Evaluation of Building Envelope Performance on the Kanisius Kalasan Junior High School Building Yogyakarta

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ABSTRACT
Building performance will have a direct impact on the performance of the activities inside the building. In an educational building, a comfortable and convenient environment should be created to improve the performance of students. Kanisius Kalasan Junior High School Building is being planned to replace the existing building that will be demolished. Located in the Kalasan area which has a fairly high daily temperature with the open-wide area characteristic, the potential for sun exposure is quite high that it becomes a challenge for building design to have good performance. The building performance will be assessed from the aspect of indoor daylighting quality and the efficiency of energy use through the design of building envelope. This study uses simulation method with Sefaira software based on the building's design and construction drawing document. Then the analysis and evaluation can be implemented on the building design to identify its performance. The simulation results show that the level of daylighting is quite good, the ideal standard of 300 lux can be achieved in most parts of the several rooms. Then the building is predicted to have an energy consumption of 151 kWh/m^2/year, which can be categorized as efficient based on the energy consumption standards of school buildings. These results indicate that the elements of building envelope, especially the shading design, have a significant influence on the building's performance.

Keywords: *Building envelope, Building performance, Simulation, Energy efficient.*

1. INTRODUCTION

Nowadays the world is faced with the phenomenon of environmental quality degradation, including the issue of climate change which has a significant impact on human life. Climate change has an impact on various sectors, especially those related to human's comfort and health, as well as economic sectors where the need for energy continues to increase. Architecture contributes to 40% of global energy consumption, which of course has an effect on climate change [1]. Based on this phenomenon, architecture should be able to respond by initiating high-performance building designs in providing indoor health and comfort while remaining environmentally friendly. The Indonesian government has begun to implement the Green Building policy to be implemented in building design, both new buildings and existing buildings. It aims to support sustainable development. Located in a tropical climate is a challenge for building design because it will have a significant impact on building energy consumption. It is known that energy consumption for air conditioning systems in countries with tropical climates can reach 45-70% of the total energy consumption [2]. To be able to reduce energy consumption, it is necessary to implement building design principles that can increase energy efficiency without compromising the comfort of building occupants.

In educational buildings, the occupant's comfort is something that is very important to pay attention to. Comfortable environmental conditions will provide many advantages for the learning and teaching process [3]. Indoor comfort is influenced by several factors, such as air quality, acoustics, lighting, and thermals. In the context of a tropical climate, certainly the thermal comfort is become a major concern. Buildings located in tropical climates are considered difficult to achieve thermal comfort standards, considering that the variables that affect thermal conditions such as air temperature, relative humidity, radiation and air velocity are less supportive [4]. Considering that heat is the main factor, the building envelope has a significant role in reducing the heat received and transmitted into the building [5]. Minimizing heat transfer into buildings is one of the main strategies for buildings in wet tropical climates [6]. The amount of heat that transmitted into the building will affect the cooling load that must be borne by the air conditioning system, which also affects the building's energy consumption [7]. Building envelope elements include outer walls, floors, roofs, windows, doors, etc. The building envelope component has an important role in relation to thermal conditioning and lighting in the building [8]. Exploration of the building envelope design generally includes:

- Shading design, which aims to reduce the heat radiation received by the building surface
- building envelope material, in order to reduce heat transfer from outside into the building (heat transfer)

Building envelope design also aims to prevent excessive energy consumption. Integration and continuity between building efficiency and occupant productivity indicates a high-performance building. This study aims to evaluate the performance of the building envelope of Kanisius Kalasan Junior High School, Yogyakarta. The new building is being planned to replace the existing building that will be demolished for developing public area of Maria Marganingsih Catholic Church. The new building site is only about 100 meters on the west side of the old building, located in Jogja-Solo main road, Tirtomartani Kalasan. Located in the Kalasan area which has a fairly high daily temperature with the open-wide area characteristic, the potential for sun exposure is quite high that it becomes a challenge for building design to have good performance. The performance of the building will be reviewed specifically on the design of the building envelope using the Sefaira software simulation. This software is able to calculate and analyze the energy consumption of a building with a fairly easy use and accurate results [9]. Simulations are also carried out on daylighting to determine the level of visual comfort in the building. The results of this study will determine the performance of the building envelope of the new building designs in terms of energy consumption and daylighting levels, as well as propose alternative design to optimize building performance.

2. METHODOLOGY

This study uses a simulation method to evaluate the performance of the building envelope in its role in creating high performance buildings. The performance of the building envelope is assessed from the parameters of energy consumption efficiency, as well as visual comfort for occupants. The performance will be analyzed using Sefaira software simulation. Through the simulation, data on daylighting and estimates of building energy consumption will be obtained. The phases in this study are:

1. Identify building envelope elements through the architecture and construction drawing document
2. Window to wall ratio calculation
3. Daylighting and energy simulation
4. Analyze daylighting level and energy consumption based on standard
5. Propose design alternative to optimize building performance

3D model of the building was made based on requirement of Sefaira simulation (Figure 1). Components of building envelope displayed as one layer, which is identified according to the typology (walls, roofs, floors, and shading).

