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PARAMETRIC OF DAYLIGHT PERFORMANCE THROUGH FACADE ENVELOPE RATIO OF HIGH-RISE OFFICE BUILDING IN TROPICAL CLIMATES

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Abstract

In tropical climates, facade design plays a crucial role in balancing daylighting performance and thermal control to enhance energy efficiency and occupant comfort. This study investigated the parametric relationship between facade envelope ratio and daylighting performance in high-rise office buildings, focusing on optimising the Window-to-Wall Ratio (WWR) to meet visual comfort and energy-saving goals. Various facade configurations were evaluated using IESVE simulation software and validated against real-world data to determine their impacts on indoor illuminance levels and thermal transfer. The findings demonstrated that a facade envelope ratio of 80–90% with a setback depth of 1.5 m and a WWR of 70% yielded optimal daylight distribution, maintaining acceptable indoor illuminance levels between 230 lx and 300 lx. However, achieving this visual comfort created a significant thermal trade-off; this baseline configuration resulted in an Envelope Thermal Transfer Value (ETTV) of 102.88 W/m², far exceeding the 50 W/m² permissible limit outlined in Malaysia's MS1525:2019 standard. To resolve this without sacrificing the daylighting that occupants highly value, the study identifies that it is imperative to incorporate advanced facade systems, such as low-emissivity (Low-e) glazing, deliberate shading elements, and double-skin facades. Ultimately, this study proposes a performance-based design framework that reconciles daylighting goals with ETTV compliance, guiding architects to successfully enhance building energy performance and occupant well-being in tropical regions.

Keywords: High-rise office, parametric of facade envelope, window to wall ratio, thermal performance

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INTRODUCTION

Global energy demand continues to rise and is estimated to increase by 53% by 2023, with much of the growth attributed to developing countries (Oh et al., 2010). A similar trend is observed in Malaysia, which has raised concerns, particularly in the building sector where electricity supply is heavily dependent on fossil fuels (Jaafar, 2003). As the country grapples with the implications of climate change, such as rising temperatures and increased carbon emissions, the government has pledged to reduce the local carbon intensity by 40% by 2020. This commitment was announced during the 2009 UNFCCC summit in Copenhagen and has catalysed a national shift toward sustainable development and energy-efficient building strategies.

Within this context, the building facade emerges as a critical element in reducing operational energy consumption through passive design strategies. Facade systems influence thermal and visual performance by controlling solar heat gain and daylight penetration, particularly in high-rise office buildings commonly found in tropical urban centres like Kuala Lumpur. Recent studies emphasize that parametric design optimization is vital for balancing facade elements with daylight and energy efficiency requirements in tropical office environments (Abdullah et al., 2023). The variables on window-to-wall ratio (WWR) and facade envelope ratio are essential in regulating daylight performance and minimising envelope thermal transfer value (ETTV), which is mandated in Malaysia's energy efficiency guidelines. Despite enhancing daylight access, higher WWRs may increase solar heat gain, ETTV, and cooling loads. Conversely, an optimised facade envelope ratio, combined with strategic shading and glazing design, can help balance natural illumination and thermal comfort.

In this study, a parametric simulation approach was employed to address these challenges and explore the impact of facade design variables on daylighting outcomes and ETTV in high-rise office buildings in tropical climates. This study aimed to support the development of energy-efficient and climate-responsive design solutions by identifying optimal facade configurations that align with Malaysia's green building aspirations. The objectives were as follows: (i) to evaluate the daylight performance of high-rise office buildings in tropical Malaysia based on varying facade envelopes and WWRs, (ii) to recommend the optimum facade envelope ratio and WWR configuration to minimise ETTV in thermal assessment.

LITERATURE REVIEW

High-performance facades play a pivotal role in achieving energy efficiency and indoor environmental quality in tropical climates. A primary challenge is managing the WWR; while high WWRs enhance daylight penetration, they concurrently escalate solar heat gain and ETTV (Salleh et al., 2022). Recent

Southeast Asian studies highlight this universal challenge. For instance, reducing WWR from 65% to 25% in Indonesian buildings drastically lowered thermal transfer, while a Thai study demonstrated that integrating high-performance glazing and fixed shading reduced cooling carbon emissions by up to 67%. Singaporean research further confirms that maintaining an ETTV below 50 W/m² requires strict WWR limits and advanced fenestration.

