A study of an adaptive building façade in West Jakarta

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Abstract. This paper presents a study of irradiance level over a building envelope in order to plan an adaptive façade. The main objective of this study is to reduce the level of solar radiation incident on the building envelope. The building is located in Jakarta. The step of the study is as follows: (1) to create an initial building mass as the reference, (2) to create several alternatives of building forms to find the optimum reduction of the irradiance level, and (3) to study shading aids and its implementation on the building. The reduction of the irradiance level can be as high as 40% from the original building form by implanting the selective adaptive facade.

Keywords: adaptive façade, solar radiation, simulation

1. Introduction
A high level of solar radiation, especially in the design site, requires an appropriate response in order to reduce the level of solar radiation that will affect the performance of energy use in buildings. The results of a study from a journal said that the building facade is a significant parameter that affects the performance of energy use in a building [1]. The use of second facades off a buildings can reduce the level of solar radiation penetration into the building, by blocking solar radiation directly so that the level of solar radiation in buildings will decrease.

However, building facades are generally static, while the high level of solar radiation is influenced by the motion and position of the sun which is not static or is continuously changing. By applying the adaptive facade to the building envelope to be designed, the nature of the building facade that was previously static, now becomes dynamic where the adaptive facade can follow changes in the direction of the sun from time to time, which in return the building's facade performance can be increased. This increased, subsequently minimize the use of electricity in buildings.[2].

2. The Methodology
2.1. Building Mass Simulation
This step is to simulate an initial building form, and subsequently to create several alternatives to get the optimum building form [3], [4]. The software used in this study is FormIt. This software has a feature, solar analysis, in which the local weather data can be automatically integrated.
2.2. Analysis of Shading Aids
The results obtained from the Formit analysis was then used to determine the type of adaptive façade. Determination of the design of the facade of the building will be focused on reducing direct solar radiation, by applying the Sun Shading Device to the building envelope.

2.3. Building Adaptive Facade Design
The results of the previous analysis was developed and then was applied to the building, namely by producing adaptive building envelope designs [5], [6]. The next step is to analyze the selection of material, the color of the building facade, and the type of movement or mechanical system to be used in this adaptive facade design. The selection was focused on responding to solar radiation that affects buildings.

3. Results and Discussion

3.1. Building Mass Simulation
The first step was to make the initial building mass based on the local regulations and the room programming. Subsequently, it was simulated in a software namely FormIt.

The simulation can be concluded as follows:

- The roof surface has the highest solar radiation : 1829 kWh / m2.
- The West and the East surface has solar radiation 881.5 kWh / m2 and 721.3 kWh / m2) consecutively.
- The North and the South are 640.1 kWh / m2 and 505.8 kWh / m2 consecutively.

These results have shown that the roof surface has a tremendous solar radiation level, followed by the West, the East, the North and the South surface. After several modification studies, the optimum form is presented in Figure 2a and 2b. In order to reduce the incident solar radiation on the roof surface, an inner court is made and also the roof top is cut diagonally to make a slope.

It can be concluded from the simulation, the optimal roof slope direction is to the southeast, while the most optimal angle is 45°. However, this angle, the 45 °, the height of the building mass exceed the permissible maximum building height regulation. Therefore, the slope of the roof the mass has to be 30°. Essentially, this angle could lower the solar radiation by 231 kWh/sqm or almost 13% reduction. In addition, the resulted building mass is not massive and rigid.
3.2. Analysis of Shading Aids

In accordance with the analysis carried out in the previous stage, the use of the facade as a visual aid that will be applied to the facade of this building are, Horizontal and Vertical Fins. On the north and the south sides, the Curtain Wall facade system will be implemented with the application of Horizontal Fins. While on the west and east sides, the Double Facade facade system will be applied with the application of Vertical Fins. Determination of the direction of the Fins is essentially associated with the movement of the sun that affects the building site. The sun's movement on the site can be seen from the data related to the Sun's path on the site.

The analysis from the Sun path picture above are as follows:

- The movement of the sun is not only from east to west (rising and setting), but the sun also moves north and south throughout the year.
- In the morning and evening (09:00 and 15:00) the sun's altitude is below 50°. Whereas during the daytime or between 09:00 and 15:00, the altitude is above 50°.
Basically, the horizontal and vertical fins have their specific functions. The horizontal fins have function to protect from direct sunlight when the altitude is above 50 degrees, while vertical fins serve to protect from direct sunlight when it is lower than 50 degrees (morning and evening).

Next is the analysis related to the dimensions and specifications of adaptive facade, adaptive facade system work, and distance of adaptive facade Air Gap. Regarding the system and facade dimensions that will be used, the adaptive facade dimensions will be adjusted by conducting a literature study by comparing several adaptive facade systems that are often used in buildings. To choose an existing system, the authors chose based on the need to design adaptive facades in this design, namely:

- Can be applied to the Double Skin Facade system.
- Ability to be applied Horizontally and Vertically.
- Ability to do Sun Tracking.
- A system that makes it possible to use Aluminum Perforated materials and bright colors (white).
- Can be applied to all sides of the building.

The system as is shown in Figure 6, can be to the building.

Figure 6. Perforated aluminium fin from DUCO Ventilation and Sun Control Brochure.

