Office with Kinetic Sunshading Application on Building Envelopes at Setiabudi

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Abstract. The Setiabudi area is a business district located in South Jakarta and is one of the business and office centers in Jakarta. With the development of the economy in Jakarta, the need for office buildings has increased. Electricity usage in the building sector reached 41% and is the biggest sector in consuming energy. The cause of excessive use of electricity is the use of AC. This is influenced by the level of solar radiation to the building. With the increasing solar radiation, building’s OTTV became out of standard. According to Governor Regulation No. 38/2012 OTTV for buildings may not exceed 45 W/m². This Electricity usage can be minimized by reducing solar radiation to the building, thus reducing the power usage of AC usage. This paper presents the study of integrating kinetic sunshading as building envelopes. The study is aimed to investigate the impact of sunshading to reduce solar radiation and reaching the standard of OTTV. The steps of study is as follows: (1) analyzing the site, (2) solar radiation simulation (3) OTTV simulation and (4) Sunshading simulation.

Keywords: Office, kinetic, sunshading

1. Introduction
This study was raised based on one of United Nations Sustainable Cities and Communities that focused on a resource efficiency and adaptation to climate change [1]. The Setiabudi area is a business district located in South Jakarta and one of the business and office centers in Jakarta. With the development of the economy in Jakarta, the need for office buildings has increased. Electricity usage in the building sector reached 41% and is the biggest sector in consuming energy [2]. The cause of excessive use of electricity is the use of air conditioners. AC usage is influenced by solar radiation to the building. With the increasing solar radiation, building’s OTTV (overall thermal transfer value) also become high and out of the standard. The regulation for buildings in Jakarta according to Governor Regulation No. 38/2012 OTTV for buildings may not exceed 45 W/m² [3].

To find out OTTV value of office buildings in the Setiabudi are at specified site, an OTTV calculation simulation will be conducted by assuming the wall construction uses white brick walls without using sunshading. The building size follows the site index guidelines so that the building size used for the simulation calculates OTTV at the site the size is 55m² for the first 3 floors and the size drops by 1 m² for every 3 floors. The results of OTTV analysis, OTTV building value reached 98 W/m² (Figure 1).
Based on Jakarta Green Building Buildings User Guide Vol.1 Building Envelopes, the potential for energy savings can be achieved through building envelopes with a passive design strategy, such as [3] wall insulation, wall reflectivity, natural light, glass, window to wall ratio, and sunshade.

According to the Jakarta Green Building Buildings User Guide Vol.1 Building Envelopes (2020) book by the Indonesian Governor sunshading as building envelopes has the greatest energy saving potential followed by window to wall ratio [3]. Therefore the use of sunshading as building envelopes is very important to reduce electricity usage of the building.

Building’s façade can be changed by natural elements such as weather, climate, and solar radiation which are dynamic or changing. Thus it appears that buildings must be able to improve with these changes by applying a Kinetic facade that will increase the building's facade efficiency capability to reduce incoming solar radiation involving buildings. Kinetic facades allow buildings to take the direction of the sun can reduce effective solar radiation and can reduce the use of electricity used in buildings.

The strategy was achieved through theories from Mark DeKay’s Sun, Wind, and Lighting Books. The book reveals various strategies for optimizing building’s envelope. One is aspect is external shades. According to the Responsive Envelopes diagram of the book, it can be illustrated in Figure 2.
simulation, that is going to prove if the solar radiation to the building has been reduced. The study is basically a simulation result of solar radiation to find the most effective sunshading for office building (Figure 3).

2.3. The case study
The study selected is at Jalan Perintis RT.3/RW.5, Kuningan, East Kuningan, Setiabudi, South Jakarta, Daerah Khusus Ibukota Jakarta (Figure 4). This location is office, market, and services zone according to Jakarta Zoning Map. This location is among one of the many high rise, mid rise building area in Jakarta. With the number of high rise and mid rise buildings in this area, the buildings in this area will be exposed to large solar radiation causing the building to heat up and the room inside the building will use a lot of air conditioning to lower the room temperature and use a lot electrical energy. Solar radiation can be reduced by applicating an external shades to the building. Therefore, the study of kinetic sunshading is considered suitable for this particular area.

