Chapter 25
Shading Performance on Terraced House Facade Designs in Malaysia

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Abstract This study analyses shading performance on front house facades in Malaysia designed with early, modern, postmodern and neo-minimalist architectural style. For the case study, four front facades of the terraced houses are selected. The reason for the selection of terraced houses as the case studies is that terraced houses are the most popular house type built in urban areas in this country. The Early Modern Terraced House Style was built in 1950s to 1970s, and Modern Terraced House Style was popularly built later in 1980s to 1990s. Postmodern Terraced House Style was commonly integrated in the building design in 2000s while the Neo-Minimalist Terraced House Style has been integrated in the house design since 2010. The selected case studies are located in Petaling Jaya, Putrajaya and Shah Alam, the new towns of Kuala Lumpur, the capital city of Malaysia. The SunTool software is used in the survey to calculate shading percentages on the front house facades. The survey will be conducted at a position when the sun path is perpendicular to the house facade. The study finds that the shading performance is improving over time. Recessed wall, balcony, attached roof and roof overhang are commonly used in the house facade design with car porch on the ground facade level.

Keywords Shading • Facade • Terraced house • Architectural styles

Nomenclature

S_{WA}	Shaded window area (S_{WA})
S_{WH}	Shaded window height (S_{WH})
W_W	Window width (W_W)
S_{OA}	Shaded opaque area (S_{OA})
S_H	Shaded opaque height (S_{OH})
F_L	Facade length (F_L)

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E_{OA} Exposed opaque area (E_{OA})
T_{OA} Total opaque area (T_{OA})
F_H Facade height (F_H)
T_{WA} Total window (glazing) area (T_{WA})
W_H Window height (W_H)
$W_N\&_T$ Window number and type ($W_N\&_T$)
E_{WA} Exposed window area (E_{WA})

25.1 Introduction

This study discusses results of shading area on house facades of selected terraced houses designed with different architectural styles built from 1950s to present. Terraced house types are selected for the case studies because they are the most popular house types built in urban area in Malaysia representing more than 43 % of the total house units in 2000 [1]. The finding of this study is able to guide the architects with information on awareness to design terraced house facades with excellent sun shading elements. Design faults and lack of consciousness about the importance of shading elements by the architects when designing the house facade are among the major reasons of this poor design. With poor design, the house facade will be exposed to direct sunlight. The benefit of this study is the providing of empirical findings and contributions which lead to design recommendations on terraced house facade design as one of the important considerations. In a tropical region like Malaysia, excellent facade design to avoid intensity of solar radiation is necessary [2]. House facade exposed to direct sunlight causes problem of solar radiation. The sun energy will reradiate the heat from outside wall transmitted to the interior of the house [3, 4]. It generates extra heat gains inside the house which causes warm temperature to the indoor area. As a result, this creates uncomfortable thermal condition to the occupants. The objectives of this study are:

- To measure the level of shading performance on four different architectural styles of front facade terraced houses in Malaysia
- To identify the types of shading elements which provide excellent shade on the house facade

25.2 The Case Studies

The case studies consist of a survey on front facades of terraced houses built in four different periods which typify atypical design in Malaysia, namely the early modern style in 1950s, modern style in 1980s, postmodern style in 2000s and neo-minimalist style in 2010s. All the selected houses are located in new towns near Kuala Lumpur. The good examples of the early and modern terraced houses are in Petaling Jaya which is the first Garden City new town built in Malaysia.

The case studies of the postmodern style are selected in Putrajaya which is the latest new town and currently functioned as an administrative city for the federal government [5, 6]. Finally the selected case studies of neo-minimalist style are located in one of the newly garden housing estates in the existing new town of Shah Alam. The summary of design and addresses of selected terraced houses for the case studies are as follows:

1. The Early Terraced Houses (Fig. 25.1) were either built by the British authority slightly before the country's independence or local authority to house the government officers and city population from 1950 to 1970 [5]. The style typifies model village concept with simplified cottage style based on terraced house design and its site planning by Raymond Unwin and Barry Parker who built the first Garden City new town, Letchworth, in 1903 near London, England [7].

   (a) Case Study A: No. 2, 6/30 Street, Section PJS6, 46000, Petaling Jaya.
   (b) Case Study B: No. 9, 3/57D Street, Section PJS3, 46000, Petaling Jaya.

2. Modern Terraced House Style (Fig. 25.2) typifies simple geometric design influenced from modern architecture during Industrial Age [8, 9] with reference from a development of simplified cottage style in the Early Modern Terraced House Style.

   (a) Case Study A: No. 17, SS1/34 Street, Section SS1, 47300 Petaling Jaya.
   (b) Case Study B: No. 25, SS2/43 Street, Section SS2, 47300 Petaling Jaya.

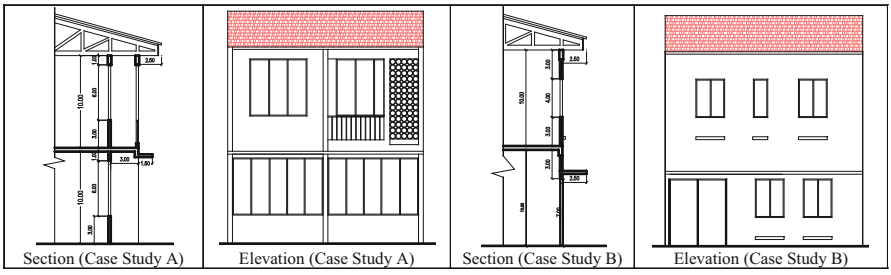

Fig. 25.1 Section and elevation in the Case Study A and B of the early terraced house facade

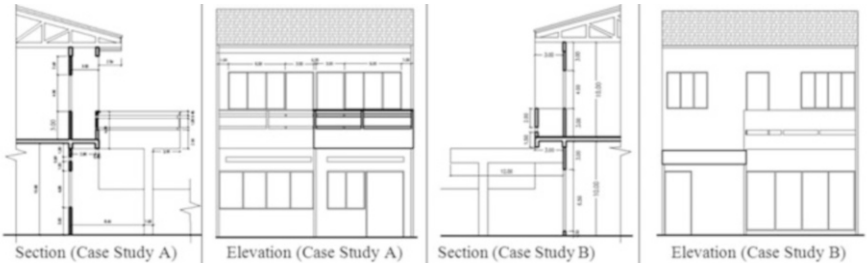

Fig. 25.2 Section and elevation in the Case Study A and B of the modern terraced house facade

