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# Daylight Performance of Middle-rise Wide Span Building in Surabaya (Case Study: G-building ITATS)

Dian P.E. Laksmiyanti[1], Poppy F Nilasari[2]

[1]Department of Architecture, Institute Technology Adhi Tama Surabaya, Indonesia
[2]Department of Interior, Petra Christian University, Indonesia

***Abstract*— *Global warming and increase of energy consumption issues has encourages architect to design energy efficient building. The most crucial aspect in designing building in warm humid climate is solar irradiance and wind flow. High level of irradiance increase heat gain of the building and it also cause a higher cooling load and cooling energy. More compact the building form, the cooling energy consumption will be less. Compact or bulky building usually consumes less cooling energy than the slim one because it has lower s/v ratio. Thus the bulky form, middle rise wide span building usually uses atrium to help distribute daylight in to every room of the building. Unfortunately the daylight from the atrium brings considerable heat because the solar radiation that hit the horizontal plane is very high and it's very difficult to minimize solar gain in the roof. This research aims to evaluate the daylight performance of middle rise wide span building in Surabaya. Case study of this research is G-Building of Institute Technology Adhi Tama Surabaya.*

*To evaluate the daylight performance daylight factor of the building was measured by lux-meter and then compared to daylight factor standard for any rooms. Daylight performance of the buildings was found to bear some relations to cooling energy performance and composition of fenestration-opaque roof in atrium.*

***Keywords*— *Atrium, Daylight, Energy Efficient, Middle-rise, Tropics.***

## I. INTRODUCTION

According to Green Building Index 2010, most of consumption of operational energy in a building used for cooling and lighting energy. Architect can save the operational energy of the building with a good design that concern the environment and climatically responsive. Indonesia is a warm humid country which has a high level of solar exposure whole year. High solar irradiance in tropics being a challenge for architect to build a comfortable building with low energy consumption. Building façade and roof should be designed to minimize the heat gain in to the building, and maximize the daylight and air circulation in the building [1].

Operational energy in a building can be reduced if the building has a good design. Right choice of building materials, proper form, appropriate location and site planning will reduce the heat gain of the building moreover the cooling load and cooling energy [1,2]. Envelope design of tropics building should be careful because architect better design room with daylight and good air circulation, on another hand daylight and air circulation in to the building may also cause heat flow in to the building. Gaining heat in the building means increasing cooling load and cooling energy.

One of factor overheating external façade caused by domination of fenestration surface on building envelope[3]. Most of fenestration surface such as clear glass, fiber glass, polycarbonate, usually have a great U-value and the decrement factor of that materials almost 0, it means that materials receive a lot of heat from environment and transmit almost all that heat in to the building.

By previous research octagonal building consume less cooling energy consumption than other shape such as rectangle, square, L shape, H shape, etc in the same volume [4]. Other research says more compact the building, energy consumption will be less[5]. Compact form has less surface to volume ratio which is mean less heat transfer from building envelope and heat gain. Trouble in bulky building is distribution of the daylight. Natural lighting can't achieve the middle of the building even though there's a huge window in the perimeter area. Put an atrium in to a bulky building can be one of easiest solution to solve this problem[1]. Skylight on the atrium let the sun light came into the middle area of the bulky building so the daylight can be evenly distributed[6]. In warm humid area envelope design has a big contribution in thermal comfort, visual comfort, and energy consumption [7], so it will be necessary too think about façade and roof design.

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## II. LITERATURE STUDY

### 2.1 Advantages of Warm Humid Climate in Daylighting

Warm humid climate has the following characteristics:

a. Cloudy sky throughout the year with cloud cover 40% -80% which can cause glare.
b. The sun shines all year long which results in high radiation
c. Very high humidity (40% -90%)
d. The difference in temperature is relatively the same day and night, and small amplitude of daily and a year temperature (23ºC – 34ºC)
e. Low wind speed 1,1m / s - 4,3m / s.
f. High rainfall (1200mm / year)

Table 1 describe the advantage and disadvantages of tropics characteristic on a building.

