Dynamic facade module prototype development for solar radiation prevention in high rise building

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Abstract. Solar radiation is an aspect that high rise building must avoid. The problem is, if high rise building facade can't overcome, the solar thermal will come in the building, and its affects on the increasing of room temperature above comfort range. A type of additional facade element that could solve solar thermal in high rise building is adding a sun shading. A dynamic facade is a shade plane in high rise building that can moved or changed on outside condition such as solar movement and intensity. This research will discuss the dynamic facade module prototype development in high rise building in Jakarta. This research will be finish through some step. (1) Static shading shadow simulation. (2) Dynamic facade concept design development. (3) Dynamic shading shadow simulation. (4) Making of dynamic facade module prototype. (5) Field test for the dynamic facade module prototype. The dynamic facade in Jakarta case will be effective to solve solar transmission in high rise building rather than static facade.

1. Introduction

Tropical area has longer exposure time, about 10 to 12 hours, compared with others. Infrared heat from sunlight to the building in a long time will increase building temperature so that the residents feel uncomfortable [1]. People who are in highrise buildings feel it. Several ways can be taken to respond sunlight and solar heat. For example, the orientation of the building, the shape of the building, the placement of service zones in the building affected and the use of insulation materials [2], shade, overhangs and blinds [3]. These things can be taken to reduce the adverse impact of sunlight and solar heat.

The solution offered is to protect the building from a single state whereas the direction of the sun rotates throughout the year [4]. Norbert in his book Heating, Cooling, Lightning, questioned whether a static system could respond to a dynamic problem [5]. He explains that the existing buildings, especially the high rise buildings, have static building elements while the natural state is always changing. This situation results a loss of excessive use of energy, especially for cooling and lighting [2]. The facade is a building envelope that separates the inside and outside [6]. This element also protects residents from the weather. Because of its function as a protector, it must be able to respond and adapt to the outside influences. Facade elements should be dynamic. For example, it can move dynamically following the direction of the sun to minimize the light but keep the heat coming into the building. In other words, changing the static facade into a dynamic facade [7]. Several studies has been found in the literature that correspond with dynamic facades.

The first study about dynamic facade was done by Maria Konstantoglou (2013). She tried to test the performance of the facade by comparing various shade solutions. Starts from the types of static facades such as overhangs, blinds, and lattices to the driven façade, the research conducted for the facade of a south-facing office building in Athens, Greece. The research method used is a simulation using the software EnergyPlus. Facade with movable parts can reduce the cooling load by 9.8% compared to the static facade. [8].

The concept of moving frame has been introduced by Kjeld Johnsesn (2015). The system they created was called the Frame Energy that was developed based on some previous research on the building. The shape of this facade is a skeletal facade system mounted on the outside of the window frame. Frames can move horizontally and vertically. The results show the facade system can solve the problem of sun shade, natural lighting control, natural ventilation and noise reduction. [9].

Furthermore, Zoltan Nagy (2015) added photovoltaic in his façade. This study was conducted by simulating the energy obtained from photovoltaic for a year. The prototype is tested on a real facade to see its effectiveness. The result of the numerical calculation is known that there is an energy saving of 25 percent when the use of adaptive solar facade [10].

Baharudin (2013) talks about the heat radiation into the building. He tried to measure how much radiation received by various building orientations. This study aims to calculate and analyze the solar radiation received by the surface of the vertical field based on horizontal solar radiation data which contained in weather data Meteonorm. For validation, weather data from IDMP stations (International Daylight Measurement Program), Hasanuddin Tamalanrea University Campus is used. The method used is a simulation method using The Ecotect software. Seen that for the annual radiation the sequential side that receives the greatest radiation until the smallest is the east side, the west side, the north side and the last south side [11].

From research on dynamic facades and solar radiation, it appears that the focus is saving energy. Solar heat radiation research helps in knowing which side of the building requires dynamic facade. In this paper, we present what kind of dynamic facade characteristic which suitable to overcome the heat radiation and optimal dynamic facade in overcoming the heat transfer from the sun in high rise building in the tropical area.

