CHAPTER 4.0

Window to Wall Ratio

Window design is one of the factors, which will affect the building energy consumption. More thought should be given to window design as they play a big role in ventilation, lighting system of a room. The added challenge of designing windows and other openings for natural ventilation is on how to control or filter out traffic noise in urban areas. A determinant factor of window design in the transmission of solar radiation into interior space is window to wall ratio (WWR). A window to wall ratio is the measure of the percentage area of a building's exterior envelope that is made up of glazing, such as windows. ASHRAE 90.1-2007 has established that Window to Wall Ratio (WWR) of 0.24 is considered ideal to allow optimum indoor daylight and natural ventilation. This does not mean that the higher of WWR, the better performance for the windows. The larger a window, more heat or light will penetrate into the room which cause overheating and glare. Windows with WWR more than 0.30 will create overheating into the building. Table 4.1 shows the summary of standard requirement for WWR.

Table 4.1: Standard requirement for WWR (ASHRAE 90.1-2007)

WWR	x<0.24	0.24	>0.30
Value	POOR	GOOD	OVERHEAT

Five British Colonial residences have been selected for the calculation of Window To Wall Ratio (WWR), for the efficiency of the window design. The WWR were calculated on all walls of the main building. The results were analysed to determine the adequacy of each WWR according to orientation for natural ventilation and daylight while at the same time controlling the internal heat gain and visual comfort, following ASHRAE 90.1-2007 standard requirement.

4.1 Calculation 1: JKR 511, Persiaran Mahameru

4.1.1 History background of the residence

This building was built in 1901, located at Persiaran Mahameru, in a residential area meant for British government officers in Kuala Lumpur. After independence in 1957, it was handed over to the Malaysian Government and turned into an official government quarters for higher ranked government officers and later in 2003, it was converted into an office (UM Core, 2005).

4.1.2 Architectural Style

JKR 511 was classified as Class I government quarters, spread out along the streets in the vicinity of the Lake Garden, which is the oldest park in Kuala Lumpur. The density and configuration of the surrounding buildings allow for a proper wind exposure. As a result, JKR 511 has yet to have wind sheltering obstruction problem.

This single storey building has a square plan with an asymmetrical massing that does not portray a strong monumental language. It comprises of two blocks connected by a covered walkway that sits on a 3.29 acre site with a built up area of 1543.4m² which is 55.7m (length); 27.7m (width) and a 5.7m of maximum height. The main building is oriented to the North East. This L shape building allows a distribution of wind to parts of the facades. As this building is square as shown in Figure 4.1 and it is orientated to the direction of windward, this building was designed with natural ventilation. The clerestory windows allows the wind path for stack effect and indirect natural lighting.

This colonial style building was designed to adapt to warm and humid climate of this region. Figures 4.2, 4.3, 4.4 & 4.5 show elevations of the building which show climatic

response design elements such as clerestory windows, double volume space, louvers and overhang. The use of timber columns in the porch and in the walkway, softens the whole architectural vocabulary.

The main block of the residence include a porte-cochere, a living area, a dining hall, a verandah, 11 bedrooms and 4 bathrooms. The second block housed a kitchen installed with a chimney for better ventilation. The residence is built with load bearing masonry construction using 210mm thick brick walls which support timber roof trusses that are covered with clay tiles. This wall thickness have high thermal mass – the ability to store heat. The walls are painted white so as to absorb less heat. The ceiling is constructed by suspended fibrous plaster and painted white. False ceiling allows some access to the thermal mass of the structure (UM Core, 2006).

4.1.3 Ventilation system

This building has a hybrid ventilation system. It is naturally ventilated by the means passive cooling and mechanically ventilated by ceiling fan and air conditioning.

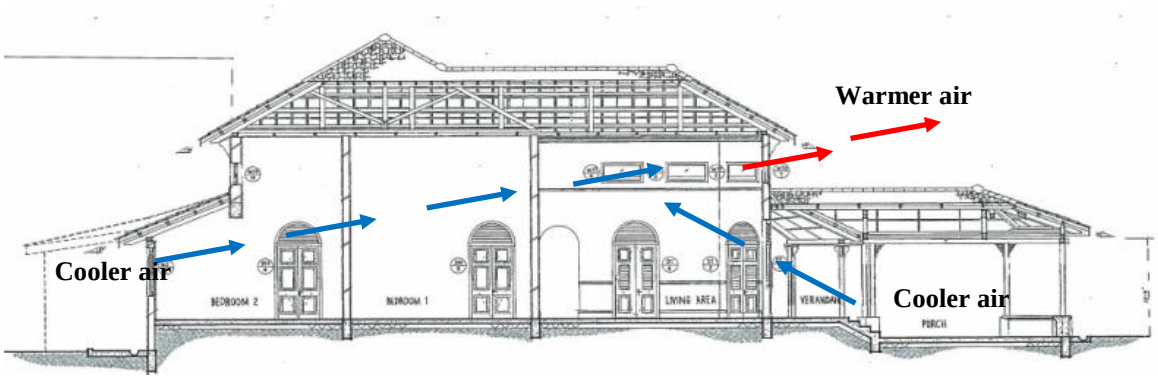

Figure 4.1: Section of JKR 511
(Source: UM CORE, 2006)

Passive cooling system involves the following: i) louvers which assist to reduce the heat and glare but allows ventilation, ii) clerestory windows which allowed hot air to escape (see Figure 4.1), iii) suspended floor that encourage cooler air to enter the house

as timber decking with large beams spanning between the masonry piers contribute in cooling the indoor air and minimizing the building's heat load, iv) high ceiling which encourage for better circulation of air in building. In addition, the JKR 511 residence has large windows for ventilation and day lighting purposes. There are a total of 60 windows in the house with 14 types of design as shown in Figure 4.2-4.6.