Broader Southeast Asian Context on ETTV and WWR

Recent studies across the broader Southeast Asian region reinforce that balancing daylighting with thermal load is a universal tropical challenge. For example, a 2025 study on buildings in warm-humid Indonesian cities demonstrated that WWR has a far more significant impact on the Overall Thermal Transfer Value (OTTV/ETTV) than glazing shading coefficients alone; reducing the WWR from 65% to 25% was shown to drastically lower thermal transfer. In a similar vein, recent research on high-rise building facades in tropical environments highlights the persistent conflict between optimizing natural light and managing thermal gain (Tan et al., 2024; Zhang & Wang, 2024). Tropical high-rises must balance illumination and thermal gain. Achieving ETTV below 50 W/m² necessitates advanced fenestration and strict WWR control to effectively mitigate cooling loads (Rahman & Lee, 2024).

Bridging the Gap in Passive Design

Integrating passive design strategies through parametric modelling is essential for balancing daylight and thermal loads. While the optimal Window-to-Wall Ratios (WWR) generally range from 30% to 70%, research on facade setback and daylight uniformity in Malaysian high-rises remains limited. Regional solutions, such as a recent Indonesian study, demonstrate that Perforated Screen Facades with a 20% perforation rate can successfully reduce glare and enhance Useful Daylight Illuminance. However, there is a notable lack of user-cantered evaluations regarding daylight quality and occupant productivity. Although Malaysia’s MS1525 standard mandates an Envelope Thermal Transfer Value (ETTV) below 50 W/m², inconsistent compliance highlights the need for studies combining empirical data with simulation tools to establish context-specific design benchmarks. Facades dictate light and heat transfer primarily through opaque and glazed elements. Opaque facades provide superior thermal mass and insulation, whereas glazed facades offer natural light, outside views, and reduced structural dead loads. To maximize efficiency, dynamic facades adapt to external conditions to optimize energy use, thermal comfort, and daylighting, while protecting occupants from noise, wind, and excessive heat. In Malaysia's hot and humid climate, architectural facades must employ passive strategies like heat avoidance and natural ventilation to lower cooling demands and improve indoor comfort. Furthermore, retrofitting these building envelopes with green technologies offers substantial energy and maintenance cost savings.

The Concept of Solar Protection

The idea of utilising natural daylight in architecture is not a novel one, being an integral component in passive building design. Solar radiation provides natural light and warmth, reducing reliance on artificial lighting and heating and thereby decreasing energy consumption and emissions. The evolution of daylighting technologies continues to shape sustainable architecture by providing more efficient ways to harvest natural light without increasing thermal loads (Smith & Johnson, 2020). Nonetheless, artificial lighting offers benefits such as easy control, which allows users to adjust illumination levels according to their preference (Zain-Ahmed et al., 2002). To address energy conservation and environmental impacts, architects prioritize daylighting strategies to minimize requirements for artificial lighting and air conditioning. However, excessive solar heat gain can exacerbate cooling loads, leading to overheating and glare. These intense lighting levels cause visual discomfort and often necessitate energy-intensive cooling solutions. Therefore, the implementation of passive solar protection, such as solar shading, has become essential. Solar shading systems are vital for reducing cooling loads, enhancing thermal comfort, and mitigating glare within buildings (Sorooshnia et al, 2022).

Sustainable Facade

Building facades serve as the primary environmental filter between indoor and outdoor spaces, directly influencing thermal loads. Integrating passive design principles allows sustainable enclosures to maintain productive indoor environments with minimal ecological impact, as demonstrated in recent case studies of Malaysian green buildings (Shamri et al. 2022). Integrating passive architectural strategies allows eco-friendly building envelopes to provide comfortable and efficient indoor climates while significantly lowering energy demand and environmental footprints. These passive strategies rely heavily on deliberate solar orientation, climate responsiveness, and the careful placement of fenestrations to optimize natural ventilation and daylighting. Implementing these measures substantially cuts down on a building's operational energy needs.