2. Method

The study is devided into five stages. The first stage is to simulate the shadow on an existing static shading device in panel module of the facade. Phase two, the development of dynamic shading device in module design based on simulation in the previous stage. The third stage is to simulate the design result. Step four, make a prototype. Last stage, testing prototypes.

2.1. Shadowing simulation

In this simulation will be tested three types of shading device that is used for shadowing: horizontal overhang, vertical fins and louvers. The angle 0^0 and 45^0 will be given to each panel. SketchUp 2017 software used to perform simulation. For the accuracy, location used for simulation test is DKI Jakarta as a generalization of the tropical area. The position of the shading device model during the simulation is at 6.2^0 south latitude and 106.7^0 east longitude. Assessment is measured by comparing at the percentage of shadows at each type that occur during the simulation. The greater percentage in shadowing, the better performance of shading device. The simulation was done on June 21st from 12 am to 5 pm. From the percentage of shadow that occurred, assessments obtained.

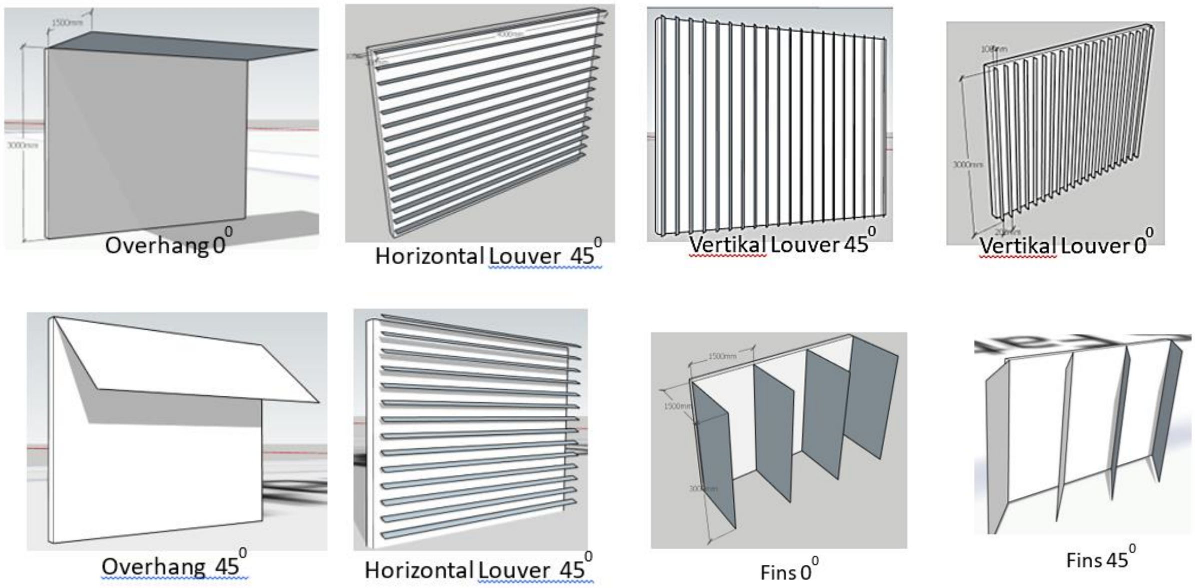
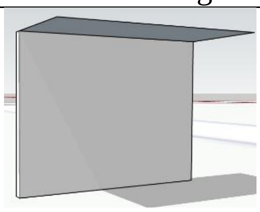
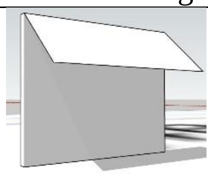
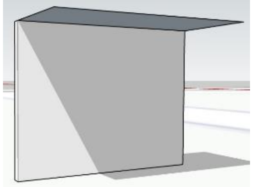
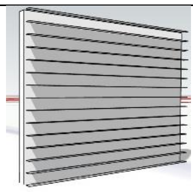
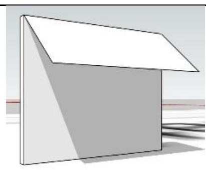
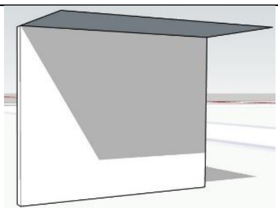
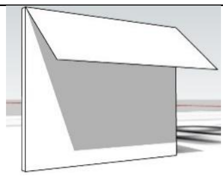
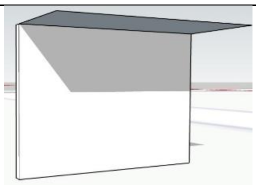
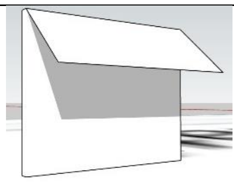


