Façade design modification in complying the Indonesia’s national standard of energy conservation for tall building envelope – Case study: Green Office Park 9, Serpong, Indonesia

A M Hajji¹ and A R. Z. Hilmi²
¹Civil Engineering Study Program, Universitas Negeri Malang, Indonesia
²Industrial Engineering Study Program, Bandung Institute of Technology, Indonesia

Abstract. Most tall buildings use glass as its façade and exterior materials, which makes the building’s envelope is exposed to heat penetration. It is important to select and design the proportion between transparent and opaque materials for building façade to reduce the heat gain from outside, which is strategic to conserve the energy use for tall buildings. This study is aimed to observe the use of building façade materials in accordance with the strategic effort to reduce the heat gain in order to conserve the energy for AC system. The façade design modification is calculated by using Overall Thermal Transfer Value (OTTV) method in compliance with the Indonesia’s National Standard of Energy Conservation for Tall Buildings. The results show that the modification on façade design can reduce the heat gain and improve thermal performance of the building. There is a dramatic change of OTTV from 124.40 w/m² on original design to 27.73 w/m² after several steps of façade modification. The biggest reductions of OTTV is obtained when modifications on openings are applied. Since the heat transmission is mainly coming into buildings through openings, modifications on glass and windows are the keys. The change of glass material, from clear-glass to those with lower shading coefficient (SC) gives reduction of 37.52 w/m².

1. Introduction
In building and construction industry, energy use and conservation is a big issue. The use of air conditioning (AC) system is the biggest portion of tall building energy use (50-70%), followed by lighting and other electrical system (10-25%), and building transportation system (2-10%) [1–3]. In very humid tropical climate like Indonesia, the AC system is commonly used in multi-tenant tall buildings to fulfill the needs for thermal comfort. The use of proper materials for building envelopes is the key for thermal comfort. Most tall buildings use glass as its façade and exterior materials, which makes the building’s envelope is exposed to heat penetration [4]. The more penetrated heat coming into the buildings, the more energy needed to get the thermal comfort. It is important to select and design the proportion between transparent and opaque materials for building façade to reduce the heat gain from outside, which is strategic to conserve the energy use for tall buildings. This study is aimed to observe the use of building façade materials in accordance with the strategic effort to reduce the heat gain in order to conserve the energy for AC system. A case study has been selected to show how the modification of both materials configuration and external wall design could lead to lower energy use for
AC system. Green Office Park (GOP) 9 building is designed and constructed for rental office use (Figure 1). This five-story building, which is located in BSD, Serpong, Banten, is owned by PT Bumi Serpong Damai. It has one basement, one lobby-reception floor, and four typical floors. The façade design modification is calculated by using Overall Thermal Transfer Value (OTTV) method in compliance with the Indonesia’s National Standard of Energy Conservation for Tall Buildings.

Figure 1. Design of Green Office Park (GOP) 9 Building, Serpong, Indonesia

2. Related studies
Building envelopes have significant impact on its thermal performance and total energy consumption, since it can affect the cooling load. The cooling load for building is determined by heat radiation through its openings, which is gained particularly from natural lighting design. OTTV method is widely used to measure the thermal performance of building envelopes, which is defined by the external heat gain transmitted through each area of building envelopes in watt/m². Generally, the external heat gain is transmitted mostly through openings rather than through solid walls. It requires careful design strategies for windows and openings to minimize heat gain by determining correct façade orientation, the area of openings, materials for windows (shading coefficients), and external shading construction [5]. Some studies have been carried out to calculate the external heat gain through building envelopes [6,7].

