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# Analysis on the OTTV of Modern-Style Apartment Facades in Bandar Sri Permaisuri, Kuala Lumpur

**Ahmad Sanusi Hassan* and Muhammad Hafeez Abdul Nasir**

*School of Housing Building and Planning, Universiti Sains Malaysia (USM), 11800 USM, Penang, Malaysia*

## ABSTRACT

The aim of this paper is to interrogate the principle of heat gain by the Overall Thermal Transfer Value (OTTV) through residential building facades. This study proposes three façade configurations as case studies to determine their capability of achieving the OTTV set by the current residential standards. Utilising the OTTV formula provided by the Malaysian Standards, the OTTV of each case study was calculated using parameters including Window-to-Wall Ratio (WWR), Shading Coefficient (SC), U-values and solar absorption (α). Results showed that each of the façade generated OTTV exceeding the regulation of 50 W$m^{-2}$. The study uncovered the increase in WWR leading to the increase in OTTV. The OTTV increased alongside window areas due primarily to the high amount of heat gained through windows, a constituent component of OTTV. Simultaneously, high Shading Coefficient (SC) and U-values were found to cause the high amount of solar heat gained through windows. The result underpins the impacts of high solar heat gain particularly from windows of a building envelope on OTTV. Recommendations for improvement of OTTV of the residential façades are also discussed..

*Keywords:* Apartment facades, Green Building Index (GBI), modern style, OTTV

## INTRODUCTION

This study examined the impacts of façade design on the Overall Thermal Transfer Value (OTTV) of modern-style apartment in Bandar Sri Permaisuri, Kuala Lumpur. In this study, three case studies were proposed to configure the facade option that offers the OTTV suitable to the current residential standards, in response to the tropical climate of Malaysia. Each of the case studies embodies different window configurations, while other parameters remain controlled. The repercussion of manipulating the window configurations alters the window-to-wall (WWR), a crucial parameter in measuring heat gain of windows (Zain-Ahmed et al.,

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*E-mail addresses:*
sanusi@usm.my (Ahmad Sanusi Hassan),
muhd9008@gmail.com (Muhammad Hafeez Abdul Nasir)
*Corresponding Author

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2002) in OTTV calculation. The OTTV of each façade was calculated using the OTTV equation set by Malaysian Standards and the results would be analysed to recommend a façade design that suits the residential OTTV regulation. The study undertaken will engender concerns over efficient building facade design which validates with minimum indoor heat gain issues. Heat gain from solar radiation can be regulated with the use of proper materials on the facades (Hassan et al., 2015). The outcome entails energy efficient facade design capable of reducing the cost of indoor cooling purposes (Al-Obaidi, Ismail, & Rahman, 2014). Apartment facades, Green Building Index Malaysia (GBI), and Overall Thermal Transfer Value (OTTV) are three significant keywords in this research study. They are the factors used in the research method to measure the façade performance. The definitions are as follows.

## Apartment Facades

One of the popular apartment styles in Malaysia is the Modern-style where multitudes can be found within decentralised city centres. Built from 1980s to 1990s, the time of rapid urban growth, the style can be physically distinguished from its apparent mass-produced façade defined by abstract and simple geometric elements (Hassan & Bakhlah, 2013). Meant to express the notion of purity of the International Style, the aftermath follows the Western patterns of design and construction, which has no basis to the Southeast Asian landscape (Hassan, 2002). In addressing mass-production, the Modern style applies modern materials like glass windows, bricks, reinforced concrete, rubbers and aluminium (Hassan & Bakhlah, 2013) in the building construction. Due to their durability to weather, these imported components are embraced as the Modern architectural styles of Malaysia which are insouciant to local values and climates (Hassan, 2002).