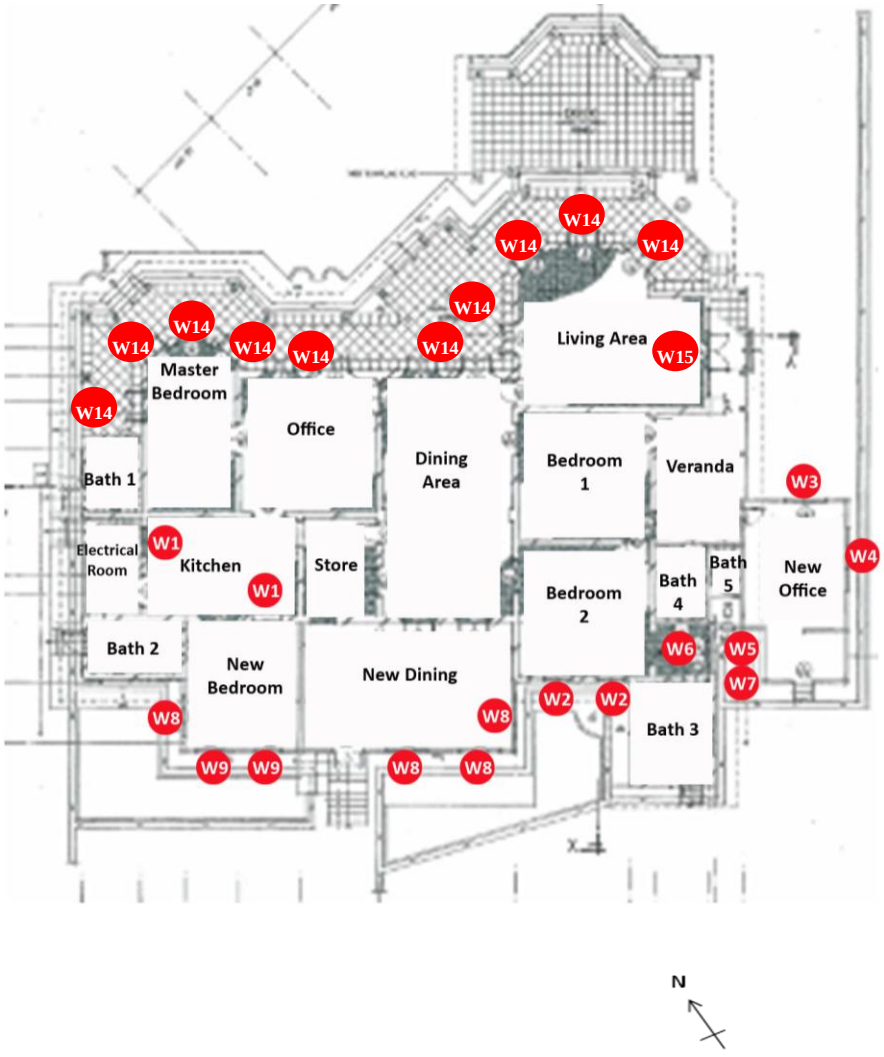

Figure 4.2: Floor plan JKR 511
(Source: UM Core, 2006)

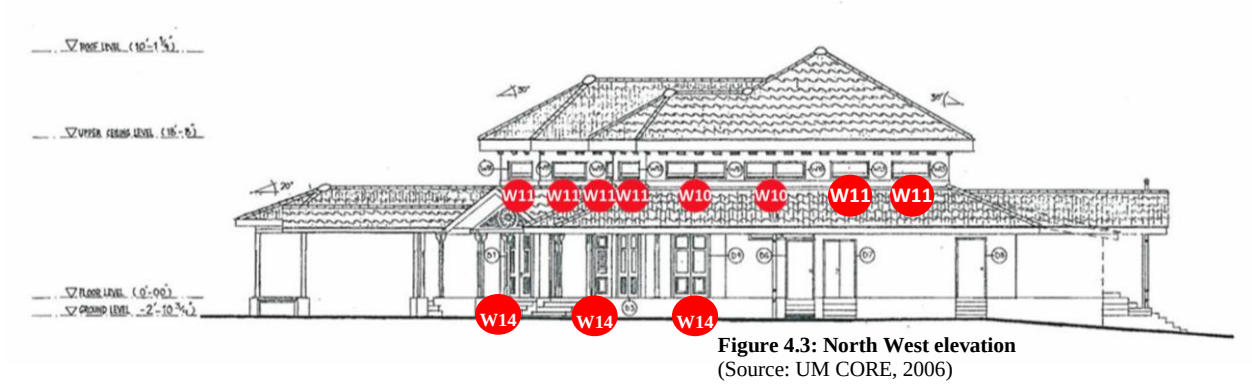

Figure 4.3: North West elevation
(Source: UM CORE, 2006)

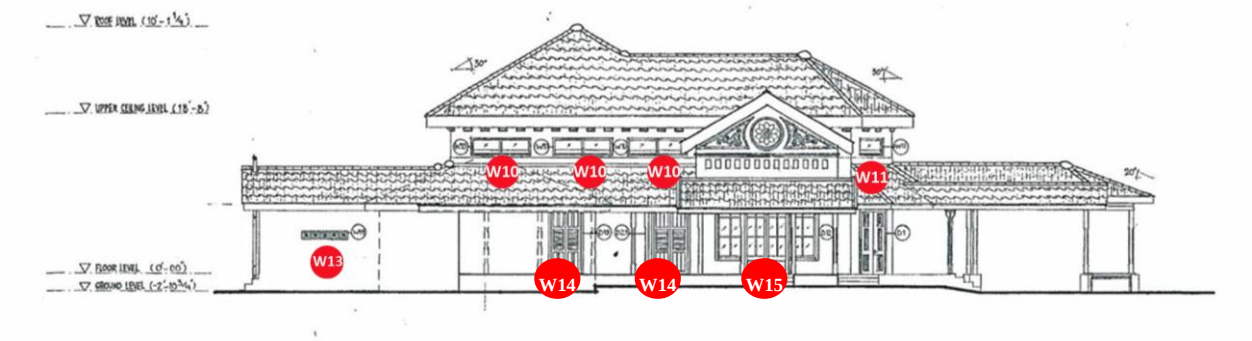

Figure 4.4: South East elevation
(Source: UM CORE, 2006)

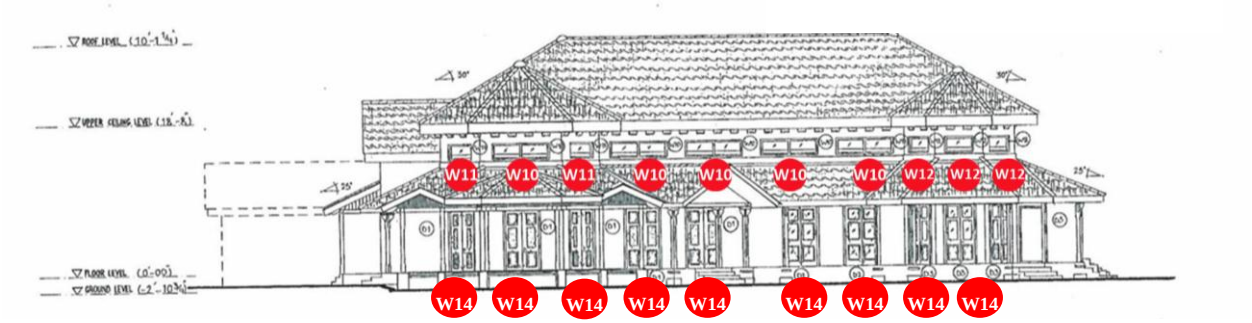

Figure 4.5: North East elevation
(Source: UM CORE, 2006)

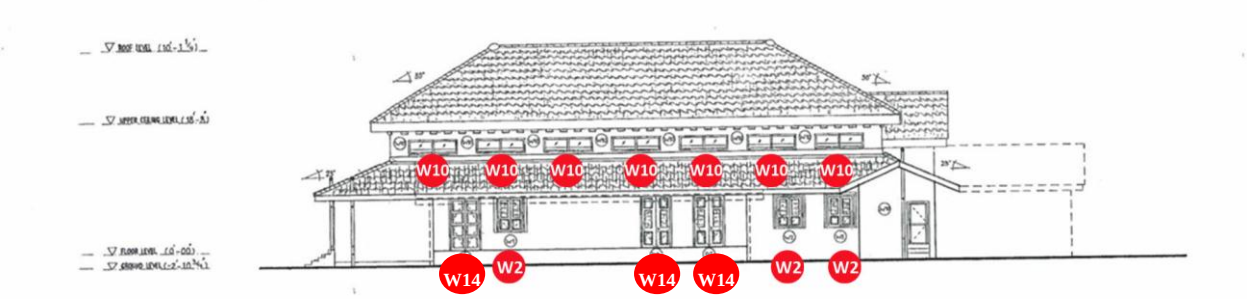

Figure 4.6: South West elevation
(Source: UM CORE, 2006)