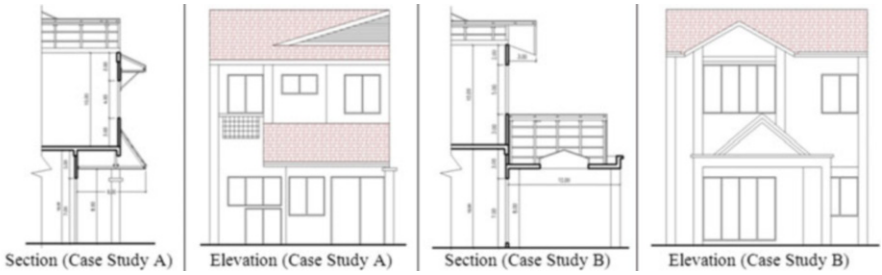

Fig. 25.3 Section and elevation in the Case Study A and B of the postmodern terraced house facade

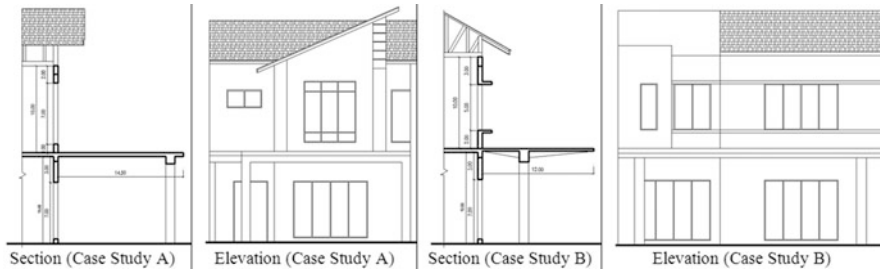

Fig. 25.4 Section and elevation in the Case Study A and B of the neo-minimalist terraced house facade

3. Postmodern Terraced House Style (Fig. 25.3) has architectural mixture of modern style with Palladian Villa, Mediterranean or Traditional Malay style. The design has complex geometric elements blending of modern, colonial and traditional styles with colourful paints on the house facade [10]. Its design deviates from regular and simple composition of modern architectural style which emphasises an expression of architectural simplicity with white colour scheme [11].
   (a) Case Study A: No. 12, Jalan P9D3 Street, Presint 9, 62250 Putrajaya.
   (b) Case Study B: No. 25, Jalan P16D2 Street, Presint 16, 62150 Putrajaya.
4. Neo-Minimalist Terraced House (Fig. 25.4) is an architectural style which typifies a style after 2010s with integration of modern design with complex simplified geometry with white and grey tones of colour facade. It has also known as "neo-geometric" or "neo-geo" art's concept [12].
   (a) Case Study A: Arabella Type A, Section 13, Shah Alam (under construction).
   (b) Case Study B: Marbella Type A, Section 13, Shah Alam (under construction).

25.3 Material and Methods

25.3.1 Computer Simulation

The SunTool software will be used in the survey to calculate the percentage of shading area on the selected front house facades. The survey will be conducted at a position when the sun path is perpendicular to the house facade during morning (east) and evening (west) session in each of the case studies. The reason having perpendicular orientation is that terraced houses are mass-produced house type built at a position of various orientations. In this study, the day time at which the sun path perpendicular to the front house facade will be used in order to generate the results when the house facade has been perpendicularly exposed to direct sunlight. By having this method, the survey will be able to do comparative analysis identifying the effectiveness of shading design on the house facades [13, 14]. Limitation of this survey is that the position of the sun path changes over time. In order to get perpendicular angle of the sun (sun path's azimuth) to the east (90°) and west (270°), the data were calculated using the SunTool software. Time and date when the sun paths were perpendicular to the house facade are illustrated in Table 25.1 and Fig. 25.5. The other limitation is that there are certain times and dates that the sun path's azimuths were not possible to have been perfectly at 90° [15, 16]. In these cases, the closest azimuths nearest to 90° will be used when the simulations are made from 7 a.m. to 6 p.m. (daytime hours) as in Table 25.1.

All data such as the location, facade orientation (east or west), time and date will be keyed in the solar position calculator in the SunTool programme (Fig. 25.6) in order to get the correct position before the simulation is made. Later, dimensions of the house facade which are the depth of exterior shading devices, floor height, wall width and sill height will be keyed in the SunTool programme. With these solar position and dimensions of the house facade, the programme will be able to generate in its drawing section to show the sun beam and shade of the house facade which provide the results of the percentage of shading area [17].

25.3.2 Calculating Shading Area on House Facade

In order to calculate shading area, the house facades will be divided into two main areas namely opaque and glazing area. The amount of shading area of opaque and glazing elements will be analysed by using the SunTool programme. The shading area will be converted to percentage of the total facade area for comparative analysis. The amount of shading area for the window (glazing), opaque and total (window and opaque) area as indicated in Fig. 25.7 will be calculated based on the following formula [18]:

Table 25.1 Time, date and azimuth of the sun when the simulations were generated

Orientation	Time	Date	Azimuth	Orientation	Time	Date (2013)	Azimuth
East 90°	7 a.m.	23 March	90°	West 270°	1 p.m.	16 September	90.5°
	8 a.m.	25 March	90°		2 p.m.	29 March	89.8°
	9 a.m.	27 March	89.8°		3 p.m.	18 September	89.8°
	10 a.m.	28 March	90.1°		4 p.m.	26 March	89.9°
	11 a.m.	29 March	90°		5 p.m.	24 March	89.9°
	12 p.m.	29 March	92.2°		6 p.m.	22 March	89.9°