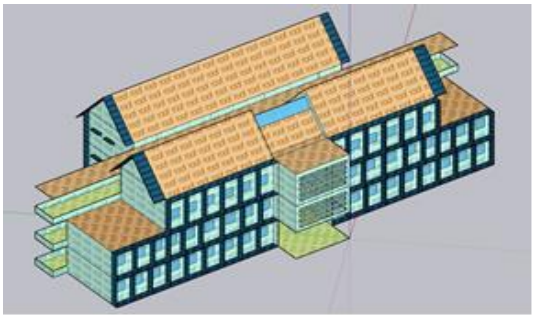

Figure 1 3D Model of building for Sefaira simulation.

The baseline data configuration used in Sefaira is ASHRAE 90.1 – 2013, for the climate zone using zone 2 which is a tropical climate zone. Selected typology is School Building with the total floor area is 2125 m^2. The material properties used are modified according to the materials used in the building (Figure 2). Changes were mainly made to the plaster brick wall material (without insulation) = 2.68 W/m^2, tile roof (without insulation) = 1.5 W/m^2, and clear glass material = 5.8 W/m^2.

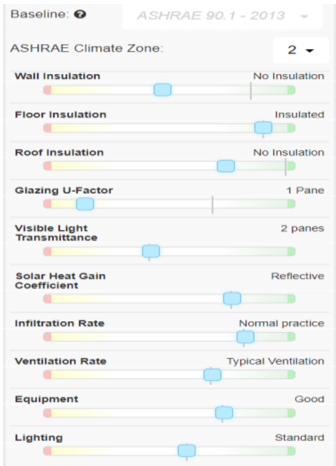

Figure 2 Material properties in sefaira software.

3. RESULTS AND DISCUSSION

The new building design for Kanisius Kalasan Junior High School has an elongated mass composition with the front side facing northeast. The main orientation is on the front and rear, while the side area is used for service functions. The window is combination of pivot window (vertical) and fixed window. This building use eggcrate-type shading, which is considered more effective because the combination of vertical and horizontal shading. The shading design for the front and back of the building is the same (Figure 3).

Figure 3 Front elevation of Kanisius Kalasan junior high school building.

3.1. Window to Wall Ratio Analysis

Through the observation on building design, first phase is analyzing window to wall ratio of the building. Window to wall ratio (WWR) considered has a significant impact on heat transfer [10]. The calculation of the WWR value for each building orientation and can be seen in table 1.

Table 1. Window to Wall Ratio

Orientation	Window area (m^2)	Wall area (m^2)	WWR
Northeast	95,24	546,29	17%
Lt. 1	31,71	175,12	
Lt. 2	36,69	200,66	
Lt. 3	26,84	170,51	
Southeast	2,88	233,71	1%
Lt. 1	0,96	64,94	
Lt. 2	0,96	76,25	
Lt. 3	0,96	92,52	
Northwest	2,9	233,71	1%
Lt. 1	0,96	64,94	
Lt. 2	0,96	76,25	
Lt. 3	0,96	92,52	
Southwest	93,6	487,69	19%
Lt. 1	27	153,23	
Lt. 2	27	153,23	
Lt. 3	18	124,55	
WWR	194,6	1501,4	13%

Based on the calculation, window to wall ratio of the whole building is 13%. The opening is dominated on northeast and southwest orientation. The front and back sides are maximized for openings because they lead to the north and south. While on the side is dominated by the service function, so the opening is very minimal with a WWR value of only 1%. The WWR value in this building can be said to be quite low (<15%). In general, for tropical areas the optimal WWR value can reach 25% [11].

3.2. Daylighting Simulation

In Sefaira, the ideal daylighting standard for school building is 400 lux. However, the National Standard of Indonesia (SNI) stated that ideal daylighting for classroom is 250-300 lux. This simulation uses the SNI reference as the basis for daylighting analysis. The data displayed is a percentage of whether a space receives sufficient daylight on a work plane during standard operating hours on an annual basis, or usually called Spatial Daylight Autonomy (sDA). Image of daylighting simulation can be seen on figure 4.

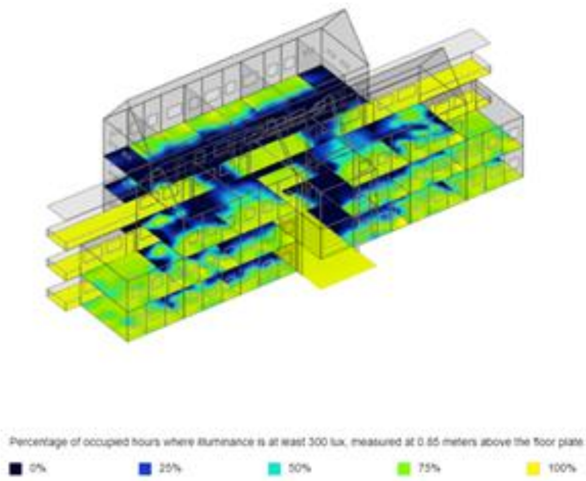

Figure 4 Daylighting analysis in Sefaira.

