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The impact of the inclination angle of perforated screen facade on daylight performance in the tropics

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Abstract
Daylighting is one of the fundamental aspects of green building principles. Utilizing daylighting in a building offers numerous benefits, including energy efficiency, enhanced comfort, improved workplace productivity, better health, and increased economic value. However, buildings with glazed facades can experience excessive illuminance, uneven daylight distribution, and glare without proper shading devices. Perforated screen facade (PSF) is one of the shading devices widely used in buildings with glass facades. PSF minimizes direct solar radiation and enhances daylighting performance while preserving outdoor views. This study focused on one design variable of PSF, the inclination angle, which had not been widely explored in previous research within the context of a tropical climate. The research aimed to evaluate the impact of the PSF inclination angle on daylight performance. The research method was experimental, using radiance-based simulation as a tool. The daylight availability and visual comfort of office buildings with vertical PSF were compared with inclined PSF. The daylight performance metrics analyzed included mean illuminance, useful daylight illuminance, and spatial disturbing glare. The results indicated that implementing an inclined PSF resulted in mean illuminance ranging from 1065 to 1105 lx, useful daylight illuminance between 95.08% and 95.55%, and spatial disturbing glare between 5.1% and 6.5%. Increasing the PSF inclination angle raises the mean illuminance and spatial disturbing glare and reduces the useful daylight illuminance. PSF can be applied with an inclination angle to buildings in the tropics, providing broader possibilities for facade design exploration.

Keywords:
Green building;
Mean Illuminance;
Regression;
Spatial disturbing glare;
Useful daylight illuminance;

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INTRODUCTION

Daylighting is an essential component of green building strategies (Figure 1). The Leadership in Energy and Environmental Design (LEED) certification recognizes and rewards buildings that provide excellent access to daylight [1]. LEED rating systems award credits for daylighting in categories including daylight and views (indoor environmental quality) and optimizing energy performance (energy and atmosphere). Proper daylighting strategies improve comfort and a healthy environment for building occupants [2], visual quality [3], and reduce building energy consumption [4][5].

Using daylight in buildings offers numerous advantages for occupants, including improved energy efficiency, enhanced comfort, health, and higher economic value. Regarding energy efficiency, daylighting reduces the energy use for electric lighting, the total energy consumption [2, 6, 7], and lowers cooling demands [8]. This reduction is crucial, since electric lighting accounts for 25-40% of a building's total energy consumption [9].

Regarding human comfort, daylight is the best light source for enhancing visual performance [10]. It introduces diverse visual effects, significantly enhancing the comfort of the indoor

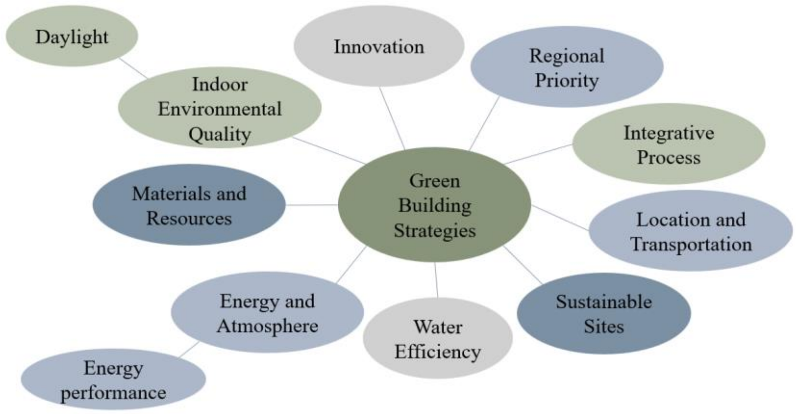


Figure 1. Daylighting as One Strategy in Green Building, Adapted from Leadership in Energy and Environmental Design (LEED)v4.1 Building Design and Construction Scorecard

lighting atmosphere [2]. Building occupants prefer natural lighting in the living and working environments. Additionally, daylight is essential for human health, since it stimulates the production of serotonin and melatonin, hormones that help regulate the body's circadian rhythm [10][11].

Buildings should allow occupants to receive sufficient sunlight exposure, facilitating vitamin D synthesis in the skin [12]. Another important aspect of daylighting is its economic value. Tenants tend to spend 5–6% more for office spaces that receive high daylight compared to those with limited daylight [1].

The tropics have significant potential for daylight utilization due to consistently available sunlight throughout the year and relatively stable sunshine duration [13]. Studies have shown that intermediate sky conditions possess the highest probability of occurrence in the tropics [14]. In the tropics, cloud formations can change within seconds [15].