4.1.4 Result of Window to Wall Ratio JKR 511

Table 4.2: Summary of window to wall ratio for JKR 511
(Source: Author, 2009)

	POOR WWR < 0.24				GOOD WWR = 0.24				OVERHEAT WWR > 0.30			
	NE	NW	SE	SW	N	NE	E	SE	NE	NW	SE	SW
W1										1		
W2				2								
W3	1											
W4			1									
W5								1				
W6												
W7											1	
W8										1	1	2
W9				2								
W10	5	4	10	7								
W11	2	2	3	1								
W12	2											
W13			1									
W14	1	2			2	2	2					
W15			1									
TOTAL	11	8	16	12	2	2	2	1	0	2	2	2
GRAND TOTAL	**47**				**7**				**6**			

Table 4.2 shows 6 windows which have Window to Wall Ratio that exceeded 0.30 and are considered as allowing too much heat into the room. The overheated rooms are located on North West, South East and South West walls. There are windows on North, North East, East and South East walls which allowed optimum ventilation and daylighting into the room. The reason it allowed optimum ventilation and daylighting is perhaps of the position, located off a tiny courtyard. According to WWR per exposure as explained in chapter 2, WWR at North and South sides should be maximized as to allow sufficient daylight in and WWR at East and West sides should be minimized to prevent too much direct light into a space which can cause glare and contribute to heat gain. Majority of the windows in JKR 511 are not directly facing East and West. However, it is noted that 47 out of 60 of windows in JKR 511 allowed insufficient ventilation and daylighting into the room.

4.2 Calculation 2: JKR 989, Jalan Stonor

4.2.1 History background of the residence

As a British government officer housing, this building is located at No. 2, Stonor Road, Kuala Lumpur. It sits on a 2.2 acre site with a built up area of 381.4m² which is 22.35m (length), 14.63m (width) 8.8m of maximum height. JKR 989 is located in Kuala Lumpur city centre and surrounded by high rise buildings. Although there is some distance from other buildings, this building is sheltered from the wind (UTM, 1998).

The main L-shaped block is linked to a smaller rectangular mass by a timber roofed and columned walkway. The third smallest block sits isolated from the other two without any linkage. A basketball field and two tennis courts are situated at the rear of the building. The main building is oriented to the South East. The current owner of this building is the Prime Minister's Department (UM Core, 2005).

This building served a number of functions from residential to barrack and was later converted into an office. The normal capacity for this building is for 8 people. However, the presence of photocopy machine, computers, printers and other office equipments generated excess heat to the building (UTM, 1998).

4.2.2 Architectural Style

This single storey L-shaped building was classified as a Class III British government quarters which is more informal in design. Figure 4.7 shows the floor plan of JKR 989. Figures 4.8, 4.9, 4.10, 4.11 show all four elevations. The central spine of the L-shaped plan contains one and half storey space that houses clerestory louvered windows. The composition of the house mass is reminiscent of the Roman Basilica type building with

a high central nave and two lower aisles. The use of timber columns in the porch and in the walkway denotes cottage architecture. The use of slender timber columns and the hipped gable roof form or ‘bumbung limas potong Belanda’ reflect the traditional vernacular architecture.

The main building with an L-shaped plan contained three bedrooms, a living room, an entrance hall, a formal dining room, a small study and a kitchen. Each of the bedroom has an adjoining toilet and bathroom. The water closet is believed to be the old bucket latrine type because there are stairs from the outside leading up to the back part of these toilets. Each of the bedrooms has an alcove with generous glass casement window area that brightens the room. The main bedroom has a door leading into one other bedroom. The kitchen has a generous floor area that fits a family table for daily meals. The formal dining room is close to the kitchen with a bay window to one side. There are two small rooms next to the second entrance which seems to be a study. The main front door is covered with a timber porch driveway whilst the second main entrance is to the left. There is third entrance which is to the right used mainly by the servants and is linked by a timber covered walkway to the second block. The whole of the main block is raised 900mm from ground. The elevated floor encourages stack effect for the building as cold air which is heavier tense to stay at the bottom and hot air which is lighter will escape from top.

Similar to the other residence this building was built with load bearing brick wall of 210mm thickness, timber floor and timber roof trusses covered with clay tiles. Green is the original color for this building but was later painted white. White paint is a very powerful architectural climatic control feature, and it is the most cost effective way to

minimize the building's heat load. The timber trusses originally are bluish green but were later painted black (UTM, 1998).

This building was first mooted in 1983 by HICOM Properties to serve as one of their branch offices. When Badan Warisan Malaysia (BWM) took over this building in Jan 1996, they restored this building and converted it into a BWM office. The main house block is converted into main exhibition and administration center. The hall and living room is furnished as gallery and exhibition space. The two bedrooms immediately adjoining the living space to cater for more exhibition space and converted into meeting room. The dining room with bay window became the Executive Director's private office. The adjoining kitchen is converted into restroom. The original restroom and bathroom are converted as storage and printing rooms. The main bedroom is turned into a resource center. The glass room houses the work station for other staffs of BWM. The second block has been renovated to be used as restrooms, prayer room and storage spaces. The third block is a shelter for the night watchman (UTM, 1998).

4.2.3 Ventilation system

This building has a similar hybrid ventilation system. It is naturally ventilated by the means passive cooling and mechanically ventilated by ceiling fan and air conditioning system. Passive cooling system involves the following: i) fixed or adjustable, timber or glass louvers which assist in reduce the heat and glare but allow ventilation, ii) clerestory windows which allowed hot air to escape, iii) suspended floor that encourage cold air to enter the house, iv) high ceiling which encourage for better circulation of air in building, and v) ceiling ventilators. Some of the rooms are of double volume to allow the warm air to be collected at the top and stratification of warm air maintains cooler air at the floor level, thus maintaining air temperature in comfortable zone. In addition,

JKR 989 has large windows for ventilation and day lighting purpose. There are 54 windows in the house with 13 types of design as shown in Figures 4.7-4.11 (UM Core, 2006).

