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INTEGRATION ANALYSIS OF THERMAL AND DAYLIGHT PERFORMANCE THROUGH THE BUILDING ENVELOPE

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ABSTRACT

Several strategies in reducing external heat gain sometimes have an impact on limited access to daylight in buildings. Therefore, an integrated study is needed between thermal and daylight performance of the building. This research focuses on building modeling and simulation on one of the buildings at UIN Walisongo Semarang to see these two parameters based on Standard Nasional Indonesia. The thermal performance through OTTV value is simulated using EnergyPlus, while the building daylight is simulated using Dialux. The existing condition showed that the thermal performance is not fully integrated with the building natural lighting. Further simulation is needed through the building envelope engineering. The results showed that the entire room has met the standard of natural lighting while maintaining the OTTV value according to the standard. This condition is the optimal point which represents the integration between thermal and daylight performance of the building.

Keywords: Thermal performance; daylight; simulation; EnergyPlus; Dialux.

INTRODUCTION

In sustainable development context, energy-efficient buildings concept has been widely used as an effort to synergize buildings with the surrounding environment. In one building, the use of air conditioning is the biggest factor in influencing the building energy consumption. Therefore, studies related to energy efficiency mostly focus on efforts to minimize the energy of cooling load or other factors that influence it (Loekita, 2006). The criteria for energy-efficient buildings in Indonesia use thermal performance calculations through the overall thermal transfer or OTTV value with a maximum limit of 35 W/m^2 according to Standard Nasional Indonesia (SNI). Of the several factors that affect the OTTV value, changes in the opening area have the greatest influence compared to other factors such as the type of glass or wall (Saud, 2012).

Architecture must be able to provide comfort for its users, both thermal comfort and visual comfort (Edrees, 2010). In addition to considering the energy efficiency aspect, the comfort aspect in the building also needs sufficient attention. Studies related to the calculation of buildings thermal performance require facade engineering such as window to wall ratio engineering or WWR and shading engineering. This affects the intensity of the lighting that enters the room, or in other words it affects the visual comfort in the room (Altan, et al., 2015). Visual comfort is directly related to building daylighting (Atthaillah, et al., 2017).To provide a balance between the thermal and daylight performance of the building, a study is needed that integrates the standardization of these two variables in the case of a building. Based on these issues, the formulations of the problem in this study are:

1. How is the thermal and daylight performance of the building in the current condition of the building?
2. How will the engineering be carried out to achieve a balanced standard of thermal and daylight performance of the building?

In general, this study aims to encourage the application of energy-efficient and comfortable buildings concept for its users. Specifically, this study aims to find the optimal midpoint between the concept of thermal and daylight performance of buildings according to SNI standards.

PREVIOUS STUDIES

Energy Efficiency Through the Building Envelope

Research related to energy efficiency through building envelopes aims to minimize external loads so as to reduce cooling loads in buildings (Hui, 1997). The heat received by the building from solar radiation will enter the room through three ways, conduction through walls, conduction through glass, and radiation through glass (Saud, 2012). High solar radiation in Indonesia encourages the use of intense air conditioning facilities so that it has an impact on the high energy consumption of the building (Gulati, 2012). The amount of heat gain per square meter of the building envelope is expressed in Overall Thermal Transfer Value (OTTV). Regulations related to OTTV are also regulated by the government to minimize cooling load and reduce the greenhouse gas effect (Chan & Chow, 2014). The OTTV calculation provisions only apply to buildings with artificial air conditioning.

Of the several elements in the building, the building envelope is the most influential factor on the level of energy consumption (Rattanongphisat & Rordprapat, 2014). Window to wall ratio (WWR) and sun shading have a significant influence on the OTTV value when compared to other building envelope components such as the type of wall or the type of glass (Saud, 2012). Sun shading levels such as different lengths, widths, or types affect the cooling load variance of buildings in tropical climates (Wati, et al., 2015). In a dense urban context, the shading factor of the surrounding environment also plays a significant role in influencing the thermal performance of a building envelope (Adi, et al., 2019). In conducting studies on several issues related to heat and energy efficiency, experimental research models using EnergyPlus software are often used because it can provide detailed and accurate simulation results (Kirimtat, et al., 2016).

Natural Lighting in Buildings

Visual comfort in a building can be achieved if the daylighting in the room is in accordance with recognized standard (Widiyantoro, et al., 2017). Natural lighting in the room is caused by lighting from the sky on a flat surface in an open field at the same time. It is explained in SNI 03-2396-2001 that the room's natural lighting parameter is based on daylight factor, which mean the ratio of lighting at one point of a certain area in the room with lighting in a flat field in an open field. The amount of light that enters the room depends on several factors such as the orientation of the building and the design of the building envelope (Kustianingrum, et al., 2016).

Indonesia, which is located around the equator, has a natural lighting level of 10,000 lux based on the explanation in SNI 03-2396-2001. Daylight factor is the percentage ratio of the level of lighting in the room with outside the room (Atthaillah, et al., 2017). Opening engineering and sun shading in the room is needed to create a room that is neither too dark nor too bright (Thojib & Adhitama, 2013). The light intensity that is too high in a room has the potential to cause discomfort such as glare (Adi, 2019). Some of the engineering strategies carried out include changing the WWR, choosing the interior colors, choosing the type of glass, and using sun shading in some rooms that are too bright (Atthaillah, et al., 2017)

Standards of OTTV and Natural Lighting

SNI 6389:2011 is intended for all parties involved in the entire building construction process to achieve efficient energy consumption conditions. Meanwhile, SNI 03-2396-2001 covers the minimum requirements for natural lighting systems in buildings in daytime conditions to support visual comfort. As previously explained, the energy efficiency of the building envelope can be expressed in terms of the OTTV value. The OTTV value of a building must not exceed 35 W/m^2. This condition can be achieved by several strategies such as engineering wall materials, glass materials, window to wall ratio (WWR), or sun shading elements.