Figure 1. Shading Device Variation

In this simulation, there is a change in the color of the panel behind the shading device from dark (gray, black) which means shaded; and light (white) which means exposed to sunlight. The more visible the dark field, the more the shade performance.

Time	H. Overhang 0^0	H. Louver 0^0	H. Overhang 45^0	H. Louver 45^0
12 am				
1 pm				
2 pm				
3 pm				

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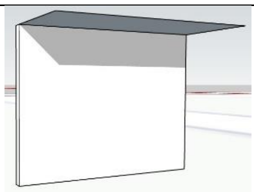
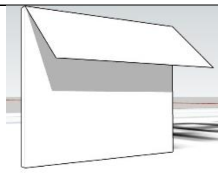
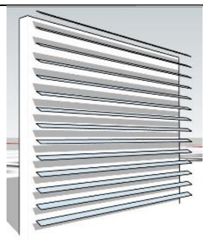
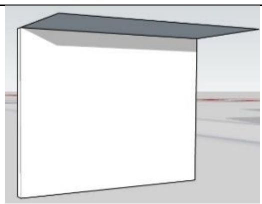
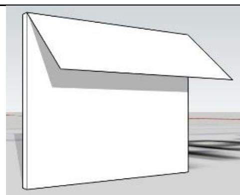
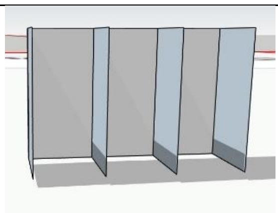
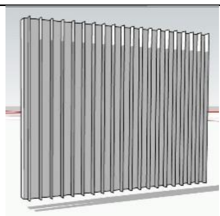
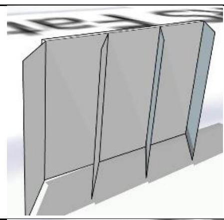
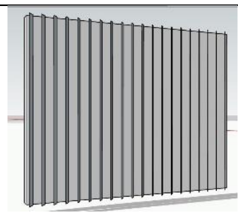
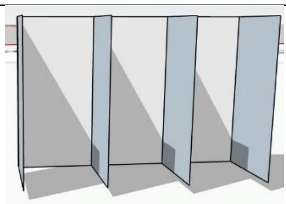
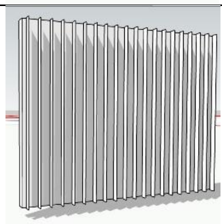
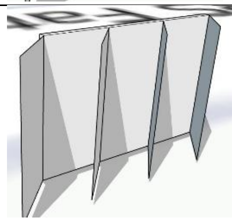
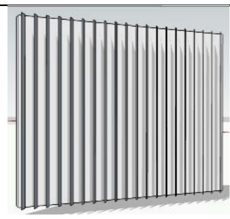
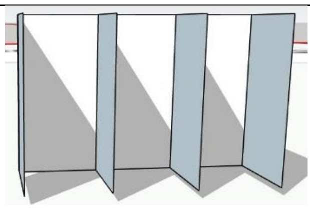
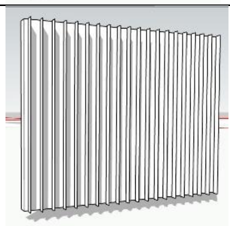
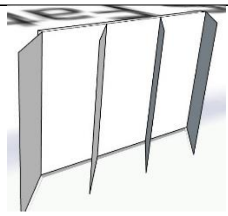
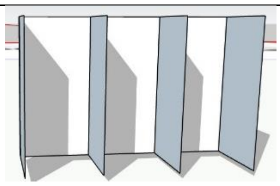
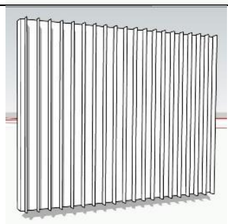
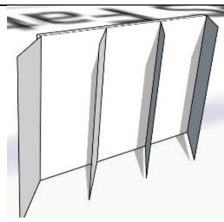
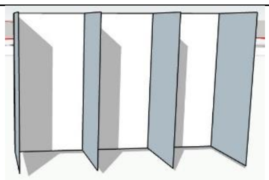
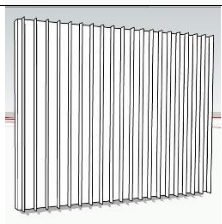
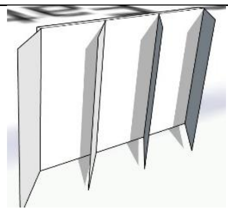
4 pm				
5 pm				

