Shading Analysis on Front Facade of Modern Terraced House Type in Petaling Jaya, Malaysia

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Abstract

This study discusses shading analysis on front facade of modern terraced house type built in 1980s. Three house facades are selected for the case studies located in SS1 and SS2 in Petaling Jaya about 12 km from Kuala Lumpur, Malaysia. The facade design typifies an idea of simple geometric style and had influenced from modern architectural style. It is an expression of purity in basic geometric design considered the design as international style which abandoned the tradition and cultural factor. The design had popularised application of new modern materials at that time like glass windows, bricks, reinforced concrete, rubbers and aluminium, the materials which were mass-produced in the factory. The survey uses simulation technique using the SunTool software with reference to dimensions of the house facades calculated at hourly interval from 7.00am to 6.00pm. The study finds that the design had emphasised on horizontal sunshade projection with integration of car porch, roof overhang and balcony as shading devices but it had lack of emphasis on vertical sunshade projection.

Keywords: shading, sunlight penetration, modern, terraced house, facade, Petaling Jaya

1. Introduction

The aim of this study is to analyse front facades of modern terraced house type in relation to their performance on the amount of shading area and extent of sunlight penetration. There are three house facades selected in this study located in SS1 and SS2. SS is a prefix which means ‘Sungai Way-Subang’ area, part of Petaling Jaya built in 1980s. Old housing areas were named Petaling Jaya Selatan (South Petaling Jaya) or PJS followed by section number like PJS1, PJS 4 and PJS7, built from 1950s to 1960s located at Petaling Jaya Old Town while the use of Section followed by its number is housing areas built in 1970s. Finally, new housing areas mostly built after

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1990s has a prefix PJU (Petaling Jaya Utara/North Petaling Jaya) accompanied with its section number like PJU1, PJU4, and PJU6.

Petaling Jaya is the first new town in Malaysia located about 12 km southwest of Kuala Lumpur built under Decentralised Programme to tackle population overcrowding problem due to migration of rural population to urban area in Kuala Lumpur which had caused dramatic increase of the city population (Brookfield, 1994; Lim, 1987). With the construction of Petaling Jaya New Town, the government was able to provide a new place for the city residents who worked in Kuala Lumpur with decent living condition (Hassan, 2005; Hall, 1988). Therefore, the Decentralised Programme was able to curb the squatter issues (Ahmad, 1980; Agus, 1994). An area located in the Petaling District was chosen as the location of the first new town, which was named as 'Petaling Jaya' from the name of the word 'Petaling', the district name and 'Jaya' which means ‘Success’ because of the authority’s expectation of the urban development marking as successful incentive by the federal government.

The design, planning and construction of Petaling Jaya New Town was first initiated by the British Administration in 1950s. The administration of Petaling Jaya Town Authority began in 1953 headed by N.A.J. Kennedy (Lim, 1987). Slightly after the country’s independence in 1959, Abdul Aziz Haji Mohd Ali was entrusted as the new director (Hassan, 2005). In 1977, this new town was upgraded to city’s status administered under Petaling Jaya City Council. Since then Petaling Jaya has experienced rapid development in ‘Sungai Way-Subang’ areas in 1970s and Petaling Jaya Utara in 1990s to house the city population booming in Kuala Lumpur. In 1995, the area development was 45 km² with ½ million people and in 2000, the area development had doubled to 97 km² populated by more than 1 million people (Department of Statistics Malaysia, 2003).

2. Case Study

There are 3 front house facades of the terraced houses chosen as the case studies (Figure 1). All the houses typify an architectural style of modern housing era built from 1980s to 1990s. The style had characterised by abstract and simple geometric elements, an expression of pure geometric shapes in plan, elevation and section design. It is a typical style used in architectural and planning design during the Age of the Industrial Revolution especially in modern era as noted by Kostof (1999). The selected case studies are as follows:

- Case Study A: No.17, Road SS1/34, 47300 Petaling Jaya, Selangor (Figure 2)
- Case Study B: No.25, Road SS2/43, 47300 Petaling Jaya, Selangor (Figure 3)
- Case Study C: No.37, Road SS2/39, 47300 Petaling Jaya, Selangor (Figure 4)
Figure 2. Front facade (left) and section (right) of Case Study A