In SNI 03-2396-2001, it is explained that the natural lighting of the room is said to be good if between 08:00 and 16:00 there is enough light entering the room. In this SNI, there are also limits on the minimum daylight factor based on several different spatial functions. Based on Table 1, the object of research refers to the standard of an ordinary classroom with a daylight factor of at least 3.5% or 350 Lux.

Tabel 1. Minimum limit of daylight factor recommended by SNI 03-2396-2001

Room Function	Lighting Intensity (Lux=lx))	*Daylight Factor* (DF=%)
Ordinary classroom	350	3.5
Special classroom	450	4.5
Laboratory	350	3.5
Wood/iron workshop	250	2.5
Gymnasium	250	2.5
Office	350	3.5
Kitchen	200	2.0
Living room	350	3.5
Bed room	180	1.8

Source: SNI 03-2396-2001, pg.12

Correlation of Building Thermal Performance with Daylight Performance

A large opening area will affect the level of natural lighting in the room, but at the same time it also includes large amounts of solar heat (Vidiyanti, et al., 2020). Recent research has tried to analyze the correlation of energy efficiency and visual comfort in the room by integrating the study of energy efficiency of the building envelope and natural lighting sustainably (Altan, et al., 2015). Energy efficiency and daylight settings can be done by engineering window glass types through SHGC, VT, and U-Value (Husin

& Harith, 2012). Engineering building envelope with WWR 20-27% could reach daylight 30.12%-37.98% with OTTV 35.06 W/m^2-43.81 W/m^2 (Athoillah & Biyanto, 2014). Even so, the research still refers to the OTTV limit of 45 W/m^2 in SNI 03-6389-2000.

Based on the results of several previous studies, the energy efficiency of buildings and natural lighting in buildings is influenced by engineering the building envelope. Engineering the WWR, glass type, or level of sun shading can affect building OTTV and daylight factor simultaneously. However, OTTV and daylight factor have different engineering strategies to achieve the standards. Even the latest SNI limits OTTV to a maximum of 35 W/m^2. This poses a more difficult challenge than the previous SNI standard which limited the OTTV to a maximum of 45 W/m^2.

METHODOLOGY

Based on the problems previously described, the appropriate research method used is the quantitative method by modeling and simulating with a computer. This research model is a solution to justify the energy performance of a building so that it can make the planning process of a building more efficient (Granadeiro, 2012).

To calculate the thermal performance of buildings, the software used is Open Studio and EnergyPlus. The calculation of OTTV with EnergyPlus is quite accurate because it uses local climate data so that the calculation results can be compared with the OTTV standard in SNI (Adi, 2017). Meanwhile, daylight factor measurements were carried out using the Dialux Evo software. This software was chosen because it can analyze data related to natural lighting, automatic technical reporting, and realistic and scalable lighting rendering (Satwiko, 2011).

The research was conducted by taking the case of an educational facility building in Semarang, namely Gedung O at UIN Walisongo Semarang. This building is one of the lecture buildings for students of the Faculty of Ushuluddin and Humanities, including students of the Art and Architecture Study Program who require a high level of accuracy in their educational activities. The average temperature of the city of Semarang reaches 29.50^0C with an average humidity of 79.08% (www.semarangkota.bps.go.id). From this data, buildings built in Semarang should pay attention to energy efficient design concepts.

The site location data is adjusted to the existing conditions of Semarang city with details of the coordinates of latitude -6.98 and longitude 110.35. While the elevation of Gedung O is at an altitude of 78m above sea level (https://en-gb.topographic-map.com, 4/9/2021). Gedung O itself has North orientation with a slight slope of $+36^0$. Energy efficiency simulation through the building envelope is run for a period of 12 months. While the simulation time in one day is set for 11 hours, starting at 07:00 to 18:00 in accordance with the provisions of the OTTV calculation in SNI 6389:2011 concerning Energy Conservation of Building Envelopes in Buildings.

To observe the building thermal performance, the OTTV value was used as dependent variable. It refers to SNI 6389:2011 with a maximum OTTV limit of 35 W/m^2. Window to wall ratio (WWR) and sun shading level were chosen as independent variables in calculating the thermal performance of the building. Meanwhile, in the building daylight analysis, daylight factor becomes dependent variable. WWR and sun shading level become independent variables in daylight factor calculation. The daylight factor limit is at least 3.5% or 350 Lux in based on SNI 03-2396-2001. As in the analysis of the building thermal performance, WWR and sun shading levels were also used as independent variables in the analysis of building daylight.

Fig. 1. Exterior and interior of Gedung O UIN Walisongo Semarang

RESULTS and DISCUSSION

Existing Condition

Gedung O UIN Walisongo Semarang is one of the lecture buildings located at the Faculty of Ushuluddin and Humanities. The building which consists of 3 floors consists of several lecture rooms, lab rooms for several study programs, and toilets. The 1st floor to the 3rd floor of Gedung O have the typical spatial form. There is a large corridor running from North to South. Around the corridor, there are spaces for the building's core activities such as lab rooms, classrooms, and toilets. The air-conditioned room consists of a lecture room and a lab room. The 1st floor consists of 4 classrooms, 2 toilets, and 2 lab rooms. The 2nd floor consists of 4 classrooms, 2 toilets, and 1 lab room. While the 3rd floor consists of 4 classrooms, 2 toilets, and 2 lab rooms. When viewed from the orientation of the building, building O is not actually facing north on the front side of the building, but there is a slope of 36^0 to the east.