## Green Building Index Malaysia (GBI)

Concerns over energy efficiency in the built environment, which proliferated globally, resulted in the inauguration of Green Building Index in Malaysia. Designed in response to primarily addressing energy efficiency and indoor environmental quality (Rahardjati, Khamidi, & Idrus, 2010), the GBI has been widely accepted as a performance assessment tool for Malaysia's homes since its introduction in 2009. Accordingly, a growing trend towards achieving green building performance has led a shift in attitudes from conventional to green building design due to its environmental and cost benefits (Kats, 2003). The ramification witnesses more houses are designed to abide to Malaysia's tropical climate and weather conditions. Kuala Lumpur, being Malaysia's capital and the epicentre of economic and urban growth, is subjected to the local hot and humid climate. Like any tropical regions in Malaysia, the city receives high solar intensity during the day time. Therefore, construction of efficient building envelope is quintessential in Malaysia (Bakhlah & Hassan, 2012), a requisite to improve energy efficiency and indoor environmental quality.

## Overall Thermal Transfer Value (OTTV)

The concept of overall thermal transfer value (OTTV) was first introduced by ASHRAE Standard 90A-1980 in the United States to gauge the average heat gain through a building envelope. In Malaysia, the OTTV concept is adopted in the Malaysian Standards 1525:2007; the standard regulates the OTTV of less than 50 $Wm^{-2}$ for air-conditioned areas exceeding 4000 $m^2$. Theoretically, the OTTV measures heat transfer through building envelope by conduction through an opaque surface, conduction through glass window and solar radiation through glass window. Measuring OTTV relies on four important parameters, namely Window-to-Wall Ratio (WWR), Shading Coefficient (SC), U-values and solar absorption ($\alpha$), with U-value and solar absorption having greater impact than other residential OTTV parameters (Saidur et al., 2009). For air-conditioned buildings, the amount of cooling load varies according to the heat gain of its respective building envelope. Consequently, the OTTV is a clear indicator of building envelope energy efficiency, by means of assessing the heat gain through a building envelope integral to the cooling load of air-conditioned buildings.

## METHOD

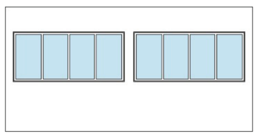
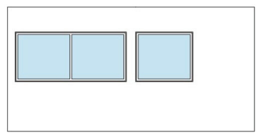
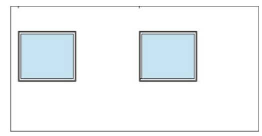
For the case study, the façade of the Cendana Apartment (Figure 1) was selected to represent a modern-style apartment to carry out the study on the OTTV of apartment façades configurations. Located at Bandar Sri Permaisuri, Cendana Apartment, a leasehold development by Tan & Tan Development is made up of a three blocks of 17-storey apartments. Comprising of 144 residential units in total, each unit is provided with 3 bedrooms and 2 bathrooms. The build-up for each unit ranges from 616 sf to 650 sf, at reasonable prices of RM65,000 to RM117,000. Temporary tenancy is also provided at the price of RM750 per month.

The façade style is defined as modern, embodying simple geometric elements, embellished with vertically arrayed repetitive glass windows on its brick walls. Strategically located in the heart of Bandar Sri Permaisuri, on the south-eastern corner of Kuala Lumpur, the apartment resides within an agglomeration of high-rise apartments, traffic networks, parklands, and shop houses. Subjected to tropical climate of Malaysia, the apartment receives high solar radiation, particularly on the west façade due to perennial solar radiation on west orientation in the evening (Hassan, Arab, & Bakhlah, 2015).

*Figure 1.* Cendana Apartment design style from 1970 – 1990 in Bandar Tun Abdul Razak, Kuala Lumpur

Referring to the façade of Cendana Apartment, two other façade configurations were generated by manipulating the area of the windows (Table 1), known as Case Study 1 and Case Study 2. While Case Study 3 mimics the original façade of the apartment. This alters the Window-to-wall ratio (WWR) of each of the case studies (Table 2).