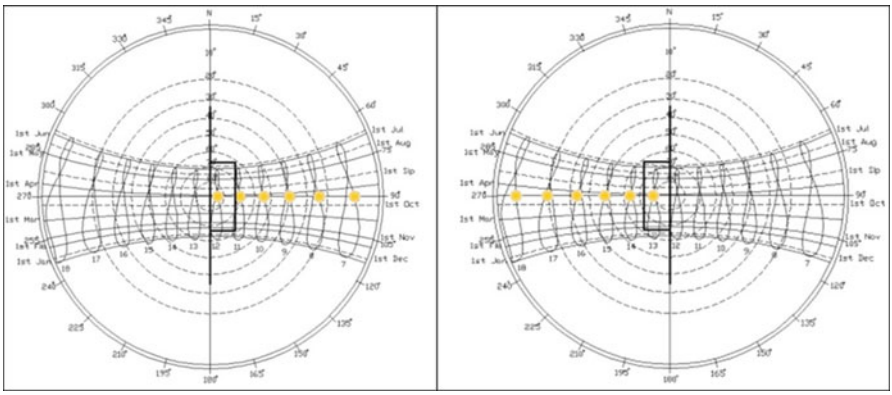

Fig. 25.5 Sun path diagrams show the position of the sun perpendicular to the house facade from 7 a.m. to 12 p.m. at east orientation (*left*) and from 1 p.m. to 6 p.m. at west orientation (*right*) during daytime hours. *Source*: SunTool software

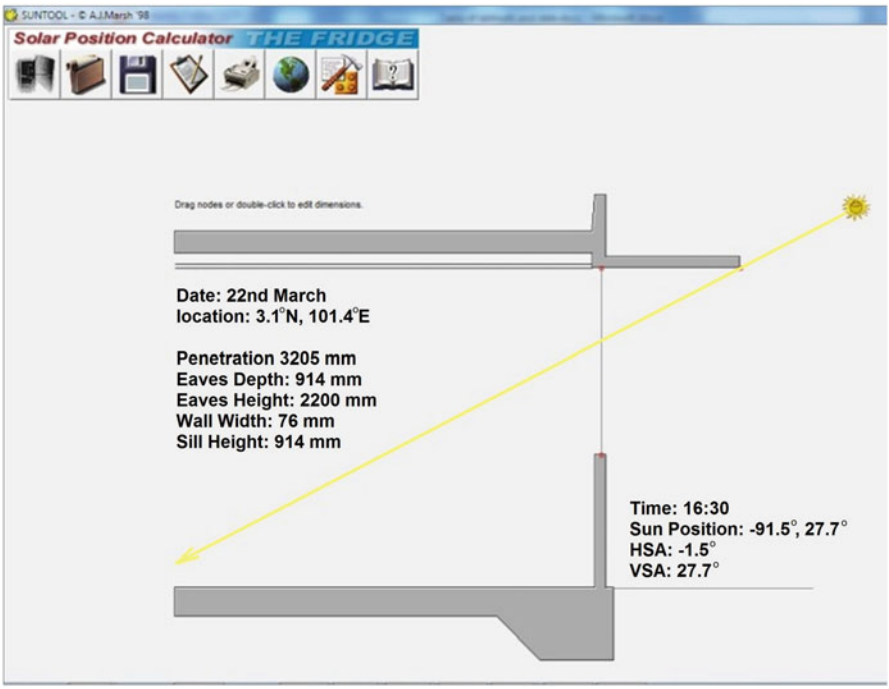

Fig. 25.6 The extent of sunlight penetration through window section. *Source*: SunTool software

1. Window (glazing) area of the house facade under shade is measured as shaded window area (S_{WA}) which is the area defined as shaded window height (S_{WH}) by window width (G_W). The equation is

$$S_{WA} = S_{WH} \times W_W$$

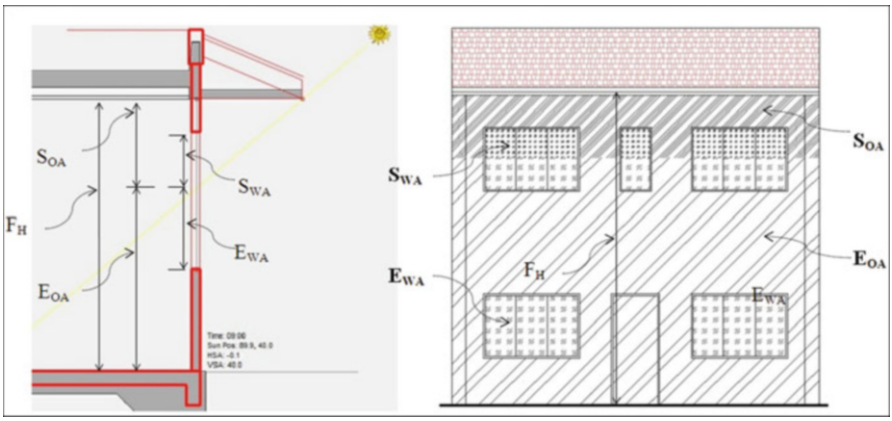

Fig. 25.7 Illustration of the house facade and section in calculation of shading area

2. Opaque (wall) area under shade is measured as shaded opaque area (S_{OA}) which is the area defined as shaded opaque height (S_{OH}) by length of the facade (F_L) minus shaded window area (S_{WA}). The equation is

$$S_{OA} = S_H \times F_L - S_{WA}$$

3. Opaque (wall) area exposed to the sunlight is defined as exposed opaque area (E_{OA}) which is total opaque area (T_{OA}) minus shaded opaque area (S_{OA}). The equation is

$$E_{OA} = T_{OA} - S_{OA}$$

4. Total opaque (wall) area of the house facade is defined as total opaque area (T_{OA}) which is the area defined as facade height (F_H) by facade length (F_L) minus total window area (T_{WA}). The equation is

$$T_{OA} = F_H \times F_L - T_{WA}$$

5. Total window (glazing) area (T_{WA}) is all window area of the house facade defined as window height (W_H) by window width (W_W) by window number and type ($W_{N\&T}$). The equation is

$$T_{WA} = W_H \times W_W \times W_{N\&T}$$

6. Exposed window (glazing) area exposed to the sunlight is defined as exposed window area (E_{WA}) which is total window area (T_{WA}) minus shaded window area (S_{WA}). The equation is

$$E_{WA} = T_{WA} - S_{WA}$$

25.4 Results and Discussion

The analysis compares results of shading area on the front house facade at the ground floor level (storey 1) and first floor level (storey 2) for each of the case studies. The scales of measurement are divided into four categories namely Category 1 from 0 to 25 % as very weak, Category 2 from 26 to 50 % as weak, Category 3 from 50 to 75 % as good and Category 4 above 75 % as excellent [17]. Table 25.2 shows percentages of the shading area of the house facades in the Case Studies from results of the computer simulation, which will be used in the analysis.

