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Annual Daylight Performance of Perforated Screen Facade in Loft Office in the Tropics

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Abstract

Implementing daylighting in office buildings offers energy savings and psychological and physiological benefits for occupants. One type of office currently developing in Indonesia is the loft office, which is characterized by a mezzanine floor, a high ceiling, and a fully glazed facade. Without adequate shading, buildings with fully glazed facades are at risk of excessive daylight exposure and glare issues. Perforated Screen Facade (PSF) is one of the shading devices that can reduce excessive daylight level and glare while still allowing daylight penetration. The research aim is to evaluate the annual daylight performance of PSF implementation with different perforation percentages in loft offices in the tropics. The research method is experimental and uses a radiance-based daylighting simulation. The useful daylight illuminance (UDI) and spatial disturbing glare (sDG) of a loft office with a fully glazed facade were compared to a loft office equipped with a PSF with different perforation percentages. The integration of a PSF reduces UDI excessive and sDG while improving $UDI_{100-3000lx}$ in areas near the glazed facade. Considering the importance of glare reduction in tropical climates, a loft office with a PSF perforation percentage of 20% was selected as the optimum configuration for annual daylight performance.

INTRODUCTION

Daylighting can lower a building's energy consumption while improving the well-being and performance of its users. Implementing proper daylighting strategies lowers the energy demand for electric lighting and overall energy usage (Chi et al., 2021; Du et al., 2022). In the tropics, daylighting with proper shading, such as a side window with L-shaped mini louvers, can reduce cooling energy consumption (Suryandono et al., 2021). Lim et al. (2017) found that a substantial lighting energy consumption occurred from daylighting in a green building office in Malaysia. Integrating optimal daylighting and active dimming of electric lighting in educational buildings in the tropics of Indonesia also decreases the lighting energy (Viriezky et al., 2023).

Additionally, daylight positively impacts the physiological and psychological wellbeing of building occupants (Wirz-Justice et al., 2021). Daylighting provides a connection to nature and positively impacts building occupants' mood (Shishegar & Boubekri, 2016). A study in an open-plan workplace in Malaysia also highlights that dynamic lighting strategies support physiological and psychological wellbeing indicators even in windowless workplaces, mimicking the benefit of daylight (Sithravel et al., 2018). Daylight exposure and proper building orientation are closely linked to sleeping quality improvement in sleeping quality, which in turn promotes overall health (Hussainzad & Gou, 2025). Exposure to daylight enhances employees' productivity, mood, concentration, and cognitive performance (Shishegar & Boubekri, 2016).

Buildings in tropical climates possess significant potential for optimizing the utilization of daylight. The tropical areas experience abundant sunlight throughout the day (Roshan & Barau, 2016). Research on daylighting in tropical regions must account for the variability in cloud formations, particularly intermediate sky conditions, which are neither clear nor overcast (Lim & Heng, 2016).

The building envelope is crucial in optimizing energy efficiency, particularly in public buildings (Shohan et al., 2021). It serves as a protective layer, separating the controlled indoor environment from external conditions (Gupta & Deb, 2023). Many office buildings in the tropics adopted a full-glazed facade to admit daylight and provide views. Figure 1 illustrates a fully glazed facade as a loft office building envelope in Indonesia's tropical climate.

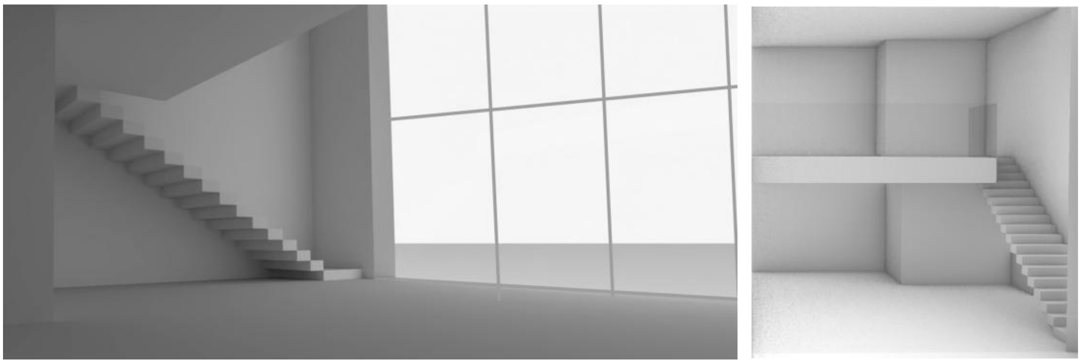


Fig.1. Typical Loft Offices with Full Glazed Facade and mezzanine floor

The scenery through a window can significantly impact physical and mental well-being (Knoop et al., 2020). However, without proper shading, a fully glazed facade produces excessive solar radiation and daylight level, uneven daylight distribution, and discomfort glare (Jakubiec & Reinhart, 2016; Papinutto et al., 2022). Proper shading devices must be integrated to reduce solar radiation and enhance daylight performance (Chi et al., 2017a).

The perforated screen facade (PSF) is one of the most widely implemented shading devices, deriving from the mashrabiya, a wooden lattice screen (Kamal, 2014) that is used in Middle Eastern architecture to protect the openings (Sherif et al., 2012a). PSF is a flat, opaque panel with perforations that has a relatively thin profile to its overall dimensions (Chi et al., 2017a). PSF acts as a double skin for building facades, effectively reducing direct sunlight penetration while maintaining visibility to the exterior environment (Chi et al., 2017a).

Previous studies on PSF mainly focused on single-floor office typologies and residential units. Previous research has analyzed various office spaces, including single-floor office rooms measuring 8 × 6.5 meters with a height of 2.7 meters (Srisamranrungruang & Hiyama, 2020); open-plan office space 7 × 7 meters with a height of 3 meters (Chi et al., 2017b; Chi Pool, 2019). Other research explored medium-depth office spaces measuring 6 × 8 meters with a height of 2.7 meters (Elsiana & Arifin, 2024) and open-plan office rooms measuring 7.2 × 7.2 meters with a height of 3 meters (Huang et al., 2024). PSF studies also have examined the living room of a typical single-floor residential unit (Sherif et al., 2012a; Sherif et al., 2012b). Figure 2 shows the building types studied in previous PSF research.

Daylight performance metrics studied in previous research include useful daylight illuminance (Srisamranrungruang & Hiyama, 2020; Chi et al., 2017a; Elsiana & Arifin, 2024), daylight availability (Sherif et al., 2012a; Sherif et al., 2012b; Srisamranrungruang & Hiyama, 2020) and daylight autonomy (Chi et al., 2017a). Other studies also evaluated the daylight glare probability (Sherif et al., 2012a; Sherif et al., 2012b; Srisamranrungruang & Hiyama, 2020), the average illuminance level (Sherif et al., 2012b), and daylight factor (Elsiana & Arifin, 2024).

A loft office is a two-story small office featuring a high ceiling and a mezzanine floor. The concept of lofts originated in New York during the 1940s when rising housing prices in city centers prompted the search for more affordable spaces on the outskirts, leading to the repurposing of factories and workshops with spacious open areas (Kliczkowski, 2005). A loft trend has grown into a luxurious residence or office that can function as a place for working and living.

Several apartment and office buildings in Indonesia also use the loft concept in their unit designs and building structures. Due to limited land, long commute times, and the high office rental price, the office concept combined with living has grown (Nahor et al., 2023). Often known by the term small office home office (SOHO), loft office users are commonly people who run businesses with small numbers of workers and flexible types of work (Nahor et al., 2023). Surabaya, one of the cities in the Tropics, has loft concept buildings, such as Ciputra World Surabaya Vie Loft SOHO, Satoria Tower, Cornell Apartment and SOHO (Figure 3).

