Correlation of Façade Characteristics on Energy and Daylighting Performance Optimization of Office Building

Abstract

GBCI's Greenship New Building is one of green building rating tools for new building in Indonesia. In Energy Efficiency and Conservation category, the OTTV value and daylight area is affected by the building's facade design. Satrio Tower is a 26 storeys office tower in Mega Kuningan CBD area, South Jakarta. In order to get the optimum point achieved for Greenship Platinum, it is necessary to do an experimental study of several facade characteristic scenario that can provide the best scenario of energy and daylighting performance. In this study, the facade characteristics, especially those related to fenestration system, such as window-to-wall ratio, shading coefficient, fenestration U-value, visible light transmittance and shading devices design is being analysed in order to find the correlation between facade characteristics and the building's performance. This study uses OTTV calculation based on SNI 6389:2020 and daylighting simulation using Dialux Evo to determine each facade scenario performance, then data is analysed by using comparative and correlation method. It is known that visible light transmittance have positive correlation to both energy and daylighting performance.

Keywords: Building Performance Simulation, Greenship New Building, High Performance Building, OTTV, Dialux

1. Introduction

There are three green building rating tools for new building in Indonesia, such as Green Building Council Indonesia (GBCI)'s Greenship New Building (NB)[1], the Minister of Public Works and Housing Regulation Number 21 Year 2021[2], and IFC's EDGE[3], [4]. Each rating tools have similarities and differences in their criteria. Greenship New Building, a type of Greenship for newly designed building or building that majorly renovated, has six categories, which include Appropriate Site Development, Energy Efficiency and Conservation, Water Conservation, Material Resources and Cycle, Indoor Health and Comfort, and Building Environment Management[5]. The Minister of Public Works and Housing Regulation Number 21 Year 2021 includes Site Management, Energy Use Efficiency, Water Use Efficiency, Indoor Air Quality, Environmental Friendly Material Use, and Waste Management[2]. On the other hand, EDGE only have three main sections, Energy, Water, and Materials[4].

Either in the Greenship NB or the Ministry Regulation, the energy efficiency is based on Overall Thermal Transfer Value (OTTV) from SNI 6389:2020, which has maximum value of 35 Watt/m^2. OTTV is heat gain from building façade, which is sum of heat gain from conduction through the opaque wall, conduction through the fenestration systems, and radiation through the fenestration systems[6]. The OTTV equation is [7], [8]

$$\mathrm{OTTV} = [\,\alpha \times Uw \times (1 - WWR) \times TDEk] + [\mathrm{Uf} \times \mathrm{WWR} \times \Delta \mathrm{T}] + [\mathrm{SC} \times \mathrm{WWR} \times \mathrm{SF}] \quad (1)$$

where

α	= Sun Radiation Absorption, that depends on color and finishing of an exterior wall
Uw	= Thermal conductivity value of opaque wall ($W/m^2.K$)
WWR	= Window-to-wall ratio
TDEk	= Equivalent temperature difference for opaque wall
Uf	= Thermal conductivity value of a fenestration system ($W/m^2.K$)
ΔT	= Temperature difference between exterior and interior side of a building
SC	= Shading coefficient of fenestration system, that depends of glass specification and shading coefficient effective from shading device
SF	= Solar Factor, that depends on façade orientation and building location (W/m^2)

In EEC 2 of Greenship NB 1.2, two points will be earned if 30% of its saleable area have daylight intensity of 300 lux or above[5], therefore integration of energy and daylighting performance is needed. Façade design must achieved sufficient daylighting without increasing cooling load[9]. Large WWR will ensure saving on lighting energy, it also let unwanted solar heat gain at the same time[10]. Kusumawati (2021) said that WWR, SC and SF have most influence on OTTV calculation [11]. Lahji (2021) concluded that energy efficiency can be achieved by dominating the façade surface with low Uf[12]. Albab (2019) has conducted an OTTV simulation and found that fenestration system with double glazing with SC less than 1.9 and Uf more than 2.6 $W/m^2.K$ can reduce heat gain up to 6.2%[8]. On the other hand, Huang (2014) said low-e glazing is the best choice in both thermal and daylighting performance, while double glazing have worst performance. Building location and façade orientation will also affects thermal and daylighting performance, where in cooling dominante climates, all window design that faced to east and west have better performance, where north facing windows have worst performance[10]. Daylight performance also depends on visible light transmittance (VLT) of a fenestration system[6].