This kind of fin is possible to control the level of solar radiation, imagery and views. The Aluminium material also has low absorption value of solar radiation making it suitable for use as a material for long-term adaptive facades. This system can be installed horizontally and vertically. It also can be directed based on system.

Continuing the previous findings, a work system will be applied to the facade by applying the Weather Station to the building. The Weather Station will be placed on the rooftop of the building and equipped with several sensors, namely: Lux Sensor for Brightness, Wind speed sensor, Water sensor (rain / ice / snow), Outdoor air temperature sensor. Furthermore, the sensor will be equipped with Sun Path data in accordance with the design site. The data include the so that the time, altitude position, and the solar movement. Subsequently, the step is to determine the Air gap or cavity. The determination of the Air Gap by implementing some studies or literatures. The findings from research conducted in several journals show that the Air Gap distance is affected by ‘thermal buoyancy’ or “stack effect”. Based on the variations of distance studied in the previous literature, it was found that the distance between 1 meter and 1.2 meter is the most optimal distance to be applied as the implementation of the Double Skin Facade (DSF). The results of the simulation that have been done show that the optimal distance of the Air Gap is 1m. However, the Air Gap distance of more than 1 meter, the DSF efficiency in reducing solar thermal gain decrease. The results of all analyzes related to
the shading aid above are combined with the results of the analysis of building mass, then re-simulated to retrieve the final data related to the level of solar radiation in buildings.

![Figure 7. Final Building Mass.](image)

Table 1. The level of solar radiation before and after the application of the facade

| No. | Building Side | Solar Radiation Level (kWh / m²) | Before | After |
|-----|---------------|---------------------------------|--------|-------|
| 1   | North         | 640,1                           | 193,2  |       |
| 2   | South         | 505,8                           | 230,1  |       |
| 3   | West          | 881,5                           | 370,7  |       |
| 4   | East          | 721,3                           | 298,7  |       |
| 5   | Rooftop       | 1829                            | 1598   |       |

3.3. Adaptive Facade Design

The material to be used in the adaptive facade is aluminum with white color painted, because both the aluminum and the white has low value of solar radiation absorbance. Therefore, the facade of the building will be dominated by white color.

The next step is to determine the building facade motion system. Based on the results of the previous analysis, a facade movement system is needed to allows for horizontal and vertical movements. There are three possible choices, namely by Retracting, Rotating, and Folding. However, because the purpose of using the adaptive facade is to respond to solar movements that affect the level of solar radiation in buildings, it requires the ability of a motion system that can track Sunpath. Therefore, the most possible motion system for tracking the Sunpath on the site is the Rotating facade movement system. Table 2 shows the comparison of the three system alternatives.

Table 2. Comparison of Rotating Solar Tracking Systems

| Solar Tracking                  | Double Tracking                                      |
|--------------------------------|------------------------------------------------------|
| Single Tracking                | Double Tracking                                      |
| East to West/North to South    | East to West and North to South                      |
| Increase solar yield up to more or less 34% | Increase solar yield up to 37%-40%                  |
| Simple. Effective design       | Complex design - more motor and sensor               |
| Low maintenance                | High maintenance                                     |
| Lower cost compared to double tracking | Higher cost                                      |
| Minimal points of failure      | Additional points of failure                         |
|                                | Less productive in the long-term                     |
Based on the table above, it can be concluded that the Single Tracking system is the optimum solution. The horizontal secondary façade is placed at the north and the south side to be able to track the higher level sun altitude. On the other hand, the vertical fin is used at the West and the East Façade to respond to the lower altitude of the sun.

4. Conclusions
High levels of radiation that affect a building need to be reduced to minimize the energy use in buildings. One of the ways to reduce the heat penetration into a building is to lessen the irradiance or the incident solar radiation level on a surface. This study has conducted several simulation on a building form to get an optimum level of irradiance without sacrificing room space for an office. The final building form is to make a diagonal cut at the roof top to reduce the high irradiance level. This modification can reduce the irradiance level by 13 percent. As for the walls, a secondary skin is applied to help minimize the heat penetration into the building. The secondary skin is a fin with different type of line. Horizontal fin is used for the North and the South façade to respond the high altitude of the sun, whereas the vertical fin is used for the West and the East façade. The irradiance level on the North and South surface can be reduced by around 60 percent with the horizontal fin. This reduction percentage of the irradiance level also occurred at the West and the East façade.

5. References
[1] D. Aelenei, L. Aelenei, and C. P. Vieira, “Adaptive Façade: Concept, Applications, Research Questions,” *Energy Procedia*, vol. 91, pp. 269–275, 2016.
[2] COST, *Adaptive facade network*, no. February 2016. 2015.
[3] K. Anderson, *Design Energy Simulation for Architects: Guide to 3D Graphics*. Routledge, 2014.
[4] J. B. Counsellor, B. V. L. Master, S. Engineering, and L. Taerwe, “Structural Adaptive Façades Chloë Marysse,” p. 254, 2015.
[5] F. U. Sjarifudin, “Studi Mekanisme Kinetik dengan Parametrik Camshaft pada Selubung Bangunan Adaptif,” *ComTech Comput. Math. Eng. Appl.*, vol. 3, no. 2, p. 1014, 2012.
[6] S. J. Choi, D. S. Lee, and J. H. Jo, “Method of deriving shaded fraction according to shading movements of kinetic façade,” *Sustain.*, vol. 9, no. 8, 2017.