Figure 3. Front facade (left) and section (right) of Case Study B
Application of the geometric features could be traced in the house design elements such as roof, facades, windows, staircase, balconies and car porch. This design prototype is common in housing area in SS1 and SS2. With basic usage of geometric design, the style became a prototype of universal architecture that was popularised by the modern architects such as Walter Gropius, Mies van der Rohe, Le Corbusier and Rietveld Gerry (Curtis, 1996). The architectural design emphasised a concept of 'purity' (originality) in using geometric forms and shapes. The result was the building design with rectangular and square boxed form as the most typical design in addition to spherical, oval, conical, cylindrical and pyramid form imitating the most basic and origin of geometry in 'purest form' (Frampton, 1992). The concept design was influenced by engineering design technique in modern era which has an emphasis on mechanical design using basic geometric elements. Application of decorative elements with fancy motifs was rejected by the modern architects during this era.

Engineering profoundly has influenced modern architecture, preceded by the Industrial Revolution. The term 'Industrial Revolution' itself defined as 'engineering' influence in architecture (Hassan, 2009). Architectural design was swayed to mechanical technique in design which promoted an idea of 'form follows function' which had emphasised a building design on function basis (Powell, 1989). As a result, any adornment which had no design function should not be part of the design. It was an era of design application with a notion of engineering perspectives. Art was defined as an image of ‘form follows function’ (Hassan, 2001). Therefore, the art of building design typified simplicity of architectural form following respective functions of the structures, facades, roofs, walls and floors. This design was known as international style as argued by Ricoeur (1961) because it was the design which did not reflect to its culture, tradition and place.

3. Research Methodology

A survey on the amount of shading area and extent of sunlight penetration will be generated using the SunTool software set at latitude N3.1° and longitude E101.4° which is the location of the case studies in Petaling Jaya. The simulation will be conducted at the sun path perpendicular to the house facades both in the morning (east) and evening (west). The reason is to generate uniform simulation process at the same position of the sun.
path to all the facades. Terraced houses are mass produced house type which has the house facades built at various orientations to the sun path. As a result, conducting simulation perpendicular to the sun path will give the best comparative results on the shading performance (Arab & Hassan, 2012; Bakhlah, & Hassan, 2012; Landry & Breton, 2009). The problem when conducting this simulation is that the positions of the sun azimuth in the sky change from time to time during the day time which are impossible to have 90° angle sun path oriented to the house facades (Mazloomi, Hassan, Bagherpour & Ismail, 2010). To solve this limitation, the study has pre-calculated the required sun path at 90° using the SunTool Software to have the sun path’s azimuth perpendicular to the east (90°) and west (270°) on the house facade as shown in Table 1 when the simulation will be conducted. The pre-calculated times and dates of the sun path’s azimuth are however not possible to have perfectly at 90° perpendicular to the house facade and therefore, only a series of the closest azimuths nearest to 90° will be used during the simulation (Shahriar & Mohit, 2006). When the simulation will be conducted, all the relevant data will be keyed to the solar position calculator in the SunTool software (Figure 5). After that, the dimensions of the house facade will be entered in the menu of the house section in the solar calculator. With these data, the solar calculator will be able to calculate the amount of the shading area on the house facade and sunlight penetration inside the house.

Table 1: Pre-calculated times, dates and azimuths of the sun path perpendicular to the house facades when the simulation will be generated in the survey.

<table>
<thead>
<tr>
<th>Orientation</th>
<th>Time</th>
<th>Date</th>
<th>Azimuth</th>
</tr>
</thead>
<tbody>
<tr>
<td>East 90°</td>
<td>7 am</td>
<td>23 March</td>
<td>90°</td>
</tr>
<tr>
<td></td>
<td>8 am</td>
<td>25 March</td>
<td>90°</td>
</tr>
<tr>
<td></td>
<td>9 am</td>
<td>27 March</td>
<td>89.8°</td>
</tr>
<tr>
<td></td>
<td>10 am</td>
<td>28 March</td>
<td>90.1°</td>
</tr>
<tr>
<td></td>
<td>11 am</td>
<td>29 March</td>
<td>90°</td>
</tr>
<tr>
<td></td>
<td>12 pm</td>
<td>29 March</td>
<td>92.2°</td>
</tr>
<tr>
<td>West 270°</td>
<td>1 pm</td>
<td>16 September</td>
<td>90.5°</td>
</tr>
<tr>
<td></td>
<td>2 pm</td>
<td>29 March</td>
<td>89.8°</td>
</tr>
<tr>
<td></td>
<td>3 pm</td>
<td>18 September</td>
<td>89.8°</td>
</tr>
<tr>
<td></td>
<td>4 pm</td>
<td>26 March</td>
<td>89.9°</td>
</tr>
<tr>
<td></td>
<td>5 pm</td>
<td>24 March</td>
<td>89.9°</td>
</tr>
<tr>
<td></td>
<td>6 pm</td>
<td>22 March</td>
<td>89.9°</td>
</tr>
</tbody>
</table>