Defined by its open-plan configuration and minimal partitions, the loft design allows access to daylight inside the occupied space (Kliczkowski, 2005). The open-plan layout with tall ceilings and expansive windows creates the impression of living in a far bigger space than its actual size (Erinanc, M, 2020). Having a high-glazed facade, buildings in the tropics can benefit from daylighting and provide a full external view but also face excessive solar radiation and glare problems (Lim & Heng, 2016). Office buildings studied in Indonesia by Dinapradipta (2015) predominantly have open-plan workspaces positioned directly near the side window. The determination of proper shading devices on high-glazed facade design in loft offices in the tropics is important, as it can provide a balance between daylight level and minimize glare.

Previous studies on perforated screen facades (PSF) have mainly focused on single-story office buildings and residential homes featuring glass facades between 2.7 and 3 meters in height. This research, however, explores loft-style office spaces characterized by mezzanine floors, high ceilings, and fully glazed facades (Figure 1). It examines annual daylight intensity and glare on the first and mezzanine floors. Identifying the optimum perforation percentages to achieve sufficient daylight while minimizing glare in loft offices is important. The research aims to evaluate the annual daylight intensity and glare of perforated screen facades in loft offices in the tropics. Furthermore, this study determines the optimum perforation percentages of PSF that provide adequate daylight intensity and minimal glare in loft offices in the tropics.

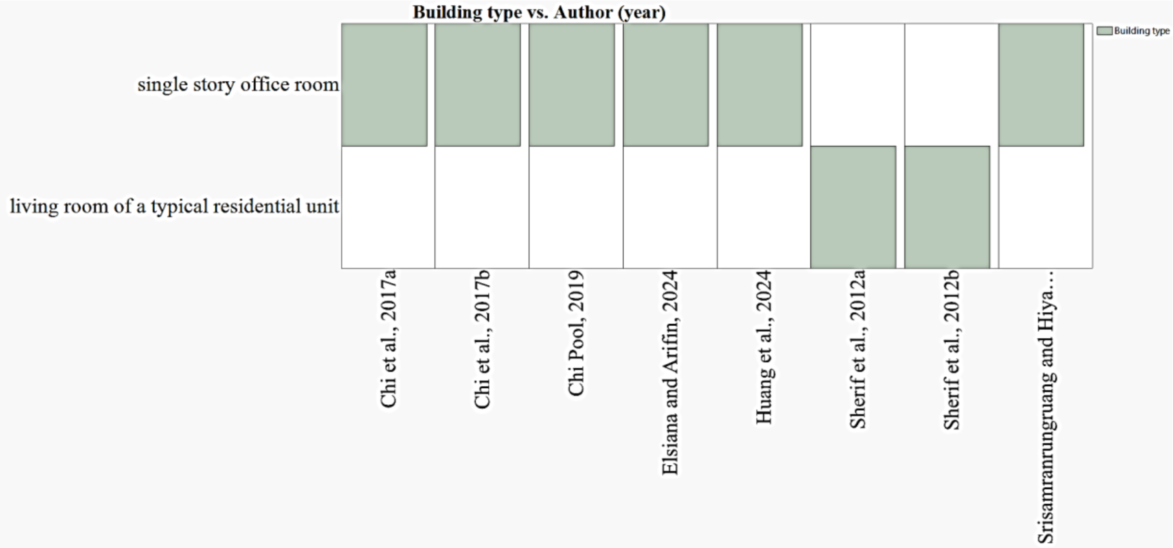


Fig.2. Building Types Examined in Previous Research on Perforated Screen Facades


(a) (b) (c)
(d) (e)

Fig.3. Some loft office buildings in Surabaya (a) Ciputra World Surabaya Vie Loft SOHO (b) Satoria Tower (c) exterior Cornell Apartment and SOHO (adapted from https://www.google.com/maps/place/) (d) interior of Ciputra World Surabaya Vie Loft SOHO (e) interior of Cornell Apartment and SOHO (https://citralandsurabaya.com/soho-cornell-corner/)

METHODS

The study employed an experimental approach using simulation as a tool. Climate Studio was used to simulate annual daylight performance. It is an upgraded version of Diva-for Rhino based on a validated simulation engine, Energy Plus, and Radiance ray-tracing engines (Sollema, 2025). The accuracy of Climate Studio has been validated in previous research by Aguilar-Carrasco et al., 2023, with a relative error under ±10%. A previous study by Sui et al., 2023 also validated the accuracy of Climate Studio by comparing the field illumination measurement with simulation and gave error values of less than 20%. It generates validated daylighting and glare performance simulations and is extensively utilized in daylighting research (Aguilar-Carrasco et al., 2023; Sui et al., 2023).

The annual daylight performance metrics analyzed in this study include useful daylight illuminance (UDI) and spatial disturbing glare (sDG). The simulation uses a Typical Meteorological Year (TMY) 2007-2021 weather file from www.climate.onebuilding.org, in the Climate Studio Location setting. This TMY file contains hourly data for various weather parameters like diffuse and direct solar radiation, humidity, windspeed and direction, temperature (Abdelhamid et al., 2023). The climate file used corresponds to Surabaya Juanda International Airport, located at latitude 7.2ºS and longitude 112ºE, which features a warm, humid tropical climate. Figure 4 illustrates the sun path diagram for Surabaya.

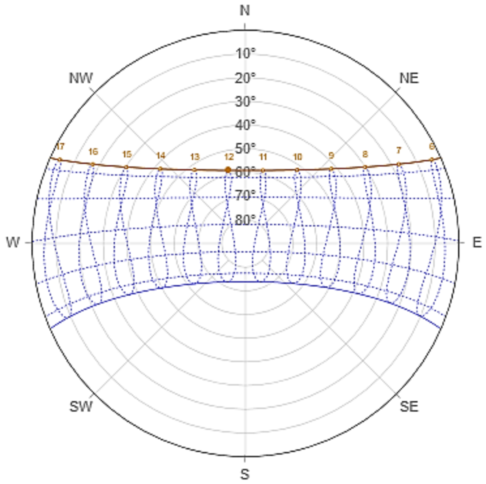
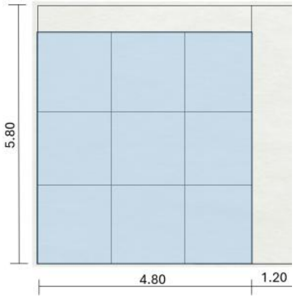
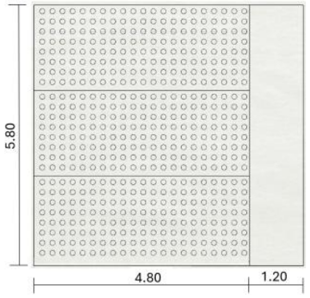
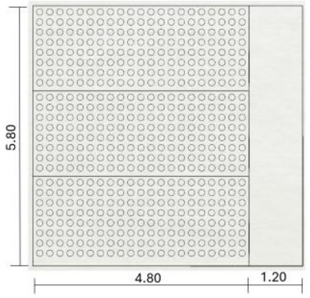
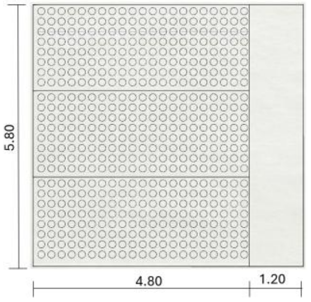


Fig.4. Sun path diagram of Surabaya

Experimental Ccheme

The annual daylight performance of the base case, a loft office with a fully glazed facade in the tropics, was compared with a loft office featuring a fully glazed facade and a perforated screen facade with varying perforation percentages. The evaluation of annual daylight performance was conducted for both the first and mezzanine floors. Case 1, Case 2, and Case 3 represent loft offices with PSF perforation percentages of 20%, 30%, and 40%, respectively (Table 1).