25.4.1 Early Terraced House Style

Tables 25.3 and 25.4 and Fig. 25.8 show the percentages of shading area for the two selected case studies of Early Terraced House Style. The results illustrate that in the Case Study A, shading area of storey 1 at 7:00 a.m. and 8:00 a.m. was under Category 1 in the scales of measurement with 9.36 % and 17.08 %, respectively. At 9:00 and 10:00 a.m., the shading areas were classified under Category 2 with 26.95 % and 43.26 % respectively. At 12:00 p.m., the facade had an excellent shading performance with 100 % shading area while at 1:00 p.m. its shading area slightly declined to 78.94 %. The results show that at 2:00 p.m., the shading area dropped to Category 3 with 64.06 %. Finally in the last 3 h, shading area was under Category 1 from 23.24 % at 4:00 p.m., 12.55 % at 5:00 p.m. to 3.54 % at 6:00 p.m. For the Case Study B, its shading area of storey 1 fell under Category 1 for the first 2 h at 7:00 and 8:00 a.m. before it had a gradual increase to Category 2 at 9:00 a.m. and Category 3 at 10:00 a.m. Shading area at 11:00 a.m. was under Category 4 with 84.82 %. At 12:00 and 1:00 p.m., shading area accounted 100 % before it had a steady decline to Category 3 with 73.98 % at 2:00 p.m., Category 2 with 40.67 % at 3:00 p.m. and Category 1 at 4:00 p.m., 5:00 p.m. and 6:00 p.m. with 24.66 %,

Table 25.2 Total facade area (percentages of the shading area of the house facades in the Case Studies from results of the computer simulation, which will be used in the analysis)

Cases		Total area (m^2)	Window (m^2)	Opaque (m^2)	Storey 1		Storey 2	
					Window (m^2)	Opaque (m^2)	Window (m^2)	Opaque (m^2)
1950s	Case A	38.5	16.7	21.7	11.1	8.1	5.6	13.7
	Case B	35.6	4.5	21.8	2.2	14.9	2.2	16.3
1980s	Case A	36.1	10.6	25.5	6.1	13.3	4.5	12.3
	Case B	40.6	11.1	29.5	7.2	13	3.9	16.4
2000s	Case A	37.2	6.9	30.3	3.2	15.4	3.7	14.9
	Case B	40.9	11.5	29.4	6.3	14.1	5.2	15.2
2010s	Case A	47.3	11.1	36.2	5.2	20.4	5.9	15.8
	Case B	53.5	16.1	37.4	9.7	17.1	6.4	20.3

Table 25.3 Shading percentages of the Case Study A (Early Terraced House Style)

Shading area								
		Storey 1		Storey 2		Total		
Facade	Time	Window %	Opaque %	Window %	Opaque %	Storey 1 %	Storey 2 %	Total shade
East 90	7:00 a.m.	3.41	15.31	0	12.81	9.36	6.40	7.88
	8:00 a.m.	17.08	17.08	12.6	28.54	17.08	20.57	18.82
	9:00 a.m.	36.16	17.74	36.03	46.03	26.95	41.03	33.99
	10:00 a.m.	64.75	19.78	66.5	76.02	42.26	71.26	56.76
	11:00 a.m.	82.16	54.67	100	77.86	68.41	88.93	78.67
West 270	12:00 p.m.	100	100	100	100	100	100	100
	1:00 p.m.	100	57.87	100	100	78.93	100	89.46
	2:00 p.m.	73.75	54.38	83.5	72.95	64.0658	78.22	71.14
	3:00 p.m.	48.08	18.15	50.66	56.98	33.11	53.82	43.47
	4:00 p.m.	29	17.49	34.06	27.09	23.24	30.57	26.91
	5:00 p.m.	12.25	16.91	13.8	11.31	14.58	12.55	13.56
	6:00 p.m.	0.33	13.67	0	7.09	7.01	3.54	5.27

Table 25.4 Shading percentages of the Case Study B (Early Terraced House Style)

Shade area 1950s case B								
		Storey 1		Storey 2		Total		
Facade	Time	Window %	Opaque %	Window %	Opaque %	Storey 1 %	Storey 2 %	Total shade %
East 90	7:00 a.m.	0	5.76	0	5.27	2.88	2.63	2.75
	8:00 a.m.	16.75	12.47	0	13.94	14.61	6.97	10.79
	9:00 a.m.	40	20.9	0	25.18	30.45	12.59	21.52
	10:00 a.m.	76.75	34.22	20	39.89	55.48	29.94	42.71
	11:00 a.m.	100	69.65	100	65.2	84.82	82.6	83.71
West 270	12:00 p.m.	100	100	100	100	100	100	100
	1:00 p.m.	100	100	100	100	100	100	100
	2:00 p.m.	94.5	53.47	73.12	52.52	73.98	62.82	68.4
	3:00 p.m.	55	26.34	0	31.98	40.67	15.99	28.33
	4:00 p.m.	31.5	17.82	0	20.96	24.66	10.48	17.57
	5:00 p.m.	10.75	10.3	0	11.01	10.52	5.5	8.01
	6:00 p.m.	0	3.2	0	2.92	1.6	1.46	1.53

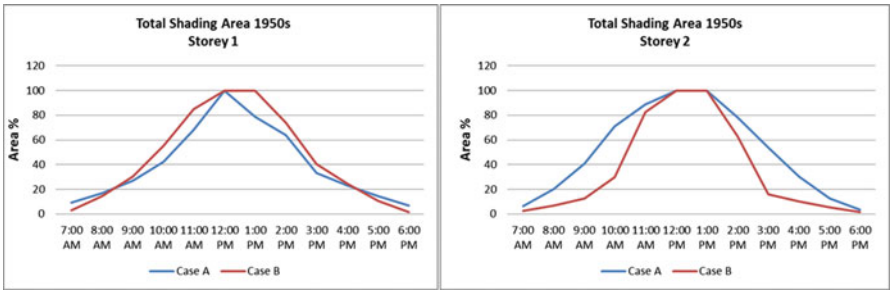

Fig. 25.8 Shading percentages of the Case Study A and B, the Early Terraced House Style. Storey 1 (*left line chart*), storey 2 (*right line chart*)

10.52 % and 1.6 %, respectively. Storey 1 in the Case Study B had slightly better overall shading performance (Fig. 25.7) than that in the Case Study A.

