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Measuring The Quality Of Natural Lighting In A Building With Double Skin Façade (DSF)

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ABSTRACT: Lately a double skin façade (DSF) has been increasingly popular as an aesthetic and shading device. A façade with a secondary skin is employed in buildings to let natural light flow into the building without glare and heat. The purpose of this study is to examine the performance of secondary skin in buildings and to investigate the level of natural lighting in buildings that meets visual comfort standards according to the function of space in buildings. The object of this research is the Henricus Constant building of Soegijapranata Catholic University Semarang Indonesia. The research method used is descriptive quantitative. The authors assessed the level of natural lighting in the building by analyzing the results of field measurement data with luxmeter measuring devices and model simulations regarding natural shadows and lighting levels with Sketchup software and dialux. The results of this study suggest that secondary skins in the Henricus Constant building manages to create shade in the building's interior, but the natural lighting level is only 30 lux, less than the standard lighting level of the classroom at 250 lux. Without the secondary skin, the average light intensity is 310 lux; thus, it causes glare and becomes visually uncomfortable.

Keywords: *Secondary Skin Façade, Natural Lighting, Computer Simulation.*

INTRODUCTION

Buildings with DSF are interesting and they deserve to be appreciated and observed. The secondary skin is a vertical layer placed either the whole façade or on part of it. The secondary skin (the second vertical sheath) is typically designed with various patterns to improve the visual quality of the façade (Fig.1). It covers any openings or windows on the buildings. The pattern of window frames or the shape of openings for the DSF serves as aesthetics for the building façade. This secondary skin façade is also referred to as a smart façade and has increasingly been popular in this decade (Campbell-Dollaghan, 2013).

In a film about a building with a secondary skin façade in Abu Dhabi, Dubai, as shown in Figure 2, the secondary skin façade of the building can be opened and closed as needed to provide comfort (Elwazer, 2012). The Al Bahar Tower's secondary skin façade can be opened kinetically in response to the temperature to decrease glare and provide more comfort.

A façade having a secondary skin is also called the Double Skin Façade (DSF). In DSF, the building has an outer façade placed in front of the building wall within a certain distance to create a cavity that allows natural ventilation. In Figure 3, the air moves, entering from below and exiting through the hole above (chimney effect or stack effect). This DSF is utilized to heat buildings in cold climates and to cool buildings in tropical climates (Poursani, 2018).

In Semarang, several buildings are designed with secondary skins; for example the Henricus Constant Building in Soegijapranata Catholic University, located in Bendan Ngisor, Semarang area (Fig. 4). This building has a secondary skin made of reinforced concrete frame and brick walls with square holes-pattern. The secondary skin in this building functions as a vertical interior shelf. The secondary skin that covers most of the building façade makes the building look distinctive and unique compared to other nearby buildings.

Literature Review

Mostafa et al. (2016) explained that one of the most important

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Fig. 1: Variety of Secondary Skin in Buildings (Source: Campbell-Dollaghan, 2013)

Fig. 2: The Building of Al Bahar Tower di Abudabi, Dubai

Fig. 3: Building with Double Skin Façade

Fig. 4: The Building of Henricus Constant of Soegijapranata Catholic University, Semarang

methods for energy savings in buildings is to carefully design the façade. The optimal double skin façade (DSF) is one of the best options in managing interactions between open space and internal space. It also provides architectural flexibility for design. The double skin façade (DSF) building is one of the energy conservations available through the latest intelligent buildings. The need for energy conservation and sustainable development in buildings causes new interest in the passive solar system.

Ghasemi & Ghasemi (2017) stated that a Double skin façade (DSF) should be considered because it is has a direct impact on natural and unnatural environmental factors. The relationship between indoor and outdoor spaces must also be provided such as the body of a living creature and, at the same time, different styles must be given to the structure of a building according to its dimension and use. In this field, modern technology from Double Skin Façade (DSF) plays a key role as new technologies in architecture, structure, and mechanical materials and other knowledge-based sectors. In addition to strengthening the aesthetic aspects of buildings and smart and creative changes based on time and climate, technology can provide many facilities in the field of natural air conditioning in addition to controlling noise, wind, and rain.

Meanwhile, Parra et al., (2015) discuss the use of Venetian blinds (VB) as protective devices that are widely used in residential and company buildings. They can reflect or transmit light into the building and to create visually attractive exterior. They can also efficiently block heat from entering the building, and if combined with heat dissipation systems such as forced ventilation, they can improve the thermal performance of the Double skin façade (DSF).