The simulation result presents that overall, the daylighting level of the building is fairly good, with an overall average SDA value of 58%. Then for the value of annual sun exposure (ASE) is about 24%, indicates quite a lot of areas with over lit conditions. This is because in this simulation it includes a corridor area which is a semi-outdoor area. This happens because in this simulation it includes the corridor area which is a semi-outdoor area. The sun's lights are quite difficult to reach the middle area, so the natural light level is lower in several room located in the middle of the building. However, simulation results show that in the middle room the value of sDA can still reach about 30%. Details of daylighting level on each floor can be seen in table 2. In terms of ideal lighting standards, daylighting conditions in this building are already in the "nominally accepted" category because they are >55%. However, the ASE is still too high where the ideal ASE value is below 10% [12].

Table 1. Daylighting Level

Elevation	SDA	ASE
1st floor	66%	28%
2nd floor	55%	18%
3rd floor	53%	25%
Total	58%	24%

3.3. Energy Simulation

Simulation on energy consumption shows that the building with three stories and 2125 m^2 have energy consumption of 151 $kWh/m^2/year$ (Figure 5). The largest proportion of energy needs is in cooling needs, followed by lighting and equipment. While the biggest source of heat that enters the building is through wall conduction.

In terms of the Energy Consumption Intensity (Intensitas Konsumsi Energi/IKE) reference standard in Indonesia, the IKE for school building set at 235 $kWh/m^2/year$, with a lower limit of 195 and an upper limit of 265 $kWh/m^2/year$. Thus, the simulation results which show energy consumption of 151 $kWh/m^2/year$ can be considered efficient because it is lower than the bottom limit.

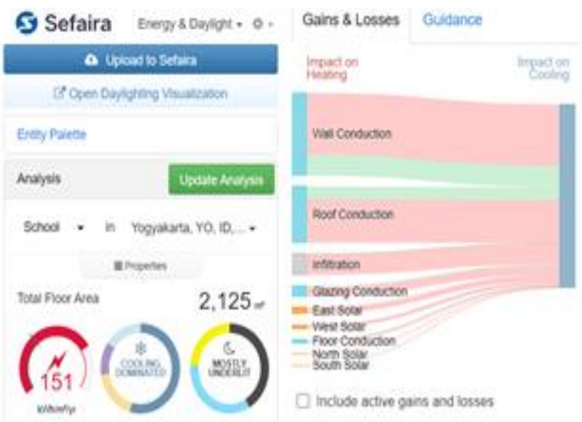

Figure 5 Energy analysis in Sefaira.

3.4. Strategy for Building Performance Optimization

Optimization strategy are applied to improve building performance, especially in terms of lighting. Although the energy efficiency it is fairly good, this study also tries to provide strategies that can make energy consumption more efficient.

There are two strategies offered to optimize building performance:

3.4.1. Modify Shading Design and Increase Window to Wall Ratio

This strategy is expected to be able to increase the percentage of indoor area that has an ideal level of daylighting. WWR was increased by 3% and the shading design was modified to adjust the opening design. The simulation results show that the value of sDA increases up to 4% with energy consumption remaining the same at 151 $kWh/m^2/year$. This indicates the performance of the building envelope works more optimally by increasing the opening without increasing energy consumption.

3.4.2. Use materials with Lower Thermal Conductivity Values

In this case, it is proposed to use Low-E Glass material with a U-value of 4.1 W/m^2, and also the use of insulation on the roof so that the U-value is around 1 W/m^2. By using these material specifications, the result is that the building's energy consumption has decreased to 147 kWh/m^2.

4. CONCLUSION

Based on the results of the analysis and simulations, it was found that the building performance of the Kanisius Kalasan Junior High School building was relatively good. This can be seen from the simulation of energy use is quite efficient (151 $kWh/m^2/year$) which is below the standard limit for energy consumption for educational buildings (195 $kWh/m^2/year$).

Daylighting is still be a concern, regarding there are several rooms that still need to be improved. This is attempted to be solved by increasing the WWR to have more daylight, by adjusting the shading design to maintain radiation exposure on the surface. This strategy was quite successful with the increase in the value of Spatial Daylight Autonomy (sDA) from 58% to 62%. However, there are still problems related to over-exposure areas, as indicated by the ASE value of more than 20%. The next strategy is to replace the building envelope material with a material that has low thermal conductivity, especially for glass and roofing materials.

The results can be seen with a decrease in building energy consumption up to 4 KWh/m^2/yr.

This study presents how the influence of architectural design, especially on the building envelope on the building performance in providing comfort for residents and also in terms of energy efficiency. However, other factors such as equipment and mechanical systems also need to be considered in terms of energy efficiency. Further studies are still needed when the building has been built to verify the simulation results with real condition.

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