Table 1. The Description of Base Case and Cases

Base Case	Case 1	Case 2	Case 3
			
Loft office with full glazed facade	Loft office with full glazed facade and Perforated Screen Façade with Perforation percentage of 20%	Loft office with full glazed facade and Perforated Screen Façade with Perforation percentage of 30%	Loft office with full glazed facade and Perforated Screen Façade with Perforation percentage of 40%

Perforation percentages between 20% and 40% were selected based on the orientation of the glazed facade, which faces west. Higher perforation percentages allow more daylight penetration, whereas lower percentages provide better solar shading (Elsiana & Arifin, 2024). Balancing daylight levels and reducing glare between areas near the glazed facade on the first floor and those farther away on the mezzanine is crucial. A previous study conducted in a non-tropical region of Japan recommends a 30% perforation percentage for west-facing facades to optimize daylight access while mitigating glare (Srisamranrungruang & Hiyama, 2021). This study evaluates the annual daylight performance of PSF with different perforation percentages and determines the optimum PSF perforation percentages for achieving sufficient daylight intensity and minimal glare in a loft office in the tropics.

Simulation Setup

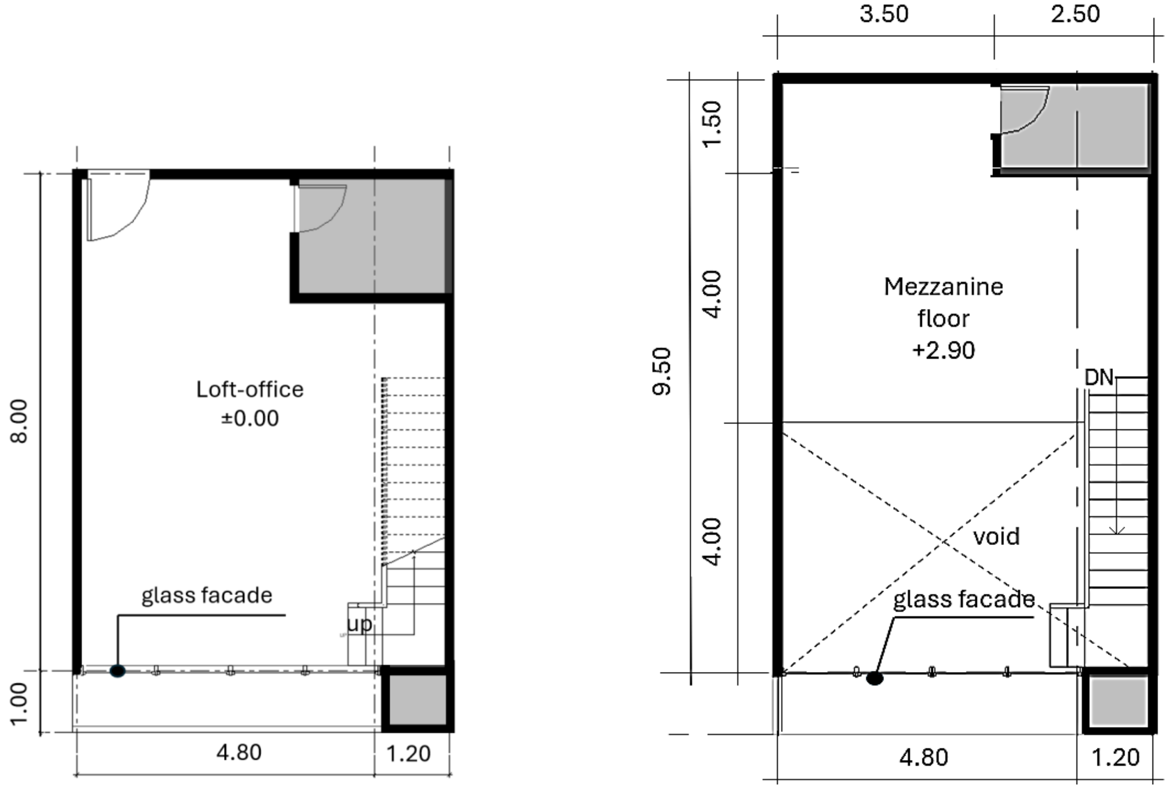
The loft office measures 6 meters in width, 5.8 meters in height, and 8 meters in depth. A mezzanine floor is positioned 2.9 meters above the first floor, located 4 meters from the glazed facade, with a depth of 5.5 meters. The service area, including the bathroom and shaft, was excluded from the annual daylight performance simulation. Figure 5 presents the loft office plan, illustrating the first and mezzanine floors. Figure 6 shows the section of the loft office. The loft office model was built using Rhinoceros 8.

The loft office features a side window measuring 4.8 meters in width and 5.2 meters in height, with a window-to-wall ratio of 80%. The west-facing glazed facade was analyzed to assess the effectiveness of the perforated screen facade (PSF) as a shading device in a tropical loft office. The window material used in the loft office is tinted glass with a visible transmittance of 46%.

The side window is positioned on the west facade to simulate a worst-case scenario. In tropical regions, unlike non-tropical areas, facade optimization should extend beyond the equator-facing direction and consider all four cardinal orientations, with particular attention to the east and west facades (Aritonang et al., 2025). With a west-facing orientation, direct sunlight at low solar altitude angles enters through the side window, particularly in the late afternoon. The material properties of the loft office's interior surfaces are presented in Table 2.

The perforated screen facade was positioned 1 m from the glazed facade. It measures 4.8 meters in width and 5.8 meters in height. The detailed specifications of the interior surface materials for the model are outlined in Table 2. The study examines PSF perforation ratios of 20%, 30%, and 40% with circular apertures. The diameters of the PSF apertures are 0.12 meters, 0.14 meters, and 0.16 meters for perforation percentages of 20%, 30%, and 40%, respectively. The spacing between each PSF aperture remains constant at 0.225 meters.

The work plane height is 0.8 meters above the floor, with a grid spacing of 0.5 × 0.5 meters. A total of 96 and 57 test points were uniformly distributed across the work planes of the first and mezzanine floors, respectively. The simulation analyzed room occupancy hours from 8:00 a.m. to 6:00 p.m. For glare assessment, spatial disturbing glare (sDG), the view plane was set at a height of 1.20 meters above the floor, with the field of view segmented into eight equal sections and a fixed view rotation of 0°



(a) (b)

Fig. 5. Loft Office Plan (a) 1st Floor (B) Mezzanine Floor

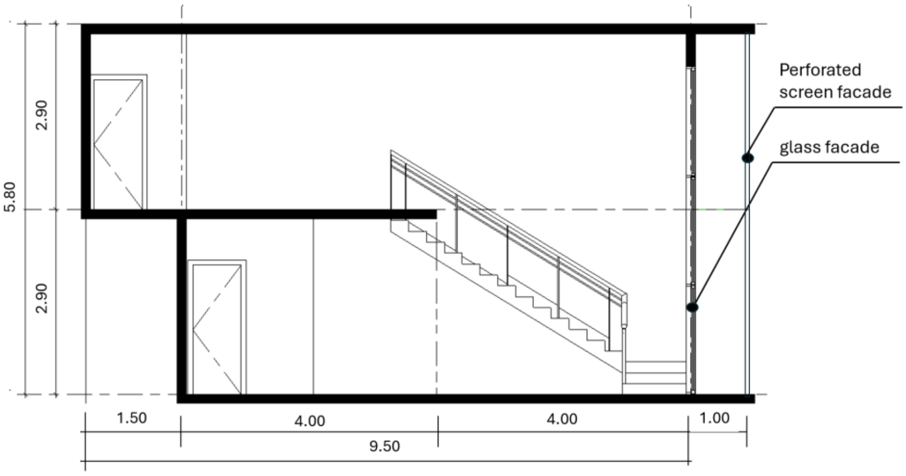


Fig. 6. Loft office Section

Table 2. Material Characteristics of Loft Office and Perforated Screen Facade

Elements	Material	Reflectance (%)	Roughness	Visible Light Transmittance (%)
Ceiling	white ceiling	85.67	0.20	0
Floor	ceramic tile floor	39.05	0.2	0
Side window	tinted glass	8.1	N/A	46
Glass railing	clear glass laminated	7	N/A	88
Exterior floor	grey concrete	39.98	0.3	0
Perforated Screen Facade	white paint finish	89.89	0.2	0