Another interesting study was carried out by Lim and Ismail (2018) who observed the use of a Double skin façade (DSF) in Phnom Penh. The use of glass façades for office buildings in Phnom Penh has increased lately, and conventional façades have led to high energy demand, especially for cooling purposes in buildings. Regarding this issue, the use of a double skin façade (DSF) as an approach to improving building energy performance has been studied. The purpose of their research is to assess the potential of DSF in building energy efficiency and to propose its optimal configuration for office buildings in Phnom Penh.

From existing research, we suggest the study of Measuring the Quality of Natural Illumination in Double Buildings with a skin façade (DSF) has never been done, especially with the Henricus Constant Building in Soegijapranata Catholic University, Semarang, Indonesia as the object of observation.

MATERIALS AND METHODS

This study evaluates a building that has a Double skin façade (DSF) with natural lighting measurements. To be able to find out the performance of natural light entering the building with the Double skin façade (DSF), a field survey was carried out, i.e. the building of Henricus Constant in Soegijapranata Catholic University, Semarang, Indonesia.

In addition to conducting research in Henricus Constant Building in Soegijapranata Catholic University, Semarang Indonesia, we also carried out simulations with dialux software to determine the performance of light in the space. The model of the building was first analyzed, then we entered the analysis into the application to be able to do the simulation.

This study evaluates the performance of light in buildings with secondary skin elements. From the analysis results, we expect to know how effective the natural light is in buildings with a Double skin façade (DSF). The results of this study will be used to provide a recommendation for a method of installing secondary skins that can produce effective natural light for rooms in buildings.

The approach in this study is a quantitative approach. The data are in the form of the numerical depiction of natural light conditions in the buildings surveyed. The analysis was carried out by describing the processed data that were tabulated. Furthermore, we determined the relationship between natural light conditions both inside and outside the building with Double skin façade (DSF), walls, and openings in the buildings observed so that it can be seen the quality of natural light in buildings in which secondary skin elements are installed.

RESULTS AND DISCUSSION

The Level of Natural Lighting of the Henricus Constant Building

The quality of lighting in the classrooms in the Henricus Constant Building is influenced by the location, orientation, shape, size of the building, and orientation of the window (Mohapatra et al., 2018). The position of the Henricus Constant Building that has a secondary skin faces East so that it enters the line of the sun's path starting at 6:00 a.m. until 12:00 noon. Consequently the façade of the building is exposed to the sun from 6:00 p.m. to 12 noon. This condition is overcome by installing a curved field with square holes- pattern façade of 1m x 1m as the skin of buildings or more popularly known as a secondskin. The Secondary skin protects the building from the direct exposure of sunlight and creates vertical shadows on the first wall. At 12.00 noon, sun exposure has a slope of 69°. When the façade of the HC building is blocked by the secondary skin area, the shadow fills the openings and only the reflected light goes into the classrooms. The color of the building elements of the Henricus Constant Building is mostly white. Therefore, it can easily reflect the sunlight. To find out the level of natural lighting of classrooms and studios in Henricus Constant Building, field measurements were carried out using lux meter at several points in the classrooms.

The measurement on the 3rd floor was done for 5 points in one room (Fig. 5). On the 3rd floor, the level of natural lighting was

Table 1: Results of Field Measurement of the Level of Natural Illumination in the Classrooms in The Henricus Constant Building

Building Floor	Measurement Point									
3rd Floor Measurement Point	1	2	3	4	5	6	7	8	9	10
Light Intensity	5	10	4	3	3	4	3	4	2	2
4th Floor Measurement Point	11	12	13	14	15	16	17	18	19	20
Light Intensity	500	100	100	100	5	5	4	6	3	3
5th Floor Measurement Point	21	22	23	24	25	26				
Light Intensity	10	12	12	15	12	10				