For storey 2 in the Case Study A, it had shading area at 7:00 a.m. and 8:00 a.m. under Category 1 with 6.4 % and 20.57 %, respectively. It had a gradual incline from Category 2 at 9:00 a.m. with 41.03 % to Category 3 at 10:00 a.m. with 71.26 %. From 11:00 a.m. to 2:00 p.m. the shading areas were under Category 4 with 88.93 % at 11.00 a.m. and 78.22 % at 2:00 p.m., and 100 % from 12:00 to 1:00 p.m. The shading percentages had a gradual decline at the last 4-h daytime from Category 3 at 3:00 p.m. with 53.82 % and Category 2 at 4:00 p.m. with 30.57 % to Category 1 at 5:00 p.m. and 6:00 p.m. with 12.55 % and 3.54 %, respectively. Compared to storey 2 in the Case Study A, storey 2 in the Case Study B had low percentages of shading area. It had lower percentages of shading area than Case A with less than 25 % at the first 3 h and last 4 h during the daytime. Its shading percentages were under Category 1 from 7:00 a.m. (2.63 %) to 9:00 a.m. (12.59 %) during morning hours and from 3:00 p.m. (15.99 %) to 6:00 p.m. (1.46 %) during evening hours. At 10:00 a.m., the shading area was under Category 2 with 29.94 %; however, at 11.00 p.m. it had a dramatic increase to Category 4 with 82.6 and 100 % at 12:00 to 1:00 p.m. At 2.00 p.m., the shading area dropped to Category 3 with 62.82 %, and after that, its percentage had a sudden decline to 15.99 % (Category 1) at 3:00 p.m. The reason for this sudden incline and drop factor is that the Case Study B does not have a recessed wall design on its facade only fitted with roof overhang as a shading element. Storey 2 in the Case Study A has good recessed wall design with a balcony as sun shading element which contributes better shading result in contrast to storey 2 in the Case Study B.

25.4.2 Modern Terraced House Style

The results are shown in Tables 25.5 and 25.6 and Fig. 25.9 which shows that both storey 1 and 2 of the house facade in the Case Study A had higher shading percentages than the Case Study B most of the time except during afternoon hours.

Table 25.5 Shading percentages of the Case Study A (Modern Terraced House Style)

Shade area 1980s case A								
		Storey 1		Storey 2		Total		
Facade	Time	Window %	Opaque %	Window %	Opaque %	Storey 1 %	Storey 2 %	Total shade %
East 90	7:00 a.m.	7.57	23.47	0	21.75	15.52	10.87	13.2
	8:00 a.m.	34.60	53.45	12.7	37.01	44.03	24.85	34.44
	9:00 a.m.	43.93	91.45	65.31	43.62	67.69	54.46	61.08
	10:00 a.m.	71.36	92.12	100	73.18	81.74	86.59	84.16
	11:00 a.m.	100	92	100	100	96	100	98
West 270	12:00 p.m.	100	97.96	100	100	98.98	100	99.49
	1:00 p.m.	100	97.96	100	100	98.98	100	99.49
	2:00 p.m.	100	91.82	100	100	95.91	100	97.95
	3:00 p.m.	55	91.57	95.93	47.03	73.28	71.48	72.38
	4:00 p.m.	39.39	89.33	44.97	40.71	64.36	42.84	53.60
	5:00 p.m.	23.03	43.84	0	34.16	33.43	17.08	25.26
	6:00 p.m.	3.78	15.31	0	21.43	9.54	10.71	10.13

Table 25.6 Shading percentages of the Case Study B (Modern Terraced House Style)

Shade area 1980s case B								
		Storey 1		Storey 2		Total		
Facade	Time	Window %	Opaque %	Window %	Opaque %	Storey 1 %	Storey 2 %	Total shade %
East 90	7:00 a.m.	0	23.97	0	21	11.98	10.5	11.24
	8:00 a.m.	0	54.58	0	29.41	27.29	14.7	20.99
	9:00 a.m.	2.76	93.38	0	36.83	48.07	18.41	33.24
	10:00 a.m.	30.61	94.07	34.25	44.95	62.34	39.6	50.97
	11:00 a.m.	93.84	93.95	100	78.42	93.89	89.21	91.55
West 270	12:00 p.m.	100	100	100	100	100	100	100
	1:00 p.m.	100	100	100	100	100	100	100
	2:00 p.m.	62.92	93.76	85.5	57.69	78.34	71.59	74.97
	3:00 p.m.	13.84	93.51	7.25	39.96	53.68	23.6	38.64
	4:00 p.m.	0	91.22	0	25.99	45.61	12.99	29.3
	5:00 p.m.	0	44.77	0	27.63	22.38	13.81	18.1
	6:00 p.m.	0	15.63	0	19.66	7.81	9.83	8.82

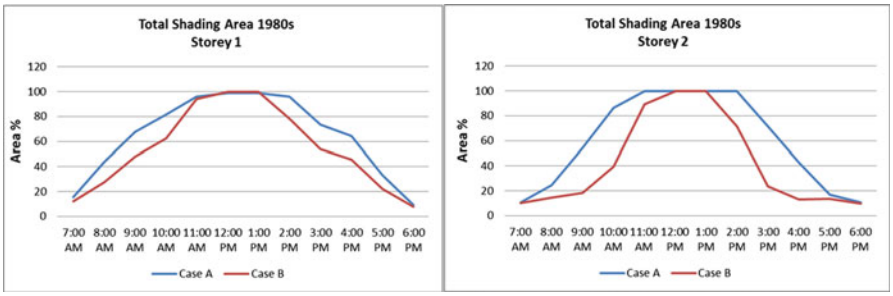

Fig. 25.9 Shading percentages of the Case Study A and B, the modern terraced house style. Storey 1 (*left line chart*), storey 2 (*right line chart*)