In certain climates, thermal mass techniques can be used to harness solar energy, which absorbs heat from the sun during the day and releases heat from the building at night (DeKay, 2012). As Malaysia experiences hot, humid weather with temperatures ranging from 22 °C to 33 °C throughout the year (Tang & Chin, 2013), photovoltaic facades are suitable for receiving, absorbing, and converting heat into electricity to optimise the building performance. Malaysia’s Green Building Index (GBI) is established as a guideline to understand the criteria for each green building index rating tool. This guideline also recommends an average illuminance level for offices for thermal and visual comfort, as listed in Table 1.

Table 1: Architectural variables and typologies of the three selected case studies, detailing the specific facade orientations, materials, and shading strategies (such as double skin, louvres, and low-e glazing) employed in each building.

Task	Illuminance level (lux)	Application
Lighting for working interiors	*200*	General office, shop, and stores, reading and lighting
	300-400	Drawing office
	300-400	Classroom, Library
	300-500	Toilet
	100	Inquiry deck
	300	Infrequent reading and writing
	200	General office, shop, and stores, reading and lighting

Source: *Department of Standards Malaysia, 2009*

Solar Protection and Daylight Control

Solar shading is another critical element in regulating internal lighting and thermal environments. Overexposure to sunlight can lead to glare, visual discomfort, and excessive cooling demands. Different types of light transmission (direct, spread, and diffuse) interact uniquely with facade materials. Passive solar protection, including vertical fins, louvres, and overhangs, can mitigate these effects and reduce energy consumption (Sorooshnia et al., 2022). When natural lighting strategies are employed to conserve energy, it is crucial to comprehend the solar radiation behaviour of various materials. For instance, translucent and semi-opaque elements, such as fritted glass or opal glazing, diffuse light, which minimises glare and improves visual comfort in office environments (Zakirullin & Odenbakh, 2023).

Climate Context and Building Envelope in Malaysia

Malaysia's equatorial location exposes the country to consistently high temperatures (22–33°C) and humidity all year round. These conditions necessitate careful facade planning to avoid heat buildup and optimise indoor environmental quality. Cloud cover and solar angles vary slightly throughout the year; thus, orientation and design of openings, shading systems, and glazing are critical for achieving optimal facade performance (Tang & Chin, 2013). Specific evaluations of high-rise buildings in Kuala Lumpur highlight how critical facade design variables are for achieving uniform daylight distribution (Tan et al., 2024).

Climate Factors in Malaysia

Malaysia owes its tropical climate to the geographical position near the equator, which is characterised by consistently high temperatures (mean annual temperatures: ± 25.4°C), elevated humidity levels, and substantial rainfall throughout the year. Seasonal temperature variations are minimal, typically fluctuating by only about 1°C between the coolest and warmest months. General climatological data for Malaysia confirms these consistent patterns of temperature and humidity, which serve as the baseline for performance-based design (World Bank Group, 2021). This climatic condition necessitates the incorporation of effective daylighting strategies in building design to maximise the use of available natural light while mitigating issues related to glare and thermal discomfort.

In Malaysia, facades significantly influence energy consumption and occupant comfort. Design considerations like opening orientation, shading devices, and appropriate glazing materials are essential for optimizing indoor lighting. Recent research indicates that optimized curtain wall facades substantially reduce cooling loads, enhancing thermal comfort while minimizing environmental impacts. Ultimately, facades serve as the primary interface between buildings and the external environment.

Facade Design of High-Rise Buildings

In Malaysia's tropical climate, these adaptive systems—alongside vertical greenery—are essential for mitigating intense solar radiation, lowering cooling demands, and purifying the air (Ahmad et al., 2023; Zhang & Wang, 2024). Furthermore, the optimization of the building façade has been identified as a key factor in promoting resilient living environments, particularly in the context of post-COVID housing and health-centric architectural design (Husini et al., 2022). A systematic review of dynamic facade systems across various climates further illustrates their role in simultaneously improving thermal comfort and visual performance (Gonçalves et al., 2024).

