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The Role of Building Thermal Simulation for Energy Efficient Building Design

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Abstract

In this paper, the results of building thermal simulation of office buildings in Jakarta, Indonesia are presented using the simulation and visualization tool of DesignBuilder, an Energy Plus based dynamic thermal simulation engine. The simulation results show that for new office design, building envelope optimization and utilizing high efficiency office equipment and HVAC system, the annual energy consumption decreased by 43%. For the renovated building, implementing task lighting will reduce the energy consumption by 25%. In addition, applying task lighting with scenario improving glazing material with increasing chiller's efficiency will give additional potential reduction of 30%.

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Keywords : office buildings; building thermal simulation; energy consumption; new building; renovated building

Nomenclature

AHU	Air Handling Unit
ACH	Air Change per Hour
COP	Coefficient of Performance
HVAC	Heating Ventilating and Air Conditioning
SHGC	Solar Heat Gain Coefficient

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1. Introduction

The energy crisis is one of the world's major current issues. In Indonesia, the energy crisis creates a significant impact on economic development. Therefore, the Government has to set the saving energy as a major priority. Further, energy saving must be in line with the efficient use of energy to have a positive influence to the environment, such as reducing GHG emission. Using energy efficiently means reducing the fossil fuel being burned and therefore decreases greenhouse gas emission.

High growth of population and economic rates in Indonesia lead to the fast growing of cities. In a context where cities are booming, energy demand for buildings become a crucial problem, as there is huge construction activity in Indonesia. In addition, the government regularly increases the electricity price as a result of the high price of world's energy, consequently government also reducing subsidy in the energy sector. Obviously, this increases the operational costs of a building, especially office buildings. In this paper, the solution to reduce the energy consumption in a high rise office building by integrating the thermal building simulations during the design phase of a building as well as for renovation project is presented.

2. Methods

2.1. DesignBuilder

DesignBuilder coupled with the software tool EnergyPlus is a powerful tool for modelling three-dimensionally building geometries as well as assessing the energy performance. There are also CAD links into the 3D modeller as well as report generation facilities. DesignBuilder combines rapid building modelling with state of the art dynamic energy simulation [1].

2.2. Weather data

Weather data is an essential variable required in thermal building simulation that is unique and depending on the location of the building. The climate data used in this simulation is based on the weather data of Jakarta, Indonesia. which is located at western part of Java Island, at 6.09° south latitude and 106.49° longitude. The weather data for the building thermal simulation is generated by Meteonorm 6.0 [2].

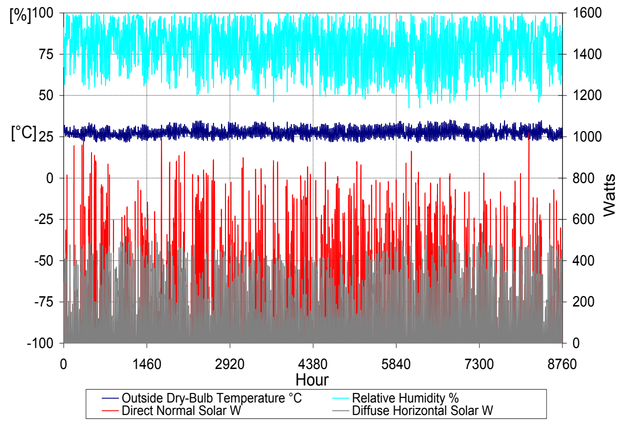


Fig. 1. Weather data of Jakarta [2].

2.3. Reference base case of new office building

The new office building simulated consists of 22 floors, with total Gross Floor area of 20,000m2 and conditioned area of 19,000m2. The building oriented to the north and south, and the building envelopes are dominated by glass facade. As a consequence, there will be potential solar radiation transferred into the building. Therefore, recommendation on high performance glazing is very essential in a context the building is dominated by glass facade. Fig. 2 shows the visualization of the building designed using DesignBuilder.