*Table.1: influence of climate[7,8]*

| No | Element | Influence | |
|---|---|---|---|
| | | Positif | Negatif |
| 1 | Sun Irradiance | • Day Lighting<br>• Solar Energy | • External heating load |
| 2 | Temperatur | • Cooling and heating need<br>• Mixture Temperature | • Heat load of structure and organism<br>• Potentially cause air pollution |
| 3 | Angin | • Ventilation design of building<br>• Reduce heating load | • Wind load on buildings<br>• Spread of air pollution<br>• Dust carrier<br>• Causes of rainwater enter the building |
| 4 | Curah Hujan | • Urban Hydrology | • Causes of flood<br>• Structural load because of water |
| 5 | Kelembaban | • Help thermal comfort | • The cause of fog<br>• Pollution modifiers<br>• The cause of rust<br>• Can raise the temperature |

The light produced by the sun and which affects the earth directly, indirectly, or both are natural light (daylight). The daylight includes:

• Sunlight (directly from the sun)
• Sky light (either clear, cloudy or partly cloudy)
• Sunlight and / or sky light reflecting off other surfaces (e.g. land, surrounding buildings, water)

Factors that affect natural lighting include:

1. The amount of sunlight in an area
2. The required level of lighting (lux)
3. Building elements that affect, such as: The size and position of the light hole, The reflection factor of light from the surfaces inside and outside the building, The width of the eaves and the size of the space and color and elements of space

### 2.2 Daylight Strategies

This following strategies of making huge daylight in to the building:

1. Building Orientation
The best building energy performance usually has North-South Orietation
2. Daylight from roof (skylight)
The horizontal opening has two advantages:
a. Let the illumination not be equally fair on the vast interior area, while the natural light from the openings is limited (fig.1).
b. The horizontal opening jg receives more light than the vertical aperture (fig.2).

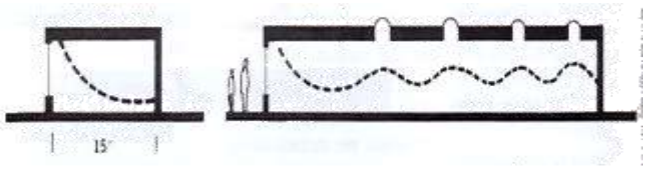

*Fig.1: When the natural lighting of the openings is confined to the outer wall, the openings on the roof will be able to flatten the illumination along the limited space area (Lechner, 2001)*

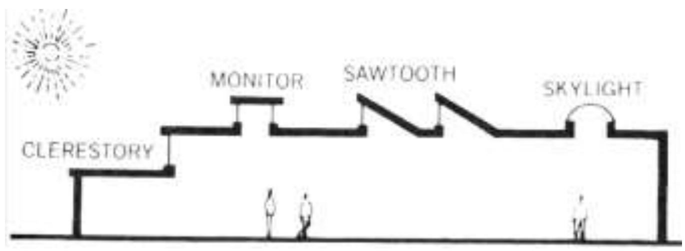


*Fig.2: Option of Skylight design of atrium (Lechner, 2001)*

3. Building Form
the square plan, 16% did not get natural light and 33% got, but only partially. On a rectangular plan can remove a central area that does not receive light, but still has a large area that gets partial light.[9]
4. Spatial plan
Open space planning is very beneficial for bringing light into the interior. The glass partition can be made of glass at an elevation above the eye level. A higher mounted surface on a wall provides a more

uniform distribution of natural lighting for every corner of the room than lowered openings. The higher openings will give less light contour lines with more coverage than the same-sized openings placed in the lower positions.[6]

### 2.3 Daylight factor

The magnitude of the ever-changing sky light makes the level of illumination from the sky into the building requires a ratio. Daylight Factor (DF) is the ratio between the bright forces at a given point in a room with the bright force of the open area in the same horizontal plane [10]. DF is influenced by:

1. Direct light from the sun on the work plane (SC = Sky Component)
2. Light reflection from the surrounding surface (ERC = Externally Sky Component)
3. Light reflections from indoor surfaces (IRC = Internally Sky Component)

$$DF = \frac{Ei \times 100}{Eo} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (1)$$

Where DF is Daylight Factor, Ei = indoor luminance, and Eo = Outdoor luminance.

## III. METHODOLOGY

To get data of Daylight Factor measure the luminance level outdoor and indoor in a same time with lux-meter and then count the DF with formula 1 in subheading 2.3. Usually DF was measured as high as work area, for Indonesia is about 0,75-1m high from floor. So in this case lux meter put in 0.8m high from floor.