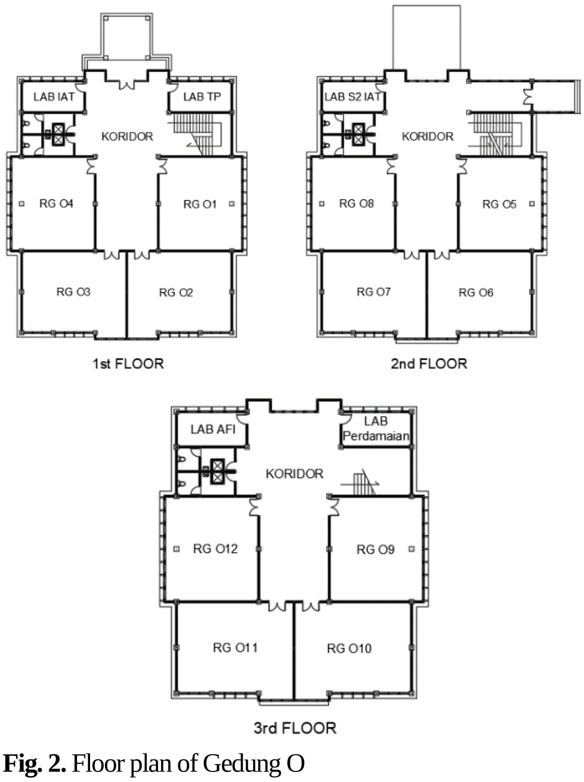


Fig. 2. Floor plan of Gedung O

The building has a floor-to-floor distance of 4 meters. The ceiling in each room is 3.3 meters from the floor, so there is 70 cm of space between the ceiling and the floor above it. There is a distance of 1.1 meters between the floor of the room and the bottom line of the window. Meanwhile, the classroom on the 1st floor has a floor distance of 1.5 meters from the bottom line of the window.

Types of windows in buildings are awning windows with a window width of 60 cm and a height of 155 cm. The size of the window width is the same on all floors to match the vertical shading arrangement on all sides of the building. The south side of the building has a slightly different configuration where there are areas of windows that are not accompanied by vertical shading, but there are only horizontal shading that shade them.

Vertical shading is between each window with a shading width of 35 cm from the wall surface. The distance between the vertical shading with each other is 110 cm. This horizontal shading has a width of 35 cm with a distance of 4 meters from each other according to the floor to floor distance of the building. In addition, there is a 4 meter high retaining wall on the east and south sides of the building.

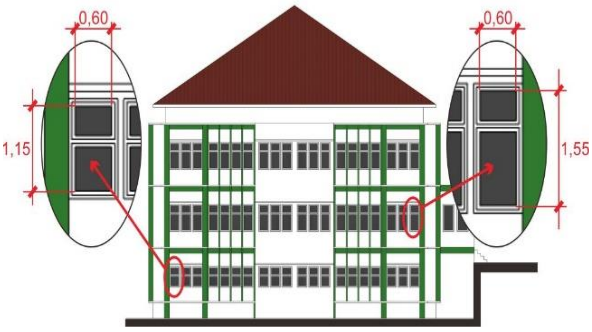


Fig. 3. Window dimensions of the building

Existing Condition Simulation

The simulation results showed that the OTTV value of Gedung O on all sides is 18.73 W/m^2. The OTTV value on the north side of the building is 23.88 W/m^2 with a WWR of 12.92%; on the east side of the building by 13.45 W/m^2 with a WWR of 8.41%; on the south side it is 21.59 W/m^2 with a WWR of 19.32%, while on the west side it is 17.84 W/m^2 with a WWR of 8.33%. The acquisition of the OTTV value is very good because it is still far from the standard OTTV value of 35 W/m^2 which has been regulated in SNI. These results are sufficient to describe the attributes of Gedung O, which is seen to pay attention to the shading aspect of the building to minimize the incoming external heat. The existence of shading elements that are evenly distributed on all sides of the building, the presence of retaining walls, and the size of the building's windows that are not too large are some of the building's attributes that all affect the low OTTV value of the building.

The condition of the different OTTV values on each side of the building is based on the characteristics of the building envelope. The North-South side of Gedung O has a higher OTTV value than the East-

Tabel 2. OTTV simulation results of existing buildings with EnergyPlus

	North	East	South	West	Total
Window Heat Gain (W)	2,849.16	2,418.84	5,069.95	3,131.92	13,469.87
Wall Conduction (W)	589.62	845.18	630.55	1,236.32	3,301.67
Total External Heat Gain (W)	3,438.79	3,264.02	5,700.50	4,368.24	16,771.54
Glass Area (m^2)	18.60	20.40	51.00	20.40	110.40
Total Area (m^2)	144.00	242.70	264.00	244.80	895.50
OTTV (W/m^2)	**23.88**	**13.45**	**21.59**	**17.84**	**18.73**
WWR (%)	12.92	8.41	19.32	8.33	12.33

West side due to the larger WWR value although protected by shading elements in the building.

Unlike OTTV simulations which have to use two software, building daylighting only use Dialux software for the simulation process, starting from the modeling stage to the simulation stage and results. The data input process is carried out simultaneously with the building modeling process. The simulation assumed three time periods that represent the three positions of the sun, solstice 21 June, equinox 21 March, and solstice 22 December. The sky conditions in the three simulation periods are set in the average sky.

The simulation results show that the level of daylighting is quite varied in each period and also between rooms in the building. The average light intensity during the solstice 21 June is 828 lux. The average light intensity in the equinox 21 March is 337 lux. Meanwhile, the average light intensity during the solstice 22 December is 419 lux. The simulation period in June has the highest results because the position of the Semarang city is south of the equator which caused the sun's orbit in the north of the building is longer than when it is south of the building. In addition to showing the average level of daylighting intensity in the room, the Dialux simulation results can also display lighting distribution in the room in false color and isolux models. False color describes the level of color gradation where one color represents an area with the same lighting level. Reddish yellow color describes a high level of daylighting intensity, while purplish blue describes a low level of daylighting intensity. Meanwhile, isolux is lines like contours that describe the boundaries of areas in a room that have the same level of daylighting.