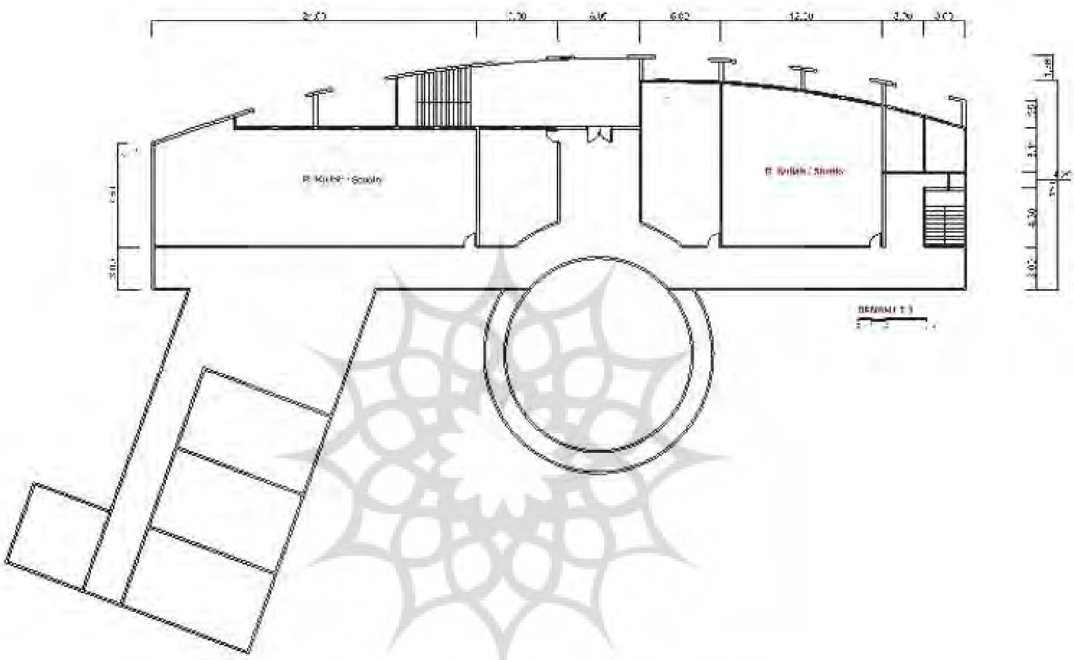


Fig. 5: Position of Measurement Point of the Level of Room Illumination (3rd Floor)

between 2 lux - 10 lux, which was low because the exposure to light was blocked by the seven-meter retaining wall in front of the building. On the 4th floor, the level of natural lighting was not evenly distributed at the point near the glass wall, with a total value of 500 lux. However, in the south, the value was smaller because the sunlight was still blocked by the retaining wall (Fig. 6) .On the 5th floor, the natural lighting level was between 10 lux and 15 lux. The quality of natural lighting increased from the 5th floor upward because the floors were not blocked by the retaining wall (Fig.7).

The measurement in the field suggests that the level of natural illumination was still below the visual comfort standard for the classroom, which is 350 lux (Tureková et al., 2018). (Table 1)

Field Imagery Simulation of Secondary Skin of the Henricus Constant Building With Sketchup

Secondary skin is a façade element of the Henricus Constant Building that functions as a protective shield for the building walls. The secondary skin of the building forms a pattern of square holes having 1m x 1m width. The secondary skin creates shades on the wall and produces vertical and horizontal shadows. To find out the position of the shadow and the position of the fall of natural light on the wall and rooms in the Henricus Constant Building, a model simulation using Sketchup software is performed. Previously, the Henricus Constant Building model was made by using Sketchup, and then the program of months and hours of the simulation was arranged. Then from Sketchup, the condition of shadows and natural light falling on the façade and space in the Henricus Constant Building will be seen in table 2.

Simulation of the Natural Lighting Quality of the Henricus Constant Building with Dialux