Figure 4.7: Floor plan JKR 989
(Source: UM Core, 2006)

Figure 4.8: South East elevation
(Source: UM CORE, 2006)

Figure4.9: North West elevation
(Source: UM CORE, 2006)

Figure4.10: South West elevation
(Source: UM CORE, 2006)

Figure4.11: North East elevation
(Source: UM CORE, 2006)

4.2.4 Result of Window to Wall Ratio JKR 989

Table 4.3: Summary of window to wall ratio for JKR 989
(Source: Author, 2009)

	POOR WWR < 0.24				GOOD WWR = 0.24				OVERHEAT WWR > 0.30			
	NW	NE	SE	SW	NW	NE	SE	SW	NW	NE	SE	SW
W1	2			1								
W2									2			
W3		1		2								
W4		1		1								
W5									1		1	
W6			5							2	4	2
W7		1		1								
W8	1	1				1						
W9		1										
W10												1
W11		3										
W12		1	1	1								
W13	6	3	4	3								
TOTAL	9	12	10	9	0	1	0	0	3	2	5	3
GRAND TOTAL	**40**				**1**				**13**			

Referring to the result shown in Table 4.3, there are 13 windows which caused overheating to the rooms in JKR 989. This building is similar to JKR 511 where only one window allowed optimum ventilation and daylighting into the room. Forty windows allowed insufficient ventilation and daylight into the rooms. It is noted that many windows in JKR 989 located at North East and SouthWest walls compared to North West and South East facades. From the results, windows that caused overheating to the room are mostly located on the south east facade. This contradict with the theory suggested by Nieuwolt, 1984 who mentioned that *"WWR at South should be maximized to allow sufficient daylight."*

4.3 Calculation 3: JKR 1331, Jalan Semarak

4.3.1 History background of the residence

JKR 1331 built in 1939, was known as PULAPOL quarters and is located at Semarak Road which used to be British police officer residence. It sits on a 0.35 acre site with a built up area of 420.7m² which is 19.2m (length) 19.8m (width) 8.8m maximum height. The main building is oriented towards North East. JKR 1331 is surrounded by bungalows. Its location is at a distance from other buildings. As a result this building is exposed to the wind (UM Core, 2006).

4.3.2 Architectural Style

This building is classified as a Class III government quarters. Besides JKR 1331, there are 2 other buildings that are of the same class and are located at the same area which is JKR 989 on Stonor Road and JKR 1716 on Ledang Road.

This single storey L-shaped building is raised 900mm from the ground. This encourages stack effect as cold air which is heavier can enter the building from the bottom of the house and warmer air which is lighter can escape through the top of the house. This house contains one and half storey space that has clerestory louvered windows. This house has three blocks of buildings. The main building with an L-shaped plan contained three bedrooms, a living room, an entrance hall, a formal dining room, a small study and a kitchen. Each of the bedroom has an adjoining toilet and bathroom. The main building is of load bearing masonry construction with timber roof trusses covered with clay tiles. The floor is of timber decking. The ceiling is constructed of suspended plaster and painted white (UM Core, 2006).

4.3.3 Ventilation system

Ventilation system for this building is similar with the previous two buildings which is hybrid ventilation system. It is naturally ventilated and mechanically ventilated by ceiling fan. As JKR 1331 is considered as a skin load dominated buildings, it does not generate much internal heat. Their cooling requirements are largely determined by exterior climate and design of the building envelope. Climatic responsive design strategies involve louvers, clerestory windows, suspended floor, high ceiling, jack roof and overhang. In addition, JKR 1331 consist large windows for ventilation and day lighting purpose. There are total of 49 nos of window in the house with 11 types of design as showed in Figures 4.12-4.16.

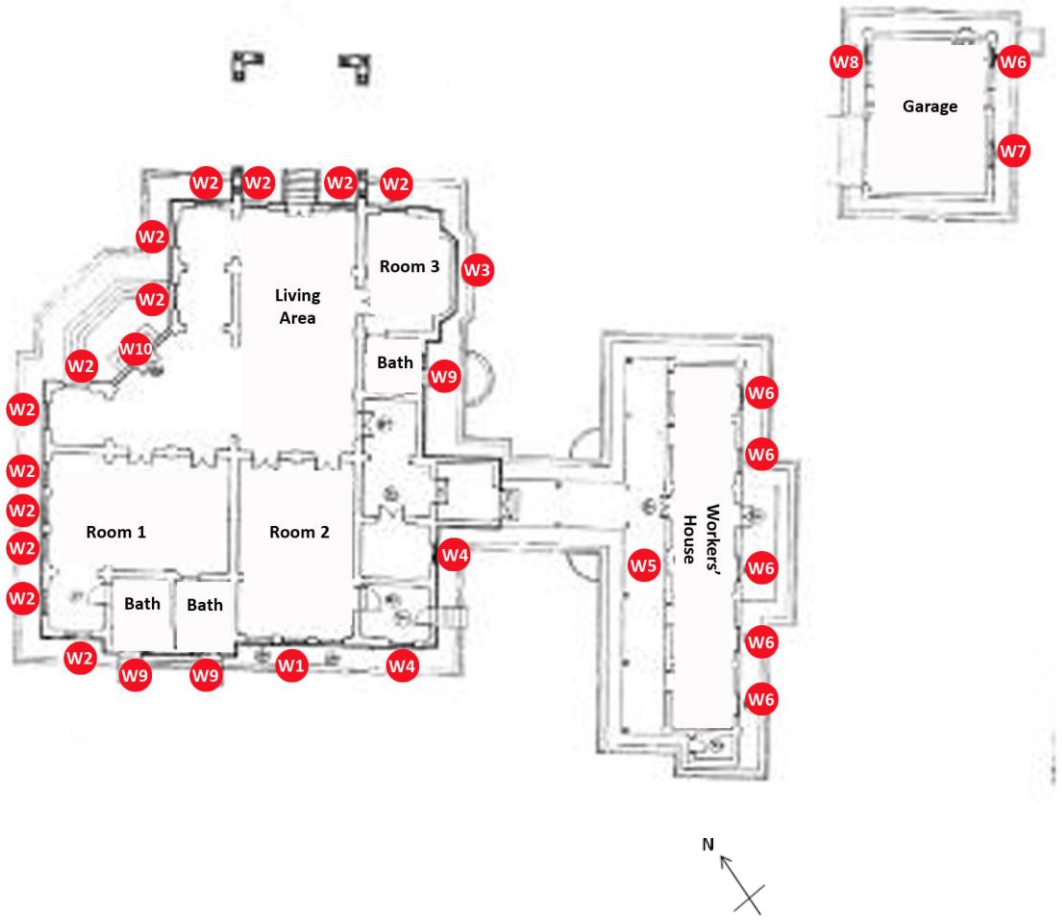

Figure 4.12: Floor plan JKR 1331
(Source: UM Core, 2006)

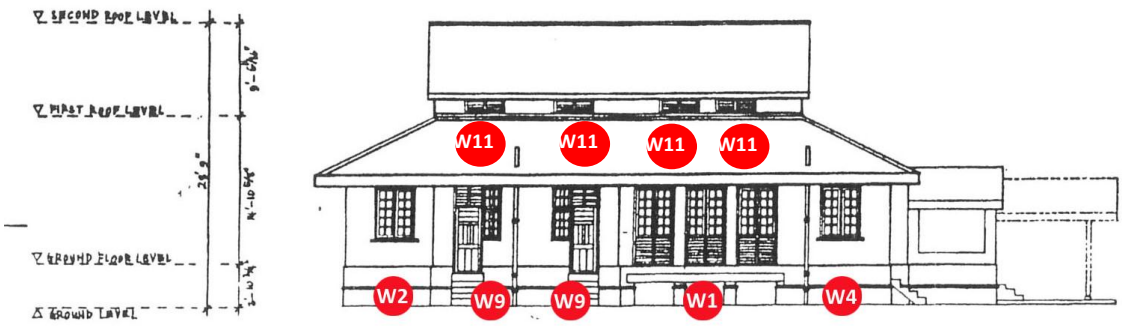

Figure 4.13: South West elevation
(Source: UM CORE, 2006)