The average daylighting simulation results for all periods in the existing condition is 528 lux. When compared with daylight standard for classroom in SNI 03-2396-2001, which is at least 350 lux or daylight factor 3.5%, the existing condition has exceeded the standard. Even so, there are variations in the level of daylighting that are quite diverse in each room. The table below shows that there are some very bright rooms where the average light intensity is very high, but there are also some rooms with a small intensity of daylighting.

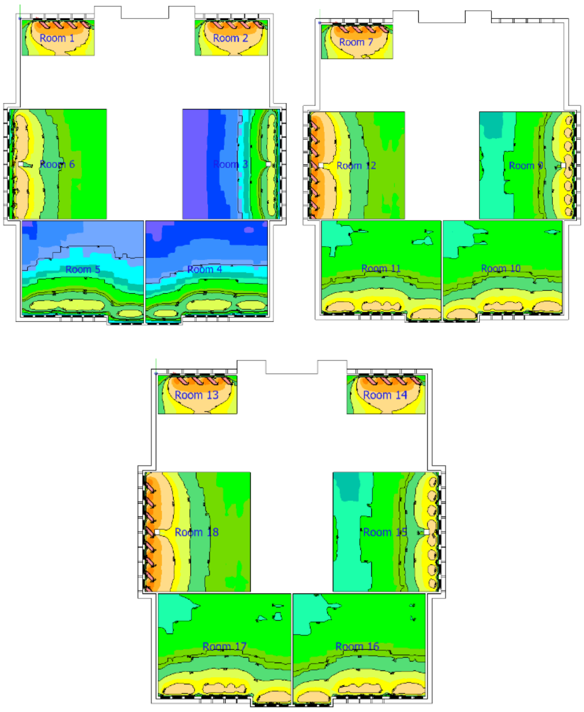


Fig. 4. Simulation results of daylighting of existing conditions in the solstice 21 June

Tabel 3. Recapitulation of daylighting simulations of existing conditions in all rooms and periods

Room ID at Dialux	Room	21 June	21 March	22 Dec	Average
Room 1	Lab IAT	1872	595	393	953
Room 2	Lab TP	1871	598	395	955
Room 3	Room O1	107	110	160	126
Room 4	Room O2	120	115	331	189
Room 5	Room O3	133	120	337	197
Room 6	Room O4	445	165	148	253
Room 7	Lab S2 IAT	1874	595	393	954
Room 9	Room O5	294	234	373	300
Room 10	Room O6	336	268	719	441
Room 11	Room O7	335	265	711	437
Room 12	Room O8	995	353	283	544
Room 13	Lab AFI	1872	596	393	954
Room 14	Lab Perdamaian	1872	599	395	955
Room 15	Room O9	295	234	373	301
Room 16	Room O10	335	268	719	441
Room 17	Room O11	335	266	711	437
Room 18	Room O12	991	352	282	542
					528

Integration on OTTV & Daylighting of Existing Building

The results of the OTTV or daylighting simulation both have a tendency of results that can be analyzed from the orientation of the room. The image below describes the simulation results related to OTTV and daylight calculations in the lab rooms located on the north side of the building. Based on OTTV values, the north side of the building containing lab rooms has met the OTTV standard below 35 W/m^2. This condition is also supported by the results of daylight simulation of the lab rooms, all of which have met the room's daylighting standards.

Fig. 5. Comparison of OTTV and daylighting in lab rooms on the north side of the building

The classrooms on the south side of the building also have a balanced level of energy efficiency and daylighting. This side has an OTTV value of 21.59 W/m^2, so that it meets the standards set by SNI. The presence of shading and orientation elements that are not facing directly towards the sunlight contribute to the small OTTV value on this side.

Most of the daylighting levels in the rooms on the south side have met SNI of at least 350 lux. Some of the rooms that still do not meet the standards are classrooms on the 1st floor. The smaller size of the windows and the presence of a retaining wall are the causes of limited access to daylighting of these rooms.

The rooms on the west and east side of the building have various OTTV values and different levels of daylighting. Rooms O8 and O12 on the west side of the 2nd and 3rd floors have no problems related to OTTV values and daylight levels. This condition is influenced by several factors, such as access to sufficient daylight in east orientation with a slight slope of +36^0. In addition, the presence of shading elements is sufficient to minimize the heat gain so that the OTTV values of these spaces already meet the standards in SNI.

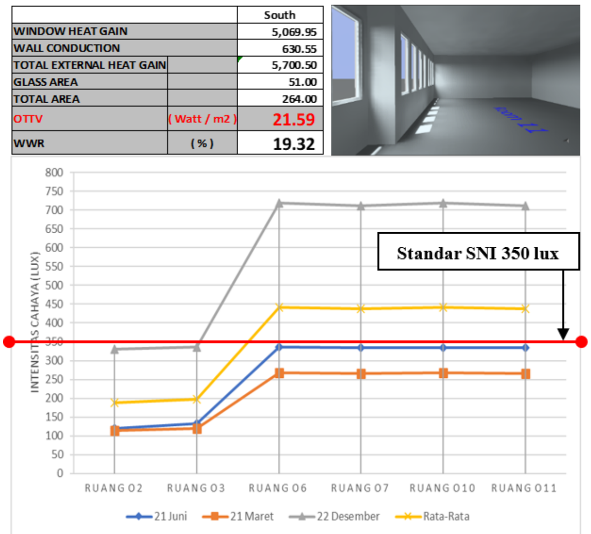


Fig. 6. Comparison of OTTV and daylighting in classrooms on the south side of the building

Fig. 7. Comparison of OTTV and daylighting in classrooms on the west side of the building

Problems occur in classrooms on the 1st floor, East classrooms on the 2nd and 3rd floors. Classrooms on the 1st floor such as room O1 on the east side and room O4 on the west side have little access to daylight and do not meet the requirements. SNI standard is a minimum of 350 lux. The small size of the windows and the presence of retaining walls are the main causes of the lack of daylighting in this classroom. In addition, the eastern classrooms on the 2nd and 3rd floors such as room O5 and room O9 also have daylight levels that do not meet SNI standards even though the OTTV is fulfilled. This is influenced by the orientation of the windows which face east with a slight slope of $+36^0$. The orientation of these windows lets in less daylighting than windows in other orientations.