To assess the quality of natural lighting in the Henricus

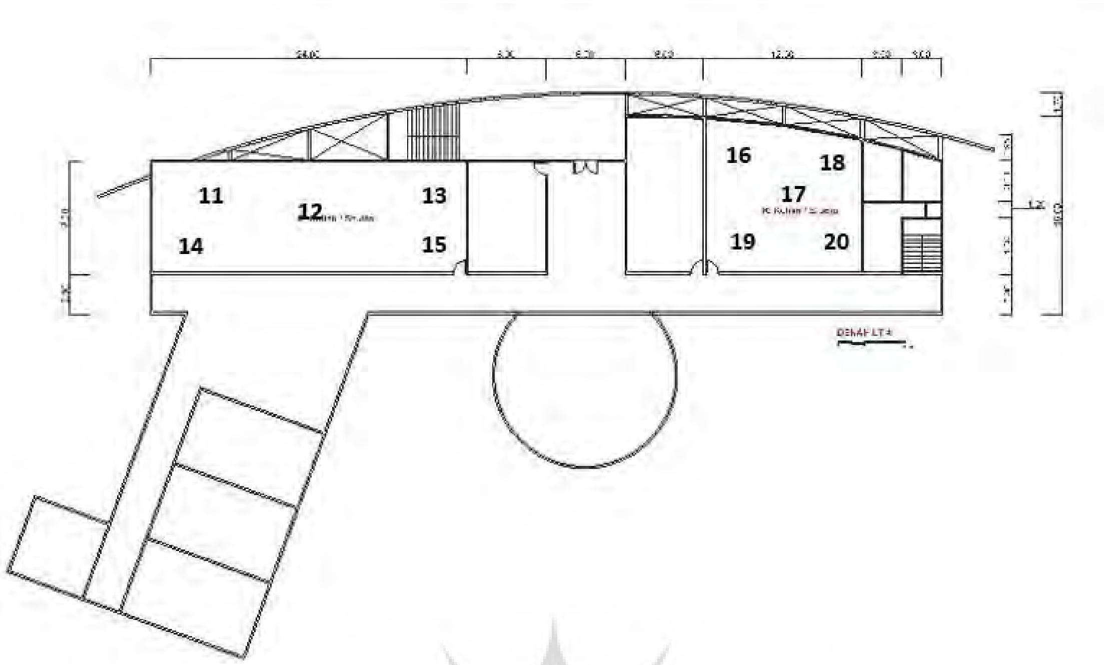


Fig. 6: The Position of the Measuring Point of the Level of Room Illumination (4th Floor)

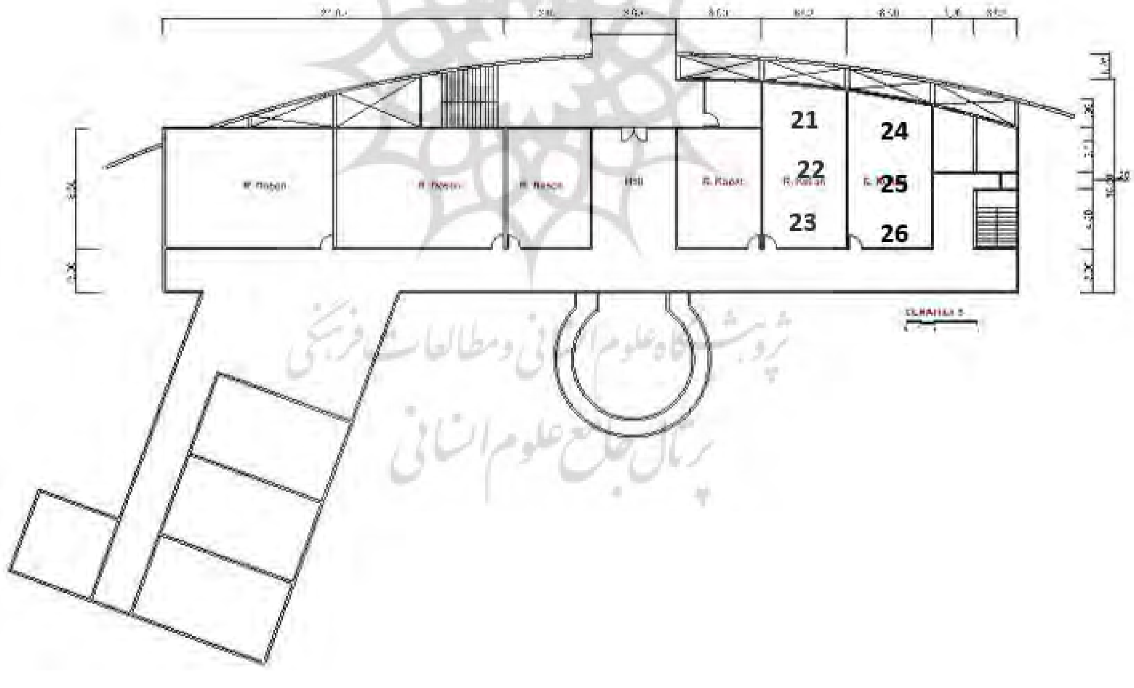
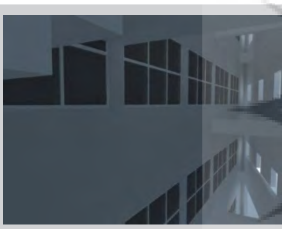


