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CORRELATION OF FAÇADE CHARACTERISTICS ON ENERGY AND DAYLIGHTING PERFORMANCE OPTIMIZATION OF OFFICE BUILDING (CASE STUDY: SATRIO TOWER, JAKARTA)

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ABSTRAK

Desain bangunan yang efisien energi menjadi kewajiban untuk mendapatkan izin mendirikan bangunan gedung baru di Jakarta. Greenship New Building adalah salah satu alat penilaian bangunan hijau untuk bangunan baru di Indonesia yang disusun oleh Green Building Council Indonesia. Dalam kategori Efisiensi dan Konservasi Energi, perolehan poin terkait nilai OTTV dan area pencahayaan alami dipengaruhi oleh desain selubung bangunan. Penelitian ini ditujukan untuk mengetahui korelasi karakteristik selubung bangunan terhadap kinerja energi dan pencahayaan alami pada bangunan kantor untuk mendapat selubung bangunan dengan kinerja yang terbaik. Penelitian ini menggunakan Satrio Tower sebagai studi kasus, sebuah gedung perkantoran 26 lantai di kawasan CBD Mega Kuningan, Jakarta Selatan. Data berupa nilai OTTV didapatkan melalui simulasi numerikal berdasarkan rumus OTTV dari SNI 6389:2020 dan kondisi pencahayaan alami dalam bangunan didapatkan dengan melakukan simulasi komputasional menggunakan Dialux Evo. Kemudian data kinerja selubung bangunan dibandingkan dan dianalisis korelasinya. Diketahui bahwa desain yang mengkombinasikan penggunaan alat pembayang horizontal 60 cm, penggunaan kaca rendah emisivitas dan rasio jendela-dinding yang rendah memiliki kinerja energi dan pencahayaan alami terbaik. Di antara karakteristif selubung bangunan, nilai transmitansi cahaya tampak dari material kaca memiliki korelasi positif terhadap kinerja energi dan pencahayaan alami.

Kata Kunci: Greenship new building; kinerja bangunan; dialux; OTTV.

ABSTRACT

Energy-efficient building design is mandatory to obtain a building permit for new buildings in Jakarta. Greenship New Building is one of the green building assessment tools for new buildings in Indonesia compiled by the Green Building Council Indonesia. In the Energy Efficiency and Conservation category, points earned related to OTTV value and daylighting area are influenced by building facade design. This research aims to determine the correlation of building facade characteristics to energy and daylighting performance in office buildings to obtain the best performing building facade. This research uses Satrio Tower as a case study, a 26-story office building in the CBD Mega Kuningan area, South Jakarta. Data in the form of OTTV values were obtained through numerical simulations based on the OTTV formula from SNI 6389: 2020 and daylighting conditions in the building were obtained by conducting computational simulations using Dialux Evo. Then the building facade performance data is compared and analyzed for correlation. It was found that a design combining the use of a 60 cm horizontal shading device, the use of low-emissivity glass and a low window-wall ratio had the best energy and daylighting performance. Among the building facade characteristics, the visible light transmittance value of the glazing material has a positive correlation with the energy and daylighting performance.

Keywords: *Building performance; greenship new building; dialux; OTTV.*

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INTRODUCTION

The construction sector is a significant contributor to energy consumption, specifically building construction and operation. In Indonesia, the energy consumed by buildings is predominantly driven by the necessities of water heating, cooling, and illumination. In comparison to various fields like transportation and manufacturing, discussions about energy efficiency often overlook the construction industry. However, addressing energy efficiency in building design is crucial to reduce energy demand, to mitigate environmental impacts, and to achieve a more sustainable future. The rise in popularity of energy-conscious architecture has triggered the formation of several sustainable building approval frameworks, which aims to reduce environmental footprint of new and built structures.