Table 1
*Case Study and the designed façade parameters*

| | Case Study 1 | Case Study 2 | Case Study 3 |
|---|---|---|---|
| |  |  |  |
| Wall type | 150 mm plastered brick wall | 150 mm plastered brick wall | 150 mm plastered brick wall |
| Window types | 5 mm aluminium window single-glazing clear glass | 5 mm aluminium window single-glazing clear glass | 5mm aluminium window single-glazing clear glass |
| Orientation | West | West | West |
| Facade area ($m^2$) | 18 | 18 | 18 |
| Opaque Wall Area ($m^2$) | 11.52 | 13.09 | 14.66 |
| Glass Area ($m^2$) | 5.24 | 4.08 | 2.72 |
| Frame ($m^2$) | 1.24 | 0.83 | 0.62 |

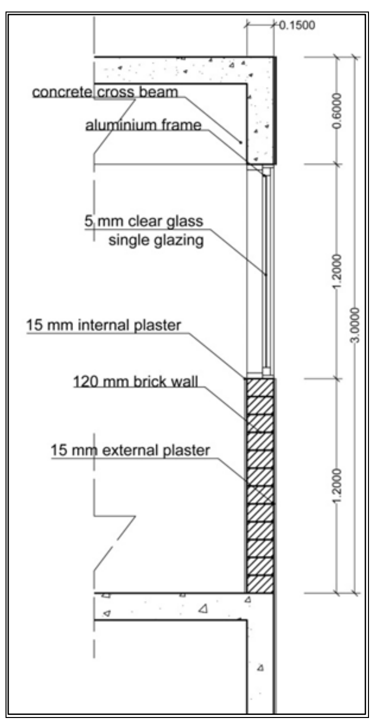



*Figure 2.* Floor to ceiling structural and wall detail

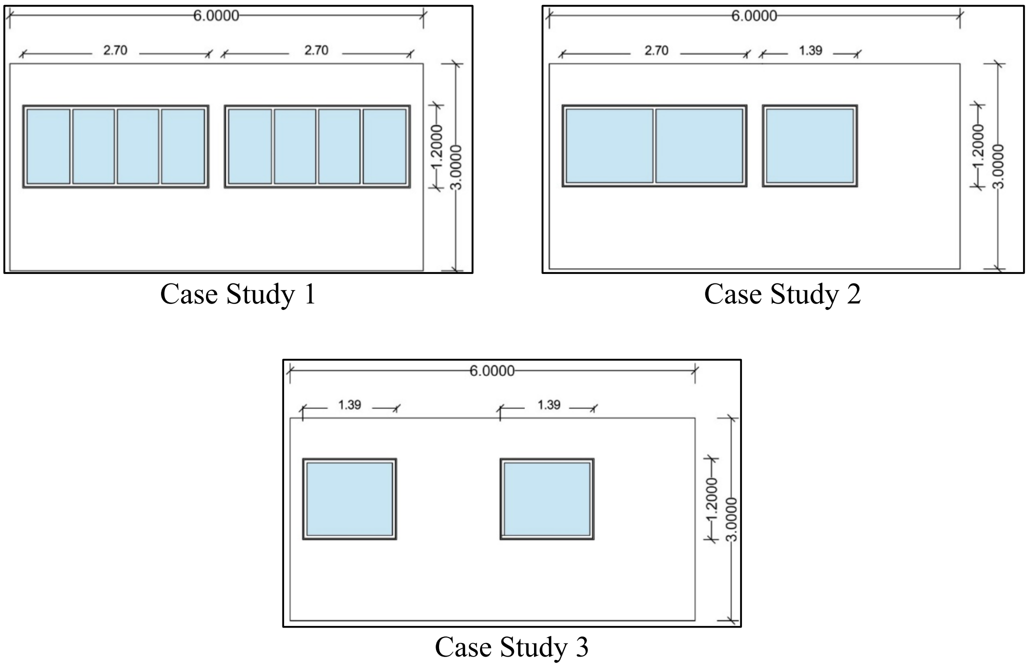



*Figure 3.* Apartment Façades in the Case Studies 1, 2 and 3

Table 2
*Window-to-wall ratio of the case studies*

| | Facade area ($m^2$) | Window Area ($m^2$) | WWR | 1-WWR |
|---|---|---|---|---|
| Case Study 1 | 18 | 6.48 | 0.36 | 0.64 |
| Case Study 2 | 18 | 4.91 | 0.27 | 0.73 |
| Case Study 3 | 18 | 3.34 | 0.19 | 0.81 |

For this study, all the façade parameters including orientation, wall and window types, and total façade area remain similar, as shown in Table 1. For each of the case studies, the Window-to-wall ratio (WWR) is different (Table 2). According to Lam et al. (2005), WWR is the ratio of window area (glass and frame) to gross wall area. Case Study 1 accounts the highest WWR of 0.36, due to its highest area of window, followed by Case Study 2 and Case Study 3. Case Study 1 to Case Study 2 records a total reduction of 31% of the window area, while Case Study 2 to Case Study 3 records a further reduction of 41% of the window area on the west façade.