Figure 5. Example of simulation in SunTool programme.
3.1. Shading Area Calculation

The solar calculator will generate the result at hourly interval starting from the time of sunrise to sunset which are approximately from 7am to 6 pm. Figure 6 and Table 2 shows the calculation’s formulas and the diagrams how the exposed and shading areas will be calculated. The wall facades are constructed from; (1). Opaque element built with brick wall plastered with cements painted in bright colour; and (2). Glazing element made from transparent glass material. This simulation will use the Imperial/British Units, not Metric Units. The reason is before 1990, all the conventional dimensioning system used in drawing the house plans, elevations and sections in Malaysia was the Imperial Units. The data generated in the simulation however will provide measurements in millimetre (Metric Units). The data later will be converted to the Imperial Units. Finally, all the results from the data will be presented in graphic line and bar charts using Microsoft Excel programme for comparative analyses.

![Figure 6: Abbreviations on facade and section](image)

### Table 2: Calculation of shading and exposed area

<table>
<thead>
<tr>
<th>Formula</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$SGA = SGH \times GW$</td>
<td>Shaded glazing area, $SGH$ = Shading Glazing Height, $GW$ = Glazing Width</td>
</tr>
<tr>
<td>$SOA = SH \times L - SGA$</td>
<td>Shaded opaque area, $SH$ = Shading Height, $L$ = Length of facade</td>
</tr>
<tr>
<td>$EOA = TOA - SOA$</td>
<td>Exposed opaque area, $TOA$ = Total Opaque Area</td>
</tr>
<tr>
<td>$TOA = FH \times L - TGA$</td>
<td>Total Opaque Area, $FH$ = Floor Height, $TGA$ = Total Glazing Area</td>
</tr>
<tr>
<td>$TGA = GH \times GW$</td>
<td>Total Glazing Area, $GH$ = Glazing Height</td>
</tr>
<tr>
<td>$EGA = TGA - SGA$</td>
<td>Exposed glazing area, $TGA$ = Total Glazing Area</td>
</tr>
</tbody>
</table>

Where: $SGA$, $SOA$, $EOA$, $TGA$, $EGA$
3.2. Extent of Sunlight Penetration

The solar calculator also will provide the data of the extent of sunlight penetration inside the terraced houses which measures ability of the sunshade projection built as a part of the facade design. In a tropical climate, most houses are constructed with sunshade projections like roof overhangs and balconies as argued by Hassan and Ramli (2010) functioned as a shading device as illustrated in the house section in Figure 7. However, there are in many cases that the extent of sunlight penetration is not only shaded by the roof overhang but also blocked by an upper window wall. To count the exact extent of the sunlight penetration, another line must be drawn parallel to the sun beam at a lower part of the upper window wall as in Figure 8. A difference of the horizontal distance (x axis) between sun beam and its lower parallel line will be deducted in this survey to get the exact extent of sunlight penetration. These occasions usually occur in early morning (7.00am to 8.00am) and late evening (5.00pm to 6.00pm) due to low sun angle in the sky. The calculation will be as follow:

Penetration = Penetration given by the software (mm) - Distance between two lines (mm)

Figure 7: An extent of sun penetration given by the SUNTOOL software
4. Result and Analysis

