Parametric facade approach for an office building to reduce the irradiance level in Jakarta

K A Salim\(^1\), R Hendarti\(^1\), R Tomasowa\(^1\)

\(^1\) Architecture Department, Faculty of Engineering, Bina Nusantara University, Jakarta, Indonesia 11480

Corresponding author: rhendarti@binus.edu

Abstract. Energy used in multi-storey office building is mostly for air conditioning, and it is acknowledged that the energy could be minimized by reducing the cooling load. In general, the cooling loads are from internal and external heat. The external heat plays significantly in determining the cooling load; therefore, it is necessary to reduce the amount of solar radiation received by the external surface of the building. The objective of the paper is to investigate the reduction of solar radiation received by the surface of the multi-storey office building by applying parametric design study and to add a building envelope as the secondary skin as well as the architectural element. There are two steps of analysis in the methodology, (1) to conduct solar radiation analysis, and (2) to conduct building facade analysis. In the process, four alternatives form were simulated to obtain the most optimum shape in relation to the incident solar radiation reduction. The final parametric study results of the solar radiation and building facade analysis showed that the reduction of the irradiance is around 25% with the additional facades.

Keywords: parametric facade, office building, irradiance reduction

1. Introduction
The Commercial Sector is one sector that consumes a large amount of electricity. Annually, the commercial sector consumes ± 25% of the total electricity supply according to the 2014-2017 ESDM data and continues to increase by around 4% per year [1].

Energy usage of an office building is mostly consumed by air conditioning. The amount of room cooling load in an office building is influenced by external and internal loads. The significant external heat is the heat acquisition of solar radiation entering through the walls and windows of the building, while the internal heat comes from office electrical equipment such as artificial lighting, computers and activities within the building [2].

2. Literature Review
There are two parametric study approaches. The first approach considers all designs to be parametric because designs are based on parameters; such as legal aspects, orientation, solar radiation, and wind, and the second approach looks at parametric design using certain tools (Rhino, Grasshopper, Processing) to improve design by connecting and coordinating design components together [3]. Parametric design technology allows architects to carry out many interactions and monitor changes...
during the design process. The interaction is mainly among the subject of the designer, the architect and the object of his work in the form of designs and models and an intermediary between the two.

3. Methodology

In order to determine the shape of the building mass, several simulations on building variation were conducted to investigate the value of each variety. At this step, the variation of the shape is constructed based on how much the amount of solar radiation is reduced by every building form.

After finding the optimum building form or shape based on the highest reduction of the incident solar radiation on the surface, then the selected building form is developed to the next step, the façade design. The façade design is developed to investigate the further reduction of the heat penetration into the building. Therefore, the design of the building façade focuses on responding to the high level of solar radiation received by the building façade [4,5].

The location of the case study is in South Jakarta. The designation of the site is as an office, trade and service zone (Figure 1).

Based on solar radiation analysis using the Ladybug analysis program, the level of solar radiation on the site was 2,037 KWh/m² (Figure 2). The high level of solar irradiance will cause a large amount of air conditioning workload and subsequently cause the higher energy consumption.

3.1. Solar radiation analysis

The solar radiation and the irradiance level analysis were conducted by applying the Ladybug analysis program to obtain the amount of solar incident over the surface of the building. The input data can be seen in Figure 3.
3.2. Building façade analysis

Building façade as an architectural element of the building envelope are designed as an element to block direct sunlight for shading throughout the surface, in order to make more reduction on the heat penetration into the building. The imagery shading was designed with the help of the Rhino and Grasshopper program. The input can be seen in Figure 4. The façade element is a diamond.

4. Result and Discussion

As previously stated, the first step is to build an initial building form. The amount of the incident solar radiation occurs at the surface of the initial building form is 811 KWh/m². Here, the total building surface is 10,862 m². As for the annual solar irradiation is 8,805,200 KWh/m². The illustration is presented in Figure 5 and 6.
Then, the next analysis is to build an alternative type of the basic shape (Figure 7). A tube is selected to investigate the irradiance level. The results showed that the tube shape reduce the irradiance level to 798 kWh/m² or around 1.6% reduction. Solar radiation analysis for one year is 8,382,900 kWh/m² and the total surface area of the building is 10,504 m².

Additionally, the second alternative building form is then twisted to investigate the further reduction (Figure 8). This twisted shape could avoid direct solar radiation.

As predicted, there is a further reduction to 784 kWh/m² or around 1.75 %. The solar radiation analysis for one year is 8,169,900 kWh/m² and the total surface area of the building is 10,408 m².
The last alternative was then chosen to be applied as the building form for an office. Subsequently, the form is modified with a secondary skin to add the reduction of the irradiance level (Figure 9). A parametric façade of a diamond pattern is applied as the secondary skin. As a results, the irradiance reduction can be as high as 15.8% or it reduces to 660 kWh/m². The level of solar radiation is 8,844,200 kWh/m² and the total area is 13,388 m² (Figure 10).

![Figure 9. Diamond Pattern Facade](image)

![Figure 10. Solar radiation analysis on the initial building mass](image)

Tabel 1 shows the all analysis and simulation. The table shows that the final reduction calculated from the first simulation is 18%.

### Table 1. The Analysis results

| No | Building Mass          | Analysis Result (Ladybug Analysis) | Solar Radiation (kWh / m²) |
|----|------------------------|-----------------------------------|---------------------------|
| 1  | Initial Building Mass  | ![Image 1](image)                  | 811                       |
| 2  | Second Building Mass   | ![Image 2](image)                 | 798                       |
| 3  | Third Building Mass    | ![Image 3](image)                 | 784                       |
| 4  | Fifth Building Mass    | ![Image 4](image)                 | 660                       |
5. Conclusion
After conducting an analysis in designing the basic form of the building mass designed by prioritizing aspects of solar radiation, it was concluded that the incident of solar radiation can be reduced through modifying the basic form of the building. Additionally, a secondary skin is designed to provide a shading effect on buildings which aims to reduce the level of solar radiation received by buildings surface efficiently. The final result of the building mass designed by applying a parametric façade as the building skin elements succeeded in reducing the incident solar radiation received by the building surface by 18%.

6. References
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