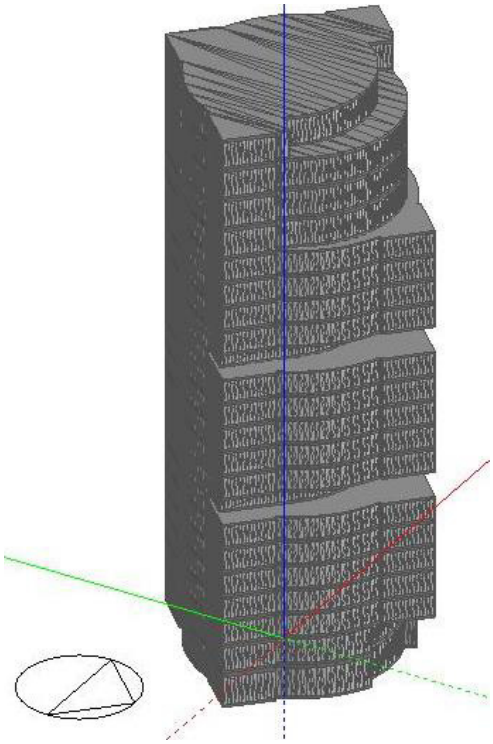


Fig. 2. Visualization of the building.

Table 1 shows the parameter setting for Reference Base Case building. The reference base case building means that the parameter was set to represent the operational condition that refers to available Indonesian National Standard (SNI).

Table 1. Parameter setting for reference base case building.

Parameter	Value	Unit
Wall U Value	2.44	W/m^2K
Glass SHGC Value	24	%
Glass Light Transmission	25.5	%
Office Equipment Power Density	10	W/m^2
Lighting Power Density	15	W/m^2
HVAC COP	2.6	No unit
Lighting Level	300	Lux
Infiltration	0.7	ACH

2.4. Optimized design

In the design process, the first recommendation suggested is by improving the building's envelope. As previously explained, the building's facade are dominated by glass facade, hence by improving the building's facade there will be benefit in reducing energy consumption especially for air conditioning system.

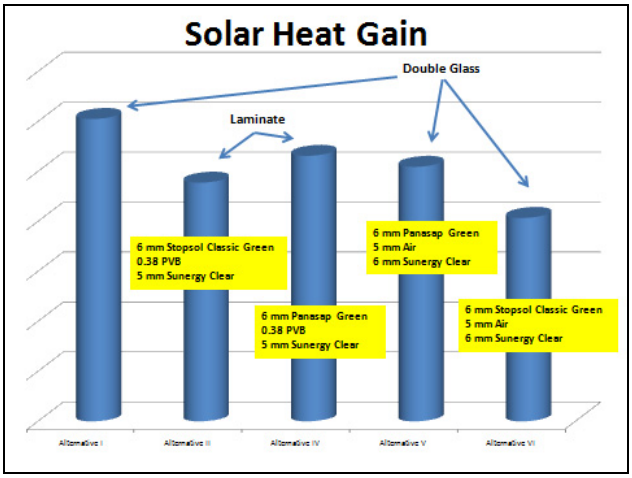


Fig. 3. Sensitivity analysis of glazing material.

The scenario applied for sensitivity analysis is by installing better property of glazing material in order to obtain the glass specification that contributes to lower solar heat radiation transmitted into the building. In this scenario, glazing material with low SHGC value was chosen. SHGC value is a coefficient that represents energy (solar radiation, heat dissipated from inner glazing) transmitted by a certain type of glazing material. The value range from 0 to 1, of which a lower value representing less energy transmitted, consequently there will be less solar energy entering the building. Generally, low SHGC value of glazing material will also influence its light transmission value. It can be seen that with the same glazing material, the double glass gives lower heat gain transmitted into the building than laminate glass. Therefore, the recommendation for glazing material with regards to its property to transfer heat is using double glass.

The represent daylight distribution as an effect of installing different type of glazing material is shown in Fig. 4 with the limitation of lighting level of 300 lux as recommended by SNI. It can be suggested that the consideration of using low SHGC value and high light transmission is essential.