Storey 1 in the Case Study A had shading area started with Category 1 at 7:00 a.m. with 15.52 %. Shading area of storey 1 in the Case Study A was under Category 2 with 44.03 % at 8:00 a.m. and inclined to Category 3 at 9:00 a.m. with 67.69 %. From 11:00 a.m. to 2:00 p.m., the percentages were under Category 4 with almost 100 % shade of the front facade. The percentages had a gradual decrease from 3:00 to 6:00 p.m. with 73.28 % (Category 3), 64.36 (Category 3) and 33.43 % (Category 2) to 9.54 % (Category 1). Storey 1 of the Case Study B had shading area started with 11.98 %. The percentage later had a steady increase to 27.29 % at 8:00 a.m., 48.07 % at 9:00 a.m. and 62.34 % at 10:00 a.m. The facade had excellent shade with 93.89 % at 11:00 a.m., followed by 100 % at 12:00 and 1:00 p.m. After 1:00 p.m., the shading area had gradually dwindled to 78.34 % at 2:00 p.m., 53.68 % (Category 3) at 3:00 p.m., 45.61 % (Category 2) at 4:00 p.m., 22.38 % at 5:00 p.m. and 7.81 % (Category 1) at 6:00 p.m.

Storey 2 had slightly lower shading performance than storey 1 in both of the case studies. Shading area on a house facade of storey 2 in the Case Study A was 10.87 % (Category 1) at 8:00 p.m. It had a steady increase to 24.85 % at 9:00 a.m. and 54.46 % at 10:00 a.m. From 10:00 a.m. to 2:00 p.m., the facade had excellent shade (Category 4) with 86.59 % at 10:00 a.m. and 100 % from 11:00 a.m. to 2:00 p.m. After that, the shading area had dwindled to 71.48 % (Category 3) at 3:00 p.m., 42.84 % (Category 2) at 4:00 p.m., 17.08 % (Category 1) at 5:00 p.m. and 10.71 % at 6:00 p.m. Storey 2 in the Case Study B had shading percentage with 10.5 % at 7:00 a.m. and had a gradual incline with 14.7 % at 8:00 a.m., 18.41 % (Category 1) at 9:00 a.m. and 39.6 % (Category 2) at 10:00 a.m. Shading area had a dramatic increase at 11:00 a.m. with 89.21 %. Storey 2 had excellent shading area with 100 % at 12:00 and 1:00 p.m. but its shading area had dwindled to 71.59 % (Category 3) at 2:00 p.m. and sudden drop to 23.6 % (Category 2) at 3:00 p.m. Later, it had a steady decrease to 12.99 % (Category 1) at 4:00 p.m., 13.81 % at 5:00 p.m. and 9.83 % at 6:00 p.m. Unlike the Case Study A, storey 2 in the Case Study B had a sudden incline at 10:00 a.m. and decline at 3:00 p.m., about 50 % difference because its overhang roof has the same width (3 ft) as its cantilevered balcony.

25.4.3 Postmodern Terraced House Style

Tables 25.7 and 25.8 and Fig. 25.10 show the results of shading area in percentages in the Case Study A and B. The analysis finds that both the case studies of Postmodern Terraced House Style had the smallest number of shading percentages with 100 % compared to other terraced house styles. Front facade of storey 1 in the Case Study B had higher overall shading percentages than that in the Case Study A. Storey 1 in the Case Study A had shading area with 15.56 % at 7:00 a.m. followed by a gradual increase of shading percentage with 36.29 % at 8:00 a.m., 56.10 % at 9:00 a.m., 64.36 % at 10:00 a.m. and 67.89 % at 11:00 a.m. Shading area at 12:00 p.m. and 1:00 p.m. fell under Category 4 with 87.45 % and 80.09 %, respectively. However, shading percentage had gradually dwindled to 66.18 % at 2:00 p.m., 62.59 % (Category 3) at 3:00 p.m., 48.10 % (Category 2) at 4:00 p.m., 29.17 % at 5:00 p.m. and 11.35 % (Category 1) at 6:00 p.m.. Storey 1 in the Case Study B had shading area under Category 2 with 26.46 % at 7:00 a.m. and Category 3 with 57.84 % at 8:00 a.m. It had excellent shading percentage under Category 4 from 10:00 a.m. to 3:00 a.m. At 4:00 p.m., the shading area had a steady decrease from 74.49 % (Category 3) at 4:00 p.m. and 47.23 % (Category 2) at 5:00 p.m. to 17.78 % (Category 1) at 6:00 p.m.

The analysis also finds that front house facade of storey 2 in the Case Study A had better overall shading performance than that in the Case Study B. The shading percentage in the Case Study A was 24.72 % at 7:00 a.m., 38.06 % at 8:00 a.m. and 63.67 % at 9:00 a.m.. The shading percentage was excellent (Category 4) from 10.00 a.m. to 2:00 p.m. From 3:00 to 6:00 p.m., it had a gradual decrease from 72.43 % (Category 3), 50 and 33.35 % (Category 2) to 22.69 % (Category 1). Storey 2 in the Case Study B had shading area started with 9.39 % at 7:00 a.m., 12.6 % at 8:00 a.m., 20.76 % at 9:00 a.m. and 42.71 % at 10:00 a.m. The percentage had a sudden incline at 11:00 a.m. with 87.81 % (Category 4), and was 100 % at 12:00 and 1:00 p.m. At 2:00 p.m., the shading area declined to 61.75 % (Category 3) but at 3:00 p.m., it had a sudden drop to 28.47 % (Category 2). For the last 3 h of the daytime, the percentage had declined to 17.37, 11.66 and 7.74 %.