In order to study the impact of OTTV on building envelope, the OTTV for each case study, which was designed with different facades, are made up of different window and wall configurations. Each parameter of the case studies is substituted into the OTTV equation set by the Malaysian Standards 1525:2007 to quantify the OTTV of respective case studies. Results of the OTTV calculation are recorded and analysed.

According to ASHRAE 90A-1980, the general OTTV equation can be expressed as:

$$OTTV_i = \frac{Q_W + Q_g + Q_s}{A_i} \quad [1]$$

$$\frac{(A_W \times U_W \times TD_{eq}) + (A_f \times U_f \times DT) + (A_f \times SC \times SF)}{A_i} \quad [2]$$

Expressing the equation in terms of WWR results in this equation,

$$OTTV_i = [TD_{eq} \times (1 - WWR) \times U_W] + [DT \times WWR \times U_f])] [SF \times WWR \times SC \times CF] \quad [3]$$

$A_f$ = the area of fenestration ($m^2$)

$A_i$ = the gross area of the walls ($m^2$)

$A_w$ = the area of the opaque walls ($m^2$)

$Q_W$ = Heat Conduction through opaque walls (W)

$Q_s$ = Solar radiation through glass windows (W)

$Q_g$ = Heat Conduction through glass windows (W)

$U_W$ = U value of the opaque part of the wall (W/$m^2$ k)

$U_f$ = U value of the fenestration (W/$m^2$ k)

SC = Shading Coefficient of window

SF = Solar factor

DT = Temperature difference between exterior and interior design conditions (°C)

$TD_{eq}$ = Equivalent temperature difference for the opaque part of the wall (K)

The OTTV concept is adopted in the Malaysian Standards 1525:2007 and the OTTV of building envelope is given by the following formula:

$$OTTV_W = 15 \times \alpha \times (1 - WWR) \times U_W + 6\ WWR \times U_f + 194 \times WWR \times SC \times CF \quad [4]$$

The absorption factor of a wall α indicates the degree a wall will absorb solar energy. For this study, the value of α of the brick wall is 0.75 (Yao & Yan, 2011). SC is the shading coefficient of a fenestration defined as the ratio of solar heat gain through a particular glass type over the solar heat gain through a 3mm clear float glass. It measures the ability of a window to reduce solar heat gain. SC value ranges between 0 and 1. Lower SC gives lower solar heat transmission, inducing greater shading capability. For this study, the facades are made up of similar 5 mm single-glazing uncoated clear glass window, which gives the SC of 0.95. CF is the solar correction factor of different orientations in Malaysia, as shown in Table 3. For the calculation involving CF, the nearest predominant orientation is selected. For this study, only the west orientation is chosen, which gives the value of 0.94.

Table 3
*Solar correction factor of different orientations in Malaysia*

| Orientation | Solar Correction Factors (Malaysia) |
|---|---|
| North | 0.9 |
| North-East | 1.09 |
| East | 1.23 |
| South-East | 1.13 |
| South | 0.92 |
| South-West | 0.9 |
| West | 0.94 |
| North-West | 0.9 |

U-value measures the rate of heat transfer through a material for every temperature difference in $W/m^2k$. The calculation of U-value of the component materials (Figure 2) of a structural brick wall is explained in Table 4. The U-value of materials is the reciprocal of thermal resistance $m^2k/W$. Therefore, the higher the U-value indicates a higher thermal transmittance of a material, thus having lower resistivity.