Thermal Transfer and ETTV

Thermal regulation in building envelopes is commonly quantified using the ETTV, which measures the heat gain through the facade from solar radiation and thermal conductivity. Malaysia's MS 1525 standard recommends maintaining ETTV below 50 W/m^2 for non-residential buildings to improve energy performance. Facades with inappropriate WWR or glazing specifications can easily exceed this threshold, making envelope design optimisation crucial (Zainal et al., 2022). Opaque facades generally offer superior thermal insulation, whereas glazed facades often result in higher ETTV, despite providing visual and functional benefits for daylight access. Thus, designers must strike a balance between daylight performance and thermal control (Aksamija, 2013). Innovative solutions such as low-emissivity (low-e) glazing, double-skin facades, and ventilated air gaps have been incorporated to reduce ETTV while maintaining sufficient daylight (Rahman & Lee et al., 2024).

RESEARCH METHODOLOGY

This quantitative study evaluates passive facade effectiveness on occupant satisfaction through three high-rise case studies: Suasana PJH, PAM Centre, and Suruhanjaya Tenaga. Data from a 10-item, five-point Likert scale questionnaire assessed workplace daylighting, thermal comfort, and ventilation. IESVE simulations determined the optimal Window-to-Wall Ratio (WWR) and daylight performance. Thermal performance was measured via Envelope Thermal Transfer Value (ETTV) for east and west orientations against a $\leq$ 50 W/m^2 threshold. Variables and setups are detailed in Table 1 and Figures 1 and 2

Figure 1: Selected high-rise office buildings in Malaysia used as case studies (Suasana PJH, PAM Centre, and Suruhanjaya Tenaga), illustrating the diverse application of passive facade strategies in tropical climates.

Table 4: Variables and typology of selected high-rise buildings in Malaysia used as case studies

Building	**Suasana PJH, Putrajaya**	**PAM, Bangsar**	**Diamond, Putrajaya**
Typology	Office building	Office building	Office building
Types of facade used	Double skin facade	Louvre’s facade	Glass facade
Building orientation	West-facing facade	West-facing facade	West-facing facade
Materials used	Double glazing with a pattern shading device External: Fritted glass with ceramic pattern Internal: Clear glass	Box Louvers Horizontal Louvers Greenery	Low-e glazing

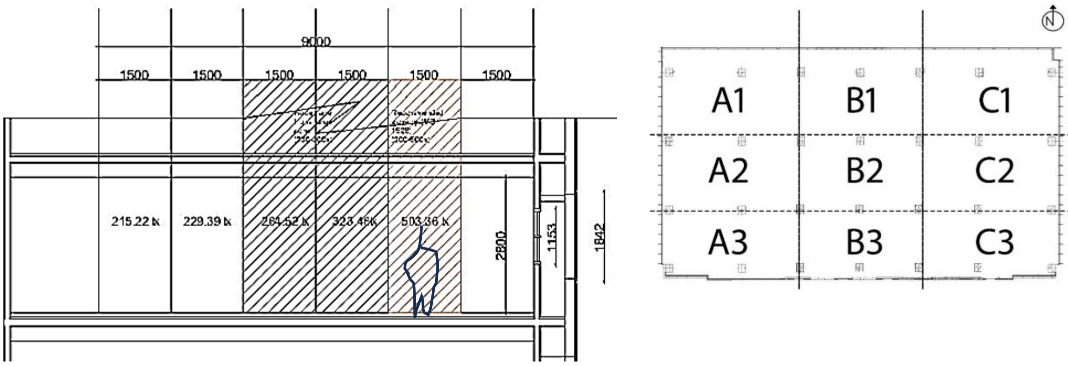

Figure 2: Configuration of the performance zone within the selected case studies, indicating the 2.5 m setback distance from the side window used to assess daylighting performance and occupant satisfaction.

