows are replaced with timber frame casement windows. These windows have glass panels which also help in providing dayligthing. However, as depth of the rooms increased in Colonial house, the daylight provided is insufficient. Daylight is unable to reach to the far end of the room. Although there are clerestory windows at the middle of the room, the room is still dark. This is due to the clerestory windows are timber louvered windows for ventilation purpose based on the theory of cooler air will stay at the bottom and warmer air escaped from the top. Artificial lighting is needed whenever there is any function on those areas.

In summary, the air temperatures in zone 2 and zone 3 are less tolerable when compared with the thermal comfort range and outdoor air temperature. However, only zone 2 was selected for further study as zone 2 has more critical physical condition compared to zone 3.

6.3 PMV & PPD

Measurement were conducted using BABUC to calculate the predicted mean value and predicted percentage of dissatisfaction of occupants. According to the ASHRAE Standard 55 -2004, it specified that an acceptable thermal environment should have 80% of occupants votes for categories of slightly cool, neutral and slightly warm. Based on the calculation from BABUC, the PPD (percentage of predicted dissatisfaction), occupants who are dissatisfied with the thermal environment of zone 2 is more than 20%. Although the respondents in the tropical environment may have a higher heat tolerance, this study found out that the respondents were unable to accept thermal environment which exceeded the Malaysia standard determined by Wong (2003), De dear (1991) and Busch (1990).

The thermal comfort assessment which is shown in Table 6.3 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 as between 22.1% and 40.3% which means the majority of respondents were dissatisfied.

Table 6.3: Result of PMV and PPD

Item	Standard	Actual	Response
PMV	$-0.5<x<0.5$	$0.9<x<1.3$	UNACCEPTABLE
PPD	<10%	22.1% - 40.3%	UNACCEPTABLE

6.4 Computer simulation

As the occupants are dissatisfied with the indoor situation in zone 2, the windows played an important role in contributing heat gain. Simulation test was conducted using AIOLOS to test the window design performance by determining the air flow and air exchange rate of the windows. All the window types found in JKR 989 were tested using AIOLOS. Variable for the testing was windows design and zone 2 which was the meeting room was constant. Ideal air flow rate determined by ASHRAE 1985 is 34 m^3/hour (20 cfm).

Result showed that existing window – W2 had the highest airflow rate compared to other window designs available in JKR 989. The width of W2 has the nearest dimension to the ideal width calculated by AIOLOS.

Table 6.4: Detail of climate

	Average Macroclimate	Average Microclimate
Temperature	27.5°C	29°C (24.8°C –calculated by AIOLOS)
Relative Humidity	79.5%	75.3%

Table 6.4 showed that average of microclimate is 1.5°C higher than macroclimate on site. Due to development, climate in JKR 989 changed dramatically as more open/green area had been giving way to high rise buildings as shown in Figure 6.1. Deficiencies in development control have seriously impacted the urban climate and environmental performance of urban buildings. As a consequence of heat balance, air temperatures in densely built urban areas such as JKR 989 are higher than the temperatures of the surrounding rural country.

Existing surrounding high rise buildings contribute to the change of microclimate that resulting heat island effects which affected the indoor thermal comfort of occupants.