Table 4
*Conductivity, resistance and $U_W$ value of structural brick wall*

| Structural Materials | Thickness (m) | Conductivity (W/mk) | Resistance ($m^2k/W$) | $U_W$ ($W/m^2k$) |
|---|---|---|---|---|
| External Finish | - | - | 0.04 | |
| Plaster (exterior) | 0.015 | 0.57 | 0.026 | |
| Brick Wall | 0.1200 | 0.77 | 0.16 | |
| Plaster (interior) | 0.015 | 0.57 | 0.026 | |
| Internal Finish | - | - | 0.04 | |
| | | | εR= 0.292 | $U_W$ = 3.42 |

Windows with coating often provide better shading than the ones without coating, thus having lower U-values, as shown in Table 5.

Table 5
*Typical U-values of different window types to measure OTTV in Malaysia (Saidur et al., 2009)*

| Name | Typical Values of U |
|---|---|
| Single Glazed Window with coatings | 4.20 |
| Single Glazed Window without coating | 5.70 |

## RESULTS AND DISCUSSION

The OTTV measures heat transfer through building envelope based on three methods, namely conduction through a wall, conduction through glass window, and solar heat gain through glass window. Tables 6-9 illustrate the results of the calculation of each constituent thermal transfer methods responsible for OTTV. The heat conduction through walls is measured using the following formula:

$$\text{Heat conduction through walls} = (1\text{- WWR}) \times U_W \times 15 \times \alpha. \quad [5]$$

For this study, the facade with greater brick wall area (1-WWR) which is Case Study 3 generates greater thermal transfer value than the facades with smaller wall area. The results of the calculation are shown in Table 6.

Table 6
*Heat conduction through calls*

| Case Study | Façade Area $m^2$ | Constant (Units) | Solar Absorption Factor(α) | 1-WWR | $U_W$ Value | Heat Conduction Through walls / $Wm^{-2}$ |
|---|---|---|---|---|---|---|
| 1 | 18 | 15 | 0.75 | 0.64 | 3.42 | 22.90 |
| 2 | 18 | 15 | 0.75 | 0.73 | 3.42 | 26.21 |
| 3 | 18 | 15 | 0.75 | 0.81 | 3.42 | 29.08 |

The heat conduction through windows was measured using the following formula:

$$\text{Heat conduction through windows} = \text{WWR} \times U_f \times 6 \quad [6]$$

For this study, the facade with greater WWR, which is Case Study 1, generates a greater thermal transfer value than facades with smaller WWR. The results of the calculation are shown in Table 7. Heat conduction through windows was shown to contribute the lowest percentage of thermal transfer value with 12.6% of the OTTV. Although the values of heat conduction through wall are significantly higher than heat conduction through windows, it is also important to note that heat conduction through windows increases with facades of lower heat conduction through walls. This is partly associated with the fact that glass window has a significantly higher U-value than the brick wall material alongside increase in WWR. Appropriate selection of wall and window materials with lower U-values will result in smaller heat conduction values through walls and windows.

Table 7
*Heat conduction through windows*

| Case Study | Façade Area $m^2$ | Constant (Units) | Window to Wall Ratio/ WWR | $U_f$ Value | Heat Conduction Through Windows/$Wm^{-2}$ |
|---|---|---|---|---|---|
| 1 | 18 | 6 | 0.36 | 5.70 | 12.31 |
| 2 | 18 | 6 | 0.27 | 5.70 | 9.23 |
| 3 | 18 | 6 | 0.19 | 5.70 | 6.50 |

The Solar Heat Gain through Windows is measured using the following formula:

$$\text{Solar Heat Gain through Windows} = WWR \times SC \times 194 \times CF \qquad [7]$$

The study highlights that higher WWR results in greater solar heat gain through windows (Table 9). From all the constituent thermal transfer methods, Solar Heat Gain through windows recorded the highest percentage of thermal transfer value, with 51% of the total OTTV for Case Study 1. The high values of heat gain through windows substantially escalate the OTTV through the building envelopes. This outcome may be due to the shading coefficient (SC) and its connection to solar heat gain as all the facades are constructed with 5 mm single-glazing uncoated clear glass window with the value of 0.95. A significant reduction in solar heat gain through windows can be induced by installing tinted or double-glazed clear low-e windows, as suggested by Hassan, Arab and Bakhlah (2015).