Annual Daylight Performance Metrics

Frequently utilized static metrics, such as the Daylight Factor (DF), average Daylight Factor (DFavg), and Point-in-Time Illuminance (Ep), provide insight into lighting conditions. However, due to variables like solar movement, seasonal shifts, and changing weather patterns, these metrics alone cannot adequately capture the dynamic fluctuations of daylight throughout the year (Bodart et al., 2008). This research then employs annual daylight performance metrics, including useful daylight illuminance and spatial disturbing glare.

Useful daylight illuminance (UDI) represents the proportion of working hours during which the desired illuminance at a specific location is met using only daylight. With a useful illuminance range of 100 to 3000 lx, this metric is defined as follows (Mangkuto et al., 2024):

$$\mathrm{UDI}_{100\sim3000} = \frac{t_{\mathrm{E}=100\sim3000}}{T} x100\% \qquad (1)$$

Where t_E=100-3000 represents the duration during which the test point receives daylight illuminance between 100 and 3000lx, while T denotes the total working hours. The requirement for $\mathrm{UDI}_{100\text{-}3000\mathrm{lx}}$ is more than 80% (Brembilla & Mardaljevic, 2019; Mangkuto et al., 2024). UDI can be divided into UDI-f (fell-short/failing, <100lx), UDI-s (supplementary, 100-300lx), UDI-a (autonomous, 300-3000lx), and UDI-e (excessive, >3000lx).

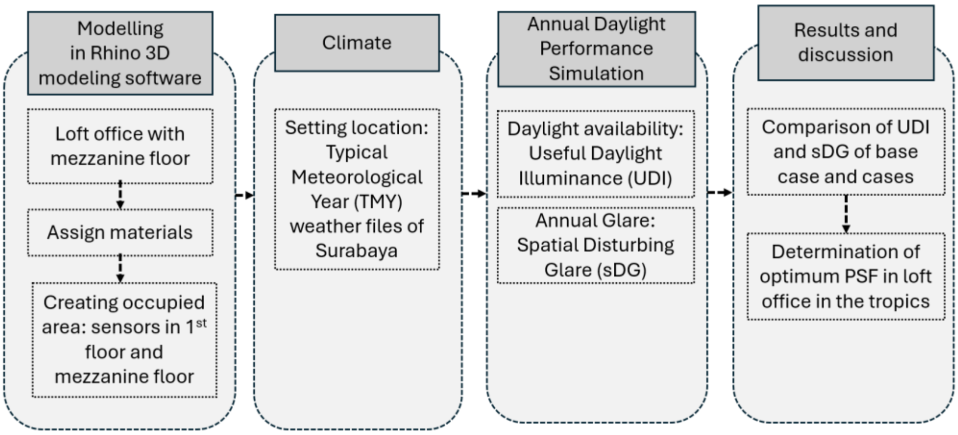


Fig. 7 Scheme of Research Method: Annual Daylight Performance Simulation Procedure, Results and Discussion

Spatial disturbing glare (sDG) represents the proportion of views within the regularly occupied floor area that encounter disturbing or intolerable glare for at least 5% of the occupied hours. The sDG is determined using daylight glare probability (DGP), which assesses the likelihood of an occupant feeling discomfort due to glare. DGP is based on vertical eye illuminance across the entire scene and its relationship to specific glare sources in the environment (Wienold & Christoffersen, 2006). The level of DGP can be divided into four categories: imperceptible glare (≤0.34), perceptible glare (0.34-0.38), disturbing glare (0.38-0.45), and intolerable glare (>0.45). Figure 7 shows the research method scheme, including the annual daylight performance simulation procedure, results, and discussion.

RESULTS AND DISCUSSION

This study evaluates the annual daylight performance of perforated screen facades (PSF) in loft offices in the tropics. The daylight availability was assessed using useful daylight illuminance (UDI), while the glare was measured using spatial disturbing glare (sDG). The study also determined the optimum PSF perforation percentages for achieving sufficient daylight intensity and minimal glare in a loft office in the tropics.

Useful Daylight Illuminance of Loft-Office with PSF

Figure 8 illustrates the UDI$_{100-3000lx}$ for the base case and cases. Figure 9 presents the UDI-f (fell-short/failing, <100lx), UDI-s (supplementary, 100-300lx), UDI-a (autonomous, 300-3000lx), and UDI-e (excessive, >3000lx) for both the base case and cases. The simulation results indicate that the first floor of the loft office with a fully glazed facade in a tropical climate had the lowest UDI$_{100-3000lx}$ and the highest UDI-e. Even with tinted glass featuring 46% visible light transmittance (VLT), the UDI-e level inside the room remained high, reaching 27.13%, while UDI$_{100-3000lx}$ was 69.43%, falling short of the minimum requirement of 80%.

Without shading, a loft office with a fully glazed facade in a tropical climate experiences a high proportion of occupied hours during which excessive illuminance may result in visual and thermal discomfort, particularly in areas near the glazed facade. In alignment with Papinutto et al. (2022), a fully glazed facade without proper shading can lead to excessive daylight levels.

In the base case, the mezzanine floor was located 4 meters from the glazed facade, achieving a UDI$_{100-3000lx}$ of 96.5%. This UDI$_{100-3000lx}$ value met the recommended UDI$_{100-3000lx}$ of more than 80%. Additionally, the mezzanine floor in the base case exhibited low UDI-e, with a value of 0.01%.

A loft office equipped with a Perforated Screen Facade (PSF) featuring 20%, 30%, and 40% perforation percentages achieved UDI$_{100-3000lx}$ values above 80% and fulfilled the requirement for UDI$_{100-3000lx.}$ A PSF perforation percentage of 20% (Case 1) resulted in UDI$_{100-3000lx}$ values of 92.73% and 86.73% for the first and mezzanine floors, respectively. A PSF perforation percentage of 30% (Case 2) achieved UDI$_{100-3000lx}$ values of 92.26% and 91.82% for the first and mezzanine floors, respectively. In comparison, a PSF perforation percentage of 40% (Case 3) yielded UDI$_{100-3000lx}$ values of 91.19% and 93.35% for the first and mezzanine floors, respectively.

On the first floor, the loft office with a PSF perforation percentage (PP) of 20% exhibited the highest UDI$_{100-3000lx}$, reaching 92.73%. The area near the glazed facade on the first floor of the loft office with PSF experienced a lower UDI-e compared to the base case, thereby increasing UDI$_{100-3000lx}$. The reduction in UDI-e on the first floor with PSF PP 20%, 30%, and 40% was significant, reaching 90.36%, 84.82%, and 79.83%, respectively.