Satrio Tower is a 26 storeys office tower in South Jakarta, Indonesia. In order to get the Greenship NB certification, an energy and daylighting performance study conducted. This research is conducted to know better on façade characteristic correlation to both energy and daylighting performance based on Greenship NB 1.2 criteria.

2. Materials and Method

This study was conducted with a case study method on Satrio Tower as it is targeted to get its green building certification. Satrio Tower is located on a business district area of Kuningan, South Jakarta. This study was a quantitative research that have 3 phases. Phase one, OTTV calculation of baseline case and alternative designs case. The OTTV calculation was conducted in accordance with SNI 6389:2020 through a numerical calculation. The alternative design was conducted through an experimental studies through the similar calculation, where the WWR, Uf, Uw, and SC are modified. Phase two, the daylight simulation on baseline case and alternative designs case that complied to SNI 6389:2020 where its OTTV value is less than 35 W/m^2. The daylighting simulation was conducted using Dialux Evo 8.0 at 10.00 AM and 02.00 PM to get the image of isolux contour of the building plan. The simulation time was chosen because it represented the highest sun latitude, where the sun light entered a building less, therefore the result will show the worst case scenario of the daylight performance. The isolux image processed later using Autocad to measure the area and know whether it is complied to EEC 2 or not (daylight area more than 30% of saleable area). Phase three, data analysis. The data gathered from phase one and two is analysed by two method; comparison and correlation. Comparative study is conducted to know which alternative design perform the best, while correlation study is conducted to know which façade elements influenced the most.

2.1. Data Collection

Table 1 shows baseline case design and 24 alternative design. There are five types of opaque wall material. Type 1 is the baseline design, where it was a combination of 8 mm clear glass, air cavity and gypsum on the inner side. Type 2 is a one meter height wall which is combination of 8 mm clear glass, air cavity, 75 mm precast concrete, 5 mm glasswool, and 12 mm gypsum. Type 3 is a one meter height wall which is combination of 4mm aluminum composite panel cladding, air cavity, 10 mm lightweight concrete blocks, and plaster. Type 4 is combination of type 2 and 3. Last, type 5 is 1,2 m of type 2 and 1 m of type 3. Then, fenestration system has 4 type of glazing system. Type A is a single clear glass. Type B is double glazing system with 8 mm Stopsol Supersilver Dark Blue, 12 mm air cavity, and 6 mm clear glass. Type C is double glazing system with 8 mm Sunergy Green, 12 mm air cavity and 6 mm Planible G. Type D is double glazing system of 8 mm Stopray Vision 51T #2, 12 mm air cavity and 6 mm clear glass. 24 alternative designs is achieved through iterative calculation from previous design until it is compliance to SNI 6389:2020.