There are three green building rating tools for new building in Indonesia, such as Green Building Council Indonesia (GBCI)'s Greenship New Building (NB) (Ardhiansyah & Azizah, 2020), the Minister of Public Works and Housing Regulation Number 21 Year 2021(PermenPUPR No 21 Tahun 2021, 2021), and IFC's EDGE (Thomas et al., 2020; Vierra, 2016). Each rating tools have similarities and differences in their criteria. Greenship New Building, a type of Greenship for a 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 (Nasir et al., 2014). The Minister of Public Works and Housing Regulation Number 21 Year 2021 includes Site Management, Energy Use Efficiency, Water Use Efficiency, Indoor Air Quality, Environmentally Friendly Material Use, and Waste Management (PermenPUPR No 21 Tahun 2021, 2021). On the other hand, EDGE only have three main sections, Energy, Water, and Materials (Vierra, 2016).

Buildings in Jakarta are now required to implement energy-efficient design and must be proven by energy calculations when applying for building permits. 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/m2. OTTV is heat gain from building façade, which is sum of heat gain from conduction through the wall system, conduction through the fenestration systems, and radiation through the fenestration systems (Fitria, 2021).

The OTTV equation is written in Equation 1 (Albab & Adi, 2019; SNI 6389:2020 Konservasi Energi Selubung Bangunan Pada Bangunan Gedung, 2020).

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

where

α = Sun Radiation Absorption, that depends on color and finishing of an exterior wall

Uw = Thermal conductivity value of opaque wall (W/m2. K)

WWR = Window-to-wall ratio

TDEk = Equivalent temperature difference for opaque wall

Uf = Thermal conductivity value of a fenestration system (W/m2. 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/m2)

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 (Nasir et al., 2014), therefore integration of energy and daylighting performance is needed. Façade design must achieve sufficient daylighting without increasing cooling load (Viriezky et al., 2023). Large WWR will ensure saving on lighting energy, it also let unwanted solar heat gain at the same time (Huang et al., 2014). Kusumawati (2021) said that WWR, SC and SF have most influence on OTTV calculation (Kusumawati et al., 2021). Lahji (2021) concluded that energy efficiency can be achieved by dominating the façade surface with low Uf (Lahji & Walaretina, 2021). Albab (2019) has conducted an OTTV simulation and found that a fenestration system with double glazing with SC less than 1.9 and Uf more than 2.6 W/m2. K can reduce heat gain up to 6.2% (Albab & Adi, 2019). On the other hand, Huang (2014) said low-e glazing is the best choice in both thermal and daylighting

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performance, while double glazing has worst performance. Building location and façade orientation will also affect thermal and daylighting performance, where in cooling dominant climates, all window designs that faced to east and west have better performance, whereas north facing windows have worst performance (Huang et al., 2014). Daylight performance also depends on visible light transmittance (VLT) of a fenestration system (Fitria, 2021).

Satrio Tower is a prominent 26-storey office tower located in the bustling business district of South Jakarta, Indonesia. As part of its commitment to sustainability and environmental responsibility, the building's owner has embarked on a rigorous process to obtain the Greenship New Building (NB) certification. This certification, developed by the Green Building Council Indonesia (GBCI), sets high standards for energy efficiency and environmental performance, making it a prestigious and challenging goal for any new building.

As the final project on Greenshp Professional training, Satrio Tower is chosen as case study where participants are have to make a certification proposal that achieve platinum certification. To achieve the minimum point of platinum level, a comprehensive study focusing on energy and daylighting performance has been conducted. This research aims to understand the correlation between various façade characteristics and their impact on both energy consumption and natural lighting within the building, as outlined in the Greenship NB 1.2 criteria. By analyzing factors such as window-to-wall ratio, shading devices, and material properties, the study seeks to identify design strategies that enhance the building's overall performance, ensuring that Satrio Tower not only meets but exceeds the stringent requirements for sustainable building certification.

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 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 study 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/m2. 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 methods; 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.