The integration of PSF improves UDI$_{100-3000lx}$ on the first floor of the loft office. The increase in UDI$_{100-3000lx}$ was 33.56%, 32.88%, and 31.34% for PSF PP 20%, 30%, and 40%, respectively. These results showed the PSF's role in reducing UDI-e in areas adjacent to the glazed facade. The findings align with the previous research of Sherif et al. (2012a), which demonstrated that a smaller PP results in lower daylight levels and over-lit areas. Implementing PSF on the glazed facade of the loft office enhances daylight performance by minimizing UDI-e and increasing UDI$_{100-3000lx}$.

PSF's incorporation also reduced UDI$_{100-3000lx}$ in the area beneath the mezzanine floor, located 4 meters from the glazed facade. PSF with PP of 20%, 30%, and 40% reduced the UDI-a by 62%, 28%, and 12% sequentially. A higher PSF perforation percentage is needed to achieve higher UDI-a in areas farther from the glazed facade. The mezzanine floor provides a shading effect to the area beneath it, resulting in a lower daylight intensity.

For the mezzanine floor, the loft office, with a PSF perforation percentage of 40%, exhibited the highest UDI$_{100-3000lx}$, reaching 92.73%. The base case and all cases demonstrated high UDI$_{100-3000lx}$ values on the mezzanine floor, measuring 96.5%, 86.73%, 91.82%, and 93.35% for the base case, Case 1, Case 2, and Case 3, respectively. The mezzanine floor, located 4 to 9.5 meters from the glazed facade, maintained a low UDI-e value of 0.01% across all cases.

Implementing PSF on the glazed facade did not affect the UDI-e value on the mezzanine floor. Instead, UDI$_{100-3000lx}$ fluctuations were primarily influenced by UDI-f. The integration of PSF on the glazed facade increased UDI-f on the mezzanine floor due to the shading effect of PSF with varying perforation percentages, leading to lower daylight levels in the mezzanine area. Compared to the base case, PSF integration increased UDI-f on the mezzanine floor by 280%, 134%, and 90% in Case 1, Case 2, and Case 3, respectively.

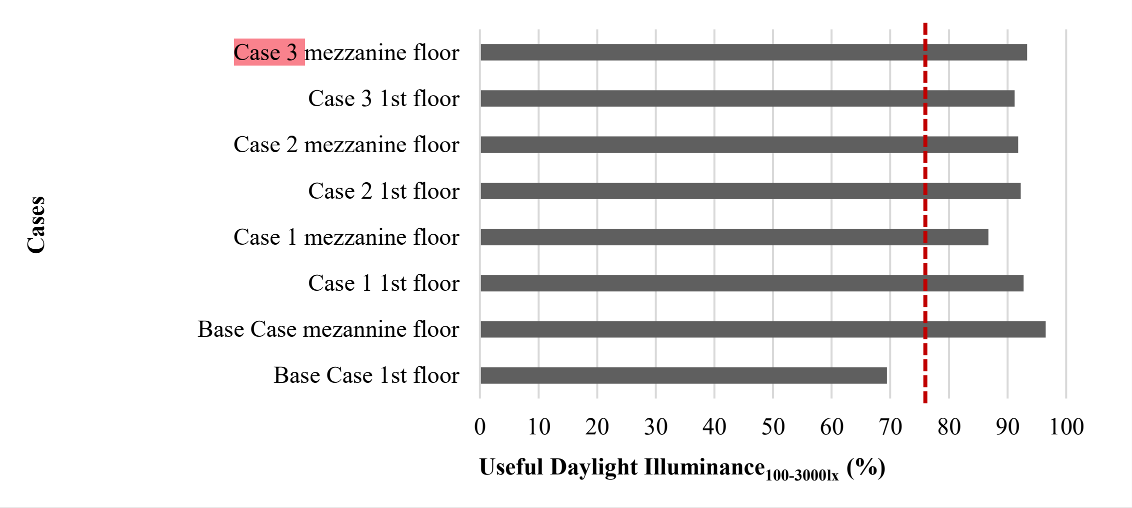
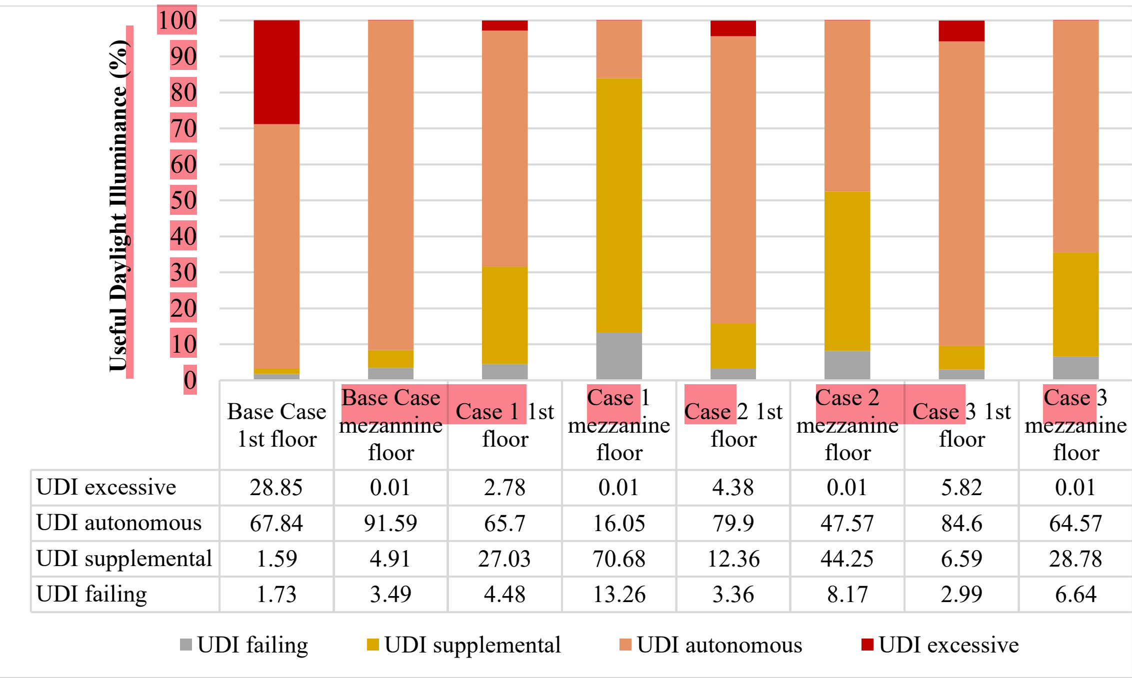


Fig. 8. Useful Daylight Illuminance$_{100\text{-}3000lx}$ of Perforated Screen Facade in Loft Office