Fig. 7: The Position of the Measuring Point of the Level of Room Illumination (5th Floor)

Constant building, a simulation model of the building was carried out using Dialux software. First, a model image of the Henricus Constant Building was made by using Dialux. Then the program was arranged to determine the location of the building, date, hour, and some settings on the model that have been made such as the width of the openings, materials, etc. The simulation process was done at certain times, i.e. at 12.00 (noon) and 3:00 p.m. (evening) to find out the difference in the position of the trajectory of the sun that affects the intensity of the sun rays on the Henricus Constant Building (Tzempelikos, 2017).

Simulations conducted at 12.00 noon showed that the level

Table 2: Analysis of Imagery in the Henricus Constant A Building

NO.	Building Picture	Analysis
1		Simulation of sun exposure at 12.00. The entire building façade/secondary skin is covered by a thin vertical shadow because the angle of the sunlight begins to rise around 69˚. The sunlight is retained by the secondary skin.
2		Simulation of sun exposure at 3:00 p.m. All building façade/secondary skin is covered by dark vertical shadows. The angle of the sunlight is more than 90˚, i.e. 140° in the western part of the building.
3		Simulation of imagery in the cavity between the second skin and the wall at 12:00 noon. Direct exposure to the sunlight does not penetrate the wall but the shadow on the wall is relatively brighter than the shadow at 10:00 a.m. At 12 noon, the angles of the sun exposure are at 69˚ so that it is blocked by the second skin of the building.
4		Simulation of imagery in the cavity between the second skin and the wall at 3:00 p.m. Direct exposure to the sunlight is already on the west side of the building or the angle is more than 90˚, i.e. 150˚ towards the west. The wall becomes rather dark due to a lack of light.
5		Light simulation in the room at 12.00 with a secondary skin. There is no direct light entering the room, only the reflection or skyline that enters the room.
6		Light simulation in the room at 3:00 p.m. with secondary skin. There is no direct light entering the room, only a little reflection or skylight that enters the room.

of illumination in room 1 (The cavity between walls and secondary skin) was 145 lux - 298 lux. In-room 2, which was not protected by secondary skin, the level of illumination in the form of the curtain wall was 107 lux - 185 lux, and in spaces 3,4,6,7,8, and 9, it was 0,49 lux - 31,4 lux. The average of simulation carried out at 12:00 noon. shows the decrease in natural illumination level compared to that of at 9:00 a.m. (for example: in room 3 from the 3rd to 8th floor, the level of natural illumination is at 1.74 lux, 8.02 lux, 19.4 lux, 19.3 lux, 19.1 lux, and 19.6 lux at 12.00; meanwhile, at 09.00 the level of illumination is at 18.1 lux, 16, 3 lux, 30.1 lux, 30.1 lux, 30.3 lux and 30.6 lux). This happens because the angle of direct exposure to the sunlight at 12 o'clock was 69˚. The secondary skin covered the main walls so that the walls of the building were completely covered by shadows. Whereas at 9:00 a.m., exposure to the sunlight can still enter the walls and openings of the Henricus Constant Building.(Table 3) (Fig. 8)

At 3:00 pm, the sun's exposure reaches 140˚ and is already on the west side of the building. In the glass-walled room the illumination level is 250˚, but on the part where the secondary skin is located, the natural lighting level drops to 10 lux - 30 lux. Only on the 3rd and 4th-floor exposure to natural light is blocked by the talud, so the value ranges from 0.8 lux - with 7 lux. Therefore, at 3:00 p.m., the space in the building becomes less bright and requires lighting support (Jafari et al., 2018) (Table 4) (Fig. 9).

Table 3: Simulation Results of the Level of Natural Illumination in the Classroom of The Henricus Constant A Building at 12:00 p.m.