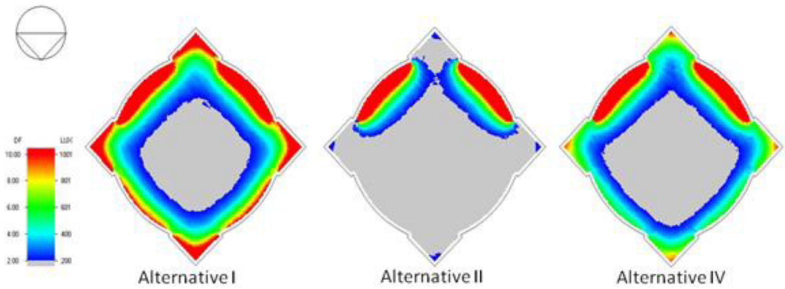


Fig. 4. Daylight distribution for respective type of glazing material.

2.5. Reference base case of renovated office building

The simulated building is built and operated since 1994, consists of 10 floors including 2 basement floors. During the site survey in 2012, the building is still not fully occupied. As the building has already been not operated for a couple of years, therefore it requires some site observations in order to obtain the actual conditions that require renovation in order to be ready to be occupied properly.

Fig. 5. The visualization of renovated building.

Based on the site survey, there are some opportunities may be applied to provide better performance the building envelope, which consist of:

- Replacing the clear glass in existing building with reflective glass or low solar transmittance glazing material to reduce heat transmitted.
- Installing shading device for window which intend to reduce the direct solar radiation. It is also possible to get additional advantage by utilizing shading device as light selves device at the same time.
- Replacing the material of floor to reduce the effect of heat absorption. It is suggested that floor with carpet will reduce not only building’s cooling load, but also for noise reduction.
- Additionally, for HVAC system, the recommendations include ; conduct online measurement to test overall chillers condition; check performance of AHUs; replace the old control valve of AHU; House Keeping and Maintenance.
- According to the building survey results for the lighting system sector, some preliminary recommendations are identified with the purpose to improve lighting level quality while at the same time, reducing overall energy consumption, such as:
  - ✓ Rearrange Lighting Zone, considering some areas that have been exposed to sunlight, therefore, it is necessary to rearrange the zoning of lighting.
  - ✓ Houskeeping control on lighting, the easiest way to saving energy with no additional cost required is to do reschedule the housekeeping, especially to control the lamp operating hours in the rooms that is unoccupied.
  - ✓ Replacing the old lamp shades with high efficient fixture/reflector
  - ✓ Replacing magnetic ballast with electronic ballast. Magnetic ballast uses approx. 5-10 Watt while electronic ballast uses only 1-3 Watt. A TL Hence, the electronic ballast will reduce electricity consumption by 3-9%.
  - ✓ Replacing TLT8 – 36 Watts lamps with TLT5 – 28 Watt lamps.

The collection of data gathered from building survey then considered as input parameter for building thermal simulation. Other data that was applied is data provided by the appointed planning consultant, such as building’s drawing. In the case of unavailability of actual data, some assumptions were made as basic approach.

3. Results and discussion

3.1. Building thermal simulation of new office building

The simulation result for the reference base case of the building is graphed in Fig. 6. It depicts the energy balance of the reference building.

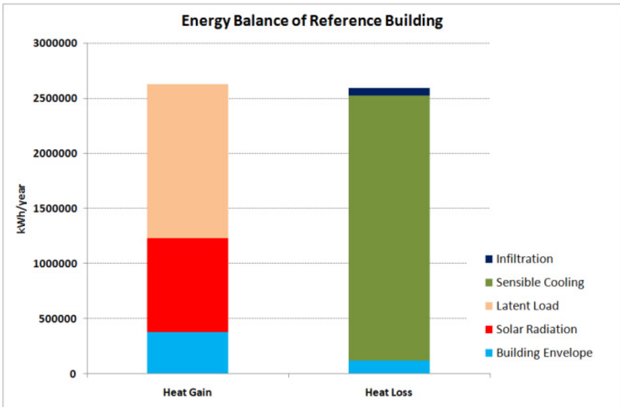


Fig. 6. Energy balance of reference base case new office building.

Heat gain means the heat transferred into the building from the environment as well as heat generated by entity in the building. Heat loss is considered as heat transferred out of the building as an effect of lower outside air temperature, or works created with the purpose of removing heat from the building to the environment. The sensible cooling energy demand is categorized as heat loss because it works to remove heat in the building to the environment in such a way, so that the indoor air temperature of the building will satisfy its setpoint. In this reference base case, it is found that the high portion of cooling energy demand is mainly devoted to compensate the heat gain transmitted through the building envelope as well as generated inside the building.