Figure 2. Simulation of shadin panel on horizontal fin pattern

Time	V Fins 0^0	V Louver 0^0	V Fins 45^0	V Louver 45^0
12 am				
1 pm				
2 pm				
3 pm				
4 pm				

5 pm

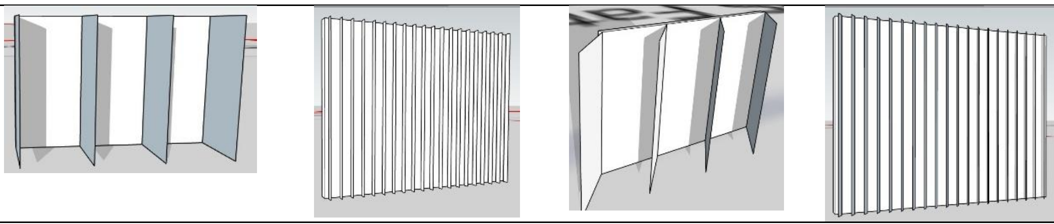


Figure 3. Simulation of shading panel on a vertical fin pattern

The results of the experiment show that the more sun is getting set (in the afternoon) or the angle of the sunlight became lower, then the shadow is getting shorter. Effectiveness of shading could be seen from the comparison between the shadowed area and the whole area. The bigger the percentage, the better the performance. For percentage values can be seen in the Table 1.

2.2. Development of shading panel design

Researchers are trying to develop a dynamic shading device design based on horizontal pattern panel type. For high sun corners (12 am to 2 pm), horizontal pattern is the best shape. For low sun corners (at 3 pm to 5pm), the vertical pattern is the best shape. The maximum shade is obtain from moving the pattern from horizontal to vertical. Comparing from the duration of the shadowing, horizontal louvers in 0^0 angled will be able to withstand from high-angle sunlight. When the horizontal louver in 45^0 angled then it will be able to withstand low-angle sunlight. Given the movement from an angle of 0^0 to 45^0 or more then shadowing is expected to be more effective (Figure 5).

Table 1. Percentage of Shadowing

Shading*	**Waktu**					
	12.00	**13.00**	**14.00**	**15.00**	**16.00**	**17.00**
Horizontal Overhang 0^0	100	78.8	62.1	37.3	20.7	6
Horizontal Louver 0^0	100	82.5	69.7	39	22.7	9
Horizontal Overhang 45^0	100	83.1	77.3	59.7	46.2	39.6
Horizontal Louver 45^0	100	70.3	73.9	56.1	40.8	27.7
Vertical Fins	100	65	65.3	58.3	54.5	49.7
Vertical Louver	100	80	47	33.8	27.4	23.2
Vertical Fins 45^0	100	65	69.3	58.5	53.8	49.8
Vertical Louver 45^0	100	76.1	47.1	33.7	26.9	23.2