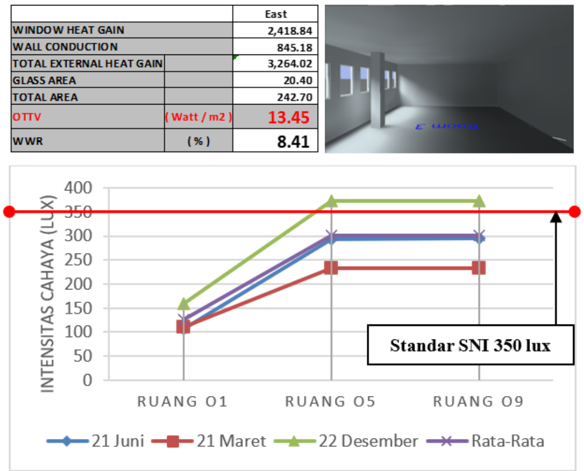


Fig. 8. Comparison of OTTV and daylighting in classrooms on the east side of the building

Based on the integrated analysis between OTTV and daylighting, it is known that Gedung O has met the OTTV standard according to SNI. Even so, there are some rooms that do not meet the daylight standards, including the room O1, O2, O3, O4, O5, and O9. The dimensions and orientation of the windows to the sun are the main factors for the daylighting of the building. Therefore, these spaces need to get architectural engineering in an effort to achieve the standards.

Advanced Simulation Modeling

This simulation stage is a response to the simulation results of existing conditions that require a more in-depth study related to better design recommendations for the thermal performance of the building envelope and daylighting of the building. The analysis at this stage will still integrate aspects of the thermal and daylight performance of the building. Although the problem occurs in the daylight aspect of the building, testing on the OTTV value of the building after the engineering action will still be carried out.

The early stage of this advanced simulation is to engineer windows on a model of rooms that still lack daylighting using the Dialux software. There are 6 rooms to be engineered such as room O1, O2, O3, O4, O5, and O9 as the previous simulation results in the existing conditions. After that, the thermal performance simulation was carried out through OTTV parameters using OpenStudio and EnergyPlus software.

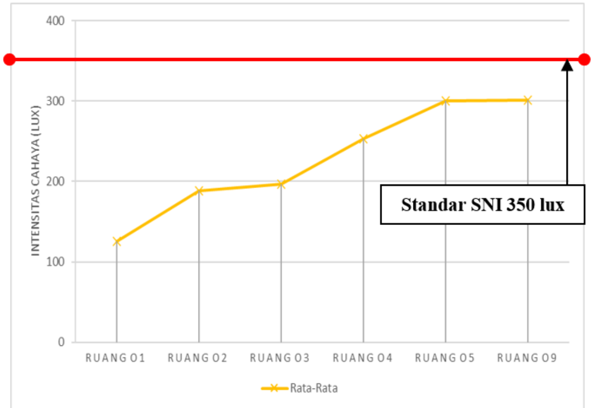


Fig. 9. Room O1-O5 and O9 which is still below lighting standard

Engineering is done by looking at the window sizes that allow it to be installed and do not change the main structure of the building. When viewed from the pattern, the vertical shadings in the building are arranged between the windows of the room at a fairly close distance from each other. Therefore, the engineering of the window model will maintain the size of the window width and only change the the height of the classroom windows.

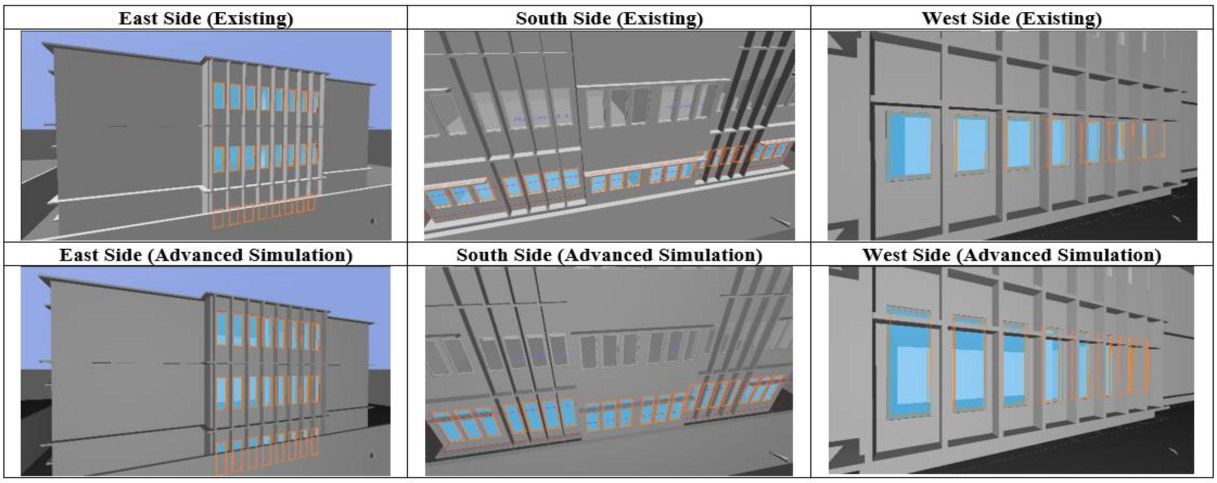


Fig. 10. Enlarged window size on the East, South, and West sides of the building

The engineering of the window models in this advanced simulation stage, in addition to considering the level of daylighting, also considers the aspect of window alignment as an exterior element of the building. This is to optimize daylighting without compromise the aesthetic aspects of the facade. Efforts have been made to uniform windows with a size larger than the existing window.