Data Collection

The baseline case design and 24 other designs are displayed in Table 1. Wall system comes in five different varieties (Figure 1). Type 1 is the initial design, consisting of an inner gypsum layer, an air chamber, and 8 mm clear glass. Type 2 is a one-meter-tall wall composed of 12 mm gypsum, 5 mm glass wool, 75 mm precast concrete, 8 mm clear glass, and an air cavity. Type 3 is a one-meter-tall wall composed of plaster, air space, 10 mm light-weight concrete blocks, and 4 mm aluminum composite panel cladding. Types 2 and 3 are combined to create type 4. Type 5 is made up of 1,2 m of type 2 and 1 m of type 3. The wall material selection is based on commonly used materials in high-rise building construction, considering that the thermal transmittance value should be lower than the initial design. In Figure 1, type 5 is combined with 60 cm horizontal sunshading to illustrate the application of sunshading.

There are four types of glazing systems in the fenestration system (Figure 2). A single transparent glass makes up Type A. Double glazing system Type B has a 12 mm air cavity, 6 mm clear glass, and 8 mm Stopsol Supersilver Dark Blue. Double glazing system Type C has 6 mm Planible G, twelve mm air cavity, and eight mm Sunergy Green panes. Type D double glazing consists

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of a 6 mm transparent glass pane, a 12 mm air cavity, and an 8 mm Stopray Vision 51T #2. Iterative calculations from the preceding design yield 24 possible designs until SNI 6389:2020 compliance is reached. The low shading coefficient value and visible light transmittance above 25% of the selected glazing materials are the deciding factors in their selection.

DISCUSSION

In the initial phase of the study, the baseline and cases 1 to 15 did not comply with the SNI 6389:2020 standard, as they failed to meet the maximum allowable OTTV value. However, Case 16 through 24 successfully complied with the SNI 6389:2020 standard, prompting further daylighting calculations for these scenarios. Case 19 has the best energy performance as its OTTV is the lowest among other cases. Meanwhile, Case 17 has the highest OTTV of 31,98 W/m^2 although it still complies to SNI 6389:2020.

For phase 2, daylighting analysis using Dialux is conducted to Case 16 through 24. Among these, Case 20 demonstrated superior daylighting performance while maintaining a low cooling load, outperforming the other case studies in this regard. The comparative analysis of daylight and energy performance for Case 16 to 24 is illustrated in Figure 3.