Table 1. Baseline and Altenative Design Case and its Façade Characteristics

NO	Opaque Wall	Fenestration Systems	Sunshading	SCglass	Uw	Uf	VLT	VLR	WWR
Baseline	Type 1	Single Clear Glass (Type A)	No	0,93	1,75	5,7	88	8	95%
1		Stopsol ss dark blue 8 mm + AC 12mm+clear glass 6mm (Type B)	No	0,31	1,75	2,019	29	32	95%
2		Sunergy green 8mm+ AC 12mm+planible g 6mm (Type C)	No	0,35	1,75	2,099	60	12	95%
3		Stopray vision51T #2 8mm + AC 12mm + clear glass 6 mm (Type D)	No	0,34	1,75	1,6	49	20	95%
4	Type 2	Type B	No	0,31	1,55	2,019	29	32	81%
5		Type C	No	0,35	1,55	2,099	60	12	81%
6		Type D	No	0,34	1,55	1,6	49	20	81%
7	Type 2	Type B	Horizontal 60 cm	0,31	1,55	2,019	29	32	81%
8		Type C	Horizontal 60 cm	0,35	1,55	2,099	60	12	81%
9		Type D	Horizontal 60 cm	0,34	1,55	1,6	49	20	81%
10	Type 3	Type B	No	0,31	0,56	2,019	29	32	81%
11		Type C	No	0,35	0,56	2,099	60	12	81%
12		Type D	No	0,34	0,56	1,6	49	20	81%
13	Type 3	Type B	Horizontal 60 cm	0,31	0,56	2,019	29	32	81%
14		Type C	Horizontal 60 cm	0,35	0,56	2,099	60	12	81%
15		Type D	Horizontal 60 cm	0,34	0,56	1,6	49	20	81%
16	Type 4	Type B	No	0,31	1,55 & 0,56	2,019	29	32	53%
17		Type C	No	0,35	1,55 & 0,56	2,099	60	12	53%
18		Type D	No	0,34	1,55 & 0,56	1,6	60	13	53%
19	Type 4	Type B	Horizontal 60 cm	0,31	1,55 & 0,56	2,019	29	32	53%
20		Type C	Horizontal 60 cm	0,35	1,55 & 0,56	2,099	60	12	53%
21		Type D	Horizontal 60 cm	0,34	1,55 & 0,56	1,6	49	20	53%
22	Type 5	Type B	No	0,31	1,55 & 0,56	2,019	29	32	46%
23		Type C	No	0,35	1,55 & 0,56	2,099	60	12	46%
24		Type D	No	0,34	1,55 & 0,56	1,6	49	20	46%

3. Discussion

Phase one shows that baseline and case 1 to 15 did not comply to SNI 6389:2020. Case 16 until case 24 complied to SNI 6389:2020, thus the daylighting calculation is conducted. From the result, it is known that Case 20 has better daylighting performance while keeping the cooling load low than the rest of the case study. Comparation of daylight and energy performance of Case 16 to 24 can be seen in Figure 1. From basecase and 24 alternative designs, correlation analysis is conducted. Using Pairwise Correlation, it is known that SC, U-value, and VLT of fenestration system and WWR has significant correlation to both energy and daylighting performance. VLT of a fenestration system must be put into consideration when designer make a design optimization for both energy and daylighting, because it's not included in OTTV calculation.

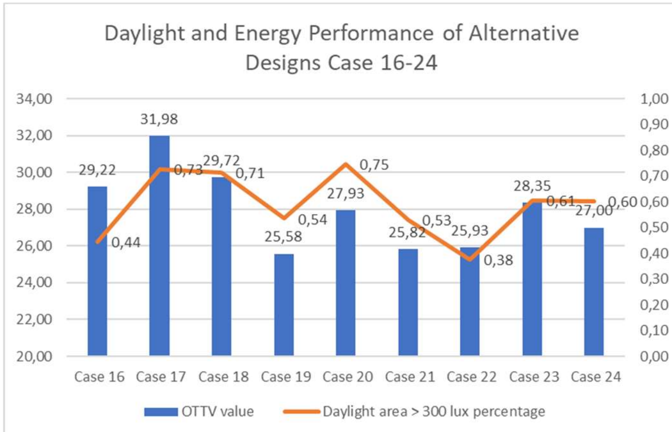

Figure 1. (a) Figure Header; (b) Figure Header

Table 2. Pairwise Correlation of OTTV and Daylight Performance to Façade Characteristics Variables

Variable	by Variable	Correlation	Count	Signif Prob
OTTV	Sunshading	-0,2382	25	0,2515
	SCglass	0,8916	25	<,0001*
	Uf	0,8496	25	<,0001*
	VLT	0,5186	25	0,0079*
	VLR	-0,3104	25	0,1310
	WWR	0,6144	25	0,0011*
Daylight Performance	Sunshading	-0,0675	10	0,8531
	SCglass	0,7312	10	0,0163*
	Uf	0,6722	10	0,0332*
	VLT	0,9328	10	<,0001*
	VLR	-0,8627	10	0,0013*
	WWR	0,7276	10	0,0171*

4. Conclusion

Façade characteristics, especially fenestration systems, shows significant correlation to energy and daylight performance. Visible light transmission, a façade characteristic which not included in OTTV calculation, can be taken as consideration, if a designer want to achieve better daylight performance. The visible light transmission should be combined with better thermal insulation, which can be achieved by using double glazing as fenestration system.

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