Node of measurement in outdoor located in free obstruction open space so the real luminance level can be recorded. Measurement in indoor area taken in every window.

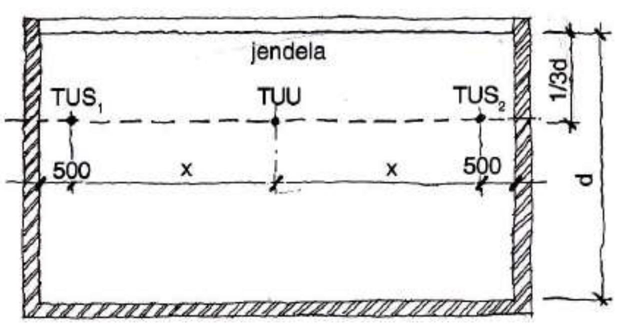


*Fig.3:. Determination of measuring point (Frick, 2008)*

In the calculation indoor luminance level used two types of measuring point:

- Main Measure Point (TUU), taken in the middle between the two side walls located at a distance of 1/3 from the effective plane of the opening.
- Side Side Assessment (TUS), taken at a distance of 0.50m from the side wall which is also located at 1/3 distance from the effective hole field of light. (fig.3)

## IV. RESULT AND DISCUSSION

G-Building in ITATS is a building for Civil engineering and planning faculty. There are classrooms, studios, workshop, café, office department and library in this building. This building is so bulky with about 50m long and 31m wide. It is 4 strореys building. It has rigid frame structure from concrete and steel. Roof of this building is made from concrete deck (for perimeter room), galvalum, and polycarbonate as a skylight in the atrium. Fig 4 and fig 5 may give a description of this building. There 4 department in this faculty: Civil engineering, Architecture, Product Design and Environmental Engineering.

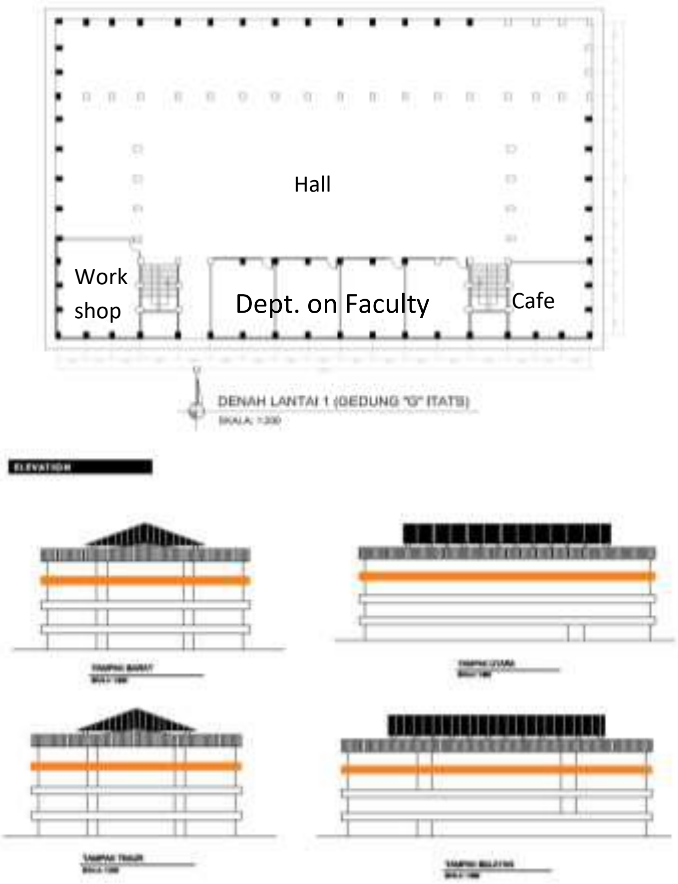


*Fig.4: 1st floor Plan and Elevation of G-Building ITATS*

Most of room in this building surrounded by fenestration wall made of a clear glass. To make a prifacy in classrooms and studio, sandblast sticker put on it up to about 1,8m high (fig.5). There is no vertical, horizontal or roler blind in every room. It may give full access of the daylight from atrium and outside separated equally in every room. The atrium used for hall. Usually collegians use this hall for indoor sport, tournament, music event, etc.