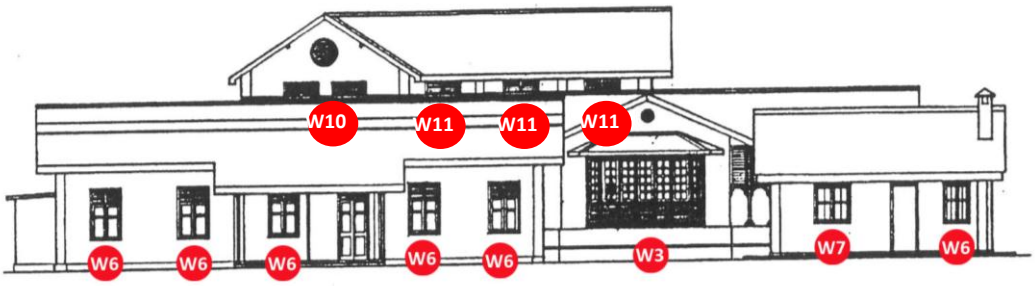

Figure 4.14: South East elevation
(Source: UM CORE, 2006)

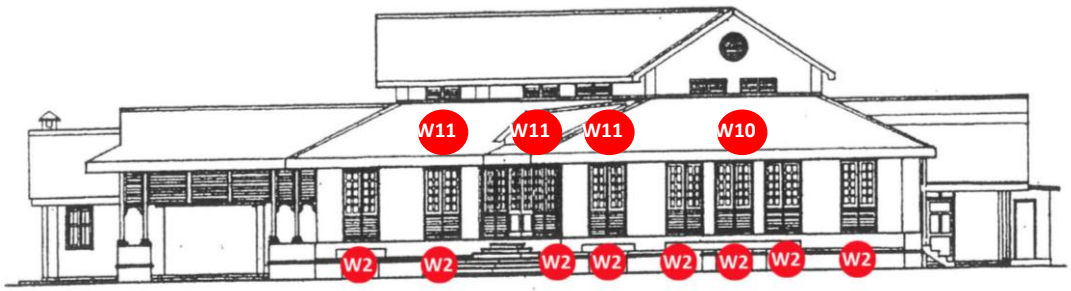

Figure4.15: North West elevation
(Source: UM CORE, 2006)

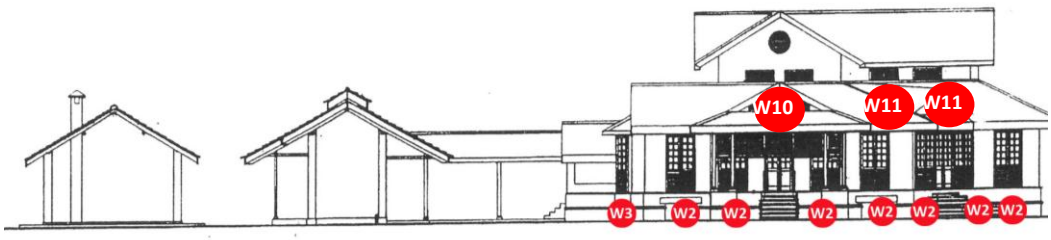

Figure4.16: North East elevation
(Source: UM CORE, 2006)

4.3.4 Result of Window to Wall Ratio JKR 1331

Table 4.4: Summary of window to wall ratio for JKR 1331
(Source: Author, 2009)

	POOR WWR < 0.24				GOOD WWR = 0.24				OVERHEAT WWR > 0.30			
	NE	NW	SE	SW	NE	NW	SE	SW	NE	NW	SE	SW
W1				1								
W2	4			1					1			
W3			3									
W4				1							1	
W5		1										
W6			6									
W7		7	1									
W8		1										
W9			2	2								
W10	1	1	1									
W11	2	3	5	4								
TOTAL	7	13	18	9	0	0	0	0	1	0	1	0
GRAND TOTAL	**47**				**0**				**2**			

Although JKR 1331 has similar floor plan as JKR 989, the window design for JKR 1331 is different from JKR 989. This is proven when window design type for JKR 1331 is less than JKR 989. Referring to Table 4.4, this building has less windows that can cause overheating to the rooms as compared to JKR 989 and has no window which allows optimum ventilation and daylighting into the room. Forty seven of windows which the majority are located on South East and North West facades allowed insufficient ventilation and daylighting into the rooms. Two windows on North East and South East caused overheating to the rooms.

4.4 Calculation 4: JKR 1716, Jalan Ledang

4.4.1 History background of the residence

JKR 1716 was built in 1931 for British government officers as residence and located at Ledang Road where the buildings in the neighborhood were mainly semi-Ds, and bungalows. It sits on a 0.55 acre site with a built up area of 1075.8m² which is 26.4m (length) 40.8m (width) 8.8m maximum height. The main building is oriented to North West (UM Core, 2006).

4.4.2 Architectural Style

This building classified as a Class III government quarters. It has similar floor plan with JKR 989. However, the orientation of JKR 1716 is different from JKR 989. It orientated to North West. It is a single storey L-shaped residence which the main building with an L-shaped plan that contained three bedrooms, four bathrooms, one store room, one server, one working area, one dining area, one living hall, one kitchen, porch and verandah. The main block is raised 900mm from ground level.

The main block is of load bearing masonry construction with timber roof trusses covered with clay tiles. The floor is of timber decking and ceiling is constructed of non- suspended plaster and painted white (UM Core, 2006).

4.4.3 Ventilation system

The design of JKR 1716 aimed to lower the indoor temperatures and enable effective natural ventilation. This building has a hybrid ventilation system which depends on mechanical ventilation such as ceiling fan and passive cooling system. Passive cooling system has been integrated within the building which includes clerestory windows,

suspended floor and roof overhang. This building similar to JKR 989, has many clerestory windows that encourage stack ventilation. This system of natural convection creates its own air current, where warmer air is evacuated at a high point, and cooler outdoor air is brought in at a lower level. JKR 1716 has large windows for ventilation and day lighting purposes. There are 62 windows in the house with 8 types of design as shown in Figures 4.17-4.21.