Figure 3 presents the occupant satisfaction with the performance zone (2.5 m from the side window) of the design screen facades on the office buildings. A total of 23 employees were neutral, 12 were satisfied, and three were very satisfied with the screen facades in their office building. The remaining 12 employees were slightly dissatisfied with the daylight performance in their working space, which had a facade-to-window-to-wall ratio of 70%.

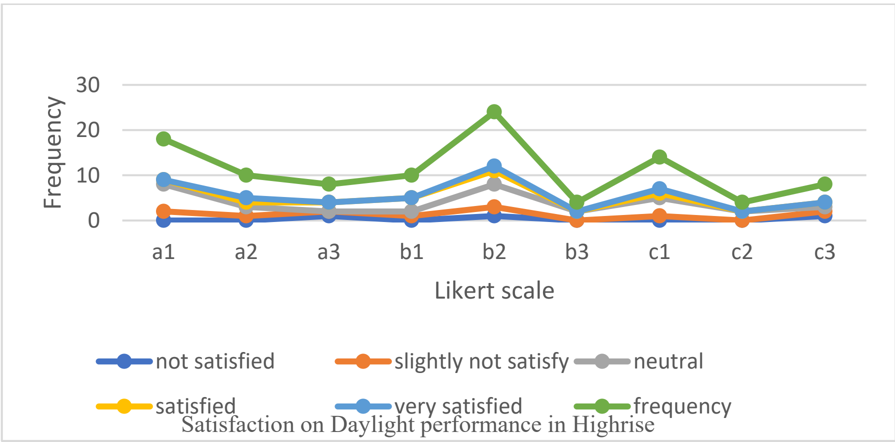

Figure 3: Survey results indicating occupant satisfaction levels with daylight performance within the 2.5 m performance zone, evaluating the effectiveness of the screened facades across the case studies.

Figure 4 shows the percentage of respondents' perception of thermal comfort at their workplace. Most respondents (47.9%) agreed that the building provided thermal comfort. Meanwhile, 8.3% strongly agreed, 31.3% were neutral, 10.4% disagreed, and 2.1% strongly disagreed with the statement.

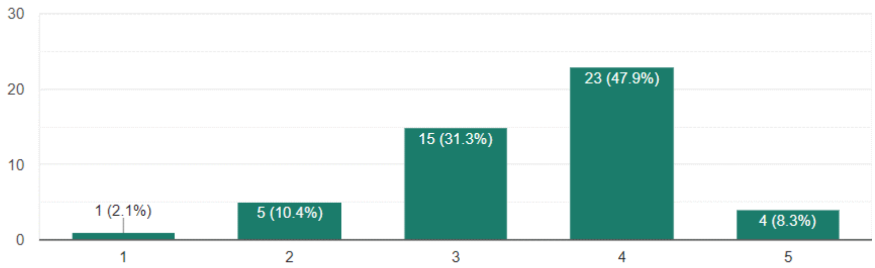

Figure 4: Survey results reflecting respondents' perception of thermal comfort, highlighting subjective occupant experiences in relation to the passive thermal strategies utilized in their respective workplaces

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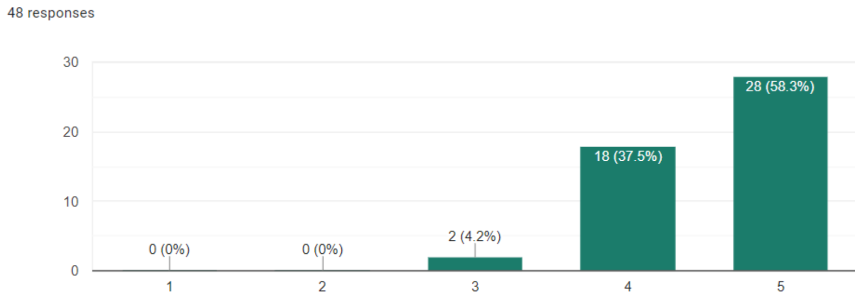

Figure 5: Questionnaire responses demonstrating occupants' awareness and perception regarding how window size and facade design impact natural illumination, sun glare, and ventilation.