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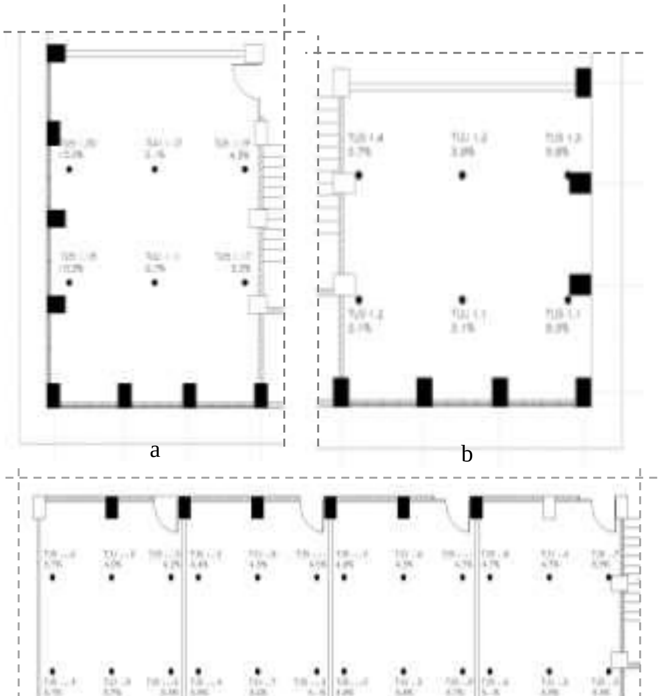
*Fig.5: Interior of atrium and windows in the envelope of G-Building ITATS*

When viewed from the results of daylight factor measurement in the this case study, the overall quality of natural lighting in this building can be said to be not eally good. Indeed a lot of light that enter into the room, but because amount of light entering too much, so it can cause glare, especially on the perimeter area.

Floor 1 used for administrative functions (Fig.4). There is a cafeteria on the lower left side. There 4 rooms for office of any departments in that faculty: Department of Civil Engineering, Department of Architecture, Department of Product design, Department of Environmental Engineering, and workshop for Product Design in the left side (fig.4). In front of the room functioned for the hall. This hall is usually used for events that invite many people such as exhibition, Introduction of Campus Life for new students, etc.

*Table.2: Average Daylight Factor in every room*

| Floor | Functin of Room | TUU/ TUS | DF | Standard of DF |
|---|---|---|---|---|
| 1 | Café | TUU | 3.5 | 4% |
| | | TUS | 6.2 | |
| | Office of department | TUU | 4.4 | 4% |
| | | TUS | 4.9 | |
| | Workshop | TUU | 5.9 | 9% |
| | | TUS | 7.5 | |
| | Hall | - | 10.7 | 4% |
| 2 | Classroom | TUU | 8.3 | 4% |
| | | TUS | 8.7 | |
| 3 | Classroom | TUU | 8.0 | 4% |
| | | TUS | 9.3 | |
| | LAB | TUU | 7.3 | 9% |
| | | TUS | 7.7 | |
| | Studio | TUU | 8.7 | 6% |
| | | TUS | 9.4 | |
| 4 | Kelas | TUU | 8.3 | 4% |
| | | TUS | 9.8 | |
| | Library | TUU | 7.2 | 4% |
| | | TUS | 7.7 | |
| | Workshop | TUU | 8.4 | 9% |
| | | TUS | 9.0 | |



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Different functions has different standard of illumination. Table 2 shows the amount of lighting needs and it result for some room functions. In general, the amount of lighting in the cafe, office, and workshop is sufficient to meet the standards. The number of natural lighting in the hall seems excessive (figure 6) because in the hall there is an atrium with a skylight composition of 50%. Quite a lot of natural light that passes through the skylights, in addition to the color of the white floor da use glossy ceramics that can add reflectance on the surface so that the Daylight Factor (DF) in this area is very high (Figure 7). Due to excessive lighting in this hall area, will cause inconvenience if the event held in the hall requires LCD display. Of the large DF in this area, can be sure LCD screen will be difficult to see because of glare.