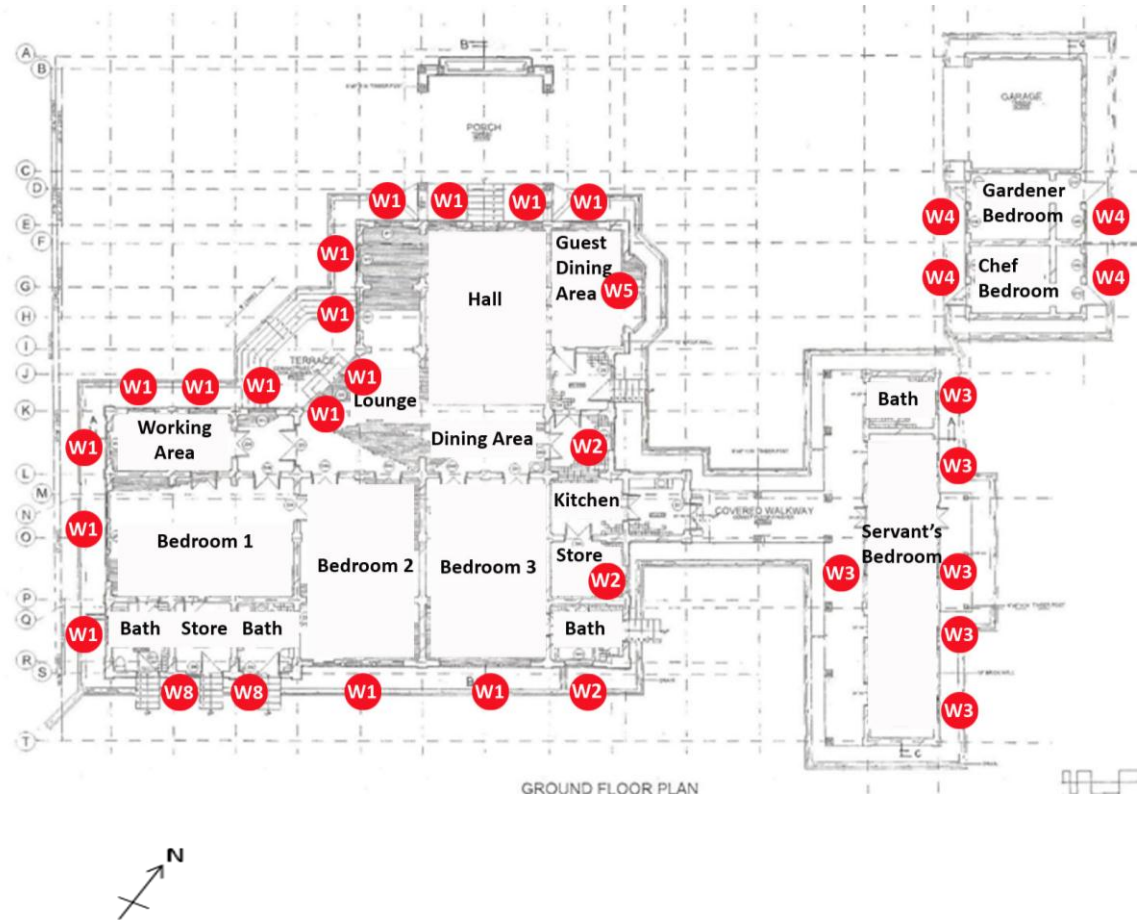

Figure 4.17: Floor plan JKR 1716
(Source: UM Core, 2006)

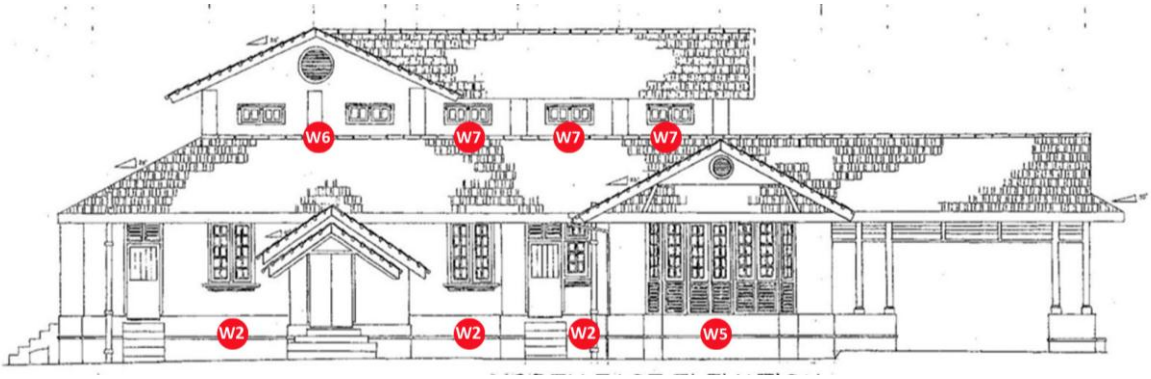

Figure 4.18: North East elevation
(Source: UM CORE, 2006)

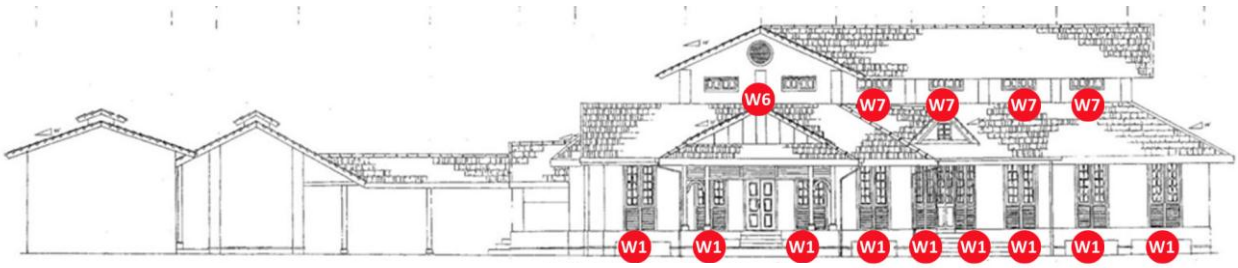

Figure 4.19: North West elevation
(Source: UM CORE, 2006)

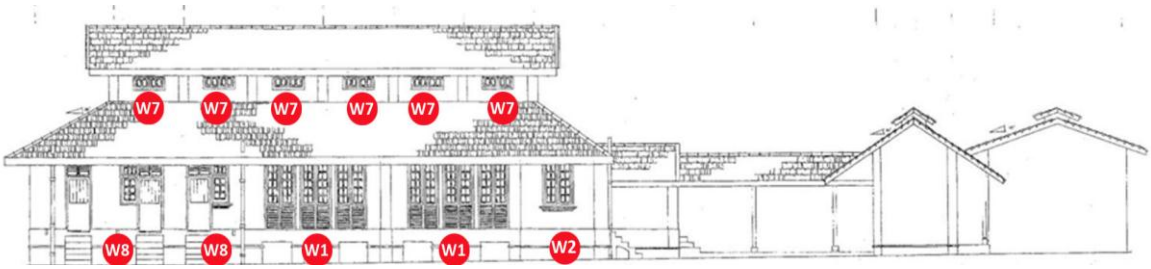

Figure 4.20: South East elevation
(Source: UM CORE, 2006)

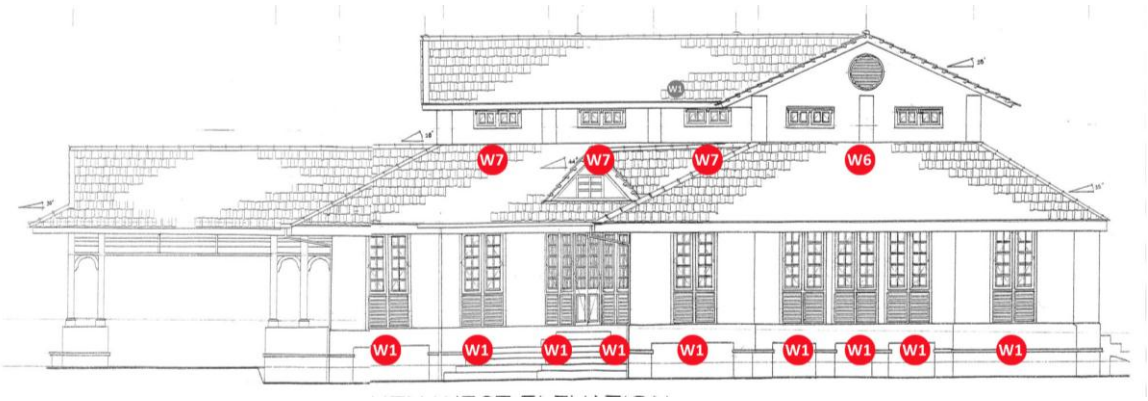

Figure 4.21: South West elevation
(Source: UM CORE, 2006)