3. Result and Discussion
3.1. Solar radiation simulation of the building
Based on earth revolution motion, The sun has shifted its position to the northern hemisphere, precisely on December 22 - June 21 and the shift from the northern hemisphere to the south on June 21 - December 21 (Figure 5).
The building mass that used as simulation is based on A-Z Persyaratan Teknis bangunan guide book regarding site index, initial building mass is formed following the shape of the building footprint, then adjusted to the Building Border. At each additional floor or level, the distance of the Building boundary is added 0.5m from the floor clearance below. Addition is made until it reaches the farthest free range of 12.50m (Figure 6).

![Figure 6. Solar radiation simulation results](image)

From the solar radiation simulation using FormIt application at yearly analysis the results are:

- Building mass in the north were exposed to solar radiation at 724.6 kWh/m²
- Building mass in the west were exposed to solar radiation at 883.8 kWh/m²
- Building mass in the east were exposed to solar radiation at 908.4 kWh/m²
- Building mass in the south were exposed to solar radiation at 522.7 kWh/m²

After analyzing solar radiation value, we must calculate OTTV building’s value to know if the building’s OTTV meet government requirements. Building OTTV calculations use the same size as the site index size to find out how many OTTV values a building produces. This OTTV calculation uses the assumption of building construction using a white brick wall with a fenestration system using colored glass that has a SHGC of 0.57 and a U value of 5.18 W/m²K. The results are shown in Figure 7.

![Figure 7. OTTV calculation without shading devices](image)

Source : OTTV calculator provided by https://greenbuilding.jakarta.go.id/

From the results of the OTTV simulation it was concluded that the results of the OTTV building with white brick construction with colored glass fenestration system without shade is 98 W/m².

3.2. Sunshades systems applicated in building

There are several sunshades systems. However, in OTTV calculator that provided by Green Building Jakarta have 3 system, there are: horizontal fins, vertical fins and eggcrate fins (Figure 8). This is the result of solar radiation of 3 systems of sunshades throughout the years based on sun equinox and sun solstice.
| Time            | shading   | North | East       | West       | South       |
|-----------------|-----------|-------|------------|------------|-------------|
| 21st March      | Horizontal fins | ![Image](image1) | ![Image](image2) | ![Image](image3) | ![Image](image4) |
| 21st June       |           | ![Image](image5) | ![Image](image6) | ![Image](image7) | ![Image](image8) |
| 23rd September  |           | ![Image](image9) | ![Image](image10) | ![Image](image11) | ![Image](image12) |
| 21st March      | Vertical fins | ![Image](image13) | ![Image](image14) | ![Image](image15) | ![Image](image16) |
| 21st June       |           | ![Image](image17) | ![Image](image18) | ![Image](image19) | ![Image](image20) |
Figure 8. Solar radiation simulation on sunshades

Table 1. OTTV results with various sunshades

| No. | Angle (°) | Horizontal (W/m²) | Vertical (W/m²) | Eggcrate (W/m²) |
|-----|-----------|-------------------|-----------------|-----------------|
| 1   | 0         | 88.68             | 93.46           | 85.54           |
| 2   | 10        | 87.53             | 93.01           | 84.53           |
| 3   | 20        | 86.67             | 92.67           | 83.76           |
| 4   | 30        | 86.13             | 92.33           | 83.27           |
| 5   | 40        | 85.96             | 91.91           | 83.10           |
| 6   | 50        | 86.15             | 91.51           | -               |
Based on solar radiation sunshade simulation mentioned above (Figure 8) and OTTV simulation (Table 1), the results can be concluded that building shade with eggcrate type is most effective shade to reduce the solar radiation value and reduce overall OTTV buildings.  

After we found out the most effective shade to reduce the solar radiation value and reduce the overall OTTV of the buildings is eggcrate, we create an alternative design based on eggcrate shape (Figure 9) to find the most efficient shape to reduce solar radiation to the building.