The existing window which has a size of 0.6m x 1.55m was changed to 0.6m x 2.15m. This change assumes that the window height reaches the ceiling level of the room, but still maintains the distance from the floor to the bottom line of the window. The picture below shows some engineering made to several parts such as East side window, South side window, and West side window of the building.

Advanced Simulation of Daylighting

The simulation results show that the intensity of daylighting in room O1, O2, O3, O4, O5, and O9 has increased significantly. Among these classrooms, room O1 still cannot meet the SNI standard regarding daylighting. Other classrooms have an average value of daylight intensity above 350 lux or have met the standards set in SNI. The room O2 has a daylight level of 361 lux, the room O3 is 370 lux, the room O4 is 485 lux, the room O5 is 379 lux, and the room O9 is 378 lux.

Room O1 on the 1st floor in east side of the building has not reached the standard of daylighting even it has been modeled with a larger window. In this advanced simulation, room O1 has an average daylight level of 230 lux, which is still far below the standard set by SNI. This condition can be influenced by several factors such as window orientation and the presence of a retaining wall. In the existing simulation stage, it is known that rooms with windows facing east with a slight slope of +36^0 tend to have less access to daylighting than other orientations. This is also happened to room O1 which faces this orientation. This condition is made worse by the presence of a retaining wall with a height of 4 meters in front of room O1 so that access to daylighting is increasingly limited.

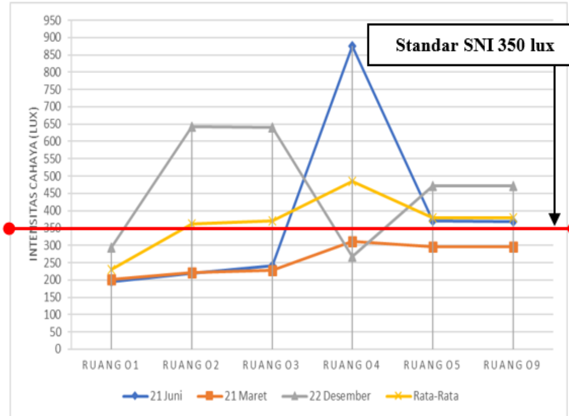


Fig. 11. Advanced simulation results in classrooms that still lack daylighting

Window Engineering in the Case of a Very Dark Room

Although the engineering of the windows has been done in the previous stage, there is one room that still does not meet the daylight standards, namely room O1 on the 1st floor of Gedung O. This condition requires further engineering to seek additional lighting access in that space.

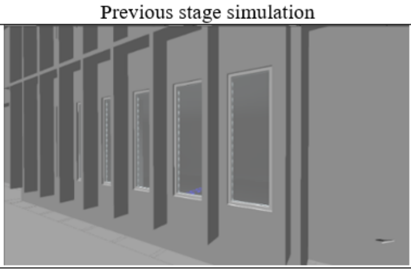
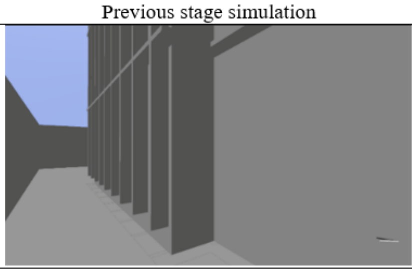
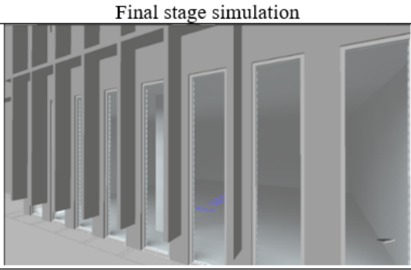
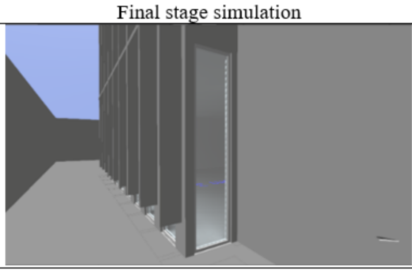
Enlarged Window Size (East side)	Enlarged Window Size (North & South side)
Previous stage simulation	Previous stage simulation
	
Final stage simulation	Final stage simulation
	

Fig. 12. Advanced engineering on the windows of room O1

Besides increasing the window size, another effort that can be made is the addition of window elements in the room O1. When viewed from the building shape, the classrooms on the west and east sides protrude 1 meter out compared to the walls next to it. This condition can be utilized in the case of room O1 by adding window elements on the protruding side. In addition, the window size has been increased to the building floor base to maximize the daylighting. This change is considered optimal because it has maximized the entire area of outdoor wall into a transparent field for daylighting.

In this simulation, the window size of room O1 is enlarged from 0.6m x 2.15m to 0.6m x 3.2m. A window model of this size was also added to the north and south sides of the wall that protrude 1 meter out. The simulation results are shown in 4 visualizations including the floor plan Isolux, the average daylight level, rendering of daylighting, and false color from an interior perspective.

The simulation results show the level of daylighting in room O1 has increased significantly. By maximizing the window height and adding windows on the North and South sides, the average daylighting of room O1 increases to 380 lux or daylight factor of 3.8%. In this way, room O1 has reached the room's daylighting standard set in SNI 03-2396-2001. Although the presence of a retaining wall blocks access to daylighting from the east, natural light can still enter room O1 through additional windows on the north and south sides of the wall that protrude 1 meter out.