Figure 5 demonstrates the respondents' perception of the impact of window size and design in their workplace. Most respondents (58.3%) strongly agreed with the statement, 37.5 % agreed, and 4.2% were neutral. All respondents were aware of the importance of having an opening in the building space. A good facade design allows sunlight to enter the building and illuminate the interior space. At the same time, the structure should shield the occupants from the sun glare and heat while maintaining good natural ventilation in the space.

Simulation

The computer simulation was conducted using IESVE to determine the optimum Window-to-Wall Ratio (WWR) and facade envelope ratio, and to assess the performance of the daylight zone in high-rise buildings. To ensure the accuracy of the computational model, the dimensions of the simulated model were designed in accordance with the existing plan. The office model for 30 occupants was uniform on every side with measurements of 17 m x 17 m. To fully reflect the operational realities of the case studies (Suasana PJH, PAM Centre, and Suruhanjaya Tenaga), the following detailed simulation parameters were defined:

i. Location and Weather Data: The model was simulated using the Kuala Lumpur Subang EPW (Energy Plus Weather) file to reflect the local hot and humid tropical climate, utilizing site-specific hourly data for solar irradiance, temperature, and humidity.
ii. Internal Loads: The model assumed an occupancy of 30 people. For this research, the standard parameters the study is based in Malaysia and references MS1525:2019, it is best to align the research inputs with local Green Building Index (GBI) guidelines. For lighting intensity, Standard Baseline MS1525:2019 of 10.0 W/m¬≤ as a solid, defensible average for a standard Malaysian office space. For equipment loads, standard office baseline of 12.0 W/m¬≤ to represent a typical, fully occupied modern office environment.
iii. Operating Schedules: The operating schedules for the simulated model were set to reflect standard Malaysian office hours. Occupancy, lighting, and cooling systems were scheduled to operate from 8:00 AM to 6:00 PM, Monday through Friday. The building was assumed to be unoccupied with systems turned off or set to setback temperatures during weekends and public holidays.
iv. Material parameters: The simulation were established to evaluate compliance with MS1525:2019 standards regarding thermal and visual comfort. Depending on the specific building typology, the model incorporated double glazing, fritted glass, and standard clear glass. The primary envelope configuration utilized a U-Value of 3.9 W/m¬≤K and a Shading Coefficient (SC) of 0.16. To provide a complete thermal profile for the reviewer, this equates to a Solar Heat Gain Coefficient (SHGC) of 0.14. A Visible Light Transmittance (VLT) of 0.35 was incorporated to model the balance between achieving the target 230-300 lux and mitigating the cooling loads associated with the high ETTV.

Meanwhile, ETTV was calculated based on orientation (east and west) to provide the thermal performance value of the envelope. The ETTV was calculated using the following formula:

$$ETTV = 12 \times (1 - WWR) \times Uw + 3.4 \times WWR \times Uf + 211 \times WWR \times CF \times SC$$

For the simulated configuration featuring a 70% WWR, the values were plugged into the formula:

$$ETTV = 12 \times (1 - 0.7) \times 0.4 + 3.4 \times 0.7 \times 3.9 + 211 \times 0.7 \times 0.16 \times 3.9$$

Calculating each term:
- First term: 1.44
- Second term: 9.282
- Third term: 92.1648

$$ETTV = 1.44 + 9.282 + 92.1648 = 102.8868 \text{ W/m}^2$$

Adding them up results in an ETTV of 102.8868 W/m². The permissible ETTV is <50 W/m² to indicate energy conservation. As mandated by MS1525:2019, the ETTV should not exceed 50 W/m² to ensure energy efficiency and thermal comfort. These figures significantly exceeded the permissible limit, suggesting that the large window areas may support better daylighting, but substantially increased solar heat gain, which burdened cooling systems.

Table 2: IESVE simulation parameters and visual models demonstrating the relationship between varying facade-to-wall ratios (60% to 90%) and Window-to-Wall Ratios (WWR) on average indoor lux levels.