OTTV calculation can be conducted by using formula as detailed in Indonesia’s National Standard SNI 03-6389 [8]. To refine and make this OTTV method more accurate and easier, some approaches have been applied particularly to support decision making process in building façade design [9]. The use of Building Information Modelling (BIM) can also be applied to help architects in using OTTV and determining the correct materials for the façade, especially for windows and openings [10]. The results of OTTV can also be used for measuring the thermal performance of building façade, observing the alternatives design for shading [11,12], windows and vents [13], exploring architectural design, and adapting local conditions in designing energy-efficient building façade [14]. The criteria in OTTV method can also determine national strategic policy on addressing the issues of energy regulation [15–17]. On policy level, the formulation of national energy conservation index and municipality regulation can also use the results of OTTV method [18].
3. Method
The concept of OTTV covers three basic elements of thermal transfer through building envelopes: heat conduction through solid walls, heat conduction through openings, and heat radiation through openings. Each material used on solid walls and openings has its specific heat transmission and absorption. OTTV is a number defined as a building envelope’s design criteria to limit the value of heat gain, which is identified as external cooling load for AC system. To reduce this cooling load, Indonesia’s National Standard through SNI 03-6389-2011[8] has defined that the energy-efficient value the OTTV is not more than 35 watt/m². OTTV in specific orientation is calculated by the following Equation 1 and 2.

\[
\text{OTTV} = \frac{(Q_w + Q_g + Q_{sol})}{A_i}
\]

\[
\text{OTTV} = \frac{(A_w U_w T_{Deq}) + (A_f U_f \Delta T) + (A_f SC SF)}{A_i}
\]

Once each OTTV of specific orientation is obtained, the OTTV of whole building envelope is calculated by Equation 3.

\[
\text{Total OTTV} = \frac{((A_1 \text{OTTV}_1) + (A_2 \text{OTTV}_2) + \ldots + (A_n \text{OTTV}_n))}{(A_1+A_2+\ldots+A_n)}
\]

\(Q_w\) = heat conduction through solid walls (w)
\(Q_g\) = heat conduction through openings (w)
\(Q_{sol}\) = heat radiation through openings (w)
\(A_i\) = total area of openings and solid walls (m²)
\(A_w\) = area of solid walls (m²)
\(U_w\) = thermal transmittance of solid walls (w/m²°C)
\(T_{Deq}\) = temperature difference equivalent (°C)
\(A_f\) = area of openings (m²)
\(U_f\) = thermal transmittance of openings (w/m²°C)
\(\Delta T\) = inside-outside temperature difference (°C)
\(SC\) = shading coefficient of openings (unitless)
\(SF\) = solar factors (w/m²)

To attain the efficient energy use of GOP 9 Building, the OTTV of its original design is calculated. The steps of façade design modification will be changing the material type of openings, or reducing the area of openings, re-constructing the solid walls, or alternating the shading design. The modifications of its original façade design are applied to minimize the total heat gain and get the value of final OTTV to less than 35 w/m².

4. Results
To know the overall thermal value transferred through the original design, it is important to calculate the basic technical parameters for gaining the OTTV. To calculate the OTTV, it needs to get the total area of exterior wall and its openings. Since the building design has facades on all orientation, the total area of façade is calculated from eight parts of the external wall: north, northeast, east, southeast, south, southwest, west, and northwest. The total area of external walls and openings is shown in Table 1.

| Orientation | Wall (m²) | Openings (m²) | Total Area (m²) |
|-------------|-----------|--------------|-----------------|
| North       | 115.78    | 1,456.85     | 1,572.62        |
| Northeast   | 48.80     | 614.04       | 662.84          |
| East        | 317.25    | 0.00         | 317.25          |
| Southeast   | 67.79     | 853.00       | 920.79          |
| South       | 168.52    | 2,120.49     | 2,289.01        |
| Southwest   | 37.76     | 475.20       | 512.96          |
| West        | 163.30    | 81.65        | 244.95          |
| Northwest   | 34.52     | 434.43       | 468.95          |
| **Total area** | **6,989.37** |              |                  |
Based on the original design, it is specified that the wall is made of concrete at 30 cm thick covered by external and internal plastering finished with white emulsion painting. From its wall composition, it is calculated that the heat absorbance ($\alpha$) is 0.27 and the heat transmittance ($U_w$) is 2.723 W/m$^2$°C. The openings of the building use clear glass cladding with prefabricated shading coefficient (SC$R$) of 0.93 and its heat transmittance ($U_f$) is 5.7 W/m$^2$°C. From its specification, heat conduction through wall ($Q_w$), heat conduction through openings or glass ($Q_g$), solar heat gain through openings ($Q_{sol}$), and the total OTTV of building’s original design are shown in Table 2.