Figure 6.1: Rear elevation of JKR 989

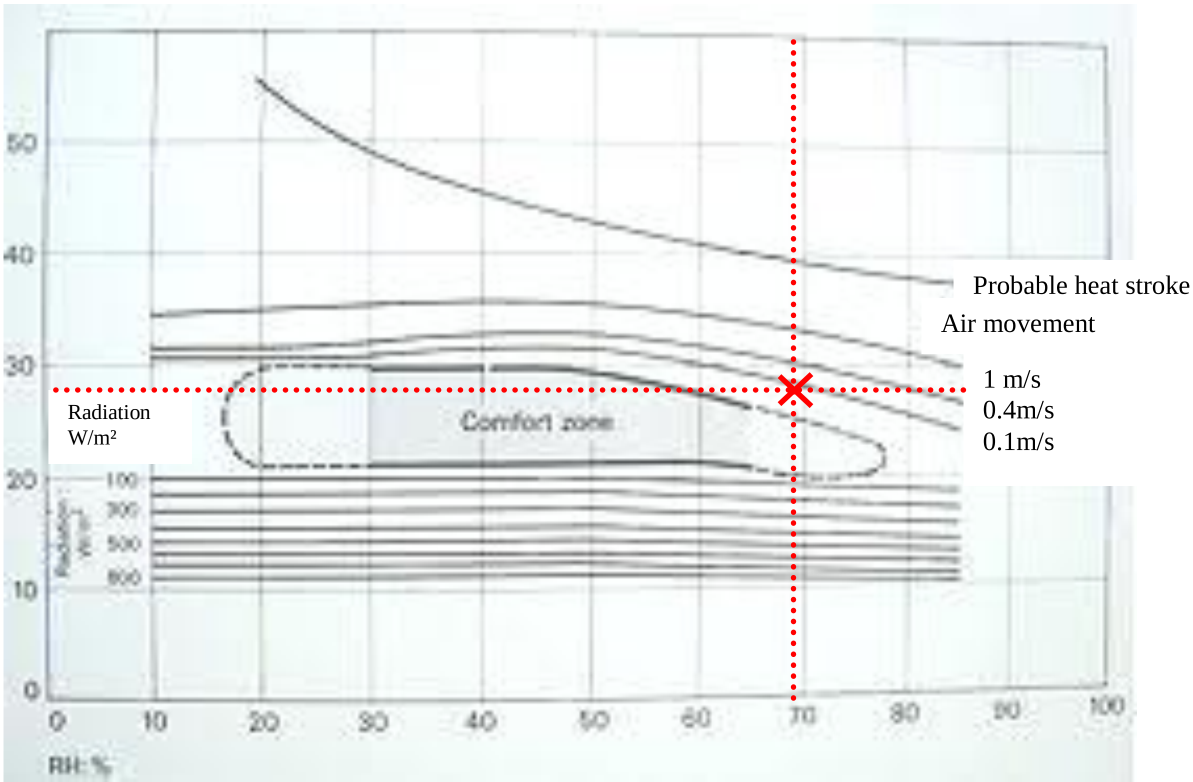


Fig. 6.2: Olgyay's bioclimatic chart, converted to metric, modified for warm climates

Olgyay(1953) introduced the 'bioclimatic chart'(Fig. 6.2) which has the DBT on the horizontal and the RH on the vertical axis, and the aerofoil shape in the middle is the 'middle zone'. Curves in figure 6.2 shows how air movement can extend the upper limits and lines below it show the extension by radiation. Refer to field measurement in Table 6.2, temperature of zone 2 is 28°C and RH is 69%. When mark on Olgyay's bioclimatic chart, it showed that condition indoor of zone 2 is not within the comfort zone introduced by Olgyay's. Condition of internal zone 2 can be improved and fall under comfort zone when humidity decrease to 65% and temperature dropped to 26°C.

Old buildings often have single sided ventilation. Single sided natural ventilation can be achieved by the exchange of air between indoors and outdoors through the same openings on one side of a space at the same height or with the flow of air into a space through other exit openings at different levels. The most common form of natural ventilation is using operable windows. For tropical regions like Malaysia, pressure differences generally caused by wind forces to induce ventilation system.

6.5 Comparison field measurement result with simulation test

When reviewing the results from measurement and simulation test, the experimental results showed that windows in JKR 989 had an impact to the thermal comfort. The size and number of windows were the main elements that provided natural ventilation. The number of walls that were directly exposed to the outdoors also had an impact on indoor air temperature. From the measurement result, it showed that openings in JKR 989 allowed heat gain into the building which caused thermal discomfort to the occupants. Although bungalow-type of houses is generally more spacious, it must be noted that all four sides of this type of house are directly exposed to the outdoors. This contributes to the higher indoor temperatures recorded for the internal spaces compared to the external surrounding. Relative humidity is within the thermal comfort range of Malaysian guidelines. Temperature and daylighting did not satisfy any standard or guideline used in this study. The computer simulation revealed that windows for this house are not well designed as they allowed insufficient natural ventilation into the building.