Figure 9 shows the results of shading areas on the house facades in the Case Study A, B and C. The study found that all the house facades had relatively similar design of shading device particularly with the application of sunshade projections like the roof overhangs, car porch and balcony. The result shows that role of sunshade projection as a part of the front facade design working as the sunshade projection was not effective in early morning and late evening. The amount of shading area casted by the overhangs was relatively small in the morning and late evening. The shading areas on the house facade were smaller than the exposed areas from sunrise (7.00am) to 9.00am and from 3.30pm to sunset. During these times, the house facades had more than 50% exposed to direct sunlight which caused solar radiation to the facade surfaces. The morning sunlight was acceptable as it supplied Vitamin D resource. The worst scenario was that from 3.30pm to 6.00pm which was the most important duration in evening times to have the house facades fully shaded from direct sunlight when it had faced the heat generated by the sunlight at its warmest temperature. By having exposed to direct sunlight during these times, the heat from the facade surface would reradiate to the indoor area of the terraced houses and caused an increase of indoor air temperature. Having a good shading device to shade the facade surface from evening sunlight was thus very necessary. In addition, the study also found that the amount of shading area had a gradual increase from sunrise. From 12.00pm to 1.00pm, it was fully shaded. At this point, the sun location was about 90° in the sky. After the afternoon, the amount of the shading area on house facade had a gradual decrease until the sunset time. From this point, the result shows that the sunshade projection did not fully able to curb the direct sunlight. In summary, the amount of shading area was larger than the amount of exposed area from 9.30am to 3.30pm. Both had reached at equal percentage at 9.00am and 3.30pm. All the facades were completely under the shade at 12.00pm and 1.00pm. After 3.30pm, the amount of shading area was smaller than exposed area.
The second assessment is to investigate the amount of shading area provided by the sunshade projections built as a part of front facade design in the case studies. In this case, a comparison was carried to measure the amount of shading area between 12ft car porch and 3ft sunshade projection (Figure 10 and 11) which also functioned as a balcony on its First Floor level. There are a large difference of the amount of shading area recorded between 12ft porch and 3ft balcony. The facade area under 12ft porch was fully shaded from 9.00am to 4.00pm while area under 3ft balcony was fully shaded from 12.00pm to 1.00pm. The average difference during
the simulation hours when the measurements were taken in hourly interval was 40.821ft². The maximum difference was 91.31ft² recorded at 4.00pm while minimum difference was 9.80ft² recorded at 6.00pm. In summary, having a car porch projection is important with its dual functions as a sunshade projection. Besides, balcony design has helped to have an increase of shading areas to the house facade.

It is worth to mention that the amount of shading area created by the balcony wall cannot be ignored in this assessment. Therefore, a comparison was carried between two house facades (Figure 12 and 13) with a 3ft projected balcony and without a balcony. The result shows that the amount of shading area on the facade with a 3ft projected balcony was larger than that of without a balcony within seven hours during a day time, starting from sunrise to 10.00am and from 3.00pm until sunset. The average difference with these hours was about 12.92ft². The maximum difference was 20.52ft² recorded at 6.00pm while the minimum difference was 0.81ft² recorded at
3.00pm. From 10.00am to 3.00pm, there was no difference with or without the balcony functioned as a shading device. In summary, it is worth to find that the presence of balcony was blocking direct sunlight during the sun’s low angle position in the sky in early morning and late evening.

![Figure 13. Shading area by balcony wall](image1)

The next assessment is the amount of shading and exposed areas on glass windows and opaque surfaces of the house facades. The result (Figure 14) shows that the amount of shading area on window area was larger than the amount of exposed area from 10.00am to 2.45pm. It however had smaller amount of shading area than that of exposed area from sunrise to 9.45am and from 2.45pm to sunset. The window area was fully under shade from 11.00am to 1.00pm when the sun position in the sky was at high vertical angle. In summary, the sunshade projection did not able to block direct sunlight especially the warm evening sunlight to the window area, which caused sun penetration into the building through the glass windows.

![Figure 14. The amount of shading and exposed area on the window areas](image2)
In addition, the study finds that the amount of shading area on the opaque wall surface of the house facade (Figure 15) was larger than that of the exposed area with a duration more than seven hours during the day time. The amount of the shading area was larger than 50% from 8.30am to 4.00pm while it was smaller than 50% in the early morning until 8.30am and from 4.00pm to sunset. The opaque wall surface was fully shaded at noon from 12.00pm to 1.00pm. About 51% to 100% of the opaque wall surface was shaded during critical hours from 9.00am to 4.00pm. In summary, the amount of shading area on opaque wall surface had better result than that of the glass windows.