| Orientation | $Q_w$ (W) | $Q_g$ (W) | $Q_{sol}$ (W) | $Q_w+Q_g+Q_{sol}$ (W) | Area (m$^2$) | OTTV (W/m$^2$) |
|-------------|-----------|-----------|----------------|------------------------|-------------|----------------|
| North       | 0.55      | 26.40     | 112.00         | 138.95                 | 1,572.62    | 218,513.89     |
| Northeast   | 0.55      | 26.40     | 97.35          | 124.30                 | 662.84      | 82,392.62      |
| East        | 7.43      | 0.00      | 0.00           | 7.43                   | 317.25      | 2,358.75       |
| Southeast   | 0.55      | 26.40     | 83.57          | 110.52                 | 920.79      | 101,763.51     |
| South       | 0.55      | 26.40     | 83.57          | 110.52                 | 2,289.01    | 252,976.64     |
| Southwest   | 0.55      | 26.40     | 151.63         | 178.58                 | 512.96      | 91,604.13      |
| West        | 4.96      | 9.50      | 75.33          | 89.79                  | 244.95      | 21,993.24      |
| Northwest   | 0.55      | 26.40     | 181.78         | 208.73                 | 468.95      | 97,885.47      |
| Total       |           |           |                |                       | 6,989.37    | 869,488.26     |

| Orientation | $Q_w$ (W) | $Q_g$ (W) | $Q_{sol}$ (W) | $Q_w+Q_g+Q_{sol}$ (W) | Area (m$^2$) | OTTV (W/m$^2$) |
|-------------|-----------|-----------|----------------|------------------------|-------------|----------------|
| North       | 0.55      | 13.73     | 112.00         | 126.28                 | 1,572.62    | 198,589.75     |
| Northeast   | 0.55      | 13.73     | 97.35          | 111.63                 | 662.84      | 73,994.86      |
| East        | 7.43      | 0.00      | 0.00           | 7.43                   | 317.25      | 2,358.75       |
| Southeast   | 0.55      | 13.73     | 83.57          | 97.85                  | 920.79      | 90,097.73      |
| South       | 0.55      | 13.73     | 83.57          | 97.85                  | 2,289.01    | 223,976.36     |
| Southwest   | 0.55      | 13.73     | 151.63         | 165.91                 | 512.96      | 85,105.25      |
| West        | 4.96      | 4.94      | 75.33          | 85.23                  | 244.95      | 20,876.58      |
| Northwest   | 0.55      | 13.73     | 181.78         | 196.06                 | 468.95      | 91,944.16      |
| Total       |           |           |                |                       | 6,989.37    | 786,943.45     |

The result of OTTV calculation based on original design shows that the OTTV is much higher than the threshold stated in the Indonesia’s National Standard through SNI 03-6389-2011 for energy conservation. The steps of façade modification below are conducted to lower the OTTV by modifying possible façade elements in order to reduce the penetrated heat gain. First modification is directed to reduce the heat transfer through openings. The original clear glass cladding will be replaced by double glass cladding that has air cavity in between. The thickness of outside and inside glass is 8 mm and 6 mm respectively. This new modification of cladding construction is applied to all side of the façade and reduces the heat transmittance through openings ($U_f$) from 5.7 to 2.96 W/m$^2$°C. As the remain components remain the same, the overall thermal transfer value after first modification is shown on Table 3.

| Orientation | $Q_w$ (W) | $Q_g$ (W) | $Q_{sol}$ (W) | $Q_w+Q_g+Q_{sol}$ (W) | Area (m$^2$) | OTTV (W/m$^2$) |
|-------------|-----------|-----------|----------------|------------------------|-------------|----------------|
| North       | 0.55      | 13.73     | 112.00         | 126.28                 | 1,572.62    | 198,589.75     |
| Northeast   | 0.55      | 13.73     | 97.35          | 111.63                 | 662.84      | 73,994.86      |
| East        | 7.43      | 0.00      | 0.00           | 7.43                   | 317.25      | 2,358.75       |
| Southeast   | 0.55      | 13.73     | 83.57          | 97.85                  | 920.79      | 90,097.73      |
| South       | 0.55      | 13.73     | 83.57          | 97.85                  | 2,289.01    | 223,976.36     |
| Southwest   | 0.55      | 13.73     | 151.63         | 165.91                 | 512.96      | 85,105.25      |
| West        | 4.96      | 4.94      | 75.33          | 85.23                  | 244.95      | 20,876.58      |
| Northwest   | 0.55      | 13.73     | 181.78         | 196.06                 | 468.95      | 91,944.16      |
| Total       |           |           |                |                       | 6,989.37    | 786,943.45     |