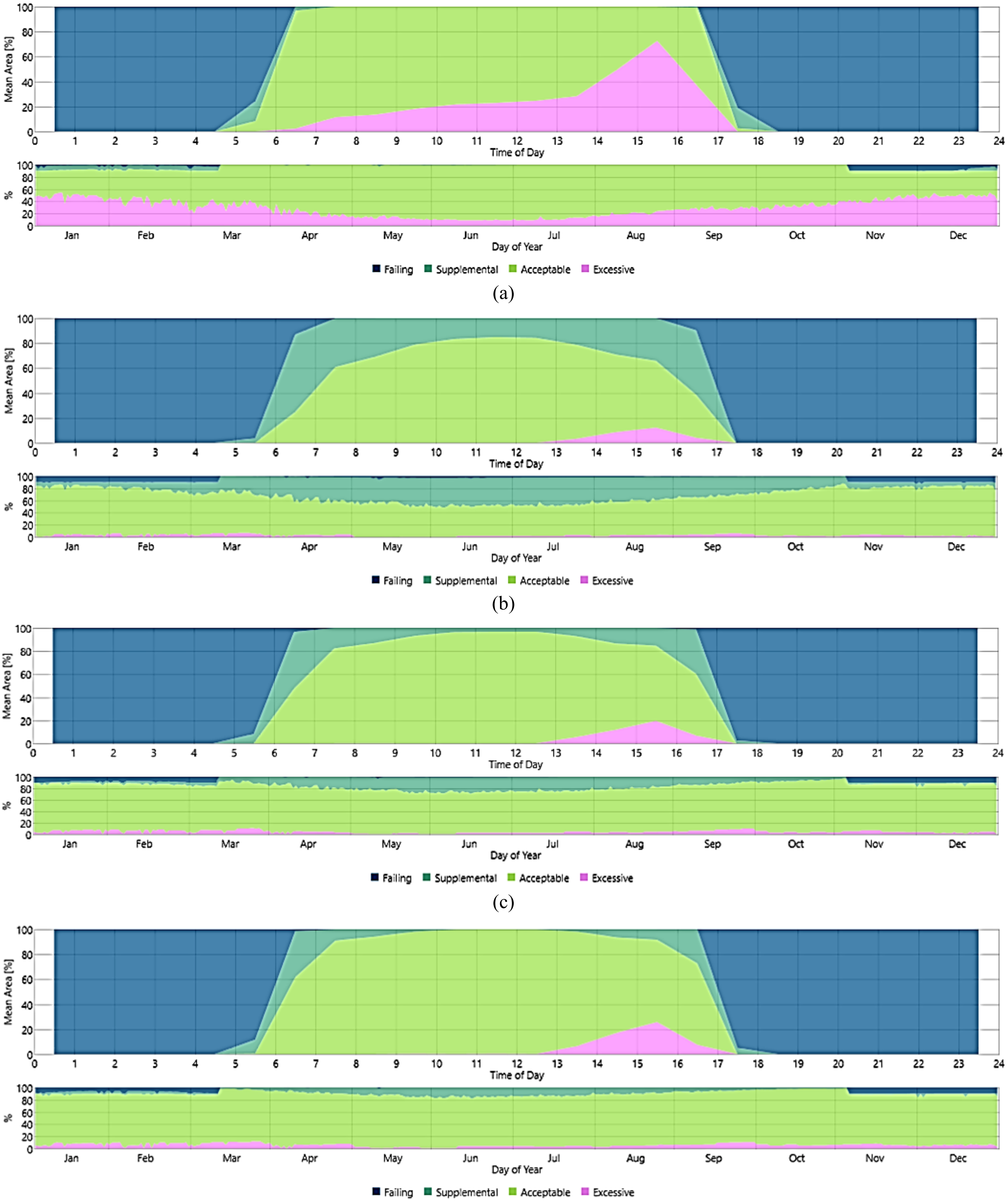
	Base Case 1st floor	Base Case mezannine floor	Case 1 1st floor	Case 1 mezzanine floor	Case 2 1st floor	Case 2 mezzanine floor	Case 3 1st floor	Case 3 mezzanine floor
UDI excessive	28.85	0.01	2.78	0.01	4.38	0.01	5.82	0.01
UDI autonomous	67.84	91.59	65.7	16.05	79.9	47.57	84.6	64.57
UDI supplemental	1.59	4.91	27.03	70.68	12.36	44.25	6.59	28.78
UDI failing	1.73	3.49	4.48	13.26	3.36	8.17	2.99	6.64

Fig. 9. The Useful Daylight Illuminance of Perforated Screen Façade in Loft-Office

Figure 10 presents the temporal graph of UDI throughout the day and year for the first floor of a loft office with a glazed facade (base case) and a loft office with a glazed facade incorporating PSF with 20% perforation percentages (Case 1). The UDI temporal graph indicates that UDI-e on the first floor of the base case peaks in the late afternoon (3:30 PM) due to the west-facing orientation of the glazed facade. The UDI-e on the first floor of the base case was also high, reaching more than 20% for most of the year, except in May, June, and July. In contrast, the UDI-e profile for the first floor of the loft office with PSF 20% perforation (Case 1) demonstrates a more controlled daylight distribution, with UDI-e never exceeding 20% at any point during the year. Figure 10 highlights the effectiveness of PSF in mitigating UDI-e on the first floor, thereby improving UDI$_{100\text{-}3000lx}$ levels. The findings also showed that increasing the PSF perforation percentage results in higher UDI-a and UDI-e while reducing UDI-f and UDI-s on the first floor of the loft office.

Figure 11 illustrates the temporal UDI graph for both the mezzanine floor of the base case and cases for a day and year. UDI-e does not occur on the mezzanine floor since its location is 4 m from the glazed facade. The base case maintains higher UDI-a values throughout the year than Case 1, whereas Case 1 exhibits higher UDI-f and UDI-s levels than the base case.

These results indicate that PSF implementation effectively reduces illuminance levels in areas farther from the side window, specifically on the mezzanine floor, situated 4 to 9.5 meters from the glazed facade. The findings suggest that increasing the PSF perforation percentage results in higher UDI-a while reducing UDI-f and UDI-s on the mezzanine floor. Moreover, UDI-e remains consistent across all cases throughout the year, demonstrating that PSF integration on the glazed facade does not impact UDI-e levels on the mezzanine floor.



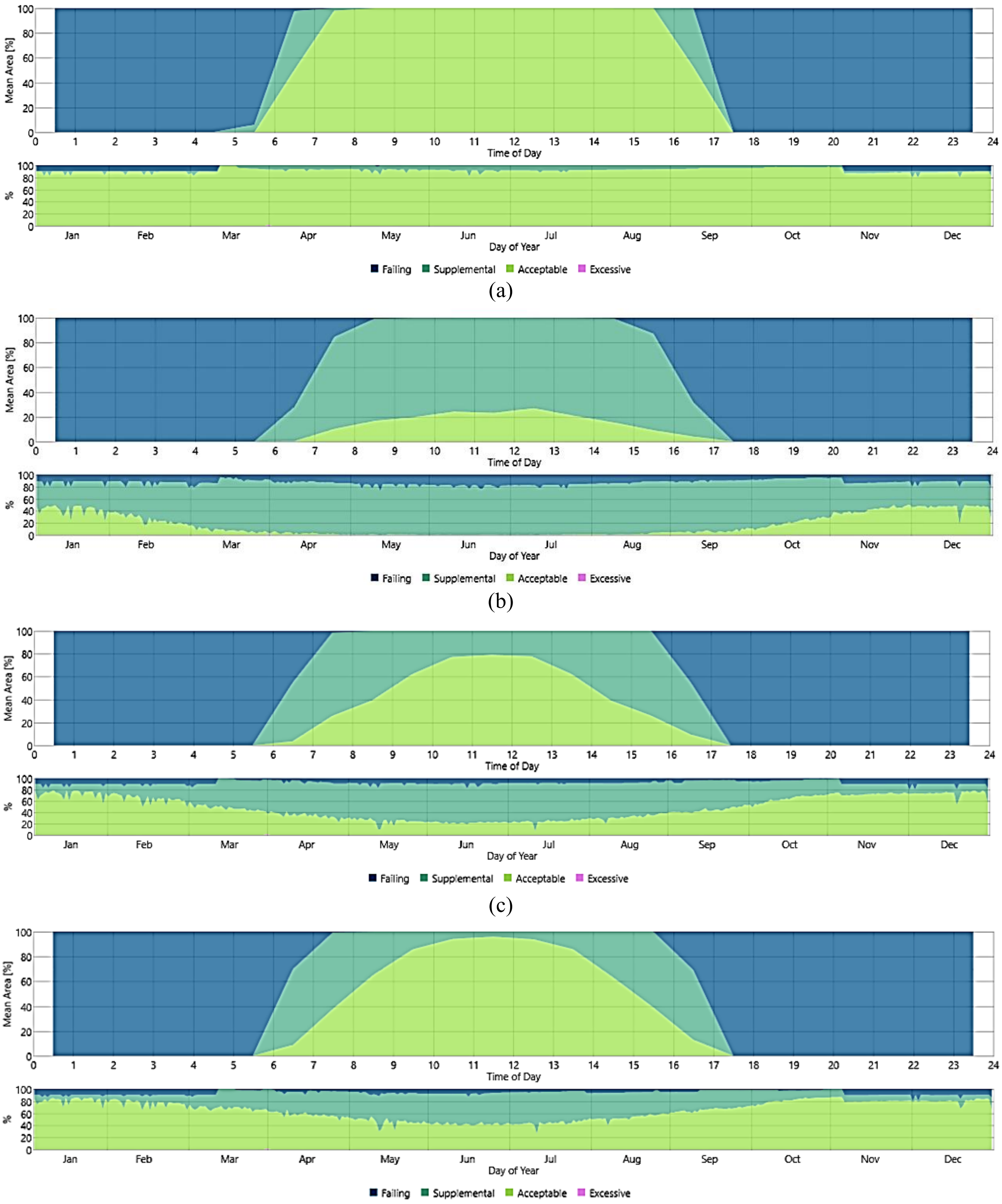
(a)