![Eggcrate shading dimensions](image)

**Figure 9. Eggcrate shading dimensions**

First alternative design is based on eggcrate sunshade shape but with different horizontal dimensions (Figure 10). After finding the first shading design, a simulation will be carried out using FormIt to find out the solar radiation to the building (Figure 11). The results are by using this first design, the solar radiations value dropped to 626 kWh/m² from 724.6 kWh/m²

![First alternative design](image)

**Figure 10. First alternative design**

![FormIt simulations result on first design](image)

**Figure 11. FormIt simulations result on first design**

Second alternative design (Figure 12) is based on eggcrate sunshade shape but with different vertical dimensions. After finding the second shading design, a simulation will be carried out using FormIt to find out the solar radiation to the building (Figure 13). The results are by using this second design, the solar radiations value dropped to 496 kWh/m² from 724.6 kWh/m²

![Second alternative design](image)

**Figure 12. Second alternative design**

![FormIt simulations result on second design](image)

**Figure 13. FormIt simulations result on second design**

Third alternative design is based on eggcrate sunshade shape with same dimensions on vertical and horizontal shade (Figure 14). After finding the third shading design, a simulation will be carried out using FormIt to find out the solar radiation to the building (Figure 15).
The results are by using this third design, the solar radiations value dropped to 421.5 kWh/m² from 724.6 kWh/m². Based on Formit simulations of three different eggrate shading shape, we found out that on the first alternative design the solar radiation dropped to 626 kWh/m², on second alternative design the solar radiation dropped to 496 kWh/m², and the third alternative design the solar radiation dropped to 421.5 kWh/m2. In conclusion, the third design is the most effective shading shape to reduce solar radiation to the building and reduce the overall OTTV of the buildings.

### 3.3 Effective sunshade angle

Based on the simulation above, eggcrate sunshade system have the most effective to reduce the solar radiation value. The selection of the eggcrate sunshade angles are determined by how much solar radiation value from four sides of the building, namely the north, east, west, and south. More detailed results from Formit simulations will be explained in Table 2.

| Time          | North (Wh/m²) | West (Wh/m²) | East (Wh/m²) | South (Wh/m²) |
|---------------|---------------|--------------|--------------|---------------|
| 21st March    | 203           | 588          | 597          | 103           |
| 21st June     | 440           | 435          | 477          | 76            |
| 23rd September| 235           | 553          | 575          | 80            |
| 22nd December | 69            | 563          | 530          | 324           |

From the results of solar radiation simulations concluded that each part of the building is exposed to solar radiation that varies from time to time. On March 21 simulation data were obtained that in the west and east were exposed to large amounts of solar radiation, it needed a shade with a large angle so that solar radiation to the building could be reduced. For the north and south have less solar radiation than the east and west then the shade of the building used will use a smaller angle so as not to reduce the view from inside the building (Table 3).

| Time          | North (*) | West (*) | East (*) | South (*) |
|---------------|-----------|----------|----------|-----------|
| 21st March    | 20        | 40       | 40       | 0         |
| 21st June     | 30        | 30       | 40       | 0         |
| 23rd September| 20        | 40       | 40       | 0         |
| 22nd December | 0         | 40       | 40       | 20        |

The shadow angle varies from 0° to 40°. The tilt position is obtained from previous solar radiation simulations which are based by sun soltice and sun equinox. The biggest solar radiation value is 597 Wh/m² on March 21 in the east. At this time the biggest shadow angle will be applied at 40°. As for the small solar radiation, which is on December 22 in the north,
where getting solar radiation of 69 Wh/m² will apply a small angle of 0°. From the results of the OTTV simulation the following data were produced (Figure 16).

![Image](https://example.com/image1)

**Figure 16. The results of solar radiation analysis on the (a) north, (b) west, (c) east, and (d) south side in a year**

After applying the eggcrate sunshades system the results of solar radiation on each side are shown in Table 4.

| Elevation | Solar Radiation with Eggcrate Sunshades (kWh/m²) | Solar Radiation without Eggcrate Sunshades (kWh/m²) |
|-----------|-----------------------------------------------|---------------------------------------------------|
| North     | 421.5                                       | 724.6                                              |
| West      | 571.5                                       | 883.8                                              |
| East      | 624.3                                       | 908.4                                              |
| South     | 301.7                                       | 522.7                                              |

### 4. Concluding Remarks

The study of kinetic sunshading in order to be applied in an office building has been conducted and the remarks can be concluded as follows:

- The building’s solar radiation varies on each side
- Eggcrate sunshades system is the most effective sunshade system to reduce building’s solar radiation and building’s OTTV.

### References

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