The second modification is based on design after applying new double glass as constructed on 1st modification, and it is still aimed on reducing the heat transfer through openings. The original area of glass cladding will be reduced by adding parapet construction along the façade (Figure 2). It will be
constructed 1 m high from each floor elevation with 15 cm thick of brick-plastering material, which has 12 cm of brick thickness, and 1.5 cm for each outside and inside plastering thickness. Based on the conductivity calculation results, this new façade design has reduced the area of openings and the heat transfer on each façade orientation. The OTTV value after second modification is displayed on Table 4.

| Orientation | Qw (W) | Qg (W) | Qsol (W) | Qw+Qg+Qsol (W) | Area (m²) | OTTV (W/m²) |
|-------------|--------|--------|----------|----------------|-----------|-------------|
| North       | 2.33   | 10.09  | 82.33    | 94.76          | 1,572.62  | 149,020.52  |
| Northeast   | 2.33   | 10.09  | 71.56    | 83.99          | 662.84    | 55,673.77   |
| East        | 7.32   | 0.00   | 0.00     | 7.32           | 317.25    | 2,320.81    |
| Southeast   | 2.33   | 10.09  | 61.43    | 73.86          | 920.79    | 68,009.17   |
| South       | 2.33   | 10.09  | 61.43    | 73.86          | 2,289.01  | 169,065.82  |
| Southeast   | 2.33   | 10.09  | 111.46   | 123.89         | 512.56    | 63,551.53   |
| West        | 5.15   | 4.38   | 66.84    | 76.38          | 231.89    | 17,711.06   |
| Northwest   | 2.33   | 10.09  | 133.63   | 146.06         | 468.95    | 68,493.81   |
| Total       | 6,976.31 | 593,846.49 |     | 85.12         | 593,846.49 | 85.12 W/m² |

In third modification, a 12 mm thick gypsum board layer will be added to the interior side of brick wall constructed in 2nd modification. This gypsum board has 0.17 W/m°C conductivity and will contribute to the new heat transmittance of wall (Uw) of 2.296 W/m²°C. Although it is designed to layer all interior side of the wall, this additional gypsum board layer has only reduced the OTTV by less than 1 W/m², from 85.12 W/m² on 2nd design modification to 84.69 W/m²). The total OTTV obtained from third modification is displayed in Table 5.
Table 5. Total OTTV after 3rd modification

| Orientation     | Qw (W) | Qg (W) | Qsol (W) | Qw+Qg+Qsol (W) | Area (m²) | OTTV (W/m²) |
|-----------------|--------|--------|----------|----------------|-----------|-------------|
| North           | 1.96   | 10.09  | 82.33    | 94.38          | 1,572.62  | 148,425.75  |
| Northeast       | 1.96   | 10.09  | 71.56    | 83.61          | 662.84    | 55,423.08   |
| East            | 6.13   | 0.00   | 0.00     | 6.13           | 317.25    | 1,944.70    |
| Southeast       | 1.96   | 10.09  | 61.43    | 73.48          | 920.79    | 67,660.93   |
| South           | 1.96   | 10.09  | 61.43    | 73.48          | 2289.01   | 168,200.11  |
| Southwest       | 1.96   | 10.09  | 111.46   | 123.51         | 512.96    | 63,357.53   |
| West            | 4.32   | 4.38   | 66.84    | 75.54          | 231.89    | 17,517.46   |
| Northwest       | 1.96   | 10.09  | 133.63   | 145.68         | 468.95    | 68,316.45   |
| **Total**       | **6,976.31** | **590,846.01** |                |               | **6,976.31** | **590,846.01** |