The final assessment is an analysis on the extent of sunlight penetration as illustrated in Figure 16. The study finds that the sunlight started to penetrate into the house through the window facade in early morning from 8.00am to 10.00am. Its penetration retreated gradually until no penetration occurred inside the house from 11.00am to 1.30pm when the sun was at high angle position in the sky. The extent of sunlight penetration however started to increase gradually from 2.00pm to 6.00pm. The average difference from 8.00am to 10.00am was 8.48ft ranging from 2.47ft to 14.85ft. On the other hand, the average difference from 2.00pm to 5.00pm was 8.76ft ranging from 0.77ft to 19.88ft. The maximum extent of sunlight penetration was at 7.00am and 6.00pm which was 41.21ft and 80.03ft respectively while the minimum was 0.77ft recorded at 2.00pm. In addition, there is no sunlight penetration occurred from 11.00am to 1.00pm.

The other comparison was to analyse the effectiveness of sunshade projection on sunlight penetration through windows between 12ft porch and 3ft overhang. The result (Figure 17) shows 12ft porch had allowed direct sunlight penetration from sunrise till 8.00am and in late evening from 5.00pm to sunset. The 12ft porch had completely blocked direct sunlight penetration about eight hours’ duration from 9.00am to 4.00pm. However 3ft sunshade projection had only allowed direct sunlight penetration from sunrise to 10.00am and from 2.00pm to sunset. It was only able to block sunlight penetration about three hours from 11.00am to 1.00pm. In summary, the integration car porch as a part of the front facade design has helped to minimise direct sunlight penetration to the indoor area.
5. Discussion

The analysis finds that the small amount of shading area (less than 50%) casted on the front house facade in early morning and late evening was due to sun position in the sky where the sun angle was low. Besides, it is typical for front facades of modern terraced houses to have 3ft sunshade projection dual functions as either a roof overhang or balcony on the first floor. The sunshade projection had gradually casted the amount of shading area on the house facade from 7.00am to 11.00am to 40% because of movement of the sun position in the sky. The house facade was fully shaded in the afternoon when the vertical sun angle is high (above 70°). Horizontal sunshade projection was popularly integrated in modern terraced house design by the architects in 1980s. Its
length thus played important role in determining the amount of shading area (Hassan & Arab, 2013) on the house facade. The large difference on the amount of shading area casted hourly between 3ft sunshade projection and 12ft car porch had demonstrated the effect on the length of the projection.

The use of horizontal projection was one of the effective shading devices to cast shadows on the house facade as argued by Hassan & Ramli (2010). Integration of 12ft car porch was a wise design approach to enhance the sunshade performance. It was however not fully able to cast the shadows in early morning and late evening as an effective horizontal sunshade projection to shade the house facade from direct sunlight when the sun angle was at low position in the sky as noted by Zain-Ahmed (2000). Integration of vertical sunshade was crucial to enhance the amount of shading performance on the house facade but it usage was unpopular in the design of modern terraced house type built in 1980s in Malaysia. The study besides finds that difference between shading and exposed area on window and opaque surface of the house facade was due to the position of window built on wall surface and the height of its sill which had determined the amount of direct sunlight on the window area. The lower was the sill height, the larger was the area exposed to direct sunlight. Without the use of vertical sunshade projection and because of low angle of the sun position in the sky, the extent of sunlight penetration from windows of the house facade was high inside the house in early morning and late evening. Like the amount of shading area, the length of sunshade projection was also functioned as the shading device (Hassan & Arab, 2012) which had played an active role in curbing the extent of sunlight penetration inside the house.

6. Conclusion

The front facade design of modern terraced houses typifies an adoption of simple geometric style which had been influenced from modern architectural style. The study finds that the design had emphasised on horizontal sunshade projection with integration of car porch, roof overhang and recessed balcony as shading devices but it had lack of emphasis on vertical sunshade projection. The effect of horizontal sunshade projection had caused the amount of shading area only larger than the amount of exposed area from 9.30am to 3.30pm. Both had reached at equal percentage at 9.00am and 3.30pm. All the facades were completely under the shade at 12.00pm and 1.00pm. After 3.30pm, the amount of shading areas was relatively small. Having a car porch projection is important with its other function as a sunshade projection. Besides, projected balcony design has helped widen the sunshade projection when combined with the roof overhangs from 3ft to 6ft, which increases the amount of shading areas on the house facade. In addition, it is worth to find that the presence of balcony was also blocking direct sunlight during the sun’s low angle position in the sky in early morning and late evening. The study also shows that the amount of shading area on opaque wall surface had better result than that of the glass windows. Integration car porch as a part of the front facade design has helped to minimise direct sunlight penetration to the indoor area.

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