(b)

(c)

(d)

Fig. 10. The Temporal Graph of Useful Daylight Illuminance of First Floor of Loft Office with (A)Glazed Facade and Glazed Facade and Perforated Screen Facade with Perforation Percentages of (b) 20% (c) 30% and (d) 40%



(a)

(b)

(c)

(d)

Fig. 11. The temporal graph of Useful Daylight Illuminance of mezzanine floor of loft office with (a)glazed facade and glazed facade and perforated screen facade with perforation percentages of (b) 20% (c) 30% and (d) 40%

Spatial Disturbing Glare of Loft-Office with PSF

Table 3 presents the useful daylight illuminance (UDI) and spatial disturbing glare (sDG) for the base case and cases on the first and mezzanine floors. Figure 12 illustrates the temporal variation of spatial disturbing glare (sDG) for the base case and tested cases on the first floor. The simulation results indicate that the first floor in the base case exhibited the highest sDG, reaching 56.77%. In the base case, the occurrence of disturbing and intolerable glare was 4% and 14%, respectively. The occurrence of both disturbing and intolerable glare was more pronounced in the afternoon due to the west-facing glazed facade. All test points on the first floor of the base case experienced disturbing and intolerable glare. Without shading, offices with fully glazed facades in tropical regions face significant glare issues, aligning with the findings of Lim and Heng (2016).

The first floor of a loft office incorporating PSF with a 20% perforation percentage (PP) exhibited the lowest sDG, measuring 10.81%. The sDG for other cases, loft offices with PSF PP 30% and 40% were 28.12% and 35.42%, respectively. These results demonstrate that the integration of PSF significantly reduces sDG on the first floor, with reductions of 80.96%, 50.47%, and 37.61% for PSF PP 20%, 30%, and 40%, respectively.

The occurrence of intolerable and disturbing glare on the first floor of a loft office equipped with PSF PP 20% (Case 1) was significantly lower than in the base case (Figure 12). In Case 1, the occurrence of disturbing and intolerable glare was 0% and 2%, respectively. A similar trend was observed in loft offices equipped with PSF PP 30% and 40%, where the occurrence of disturbing glare and intolerable glare was 0% and 3% in Case 2 and 1% and 4% in Case 3, both of which were lower than in the base case. These results align with the previous research of Sherif et al. (2012a) on the effectiveness of PSF in reducing glare in non-tropical areas, extending these findings to tropical climates.

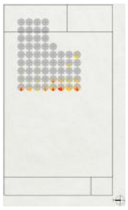
Figure 13 illustrates the relationship between PSF perforation percentages and spatial disturbing glare on the first floor of the loft office. The results indicate that smaller perforation percentages correspond to lower sDG levels. In tropical climates, glare reduction is important since glare inside a space often leads occupants to close the glazed facade with internal shading, thereby increasing reliance on electric lighting (Lim & Heng, 2016).

Positioned 4 to 9.5 meters from the glazed facade, the mezzanine floor maintained a low sDG. The base case recorded an sDG of 1.1%, while loft offices with PSF exhibited an sDG of 0%. Additionally, no disturbing or intolerable glare occurrences were observed across all cases, including the base case.

Optimum PSF for Useful Daylight Illuminance and spatial Daylight Glare

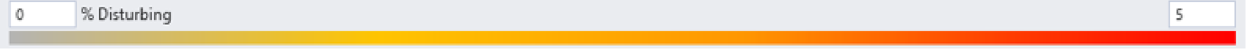
Given the importance of glare reduction in the tropics, a loft office with a PSF perforation percentage of 20% was selected as the optimum configuration for UDI$_{100-3000lx}$ and spatial disturbing glare. The loft office equipped with PSF PP 20% exhibited UDI$_{100-3000lx}$ values of 92.73% and 86.73% on the first and mezzanine floors, respectively. Additionally, it recorded the lowest sDG among all cases, measuring 10.81% on the first floor and 0% on the mezzanine floor.

Table 3. Annual Daylight Performance of Cases

Annual Daylight Performance	**Base case (loft office with full glazed facade)**		**Case 1 (loft office with full glazed facade and perforated screen facade PP 20%)**		**Case 2 (loft office with full glazed facade and perforated screen facade PP 30%)**		**Case 3 (loft office with full glazed facade and perforated screen facade PP 40%)**	
	1st floor	Mezzanine floor	1st floor	Mezzanine floor	1st floor	Mezzanine floor	1st floor	Mezzanine floor
Useful daylight illuminance $_{100-3000lx}$ (%)								
	69.43	96.5	92.73	86.73	92.26	91.82	91.19	93.35
Spatial disturbing glare (%)								
	56.77	1.1	10.81	0	28.12	0	35.42	0

Useful daylight illuminance:

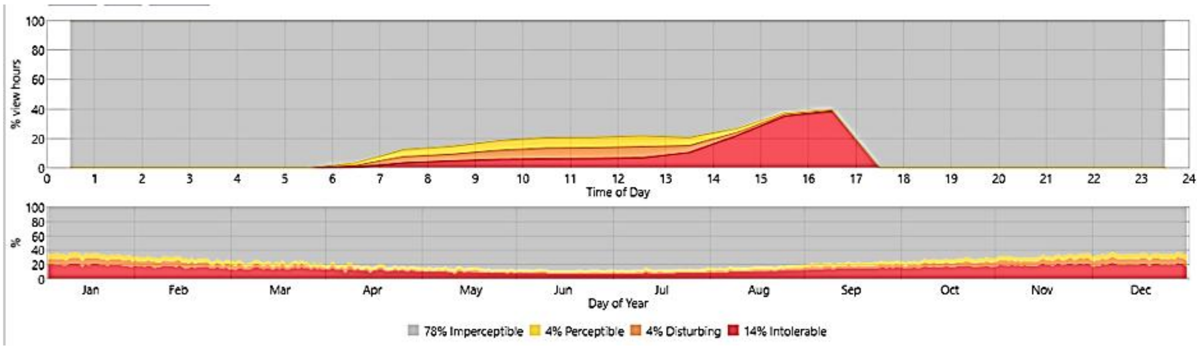
Spatial disturbing glare:



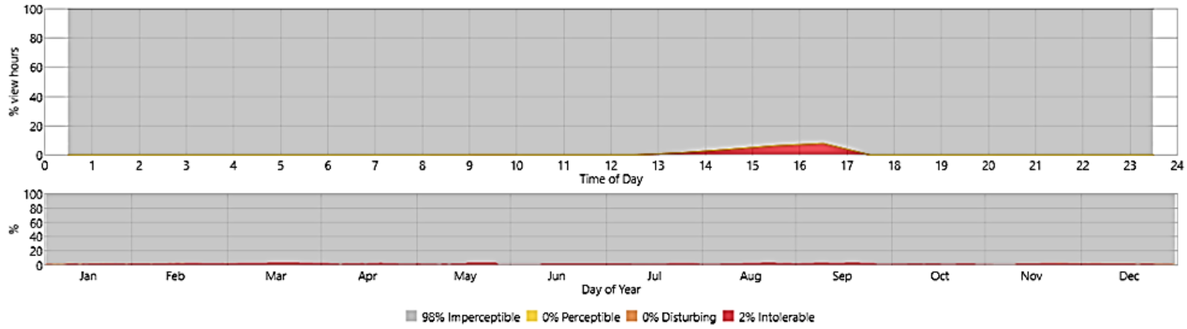
The previous study by Srisamranrungruang and Hiyama (2021) recommends a PSF perforation percentage of 30% for west-facing façades in non-tropical regions of Japan to optimize daylight level while mitigating glare. In tropical climates, where daylight intensity is high throughout the year, glare reduction becomes critical and demands a lower PSF perforation percentage to achieve optimal daylight intensity and glare reduction. Based on the findings of this research, a PSF perforation percentage of 20% was determined to be the most effective in tropical conditions.

The first and mezzanine floors of the loft office have different daylighting needs for achieving optimum daylighting performance. The first-floor area near the glazed facade requires protection using a PSF with a smaller perforation percentage (PP) to mitigate glare due to its west-facing orientation. On the other hand, the mezzanine floor, which is positioned farther from the glazed facade, does not experience significant glare issues and can accommodate a larger perforation percentage for optimizing UDI.

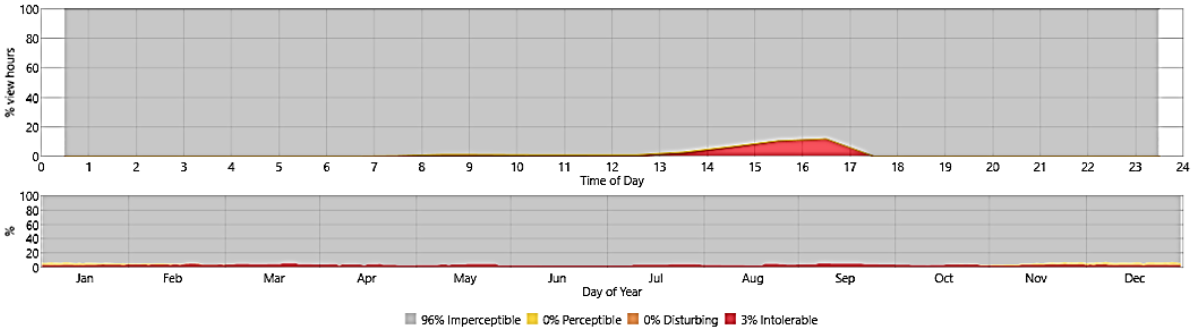
Given the varying UDI and sDG trends between the first and mezzanine floors in loft offices, PSF in a loft office in the tropics can feature different perforation percentages for the upper section, aligned with the mezzanine floor and the lower section, aligned with the first floor, to achieve maximum $UDI_{100\text{-}3000lx}$ and minimum sDG.



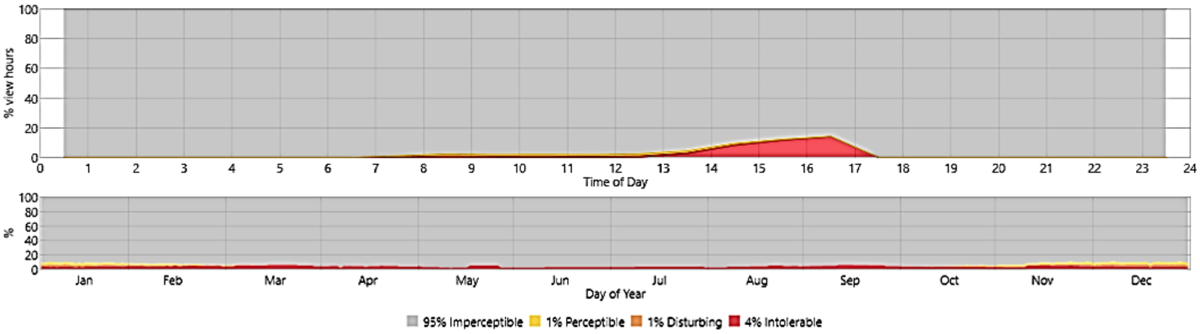
(a)



(b)



(c)



(d)

Fig. 12. Temporal Graph of Spatial Disturbing Glare of Loft Office with (a) Full Glazed Façade (b) and Perforated Screen Façade 20% (c) Perforated Screen Façade 30% (d) Perforated Screen Façade 40%

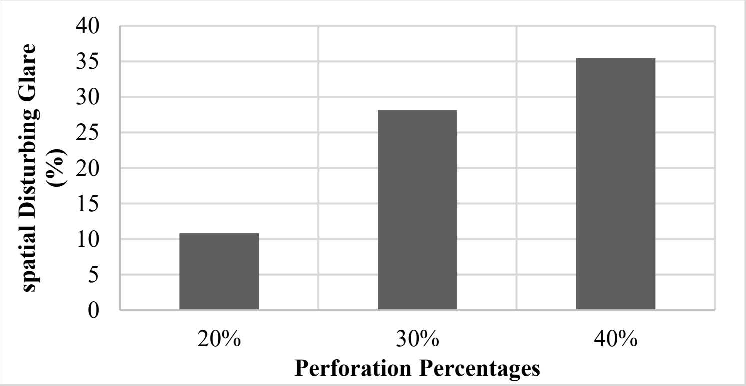


Fig. 13. The Relationship of Perforation Percentages of Perforated Screen Facade and spatial Disturbing Glare

CONCLUSION

In loft offices in the tropics with fully glazed facades and no shading, a significant portion of occupied time is exposed to excessive illuminance, which can cause visual and thermal discomfort, particularly in areas close to the glazed facade. The integration of PSF reduces UDI excessive and spatial disturbing glare while providing higher $UDI_{100\text{-}3000lx}$ in areas near the glazed facade.

Compared to a loft office with a fully glazed facade, the reduction of UDI excessive was significant, ranging from 79.83% to 90.36% with PSF PP 20–40%. The improvement in $UDI_{100\text{-}3000lx}$ reached 31.34% to 33.56% on the first floor, with PSF PP 20-40%. Similarly, the reduction in sDG on the first floor of the loft office was notable, reaching 80.96% to 37.61% for PSF PP 20% to 40%, respectively. The mezzanine floor in the loft office exhibited low UDI excessive and high $UDI_{100\text{-}3000lx}$. Located 4 to 9.5 meters from the glazed facade, the mezzanine floor area also maintained low sDG values.

Given the importance of glare reduction in tropical climates, a loft office with a PSF perforation percentage of 20% was identified as the optimum configuration for annual daylight performance. Since UDI and sDG trends differ between the mezzanine and first floors, PSF in tropical loft offices can be designed with varying perforation percentages (PP) for the upper and lower sections, ensuring optimal $UDI_{100\text{-}3000lx}$ and sDG performance.

Future research could focus on assessing the daylight performance of PSF with different perforation percentage (PP) configurations on facades, including optimizing PSF for improved daylight performance in loft offices in the tropics. Additionally, an analysis of user perceptions regarding the implementation of PSF in loft offices could be conducted.

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