TOTAL OTTV 84.69 W/m²

Lowering the shading coefficient (SC) is the main goal for fourth modification. Additional metal-vertical and horizontal shading (SCeff) will be constructed on northwest, west, and southwest façade, since those three elevations have the most exposed surface to solar radiation (highest solar factor). As shown on Figure 3, the vertical shading will have 40 cm of width (X), 12 mm of thickness, and constructed every 100 cm (Y) along the façade. Meanwhile, the horizontal shading will be designed to have 80 cm of length (X) for covering overall height (220 cm) of the glass cladding.

Both vertical and horizontal shading have the ratio (R) between its horizontal projection and the span of 0.40 and 0.36 with prefabricated shading coefficient (SCk) of 0.93. The combination of SCk and shading construction (SCeff) gives the total shading coefficient (SC) for the openings on northwest, west, and southwest façade of 0.581, 0.661, and 0.569 respectively. This design of physical shading has successfully reduced the solar heat gain through the openings (Qsol) on northwest façade from 133.63 W to 83.50 W, on west from 66.84 W to 47.49 W, and on southwest from 111.46 to 68.23 W. Following the solar heat gain reduction, the OTTV has also been decreased to 77.50 W/m² (Table 6).

Other than constructing physical shading, reducing the solar heat gain through openings will also be conducted by modifying the prefabricated shading coefficient (SCk). In fifth design modification, the original clear-glass cladding (SCk of 0.93) will be replaced by 8 mm dark-blue glass with SCk of 0.4. Since the value of new SC is much lower than the original, this modification gives almost half of solar
heat gain \((Q_{\text{sol}})\) of original clear glass usage for all façade orientation. The OTTV is also significantly reduced from 77.50 W/m\(^2\) to 39.98 W/m\(^2\) (Table 7).

### Table 6. Total OTTV after 4\(^{\text{th}}\) modification

| Orientation | \(Q_w\) (W) | \(Q_g\) (W) | \(Q_{\text{sol}}\) (W) | \(Q_w+Q_g+Q_{\text{sol}}\) (W) | Area (m\(^2\)) | OTTV (W/m\(^2\)) |
|-------------|-------------|-------------|----------------|-----------------|-------------|-----------------|
| North       | 1.96        | 10.09       | 82.33          | 94.38           | 1,572.62    | 148,425.75      |
| Northeast   | 1.96        | 10.09       | 71.56          | 83.61           | 662.84      | 55,423.08       |
| East        | 6.13        | 0.00        | 0.00           | 6.13            | 317.25      | 1,944.70        |
| Southeast   | 1.96        | 10.09       | 61.43          | 73.48           | 920.79      | 67,660.93       |
| South       | 1.96        | 10.09       | 61.43          | 73.48           | 2,289.01    | 168,200.11      |
| Southwest   | 1.96        | 10.09       | 68.23          | 80.28           | 512.96      | 41,178.39       |
| West        | 4.32        | 4.38        | 47.49          | 56.19           | 231.89      | 13,029.47       |
| Northwest   | 1.96        | 10.09       | 83.50          | 95.55           | 468.95      | 44,807.82       |

**TOTAL OTTV** 77.50 W/m\(^2\)

### Table 7. Total OTTV after 5\(^{\text{th}}\) modification

| Orientation | \(Q_w\) (W) | \(Q_g\) (W) | \(Q_{\text{sol}}\) (W) | \(Q_w+Q_g+Q_{\text{sol}}\) (W) | Area (m\(^2\)) | OTTV (W/m\(^2\)) |
|-------------|-------------|-------------|----------------|-----------------|-------------|-----------------|
| North       | 1.96        | 10.09       | 35.41          | 47.46           | 1,572.62    | 74,638.81       |
| Northeast   | 1.96        | 10.09       | 30.78          | 42.83           | 662.84      | 28,389.84       |
| East        | 6.13        | 0.00        | 0.00           | 6.13            | 317.25      | 1,944.70        |
| Southeast   | 1.96        | 10.09       | 26.42          | 38.47           | 920.79      | 35,424.85       |
| South       | 1.96        | 10.09       | 26.42          | 38.47           | 2,289.01    | 88,063.59       |
| Southwest   | 1.96        | 10.09       | 29.34          | 41.39           | 512.96      | 21,233.82       |
| West        | 4.32        | 4.38        | 20.42          | 29.13           | 231.89      | 6,753.95        |
| Northwest   | 1.96        | 10.09       | 35.91          | 47.96           | 468.95      | 22,492.64       |