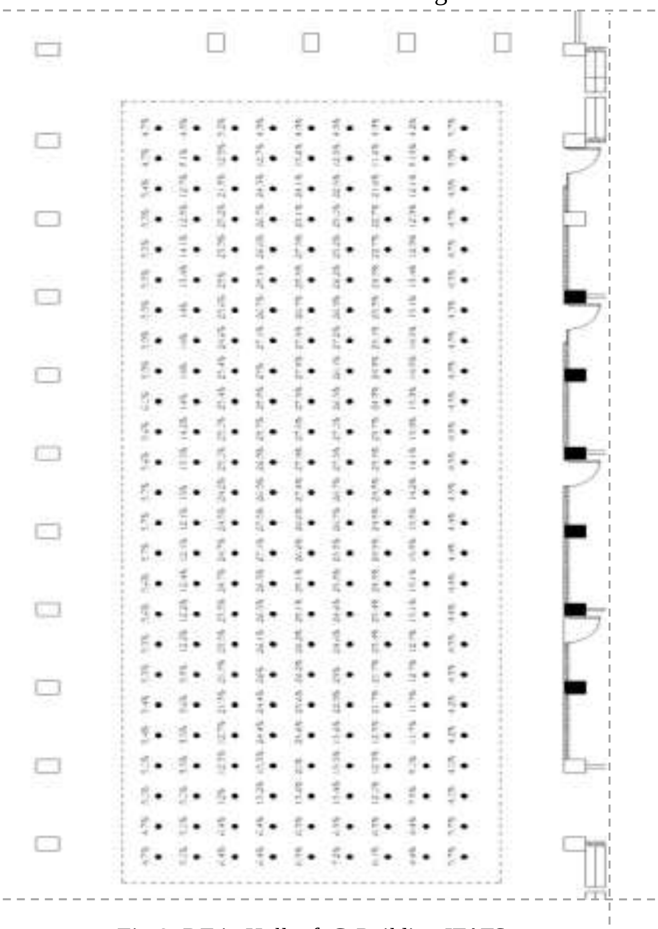

*Fig.6: DF in Hall of G-Building ITATS*

2nd floor is functioned for classroom of theoretical course and lecture room of civil engineering. Natural lighting needs in each room about 400 lux. With the atrium in the G building and the wall adjacent to the corridor in the form of a transparent wall, the amount of natural light entering into the classroom little bit more, up to doubled from the existing standard. Indeed, with the atrium and transparent walls along the space adjacent to the corridor cause the spreading of sunlight into the room becomes more evenly distributed, but if the amount of incoming light is too much it will have the potential to cause discomfort. In terms of architecture, the use of transparent walls in the classroom is considered not effective and can disrupt the teaching-learning process in it.

The amount of natural light in the class on the north side more than the classrooms on the other side because on the north side of this building there is no obstraction. Seen in Figure 7, with the Daylight Factor data in the building, it is certain that the building is capable of not using artificial lighting at all during the day in fine weather. On the second floor of this building students are less able to see the clear LCD screen because too many light sources into the classroom.

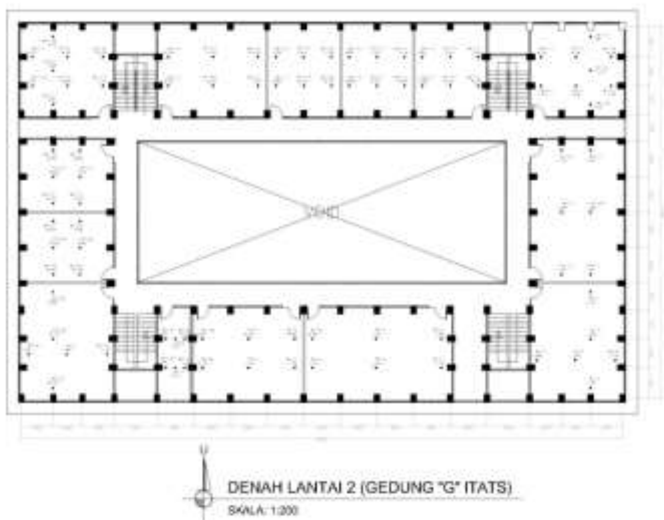


*Fig.7: DF in 2nd of G-Building ITATS*

3rd floor of this building function as classes, studio and laboratory of architecture majors. The architecture department needs a class for drawing and modeling design. Lighting requirements for the studio is larger than the any classroom because in the studio there are several other activities besides reading and writing, among others, create a drawing, making a model, assemble lego and so on. Likewise for the architecture lab. There are 4 labs on the 3rd floor, including the Science lab and the structure, the Design lab, the urban and residential labs, as well as the History Lab and the Architecture theories. Activities covered in this lab include literature studies, design experiments and form ideas, simulations, experiments