Table 8
*Solar heat gain through windows*

| Case Study | Façade Area $m^2$ | Constant (Units) | Window to Wall Ratio | Orientation Correction Factor (CF) | SC | Solar Heat Gain Through Windows /W$m^{-2}$ |
|---|---|---|---|---|---|---|
| 1 | 18 | 194 | 0.36 | 0.94 | 0.95 | 62.40 |
| 2 | 18 | 194 | 0.27 | 0.94 | 0.95 | 46.77 |
| 3 | 18 | 194 | 0.19 | 0.94 | 0.95 | 32.91 |

In order to measure the OTTV of a building envelope, all the constituent thermal transfer values were added, as shown in equation [4]. Apparently, from the calculation, Case Study 1 accounted for the highest OTTV of 97.60 Wm$^{-2}$, followed by Case Study 2 with 82.21 Wm$^{-2}$ and Case Study 3, which resembles Cendana Apartment that accounted for 68.49 Wm$^{-2}$ or the lowest amount of OTTV. Table 9 elucidates on the OTTV of each case study.

Table 9
*Overall thermal transfer values of each of the case studies (OTTV)*

| Case Study | Heat Conduction Through Walls (Wm$^{-2}$) | Heat Conduction Through Windows (Wm$^{-2}$) | Solar Heat Gain Through Windows (Wm$^{-2}$) | OTTV (Wm$^{-2}$) |
|---|---|---|---|---|
| 1 | 22.90 | 12.31 | 62.40 | 97.60 |
| 2 | 26.21 | 9.23 | 46.77 | 82.21 |
| 3 | 29.08 | 6.50 | 32.91 | 68.49 |

In general, the OTTV of all the case studies exceeds the requirement of OTTV set by the Malaysian Standards which is 50 Wm$^{-2}$. This result does not reflect the average mean OTTV mentioned in a previous study (Saidur et al., 2009), which suggests that mean residential OTTV in Malaysia is 41.7 Wm$^{-2}$. This may partly be due to the higher WWR values of more than

0.19 used in this study to calibrate OTTV compared to the recommended value of 0.01 to 0.18 by the previous study. Case Study 1, with the total window area of 6.48, recorded an OTTV value of 97.60 $Wm^{-2}$, while Case Study 2, which was designed to embody 31% less window area than Case Study 1, recorded an OTTV value of 82.21 $Wm^{-2}$. A further reduction of 41% of the window area from case study 2 generated the OTTV of 68.49 $Wm^{-2}$ for Case Study 3.

The reduction value of WWR carried out by this study is insubstantial to generate the OTTV of less than 50 $Wm^{-2}$. Therefore, it is proposed that further reduction in WWR must be implemented, which echoes the previous study by Fadzil, Abdullah and Harun (2009), which suggests that the value of WWR should be less than 25% for residential rooms. This study finds that the higher the WWR, the higher the OTTV will be in watt per square metre ($Wm^{-2}$ or $W/m^2$). It demonstrates that the apartment design should have the optimum WWR less than 19% for the West façade for an apartment room to achieve a satisfying OTTV requirement.

## CONCLUSION

The study reveals that different façade designs generate different OTTV. An increase in the area of windows for the west façade of apartment buildings constitutes to the increase in WWR, triggering the value of Solar Heat Gain through Windows and Heat Conduction through windows. In Malaysia, all the proposed façades of the Modern style apartment exceeded the OTTV set by the residential standards of 50 $Wm^{-2}$. Therefore, additional cooling load is required to substantially mitigate heat gain through the building envelope to harness energy efficient indoor environmental quality. Solar heat gain through windows contributes the highest amount of OTTV. Therefore, measures to reduce solar heat gain through windows should be implemented to reduce OTTV. For instance, since shading coefficient (SC) is one of the parameters of heat gain through windows, providing windows with lower SC could help to reduce solar heat gain and thus reducing OTTV. The residential OTTV result underscores the importance of solar heat gain reduction in windows advocating on the needs for architects to design shading elements to give shades to the window areas, alongside windows material selection (Hassan & Al-Ashwal, 2015) and self-shading strategy (Nikpour et al., 2011) for residential building façade, in accordance with energy efficiency and improvement in indoor environmental quality.

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