Floor	Intensity Of Natural Light (Lux)									Amount (Lux)
	R1	R2	R3	R4	R5	R6	R7	R8	R9	
3rd Fl.	145	107	1.74	0.49	0	0.89	0.30	0.60	0.82	256.84
4th Fl.	226	141	8.02	8.02	0	2.77	2.34	4.13	5.63	392.68
5th Fl.	297	185	19.4	19.4	0	18.5	24.8	21.3	25.3	591.90
6th Fl.	297	184	193	19.3	0	18.5	15.1	20.9	30.6	596.00
7th Fl.	298	185	19.1	19.1	0	18.2	18.3	20.9	25.6	596.10
8th Fl.	298	185	19.6	19.6	0	18.5	13.4	20.7	31.4	507.40

Fig 8: Dialux Simulation Results on Level 3, 4 & 5 at 12:00 noon

Table 4: Results of Simulation Level of Natural Lighting in the Classroom of Henricus Constant A Building at 3:00 p.m.

Floor	Intensity Of Natural Light (Lux)									Amount (Lux)
	R1	R2	R3	R4	R5	R6	R7	R8	R9	
3rd Fl.	106	81.2	1.36	0.36	0	0.76	0.22	0.52	0.72	191.14
4th Fl.	182	114	7.79	2.72	0	2.62	2.08	3.70	5.28	320.19
5th Fl.	246	160	20.1	10.8	0	18.8	14.6	21.7	25.2	517.20
6th Fl.	254	160	19.9	11.0	0	18.6	14.9	21.4	30.8	530.60
7th Fl.	254	160	19.9	11.1	0	18.5	14.9	21.4	30.8	530.6
8th Fl.	254	160	20.0	10.9	0	18.7	13.0	20.9	31.8	529.30

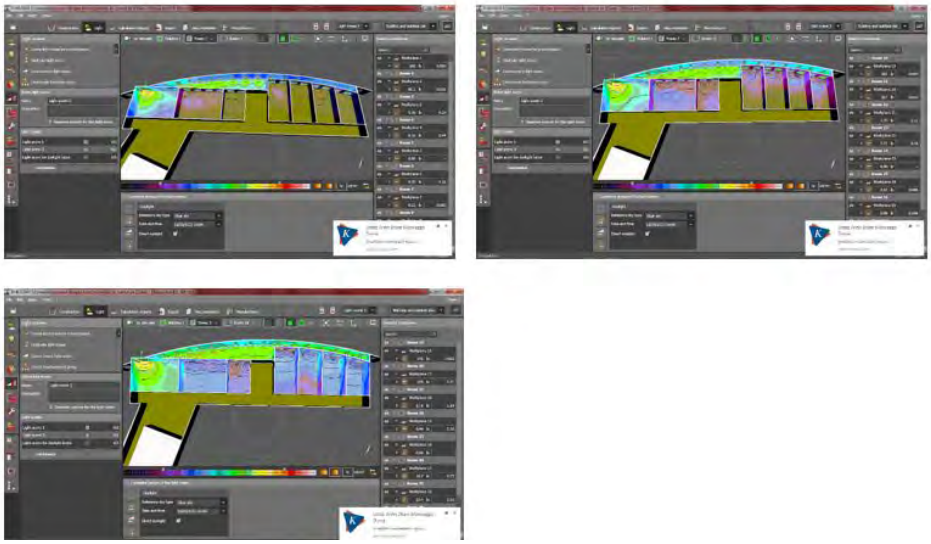


Fig. 9: Dialux Simulation Results on Level 3, 4 & 5 at 3:00 p.m.

CONCLUSIONS

After reviewing the effect of secondary skin on the level of natural lighting in the Henricus Constant Building, it can be concluded that:

Secondary Skin in the Henricus Constant Building can withstand direct exposure to the sunlight as a source of natural lighting so that it does not cause the level of lighting in the room to meet the lighting level standards for classrooms. The average measurement results are 30 lux and the standard set by SNI is 350 lux. Artificial lighting assistance from electric lights, therefore, is still needed. To overcome this problem, we suggest the opening of the building walls be widened. Another suggestion is to install a curtain wall (glass wall) so that more reflected light enters the room.

The color of building materials affects the level of reflection of light. The darker the color of the building elements, the less reflective it is. It is, therefore, recommended to use soft and bright colors to reflect a lot of light, but not reflect glare. In order not to glare, it is necessary to measure the light through the model simulation process first to produce a non-dazzling reflection of light.

The position of the Henricus Constant A Building faces east and west so that the installation of the secondary skin on the east is in accordance with its position to withstand exposure to the sunlight starting at 12:00 noon. The secondary form with a square holed-pattern of 1m x 1m manages to shade the classrooms. However, the ratio of openings in the walls of the building needs to be widened to let the natural light enter the building.

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