4.4.4 Result of Window to Wall Ratio JKR 1716

Table 4.5: Summary of window to wall ratio for JKR 1716
(Source: Author, 2009)

	POOR WWR < 0.24				GOOD WWR = 0.24				OVERHEAT WWR > 0.30			
	NE	NW	SE	SW	NE	NW	SE	SW	NE	NW	SE	SW
W1			6	2		1		1		4		4
W2	5								3		1	
W3				5								
W4	2			2								
W5									5			
W6	1	1		1								
W7	3	4	6	3								
W8											2	
TOTAL	11	5	12	13	0	1	0	1	8	4	3	4
GRAND TOTAL	**41**				**2**				**19**			

Although JKR 1716 has same design floor plan layout as JKR 989 and JKR 1331, the window design for JKR 1716 is less compared to the previous two buildings. Based on Table 4.5, JKR 1716 has the most windows which caused overheating to the rooms compared to JKR 989 and JKR 1331. There are 41 windows which allowed insufficient ventilation and day lighting into the room. Nineteen windows caused overheating to the room and only 2 windows which are located on North West and South West facades allowed optimum ventilation and day lighting into the room Many of the windows that have high WWR value are located on North East facades.

4.5 Calculation 5: JKR 541, Jalan Belfield

4.5.1 History background of the residence

This building was built in 1906 and located at the Belfield Road residential area. It sits on a 1.1 acre site with a built up area of 193m² which is 57.7m (length) 41.5m (width) 7.9m of maximum height. The main building is oriented to the South (UM Core, 2006).

4.5.2 Architectural Style

This building was classified as a Class IV government quarters. It is single storey I-shaped plan which is elevated 0.83m from the ground to prevent wild animal, flood and encourage better ventilation. The main block consists of veranda, living area, two bedrooms with attached bathrooms, kitchen, store room and utility room. The other block consists of 3 servant bedrooms with attached bathroom and a store room (UM Core, 2006).

4.5.3 Ventilation system

This building has a hybrid ventilation system. It is naturally ventilated through open windows and passive cooling system and mechanically ventilated by ceiling fan. Passive cooling system involves clerestory windows which allowed warmer air to escape, suspended floor that encourage cooler air to enter the house (Figure 4.22), overhang which reduce glare and allow ventilation.

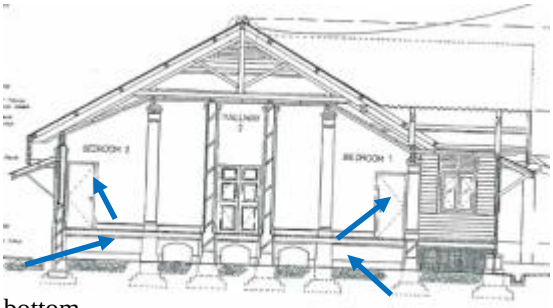

Figure 4.22: Section JKR 541
(Source: UM Core, 2006)

As JKR 541 has an 'I' shape plan, it has windows that allowed for cross ventilation at bedrooms. They are very open to the breezes yet shaded from direct solar radiation due to the large overhang. In addition, JKR 541 has large windows for ventilation and day lighting purpose. There are total of 25 windows in the house with 6 types of design as shown in Figure 4.23-4.27.

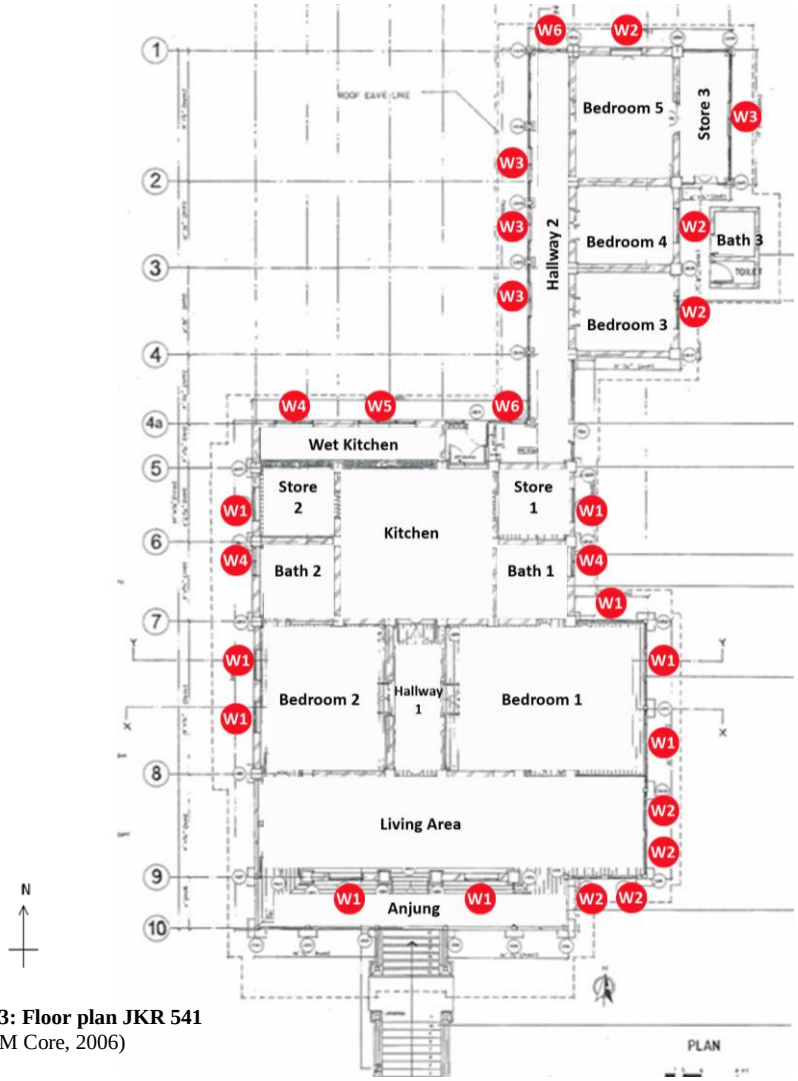

Figure 4.23: Floor plan JKR 541
(Source: UM Core, 2006)