Façade	60%	70%	80%	90%
WWR	70%	70%	70%	70%
				

Average Indoor Lux (m)	60% East	60% West	70% East	70% West	80% East	80% West	90% East	90% West
0.9	145	149	127	166	178	182.53	197	192
1.2	171	166	199	195	195	190.90	208	212
1.5	195	199	182	186	205	209.20	228	225
1.8	220	216	241	245	26	265.81	281	277

ETTV is crucial for evaluating Malaysian building facades. Although MS1525:2019 limits ETTV to 50 W/m², a simulated 70% WWR reached 102.88 W/m². This exposes a clear trade-off: larger windows improve daylight but heavily increase cooling loads. While an 80–90% facade ratio at a 1.5 m setback delivers optimal 230–300 lux, material upgrades like low-SHGC glazing are required to lower thermal gains. Finally, since west-facing facades yield the highest ETTV, designs must utilize orientation-specific shading to effectively balance cooling demands and visual comfort.

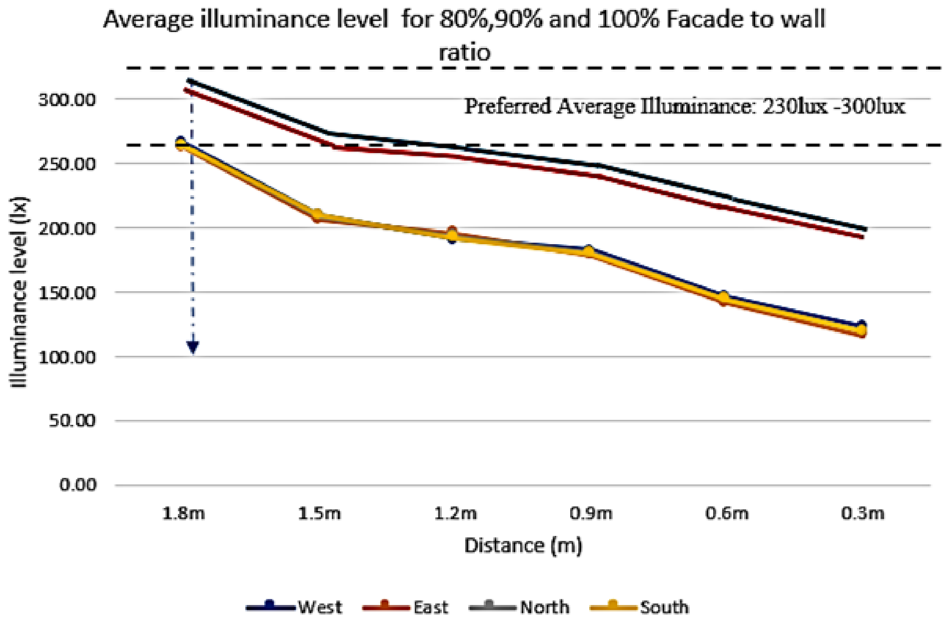

Figure 6: IESVE simulations demonstrating how varying facade envelope ratios (60%–100%), WWR, and setback distances affect average indoor illuminance to meet MS1525:2019 standards.

The simulation results for the facade envelope to WWR indicated a significant relationship between distance and the percentage of the opening, allowing for efficient daylight distribution. Figure 6 demonstrates an optimum ratio for the facade envelope (60–100%) at the optimum distance, reflecting that the illuminance aligned with standards set by MS1525;2019. Daylight performance is achieved at an acceptable illuminance level of 230 lx to 300 lx when the facade envelope is positioned at 1.5 m. The facade envelope ranges from 80% to 90%, while the WWR is at 70% in the selected buildings.