For the optimized building design, the scenario applied for sensitivity analysis is by implementing better configuration of building envelope by reducing the area of glass facade is reduced by raising the height of window stool in order to reduce solar radiation transmitted into the building.

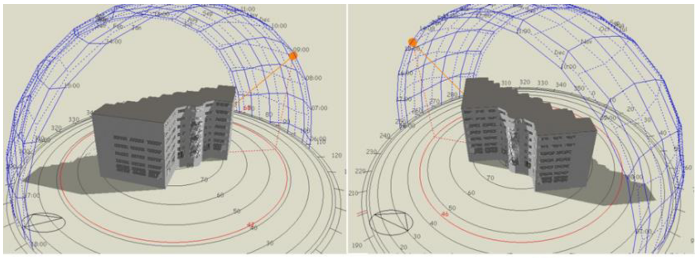
Additionally, the setting parameter for optimized building will result to better energy performance of the building. The accumulation of electricity reduction is accounted that the reduction of Electricity Consumption Index in kWh/m^2/year is about 43%.

Table 2. Parameter setting for optimized new office building.

Parameter	Value	Unit
Wall U Value	2.44	W/m^{2}K
Glass SHGC Value	24	%
Glass Light Transmission	25.5	%
Office Equipment Power Density	8	W/m^2
Lighting Power Density	7	W/m^2
HVAC COP	4.5	No unit
Lighting Level	300	Lux
Infiltration	0.7	ACH

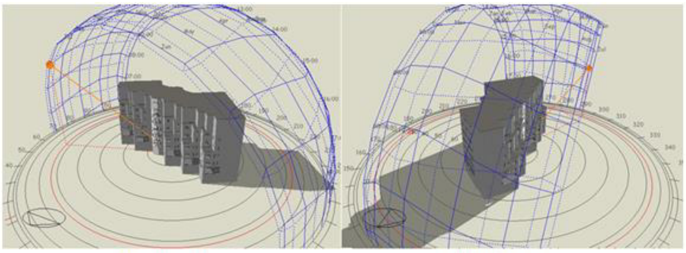
3.2. Building thermal simulation of renovated building

Shadow analysis was performed in order to obtain the general knowledge on how the building exposed to the solar radiation. In January, while the sun position on the southern hemisphere, during the morning and afternoon hours the south side will be exposed to the solar radiation as shown in Fig. 7. In July, the northern part of the building will be highly exposed to the solar radiation as shown in Fig. 8. Form this analysis, it is recommended that in order to minimize solar transmission, either by reducing the window area or by reducing solar transmittance coefficient.



January 16th, 09.00 January 16th, 15.00

Fig. 7. Shadow position for January 16th .



July 16th, 09.00 July 16th, 15.00

Fig. 8. Shadow position for July 16th .

Other possible alternative to reduce solar radiation is by reducing the SHGC for the glass material. By applying lower SHGC value of glazing material, the hourly solar heat gain transferred into the building drops dramatically, on average 75% of the reference base case. On the other hand, as lower SHGC value normally followed by lower light transmission value, as the results, there is also significant increase of lighting energy required of the building. Therefore, installation of task lighting is very important in order to optimize the use of additional artificial lighting.

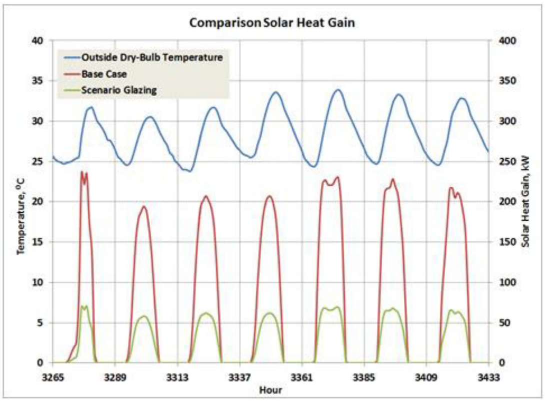


Fig. 9. Comparison solar heat gain as an effect of better glazing material.