25.4.4 Neo-Minimalist Terraced House Style

Tables 25.9 and 25.10 and Fig. 25.11 show the results of shading percentages of Neo-Minimalist Terraced House Style. Both the case studies had excellent (Category 4) shading percentages on storey 1 front house facade from 9:00 a.m. to 4:00 p.m. They have wide car porch which gives shade to the facade of storey 1. Storey 1 house facade in the Case Study B had slightly higher overall shading percentages than that in the Case Study A. In the Case Study A, storey 1 had a shading area with 16.5 % at 7:00 a.m., followed by 59.72 % (Category 3) at 8:00 a.m. Similar pattern occurred in the evening hours with 43.89 % at 5:00 p.m. before it

Table 25.7 Shading percentages of the Case Study A (Postmodern Terraced House Style)

Shade area 2000s case A								
		Storey 1		Storey 2		Total		
Facade	Time	Window %	Opaque %	Window %	Opaque %	Storey 1 %	Storey 2 %	Total shade %
East 90	7:00 a.m.	4.7	26.43	0.6	48.84	15.56	24.72	20.14
	8:00 a.m.	34.7	37.87	19.05	57.08	36.29	38.06	37.17
	9:00 a.m.	56.23	55.96	65.1	62.25	56.1	63.67	59.89
	10:00 a.m.	64.7	64.02	84.575	77	64.36	80.79	72.57
	11:00 a.m.	64.7	71.08	100	89.22	67.89	94.61	81.25
West 270	12:00 p.m.	91.17	83.73	100	93.75	87.45	96.87	92.16
	1:00 p.m.	83.67	76.5	100	93.75	80.09	96.87	88.48
	2:00 p.m.	64.7	67.66	100	88.55	66.18	94.27	80.23
	3:00 p.m.	60.35	64.83	78.25	66.61	62.59	72.43	67.51
	4:00 p.m.	52.35	43.85	41.175	58.83	48.1	50	49.05
	5:00 p.m.	24.05	34.28	12.225	54.48	29.17	33.35	31.26
	6:00 p.m.	0	22.71	0	45.39	11.35	22.69	17.02

Table 25.8 Shading percentages of the Case Study B (Postmodern Terraced House Style)

Shade area 2000s case B								
		Storey 1		Storey 2		Total		
Facade	Time	Window %	Opaque %	Window %	Opaque %	Storey 1 %	Storey 2 %	Total shade %
East 90	7:00 a.m.	14.82	38.10	0	18.79	26.46	9.39	17.93
	8:00 a.m.	62.47	53.22	0	25.21	57.84	12.6	35.22
	9:00 a.m.	89.23	68.13	4.91	36.62	78.68	20.76	49.72
	10:00 a.m.	97.26	69.32	34.71	50.7	83.29	42.71	63
	11:00 a.m.	100	77.63	99.46	76.17	88.81	87.81	88.31
West 270	12:00 p.m.	100	100	100	100	100	100	100
	1:00 p.m.	100	87.96	100	100	93.98	100	96.99
	2:00 p.m.	100	71.6	64.35	59.14	85.8	61.75	73.77
	3:00 p.m.	92.32	68.59	14.01	42.93	80.45	28.47	54.46
	4:00 p.m.	86.32	62.66	6.5	28.24	74.49	17.37	45.93
	5:00 p.m.	45.97	48.49	1.07	22.26	47.23	11.66	29.45
	6:00 p.m.	1.98	33.59	0	15.48	17.78	7.74	12.76

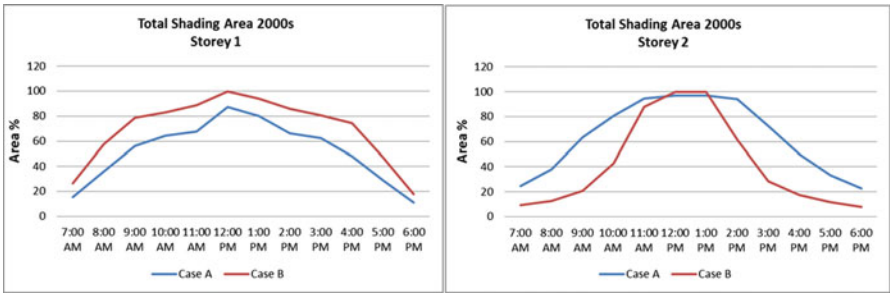

Fig. 25.10 Shading percentages of the Case Study A and B, postmodern terraced house style. Storey 1 (*left line chart*), storey 2 (*right line chart*)

declined to 10.5 % at 6:00 p.m. In the Case Study B, storey 1 had a shading percentage of 24.77 %. In contrast to storey 1 in the Case Study A, the shading percentage was excellent (Category 1) with 81.43 % at 8:00 a.m. At 5:00 p.m., it was 63.4 %, and had suddenly dwindled to 13.2 % at 6:00 p.m.

Storey 2 in both the Case Study A and B had lower shading percentages than storey 1. It has poor shading designed only with roof overhangs. Shading percentage of storey 2 in the Case Study A started with 1.85 % at 7:00 a.m. It had a gradual increase to 5.27 % at 8:00 a.m., 10.8 % at 9:00 a.m. and 30.2 % at 10:00 a.m. From 11:00 a.m. to 1:00 p.m., the shading area had excellent percentages (Category 4). The percentages had a steady decline from 40.85 % (Category 2) at 2:00 p.m., 15.27 % (Category 1) at 3:00 p.m., 8.42 % at 4:00 p.m. and 4.12 % at 5:00 p.m. to 2.02 % at 6:00 p.m. Storey 2 in the Case Study B had shading area with 5.88 % at 7:00 a.m., 12.99 % at 8:00 a.m., 24.25 % (Category 1) at 9:00 a.m., 38.05 % at 10:00 a.m. and 71.53 % (Category 3) at 11:00 a.m. It had excellent shading percentage at 12:00 and 1:00 p.m. with slightly above 75 %. Starting at 2:00 p.m., it had gradually dwindled from 49.25 % (Category 2) to 25.36 % at 3:00 p.m., 18.62 % (Category 1) at 4:00 p.m., 10.7 % at 5:00 p.m. and 4.19 % at 6:00 p.m.