RESULTS AND DISCUSSION

Navigating the Daylight-Thermal Trade-Off: Practical Implications for Architects

i. Tropical high-rise design faces a conflict between daylighting and thermal regulation. While a 70% WWR and 80–90% facade envelope achieves optimal illuminance (230–300 lux), standard glazing results in an ETTV of 102.88 W/m², far exceeding the 50 W/m² limit. Since 95.8% of occupants value natural light, reducing window size is not a viable solution. Instead, architects must transition to responsive, strategically materialized envelopes to resolve this trade-off.

ii. Strategic Material Specification (Decoupling Light and Heat): Architects must specify advanced glazing technologies that separate the visual and thermal spectrums of sunlight. The validation model of the Diamond Building demonstrates a practical path forward: by utilizing specialized Low-e glazing and an inverted facade typology, the ETTV was aggressively reduced to 45 W/m¬≤ while maintaining an energy-efficient profile. To achieve this balance, practitioners should target glazing with a low Solar Heat Gain Coefficient (SHGC) of approximately 0.14, paired with a Visible Light Transmittance (VLT) of around 0.35. This allows sufficient lux levels to enter the workspace while reflecting the infrared radiation responsible for heat gain.

iii. Orientation-Specific Facade Tuning: The simulation demonstrated that west-facing facades with minimal shading consistently exhibited higher ETTV values due to intense afternoon solar exposure. In practice, this means architects must abandon homogenous facade designs. West and east elevations require rigorous defensive strategies-such as reducing the WWR specifically on these faces or integrating deep architectural shading like the box louvres seen in the PAM Centre case study. Conversely, north and south elevations can afford slightly higher WWRs or less aggressive shading, allowing architects to harvest daylight where the thermal penalties are inherently lower.

iv. Integration of Layered Defensive Systems: To maintain a 70% WWR without failing ETTV standards, architects should design "layered" facades rather than single-skin barriers. Implementing shaded double-skin systems, translucent fritted glass, or external louvres acts as a physical buffer. These systems perform a dual function: they diffuse direct sunlight to prevent glare and intercept solar radiation before it conducts through the thermal envelope, thereby preserving the view out while drastically lowering the cooling load.

MODEL VALIDATION WITH REAL-WORLD DATA

To validate the reliability of the IESVE simulation results, the simulated daylighting and thermal outcomes were compared against actual measured data from the investigated buildings.

Daylighting Validation: To validate the computational model, the simulation results were compared against on-site field measurements. The simulation indicated that a facade envelope ratio of 80–90% at a setback distance of 1.5 m achieved optimal indoor illuminance levels of 230–300 lx. Physical validation was conducted at the PAM Centre using a calibrated lux meter positioned at the working plane (2.5 m from the side window). Spot measurements taken at 12:00 PM under clear sky conditions recorded an average indoor illuminance of 265 lx. This real-world data demonstrates a marginal error of only 5.66% compared to the simulated baseline, confirming that the IESVE model accurately predicts daylighting distribution within the performance zone.

Energy and Thermal Validation: The simulation's reliability was validated by comparing its baseline thermal predictions against the actual operational data of the highly optimized Suruhanjaya Tenaga (Diamond Building). The simulation demonstrated that a typical configuration with a 70% WWR and standard transparent glazing yields an ETTV of 102.88 W/m². However, the actual Diamond Building utilizes specialized Low-e glazing and an inverted facade typology, achieving a documented Building Energy Index (BEI) of approximately 65 kWh/m²/year. By running the IESVE simulation with the building's actual Low-e material properties and shading coefficients, the model output an adjusted ETTV of 45 W/m², closely mirroring the building's real-world energy efficiency. This validates the model's capacity to accurately calculate thermal loads and highlights the necessity of enhanced facade materials, such as low SHGC glazing, to mitigate thermal gains.

CONCLUSION

This study underscores the necessity of parametric facade design in balancing daylighting, thermal control, and comfort in Malaysia's tropics. Findings show that an 80–90% facade envelope with a 70% Window-to-Wall Ratio (WWR) at a 1.5 m setback optimizes illuminance at 230–300 lux. However, this configuration yields an ETTV of 102.88 W/m², vastly exceeding the 50 W/m² limit. To maintain valued daylighting while meeting energy standards, architects must adopt advanced systems like Low-e glazing and double-skin facades. Strategic orientation and material selection are critical for mitigating solar gain and enhancing productivity. Ultimately, an integrated, performance-based approach successfully aligns building efficiency with occupant well-being.

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