*value in %

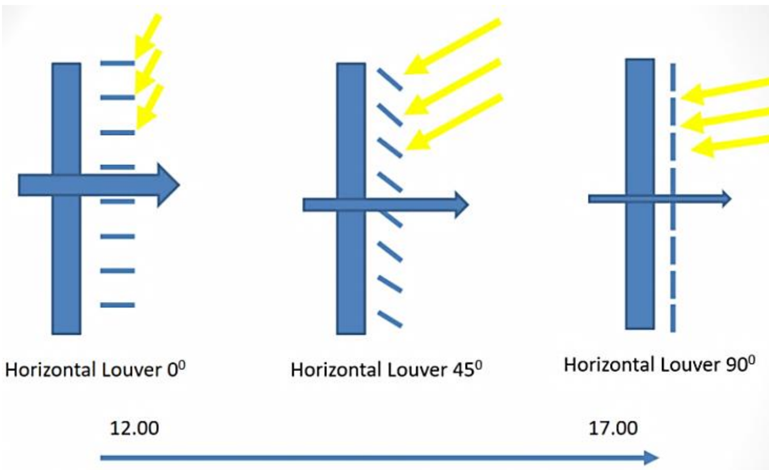


Figure 4. Dynamic Facade Development Process for Shadowing

Problems arise when the louver in 90^0 angle. The enclosure of all the fins resulting in visuality of the exterior becomes non-existent. Furthermore, development is needed to ensure that not only effective shadowing but also visibility exterior visual is maintained. This is regenerate by modifying the louvers as shown in Figure. 6 and 7.