Advanced OTTV Simulation

The addition of the size and number of windows in the advanced simulation model has an impact on the addition of the window to wall ratio or WWR. The new model created shows a WWR value of 16.4%. The addition of the WWR value from the existing conditions will clearly affect the OTTV value of the building at this simulation stage.

The simulation results show the OTTV value of the advanced simulation is 22.56 W/m^2 on all sides of the building. If described in more detail on each side, the OTTV value on the north side of the building is 25.84 W/m^2 with a WWR of 14.31%; on the east side

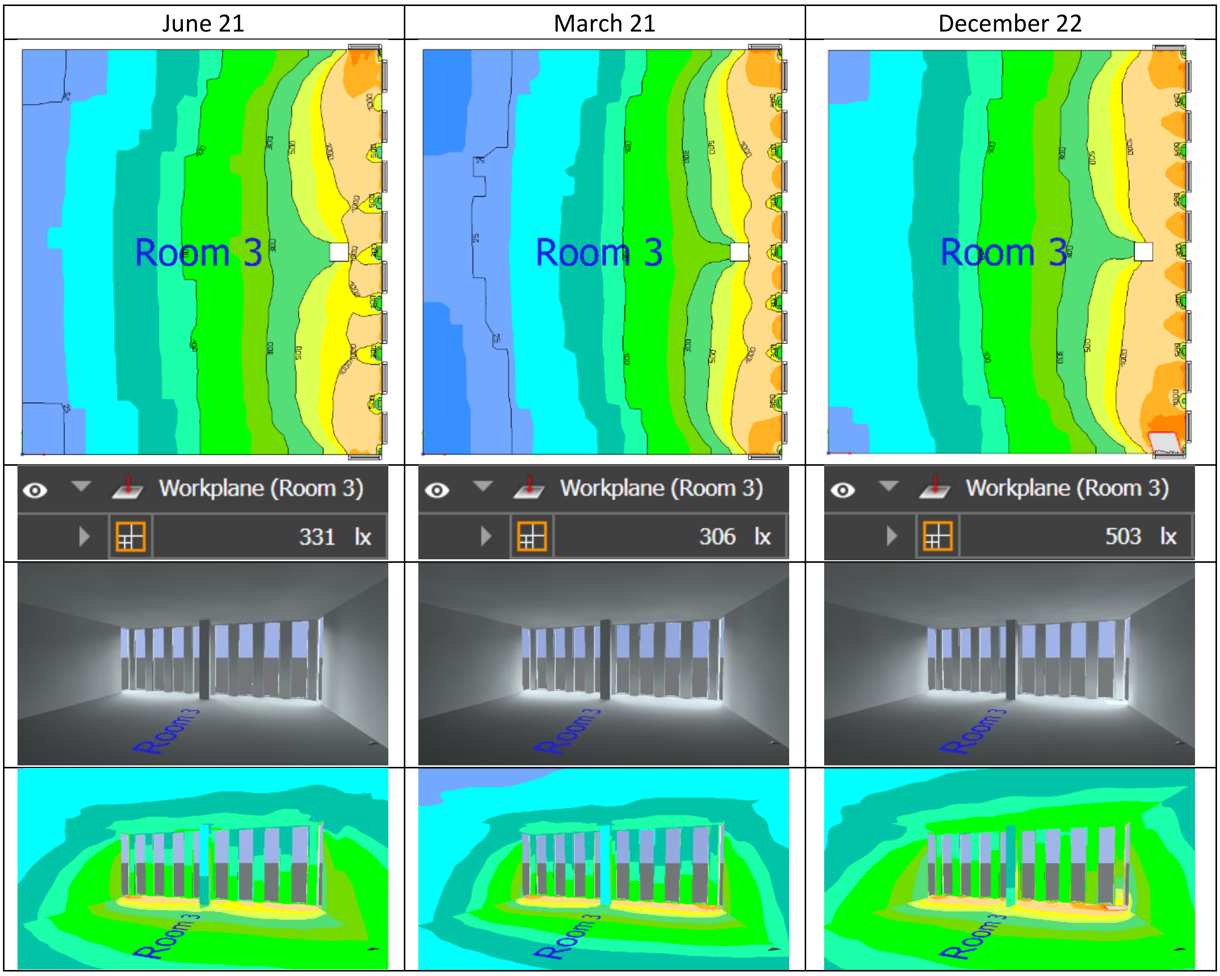


Fig. 13. Simulation results of room O1 daylighting after increasing the size and number of windows

is 18.81 W/m^2 with a WWR of 14.83%; on the south side is 25.30 W/m^2 with a WWR of 24.62%, while on the west side is 21.40 W/m^2 with a WWR of 10.29. The acquisition of the OTTV value is very good because it is still far from the OTTV standard of 35 W/m^2 which has been regulated in SNI 6389:2011.

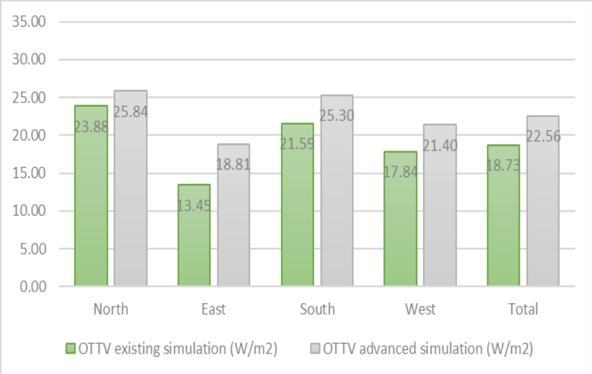


Fig. 14. Comparison graph of OTTV simulation of existing condition and advanced simulation

The OTTV value on the East side has the most significant improvement compared to other orientations. If the existing simulation on the East side of the building only has an OTTV value of 13.45 W/m^2, in the advanced simulation stage the OTTV value on the East side is 18.81 W/m^2. This is mainly due to the optimization and addition of windows in room O1 as well as the addition of the window size in room O5 and room O9 which are also on the east side of the building. The smallest difference in OTTV values is on the north side of the building, from the original 23.88 W/m^2 to 25.84 W/m^2. This is because the lab rooms located on the north side of building do not change the window size in the advanced simulation stage.