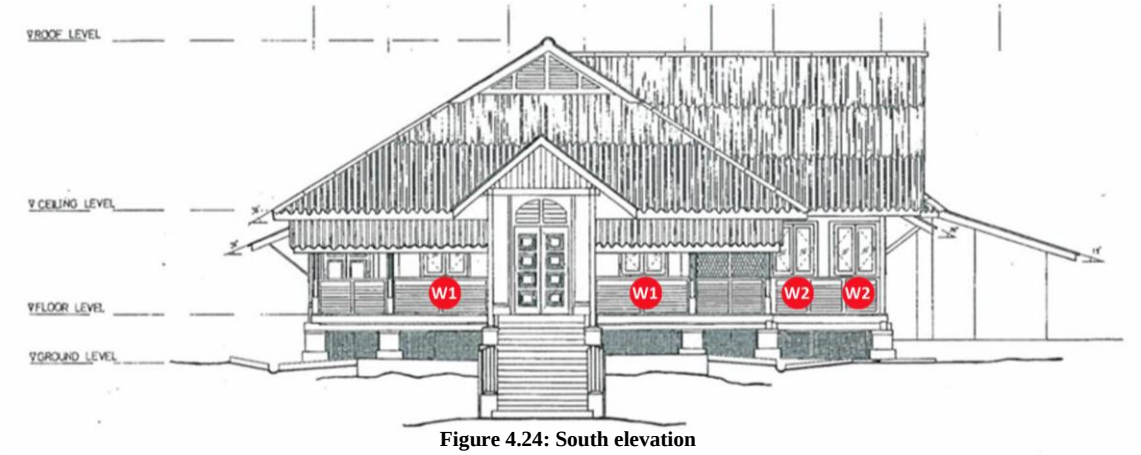

Figure 4.24: South elevation
(Source: UM CORE, 2006)

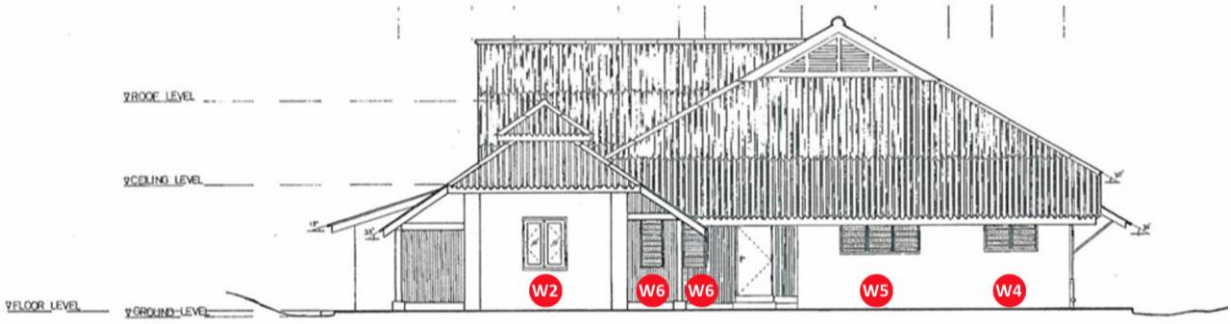

Figure 4.25: North elevation
(Source: UM CORE, 2006)

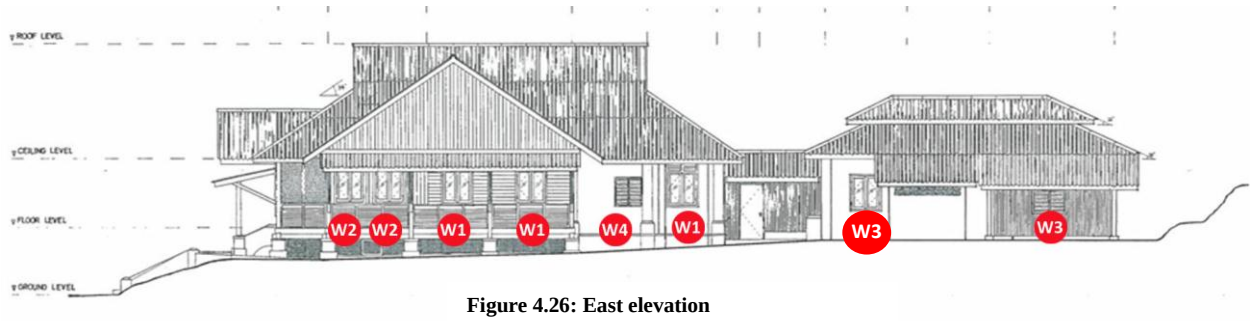

Figure 4.26: East elevation
(Source: UM CORE, 2006)

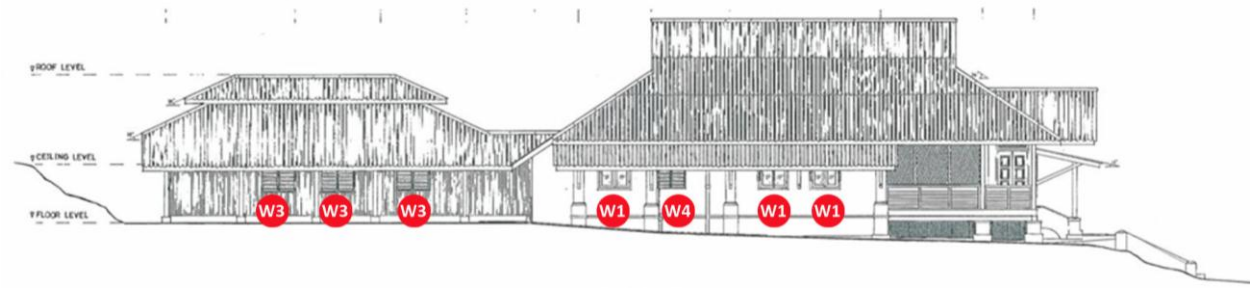

Figure 4.27: West elevation
(Source: UM CORE, 2006)

4.5.4 Result of Window to Wall Ratio JKR 541

Table 4.6: Summary of window to wall ratio for JKR 541
(Source: Author, 2009)

	POOR WWR < 0.24				GOOD WWR = 0.24				OVERHEAT WWR > 0.30			
	W	S	N	E	W	S	N	E	W	S	N	E
W1	1	2		2	2			1				
W2			1					4		2		
W3	3			1								
W4	1		1	1								
W5			1									
W6			1				1					
TOTAL	5	2	4	4	2	0	1	5	0	2	0	0
GRAND TOTAL	**15**				**8**				**2**			

Refer to Table 4.6, JKR 541 has 8 windows that allowed for optimum ventilation and daylighting into the room; 15 windows allowed insufficient ventilation and daylight into the room and 2 windows caused overheating. This building design is different from the other buildings selected for the calculation of WWR as it does not have any clerestory windows. Therefore, the number of windows for this building is less compared to other buildings.

4.6 Summary of Window to Wall Ratio

- In general, the majority of windows in selected British Colonial residences allowed insufficient day ligthing and natural ventilation to the interior areas with 47nos out of 60nos of windows in JKR 511; 40nos out of 54 nos of windows in JKR 989; 47 out of 49 windows in JKR 1331; 41 out of 62 of windows in JKR 1716 and 15 out of 25 windows in JKR 541 showed poor WWR rating which is less than 0.24. This shows the British Colonial residences

that are supposed to be designed as climatic responsive as suggested by A. Ghafar Ahmad were not complied by all the case studies.

- It is noted that windows which had optimum WWR located at different orientation for different case studies. JKR 511 had 7 windows which located on North, North East, East and South East, JKR 989 had 1 no which located at North East, JKR 1716 had 2 nos which located at North West and South West respectively and JKR 541 had 8 nos which located at North, East, West. All these windows are not located at North or South which is ideal for window orientation as East and West allowed direct light into the room and caused heat gain.

- From the Window to wall calculation, most windows of JKR 511 provide insufficient daylight and ventilation.

- JKR 1716 has the most windows which contribute to overheat to the rooms. JKR 1331do not have any windows that allow optimum ventilation and daylighting into the house.

- JKR 541 has the most windows which had been modified in design and changed to fixed glass windows.