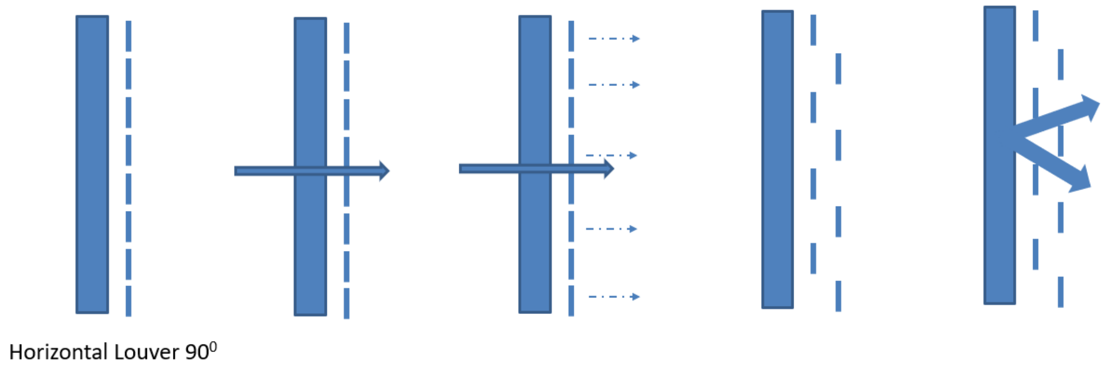


Figure 5. Dynamic Facade Development for Visibility

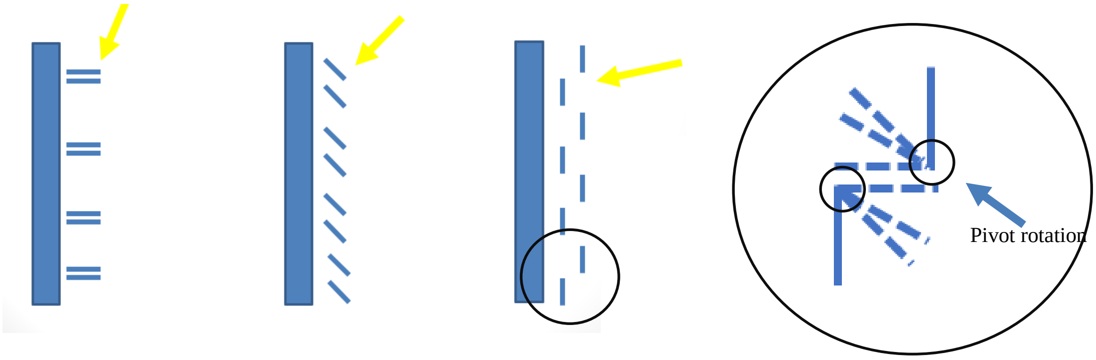


Figure 6. Louver Double Layer and Louver Rotation Process

2.3. Shadowing Simulation of the Design

The development of a dynamic shading device that has been performed should be tested for effectiveness in shadowing simulation in SketchUp software. Simulation is run by changing the time periodically from 12 am to 5 pm within 10 minute interval. When the change occure of the shadow, the shading device also participated in movement to stay to protect from the sunlight. The simulation will take place on 21st of March, 21st June, 21st September and 21st December. The effectiveness will be seen from the percentage of shadow that occurs.

2.4 Making Prototype

The prototype is be made from aluminum metal. The reason using aluminum due to the characteristic of metal is light and it also easy to obtain. Common drive technologies are motor, hydraulic, pneumatic and material-based. In this study the motor is selected as a main drive because it is easy in the maintenance and replacement of spare part used louver spare parts 8 cm wide and 90 cm long. To get the rotating motion, the plate is attached to the pipe as a pivot. When viewed from the picture, one module element consists of two moving plates in reverse. The upper plate will move upwards, while the bottom plate will move downwards. The rotation angle of the adjustable jagged pipe can rotate by 90^0 angled. The making of the prototype is still in progress.

Figure 7. Louver Double Layer

2.5 Testing Prototypes

Testing prototypes were conducted to measure indoor and outdoor temperatures. The instrument used is the HOBO tool. In this test, HOBO will be placed inside a test box measuring 100cm long, 100cm wide and 120cm high. The position of the measuring instrument will be at a height of 70 cm from the floor and 30 cm from the side to be tested. The side to which the facade will tested is the west side. For more details can be seen in Figure 9.

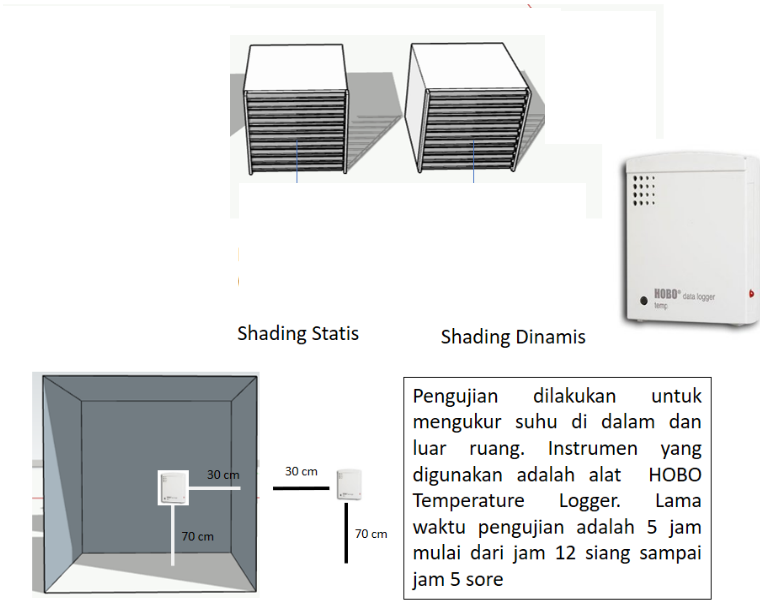


Figure 8. Dynamic Facade Testing Scheme

3. Results and Discussions

In the simulation of the dynamic facade design that has been done, the effectiveness of the shadowing was increased. In the test time range, at 12 am to 5 pm, it is seen with the movement and location that in such a way is able to create a nearly complete shadow pattern all the time. For the percentage of shadows occurring, the design of shading device (Double Layer Louver) is able to sustain more than 50% shade. This is because the shade movement. The percentage of shadow on another several time, illustrated in Table 2.