Integration Analysis of OTTV and Daylighting in the Advanced Simulation

Simulation of thermal performance and daylighting through the building envelopes is carried out in an integrated manner to see the relationship between these two variables in one building model. The window model engineering used for simulating daylighting with Dialux software has an effect on the OTTV value of the building. Although the windows of the room are larger to achieve the daylight standard, this does not sacrifice the OTTV value beyond the standard set in SNI. This can be done because the model engineering is carried out in a measurable manner by considering several factors such as the shading structure of the building envelope, the type of

Tabel 4. Overall Recapitulation of the OTTV Value Based on Advance Simulation

	North	East	South	West	Total
Window Heat Gain (W)	3.138,68	3.829,60	6.123,99	4.055,45	17.147,72
Wall Conduction (W)	581,64	734,68	555,43	1.182,36	3.054,12
Total External Heat Gain (W)	3.720,32	4.564,27	6.679,42	5.237,82	20.201,83
Glass Area (m^2)	20,60	36,00	65,00	25,20	146,80
Total Area (m^2)	144,00	242,70	264,00	244,80	895,50
OTTV (W/m^2)	**25,84**	**18,81**	**25,30**	**21,40**	**22,56**
WWR (%)	14,31	14,83	24,62	10,29	16,39

Tabel 5. Final recapitulation of OTTV and building daylighting based on advanced simulation results

		North		East		South		West		Total
WINDOW HEAT GAIN		3,138.68		3,829.60		6,123.99		4,055.45		17,147.72
WALL CONDUCTION		581.64		734.68		555.43		1,182.36		3,054.12
TOTAL EXTERNAL HEAT GAIN		3,720.32		4,564.27		6,679.42		5,237.82		20,201.83
GLASS AREA		20.60		36.00		65.00		25.20		146.80
TOTAL AREA		144.00		242.70		264.00		244.80		895.50
OTTV	(W/m2)	25.84		18.81		25.30		21.40		22.56
WWR	(%)	14.31		14.83		24.62		10.29		16.39
PENCAHAYAAN ALAMI		Room Zone	(LUX)	Room Zone	(LUX)	Room Zone	(LUX)	Room Zone	(LUX)	Average
	1	lab IAT	951.67	room O1	380.00	room O2	361.00	room O4	484.67	585.39
	2	lab TP	953.67	room O5	378.33	room O3	369.67	room O8	541.00	
	3	lab S2 IAT	952.33	room O9	378.33	room O6	440.00	room O12	540.67	
	4	lab AFI	952.33			room O7	436.67			
	5	lab perdamaian	954.00			room O10	440.33			
	6					room O11	437.00			

window that allows it to be replaced, and the appearance of the building's facade that need to be maintained.

In the advanced simulation that has been carried out, the daylighting of the building as a whole is 585 lux or a daylight factor of 5.85%. All rooms in the building have also met the standard where the lab rooms have the highest daylighting in the range of 952-954 lux and the rooms on the East-South side have the lowest daylighting in the range of 361-440 lux. Meanwhile, the thermal performance level of the building through the OTTV parameter is 22.56 W/m^2. All sides of the building have met the energy efficiency standards of the building envelope set by SNI where the North side has the highest OTTV value of 25.84 W/m^2 while the East side has the smallest OTTV value of 18.81 W/m^2. The two variables that are the focus of this research have both met the standards set by SNI.

The simulation process of building thermal and daylight performance that has been carried out is to achieve the target of energy-efficient buildings that are comfortable for users. Energy saving is about how to minimize incoming external heat gain. While the comfort aspect is related to the adequacy of daylighting in the room. The small OTTV value of 22.56 W/m^2 can be an indication that the building heat gain is not large. This condition allows the energy load, especially the cooling load to be not too large. The OTTV value is supported by the building daylighting of 585 lux with the condition that all rooms in the building have a daylight level above the SNI standard, which is at least 350 lux. This condition can be said to be the optimal point between the concept of energy efficiency through building thermal performance with building daylight-ting according to SNI standards in the context of Gedung O UIN Walisongo Semarang.

CONCLUSION

The concept of sustainable development in the context of architecture requires a comprehensive study not only at the theoretical level, but also at the practical stage. One of the things that is attempted in this research is to conduct a measurable study to answer the problem of high energy consumption in a building, particularly related to the thermal and daylight performance of the building. These two variables are related to the building envelope so that the analysis can be carried out in an integrated manner.

Gedung O UIN Walisongo Semarang has a good energy efficiency of the building envelope, but still lacking in daylighting. Modeling and simulation of existing buildings shows a low OTTV value of 18.73 W/m^2. The orientation factor of the windows in the building and the exterior shading elements greatly affect the building heat gain during the day. However, the small value of the OTTV has an impact on the lack of daylighting in some rooms. This happened due to several factors such as window orientation, window size that was too small, and external factors in the form of retaining walls around the building.

Further modeling and simulation are needed as an effort to evaluate and design recommendations in order to achieve a balanced condition of thermal and daylight performance of the building. Because the building's OTTV value is already good, model engineering is focused on optimizing the daylighting of the building. Several strategies have been tried, such as adding a larger window size and adding new window elements in a room that’s still very dark. Through measurable engineering, the daylighting in all rooms can reach the standard while maintaining the OTTV value according to standards set in SNI.

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