From the simulation, it is found that using task lighting will reduce the total electricity consumption by 25%. This reduction is contributed by the decrease of chiller's electricity consumption by 13% and lighting's electricity consumption by 67%. The significant decrease of lighting's electricity consumption due to less lighting device operated as well as less power delivered for operational.

The scenario of increasing the chiller's efficiency aims to obtain the influence of chiller efficiency to the energy consumption of the building. The reference base case considered that the chiller efficiency was of COP 1.8. This value was used as an assumption that the chiller's age is already 18 years old, and the consideration of annual efficiency reduction. In this scenario it was set that the chiller is assumed at its newest condition or as written on its technical data specification, that is of COP 3.0. The simulation result shows that by improving chiller's efficiency will influence significantly to the reduction of electricity consumption. Fig. 10 elucidated that electricity consumption of chiller with higher efficincy essentially decrease approximately by 40%.

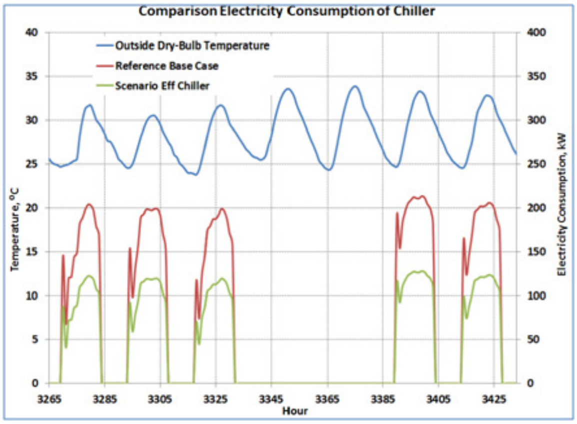


Fig. 10. Comparison of chiller's electricity consumption as an Effect of better chiller's efficiency.

Observation on indoor air setpoint temperature however is not part of renovation project. It is more focusing on the operational concern. The simulation on the variation of the comfort temperature has been done by changing the indoor air set point temperature. The set point temperature means the temperature at which the cooling device will operate when the indoor air temperature is above this value. The initial value of the temperature set point was 25°C, which is suggested by SNI. The scenario was made by decreasing the indoor air setpoint temprature by 1^{O}C, or become 24^{O}C. The simulation result shows that chiller will consume more energy when the indoor air setpoint temperature is lower. It is accounted that the increase of energy consumption is 7%.

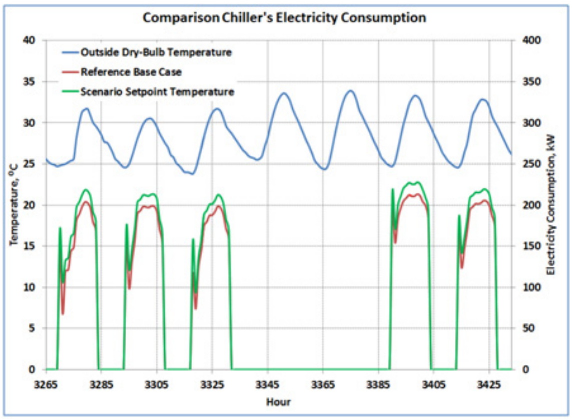


Fig. 11. Comparison of chiller's electricity consumption as an effect of decreasing indoor air setpoint temperature.

The following figure shows the comparison of electricity consumption for all simulation scenarios in percentage. The reference base case is represented in 100% of electricity consumption.

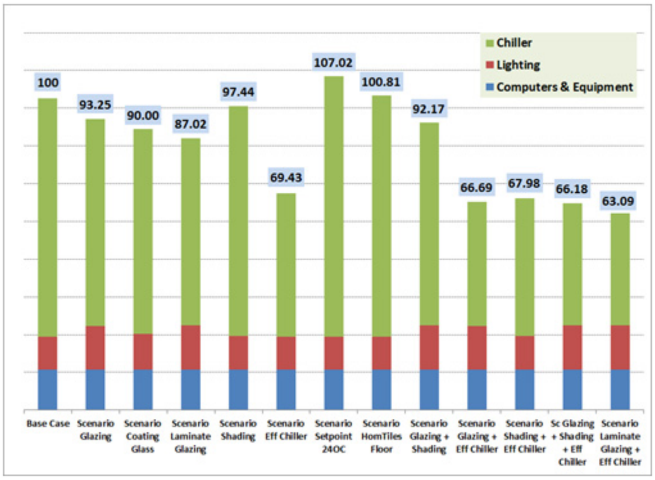


Fig. 12. Comparison of electricity consumption for simulation scenarios.