**TOTAL OTTV** 39.98 W/m\(^2\)

### Table 8. New total area of external walls and openings after 6\(^{\text{th}}\) design modification

| Orientation | Wall (m\(^2\)) | Openings (m\(^2\)) | Total Area (m\(^2\)) |
|-------------|---------------|-------------------|----------------------|
| North       | 711.29        | 861.33            | 1,572.62             |
| Northeast   | 421.06        | 241.78            | 662.84               |
| East        | 317.25        | 0.00              | 317.25               |
| Southeast   | 503.35        | 417.44            | 920.79               |
| South       | 939.84        | 1,349.17          | 2,289.01             |
| Southwest   | 373.24        | 139.72            | 512.96               |
| West        | 163.30        | 68.59             | 231.89               |
| Northwest   | 359.20        | 109.75            | 468.95               |

**Total area** 6,976.31

The dramatic change of façade design is conducted in sixth modification. Without changing both structural and architectural layout plan, in this modification there will be additional all-floors vertical walls constructed on each curved corner of the building. The span of this new walls will be 4 m stretched
from the middle of each corner, replacing 4 m span of glass cladding at the same stretch. As shown in Figure 4 this replacement will reduce the area of openings, therefore reduces the total solar heat gain. The changes of total area of walls and openings after this modification is displayed in Table 8.

Table 9. Total OTTV after 6th modification

| Orientation | Qw (W) | Qg (W) | Qsol (W) | Qw+Qg+Qsol (W) | Area (m²) | OTTV (W/m²) |
|-------------|--------|--------|----------|----------------|-----------|-------------|
| North       | 2.77   | 8.12   | 17.54    | 28.43          | 1,572.62  | 44,704.32   |
| Northeast   | 3.89   | 5.41   | 10.30    | 19.60          | 662.84    | 12,993.89   |
| East        | 6.13   | 0.00   | 0.00     | 6.13           | 317.25    | 1,944.70    |
| Southeast   | 3.35   | 6.72   | 17.59    | 27.66          | 920.79    | 25,470.12   |
| South       | 2.52   | 8.74   | 22.87    | 34.12          | 2,289.01  | 78,108.86   |
| Southwest   | 4.46   | 4.04   | 11.74    | 20.23          | 512.96    | 10,379.65   |
| West        | 4.32   | 4.38   | 20.42    | 29.13          | 231.89    | 6,753.95    |
| Northwest   | 4.70   | 3.47   | 12.34    | 20.51          | 468.95    | 9,616.55    |
|             | TOTAL  |        |          |                | 6,976.31  | 189,972.05  |

TOTAL OTTV 27.23 W/m²
5. Conclusion
The results show that the modification on façade design can reduce the heat gain and improve thermal performance of the building. There is a dramatic change of OTTV from 124.40 w/m² on original design to 27.73 w/m² after several steps of façade modification. The biggest reductions of OTTV is obtained when modifications on openings are applied. Since the heat transmission is mainly coming into buildings through openings, modifications on glass and windows are the keys. The change of glass material, from clear glass to those with lower shading coefficient (SC) gives reduction of 37.52 w/m². Another significant modification that can lead to general façade design strategies is reducing the area of openings by replacing them with solid wall. In the case of GOP 9 Building, constructing new parapet and vertical solid wall can reduce OTTV by 27.47 w/m² and 12.25 w/m² respectively. Some good options of modification that will not substantially affect the overall architectural appearance are on glass and shading construction. Adding shading construction on openings and changing the double glazing can reduce the OTTV by 7.19 w/m² and 11.81 w/m² respectively.

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