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using wind tunnel and helliodon. Lighting requirements for a 900lux or DF 9% lab.

In general, the performance of lighting on the 3rd floor is quite good and the spread is also evenly distributed (figure 8). In DF classes and incoming studios is greater than the standard, but the natural incoming LAB inbox is still less than required. This is because the layout of the room is less laid out optimally.

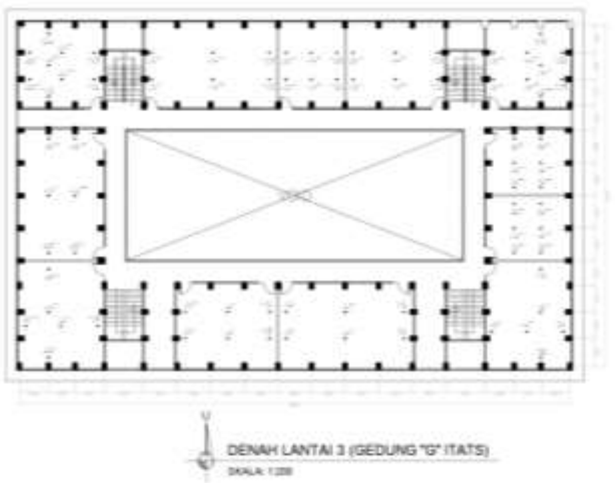


*Fig.8: DF in 3rd of G-Building ITATS*

The 4th floor has an identical floor plan with 3rd floor. This 4th floor room is used for classrooms, reading rooms and studios in department of product design. Studio product design more likely a workshop so that the need for lighting is also greater than the studio in architecture department. The 4th floor in overall has an average bigger lighting than 1st-3rd floor. This is because the 4th floor does not have any obstruction outside the room and is the top floor so that the natural daylight distribution in the atrium can be directly distributed in the classroom. (Figure 9)

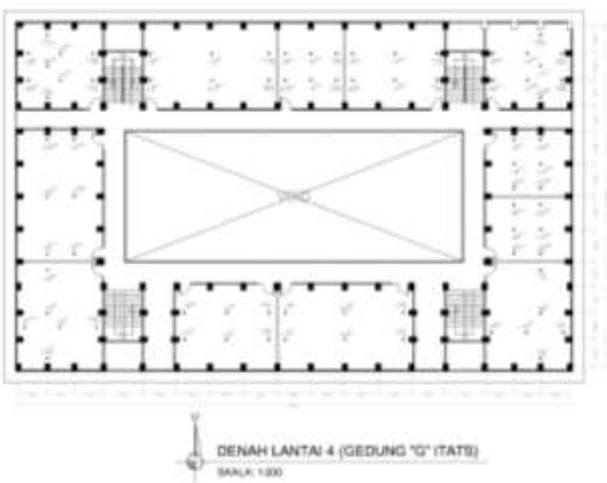


*Fig.9: DF in 4th of G-Building ITATS*

The natural light on the 4th floor in the workshop room is enough to fulfill the standard and the spreading of the light is quite evenly, for the reading room and classroom too much natural light coming into the room so this allows inconvenience for the users in it. Solutions for the classroom can be overcome with curtains or blinds on the room so that when teaching and learning process lecturers and students can adjust the amount of natural light that enters the room.

## V. CONCLUSION

Building with 50% fenestration roof in the atrium was able to provide a lot of natural lighting into the building and quite effective in helping the distribution of lighting in the perimeter space. Indeed, in some rooms amount of natural light level is too big, but there is a solution by installing the curtain on the window. Subsequent research can evaluate the amount of percentage of skylight on the atrium to make the distribution of natural lighting more evenly and the amount of heat entering the building is not too large.

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