The results of thermal simulation and cooling energy sensitivity analysis shows that the application of better glazing material property gives substantial impact to the reduction of cooling load. Compared to the application of shading device, better characteristic of glazing material gives more essential reduction of solar heat gain. Negatively, the lower the solar transmittance value is normally followed by lower light transmittance. Consequently, the lighting load of lower transmittance glazing will increase. As lighting contributes only 10% of the total energy consumption, therefore the increase of 32% is still acceptable.

In addition, by improving chiller's efficiency will reduce significantly the electricity consumption of chiller. The more important aspect other than renovation point to be considered concerning energy consumption is the indoor air setpoint temperature. It is found that by decreasing the temperature by 1^{O}C will cause the increase of cooling load and corresponding chiller electricity by 9%. This value is obviously essential as chiller distributes 76% of the total electricity consumption. By improving the building design, it is found that glazing material gives significant impact to the reduction of cooling load, and combining scenario glazing with chiller's efficiency will significantly improve the overall energy performance of the building.

4. Conclusion

Thermal building simulation is a powerful tools to assess the energy performance of a building. The simulation is recommended to be integrated during the design phase of a building. During this stage, there are more opportunities to influence the design of the building and to change the design as it is far cheaper to change the design rather than the real building. Moreover, various numbers of scenarios can be modelled in order to obtain the most optimum design, not only on the physical design, but also the operational scenario. Nevertheless, in the renovation project, during the planning stage, building thermal simulation plays an important role in providing recommendation for renovation to achieve better performance concerning energy consumption.

In this study, different purpose of building thermal simulation is presented. The first case is the role of simulation for designing new building and the second case is for renovation project The simulation results show that in general, the factors that give significant influence to the reduction of cooling energy demand consist of the implementation of high performance glazing material (low SHGC value and high light transmission value) for building envelope with majority glass facade, the efficiency of HVAC system, task lighting which is represented by lighting sensor, and indoor set point temperature.

Acknowledgements

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References

[1] DesignBuilder. DesignBuilder 1.2 user manual; 2006.
[2] Meteonorm. Meteonorm version 6.0.0.7. Switzerland: Meteotest; 2007.
[3] DesignBuilder Software, Ltd. DesignBuilder.
[4] National Standardization Agency of Indonesia. SNI 03-6196-2000: Prosedur audit energi pada bangunan gedung; 2000.
[5] National Standardization Agency of Indonesia. SNI 03-6197-2000: Konservasi energi sistem pencahayaan pada bangunan gedung; 2000.
[6] National Standardization Agency of Indonesia. SNI 03-6389-2000: Konservasi energi selubung bangunan pada bangunan gedung; 2000.
[7] National Standardization Agency of Indonesia. SNI 03-6390-2000: Konservasi energi sistem tata udara pada bangunan gedung; 2000.
[8] National Standardization Agency of Indonesia. SNI 03-6759-2002: Tata cara perancangan konservasi energi pada bangunan gedung; 2000.
[9] National Standardization Agency of Indonesia. SNI 04-6958-2003: Label tingkat hemat energi pemanfaatan tenaga listrik untuk keperluan rumah tangga dan sejenisnya; 2003.
[10] Andarini R *et al.* Thermal simulation and cooling energy sensitivity analysis of a typical shophouse in Jakarta, Indonesia. In: Building Simulation 2009, Eleventh International IBPSA Conference. Glasgow, UK; 2009. p. 1887-1893.
[11] ASHRAE STANDARD: Standard method of test for the evaluation of building energy analysis computer programs; 2004.
[12] Clarke J. Energy simulation in building design. 2nd ed. UK: Butterworth-Heinemann; 2001.
[13] Streicher W. Energy efficient buildings. Lecture Note. Institut of Thermal Engineering, TU Graz. Austria; 2007.