Figure 25.12 shows the overall results on shading percentages of all terraced house styles. Storey 1 had better overall shading performance on front house facade than storey 2. Integration of car porch in the design of front house facade created excellent shading area in Modern, Postmodern and Neo-Minimalist Terraced House Style. Only Early Modern Terraced House Style does not have front facade design with a car porch. Neo-Minimalist Terraced House Style had the best shading percentage on storey 1 followed by Postmodern and Modern Terraced House Styles because it had the widest car porch design covering its ground facade level (storey 1). Postmodern and Modern Terraced House Styles do not have wide cover with a car porch but they have integrated a car porch with recessed wall design on the ground level of the house facade. For storey 2, Postmodern Terraced House Style had the best design with shading elements followed by Modern Terraced House Style and Early Modern Terraced House Style. Neo-Minimalist Terraced House Style had the worst shading performance on front facade of Storey

Table 25.9 Shading percentages of the Case Study B (Neo-Minimalist Terraced House Style)

Shade area 2010s case A								
		Storey 1		Storey 2		Total		
Facade	Time	Window %	Opaque %	Window %	Opaque %	Storey 1 %	Storey 2 %	Total shade %
East 90	7:00 a.m.	2.14	30.86	0	3.702	16.5	1.85	9.17
	8:00 a.m.	63.07	56.37	0	10.54	59.72	5.27	32.49
	9:00 a.m.	100	81.9	0	21.6	90.95	10.8	50.87
	10:00 a.m.	100	94.64	22.01	38.39	97.32	30.2	63.76
	11:00 a.m.	100	100	82.81	82.84	100	82.83	91.41
West 270	12:00 p.m.	100	100	100	100	100	100	100
	1:00 p.m.	100	100	100	97.74	100	98.87	99.43
	2:00 p.m.	100	100	34.31	47.38	100	40.85	70.42
	3:00 p.m.	100	100	3.045	27.50	100	15.27	57.63
	4:00 p.m.	100	77.38	0	16.84	88.69	8.42	48.55
	5:00 p.m.	38.15	49.64	0	8.25	43.89	4.12	24.01
	6:00 p.m.	0	21.01	0	2.02	10.5	2.02	6.26

Table 25.10 Shading percentages of the Case Study B (Neo-Minimalist Terraced House Style)

Shade area 2010s case B								
		Storey 1		Storey 2		Total		
Facade	Time	Window %	Opaque %	Window %	Opaque %	Storey 1 %	Storey 2 %	Total shade %
East 90	7:00 a.m.	4.61	44.93	0.98	10.77	24.77	5.88	15.32
	8:00 a.m.	81.76	81.10	2.72	23.26	81.43	12.99	87.93
	9:00 a.m.	100	100	5.39	43.12	100	24.25	112.12
	10:00 a.m.	100	100	26.26	49.85	100	38.05	119.02
	11:00 a.m.	100	100	76.4	66.66	100	71.53	135.76
West 270	12:00 p.m.	100	100	86.95	66.66	100	76.81	138.4
	1:00 p.m.	100	100	86.95	66.66	100	76.81	138.4
	2:00 p.m.	100	100	43.13	55.38	100	49.25	124.62
	3:00 p.m.	100	100	6.26	44.46	100	25.36	112.68
	4:00 p.m.	100	100	4.05	33.2	100	18.62	109.31
	5:00 p.m.	57.69	69.12	2.14	19.26	63.4	10.7	68.76
	6:00 p.m.	0	26.4	0.52	7.86	13.2	4.19	15.29

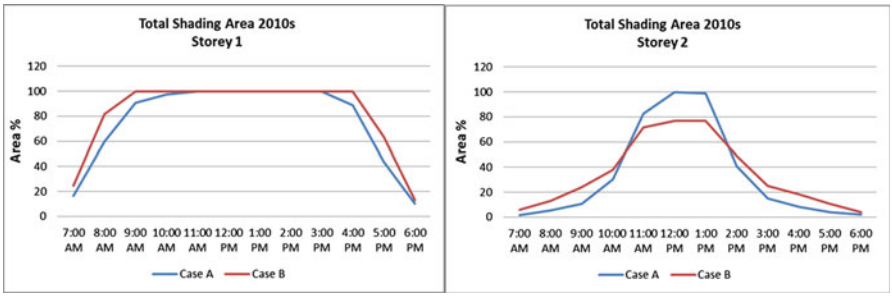

Fig. 25.11 Shading percentages of the Case Study A and B, neo-minimalist terraced house style. Storey 1 (*left line chart*), storey 2 (*right line chart*)

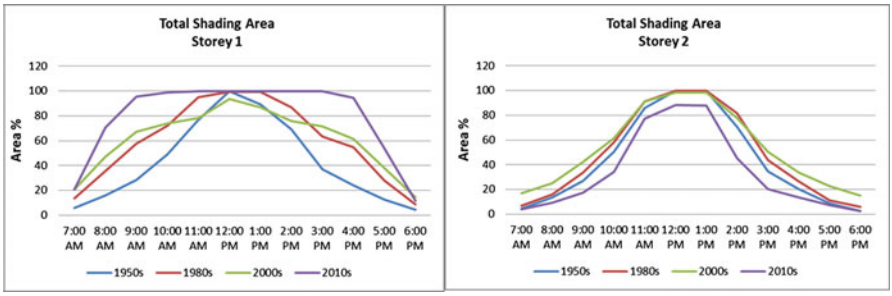

Fig. 25.12 Shading percentages of the Case Study A and B in all front facades of the terraced house styles. Storey 1 (*left*), storey 2 (*right*)

2 because it had only roof overhang as a part of its facade design. Postmodern, Early Modern and Modern Terraced House Styles had a front facade design integrated with roof overhang, attached roof, recessed wall and balcony.

25.5 Conclusion

The study finds that shading performance of the front house facades is poor in the early morning and late evening in all case studies of the terraced house styles except Neo-Minimalist Terraced House Style because the facades were exposed to direct sunlight due to the low angle of the sun position in the sky during these times [19]. However, this study does not concern to early morning hours before 10:00 a.m. due to cool morning temperature below 28 °C [3]. Having exposed to direct sunlight before 10:00 a.m. is permissible in a tropical country like Malaysia as it is morning sunlight. Having exposed human skin to UV radiation from morning sunlight is necessary formation for vitamin D [20]. The most concern hours are from 11:00 a.m. to 4:00 a.m., the time when the front facades are exposed

to warm and harsh sunlight. This study finds that all facades in general are well designed with shading devices. Most facades had shading percentages under Category 3 and 4 during these hours. Most facades had 100 % shading at 12:00 to 2:00 p.m.. Car porch, recessed wall, balcony, attached roof and roof overhang are atypical sun shading elements integrated in the front facade design in Malaysia. These devices are very effective sun shading elements preventing solar radiations on the house facade. The study finds that shading performance is improving over time on the ground facade level (storey 1) of the terraced house design, except the facade on the first floor level (storey 2) of Neo-Minimalist Terraced House Style.

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