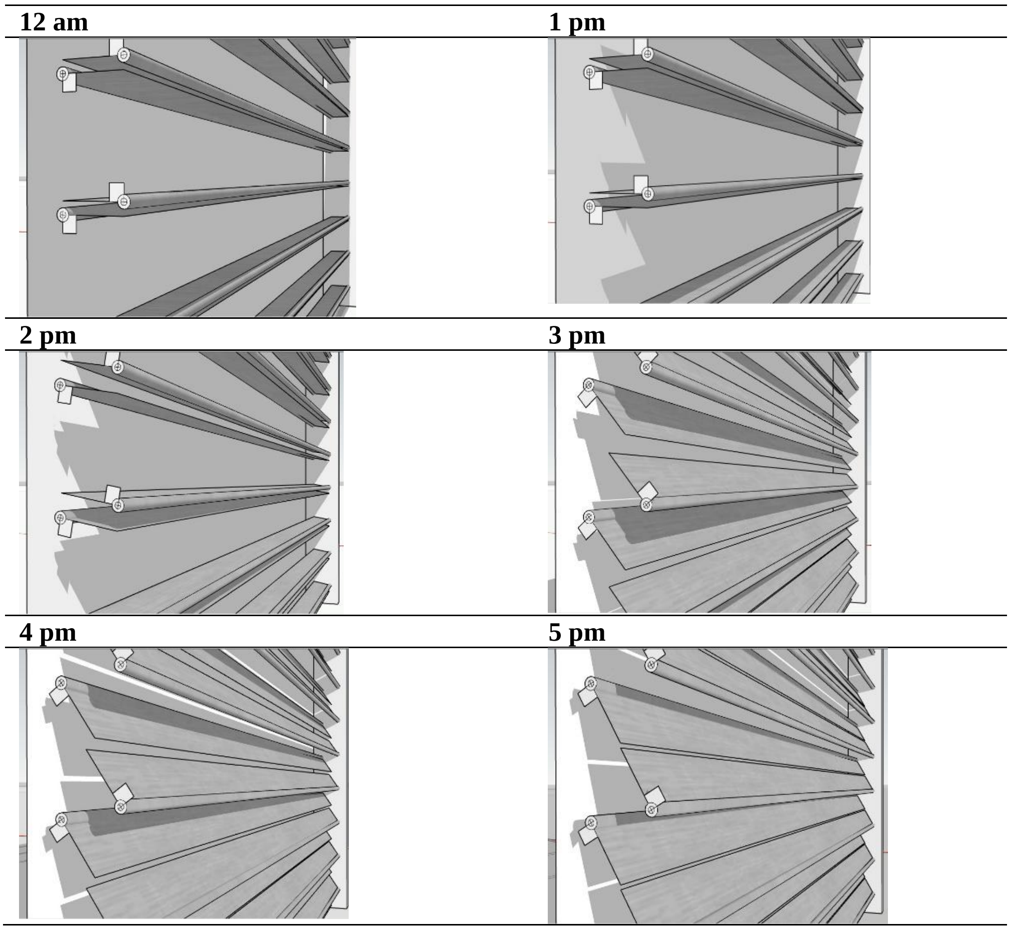


Figure 9. Results of Double Layer Louver Simulation

Table 2. Percentage of Shadowing

Date of Simulation	Time					
	1200	**1300**	**1400**	**1500**	**1600**	**1700**
21 June	100	82.6	89.8(15)	84.3(30)	91.5(55)	94.2(60)
21 March/ 21 September	100	87.2	82.7	94.2(40)	93(55)	93(60)
21 Desember	100	86.7(15)	91.4(30)	91.7(45)	91.4(55)	91.4(60)

*value in %

4. Conclusions

Based on the simulation, at 21st June, vertical fins device show the best result. But from the visibility side, horizontal shading device is better. Therefore, the research continued with the development of horizontal shading device. Dynamic shading device design simulation shows that it is has better performance than another eight static panel in shadowing simulation. Percentage of shade only decreased by 10% with louvers rotation movement of 60^0. It is possible to take dynamic shading device movement from other forms such as fins or overhangs with certain modifications. Other simulations such as heat sunlight radiation simulations and wind-simulation with other software are required to know the performance of design results.

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