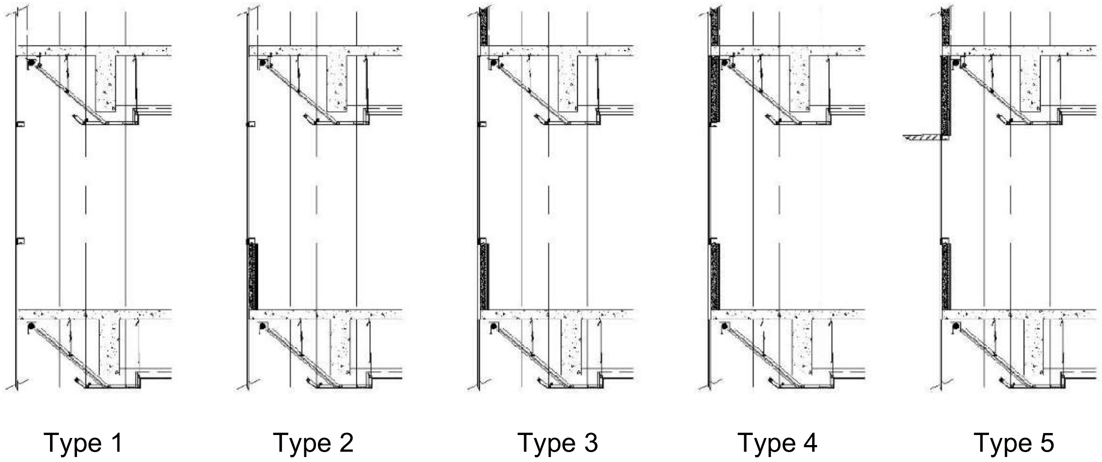

Figure 1. Five varieties of wall systems

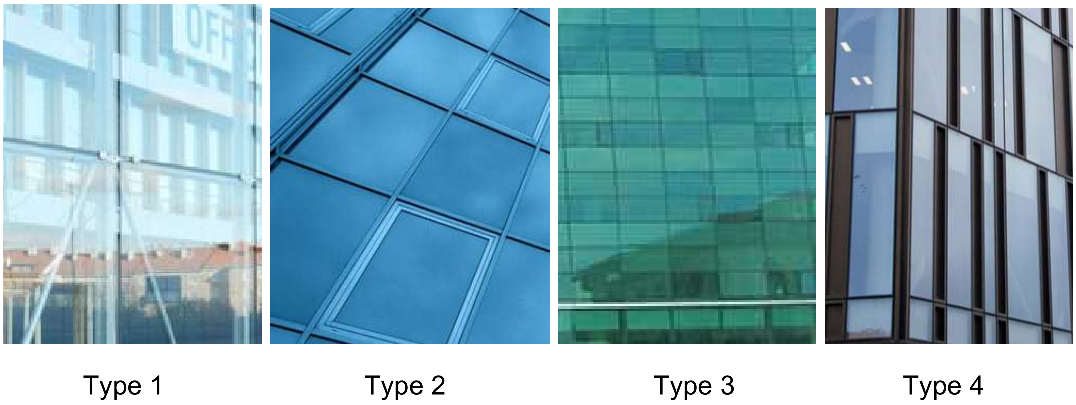

Figure 2. Four Types of Fenestration System

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

No	Wall System	Fenestration Systems Type	Sunshading	SC_{glass}	U_{wall}	$U_{fenestration}$	VLT	VLR	WWR
Baseline	Type 1	Type A	No	0,93	1,75	5,7	88	8	95%
1		Type B	No	0,31	1,75	2,019	29	32	95%
2		Type C	No	0,35	1,75	2,099	60	12	95%
3		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%

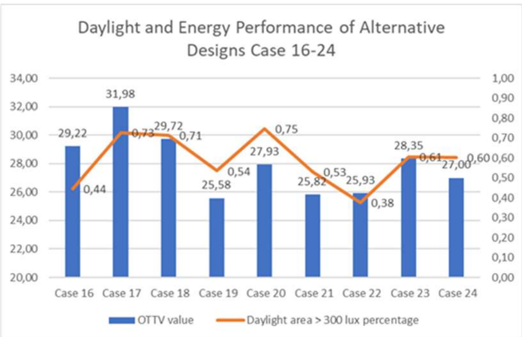

Figure 3. Daylight and Energy Performance of Alternative Design Case no 16-24

Following the evaluation of the baseline and the 24 alternative designs, a correlation analysis was performed to identify key factors influencing energy and daylighting performance as part of Phase 3. The Pairwise Correlation method revealed significant correlations between the shading coefficient (SC), U-value, visible light transmittance (VLT) of the fenestration system, and the window-to-wall ratio (WWR) with both energy and daylighting outcomes. The variable is considered as significant if its value below 0,05. This indicates that these parameters are crucial in determining the building's overall performance. The correlation analysis is shown in Table 2.

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*

Particularly noteworthy is the role of VLT in design optimization. Although VLT is not included in the OTTV calculation, it significantly impacts both energy and daylighting performance. Therefore, it should be a key consideration for designers aiming to optimize building designs for energy

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efficiency and adequate natural lighting. This insight underscores the importance of a holistic approach in façade design, balancing various factors to achieve sustainable and efficient building performance.

CONCLUSION

Façade characteristics, especially fenestration systems, show a significant correlation to energy and daylight performance. There are keypoints that can be concluded from the study related to facade characteristics, energy and daylight performance.

- WWR are significantly correlated with OTTV and daylight performance. Increasing WWR shows higher OTTV, thus higher energy consumption for cooling, but it also shows higher daylight performance.
- Glazing material optical and energy characteristics such as U-value, VLT and SC are significantly correlated with both OTTV and daylight performance, where higher U-value, VLT and SC will lead to higher OTTV and better daylight performance
- Among the facade characteristics, visible light transmission, a façade characteristic which not included in OTTV calculation, can be taken into consideration if a designer wants 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 a fenestration system to reduce OTTV while promoting the daylight performance

As we already know which facade characteristic that have strong correlation to both energy and daylight performance, future research should develop a concept of facade systems that can optimize light transmission into the building while still maintaining building energy efficiency.

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