Despite the high availability of daylight in tropical climates, its utilization remains limited due to ineffective facade strategies. Fully glazed facades are commonly used in office buildings, but lead to excessive illuminance, uneven daylight distribution, and glare issues without proper shading devices [16][17]. As a result, building occupants often cover glass openings with internal shading and rely on artificial lighting for indoor illumination.

A perforated screen facade (PSF) is a widely implemented shading device in buildings with glass facades [17]. PSFs typically consist of flat, opaque panels with perforations, which are relatively thin compared to their overall dimensions, which form a double skin for glazed facades [6]. These screens are predominantly located in front of fully glazed facades. PSF can reduce direct solar radiation and provide daylight and aesthetic facade while allowing a view outside [18].

Previous studies about PSF have primarily focused on non-tropical areas. A study about non-uniform perforated screens took the context of Wuhan [17]. El-Bahrawy [19] examined PSF in the context of office building in Cairo. Abdelhamid et al. [20] studied about the impact of parametric patterned PSF variations in Cairo. Additionally, Chi et al. [21] examined the daylight and thermal performance of PSFs in Seville, while Srisamranrungruang and Hiyama [18] explored their implications for daylight, ventilation, and thermal regulation in Japan. Although some previous studies have discussed PSF in the tropical climate, the focus is limited to the specific variables, for example, perforated egg crates [16] or integrating PSF with light shelves [22]. However, these studies have not specifically explored the PSF inclination angle, especially in the context of a tropical climate.

Table 1 illustrates the PSF design variables studied in previous research. These variables include perforation percentages [18], PSF matrix, perforation percentage, thickness, and separation distance [19]. Other parameters investigated include perforation percentage, distribution of openings, shape of openings, orientation [21], perforation percentage, matrix, shape of openings, and orientation [6]. Additionally, previous studies have explored non-uniform perforation patterns [17], parametric patterned [20], perforated egg crates [16], and combinations with daylighting systems such as light shelves [22].

However, prior studies have not explored inclined perforated screens, particularly in tropical climates. Given the widespread use of perforated solar screens as exterior building facades, the flexibility of PSF implementation, particularly in terms of inclination angle, requires further investigation. Examples of buildings incorporating inclined PSFs include 72 Screens in Jaipur, India, and the faceted PSF facade on the office extension building in Lund, designed by Johan Sundberg Arkitektur and Blasberg Andréasson Arkitekter.

The state-of-the-art aspect of this research lies in studying the inclined angle as a key PSF design variable in a tropical climate context. The inclination angle determines how effectively the PSF blocks sunlight while providing sufficient daylight for specific office tasks and minimizing glare. This study aims to evaluate the impact of PSF inclination angle on daylight performance.

The paper is structured as follows: the Introduction section presents the research and reviews previous studies on the daylight performance of perforated screen facades. The Method section outlines the experimental method utilizing simulation as a tool. The Results and Discussion section discusses experimental findings and analysis. Finally, the Conclusion section summarizes the key findings about the impact of the inclination angle of PSF on daylight performance and directions for future research.

Table 1. Variables of the Perforated Screen Facade in Previous Research

PSF variables	References [6]	[16]	[19]	[20]	[21]	[18]	[17]	[22]
Perforation percentages	v		v		v	v		
PSF rotation angle								
Matrix	v		v					
Opening aspect ratio								
Distribution openings					v			
Shape of the opening	v				v			
Thickness			v					
Separation distance			v					
Orientation	v				v			
Non uniform perforation patterns							v	
Parametric patterned				v				
Perforated screen facade and light shelf								v
Perforated egg crates		v						

METHOD

The research method was experimental, utilizing simulation as a tool. The daylight performance of the inclined PSF was analyzed using Climate Studio, an advanced environmental simulation software based on validated Radiance path-tracing technology [23]. The accuracy of Climate Studio has been verified in previous research [24][25].

Simulation Setup

The office building model was developed using Rhino 8 software. Its dimensions were 6 m in width and 8 m in depth, representing a medium-depth office space. The building's height was 2.7 m. It featured a south-facing side window with a window-to-wall ratio of 67%. A horizontal shading element, 1 meter wide, was also positioned 2.7 meters above the floor. The material characteristics of the office building are detailed in Table 2.

The perforated screen facade had circular apertures. The distance between each aperture and the aperture diameter were 0.225 m and 0.16 m, respectively (Figure 2). The perforation percentage was set at 40%, aligning with previous research [18], which recommended this value for adequate daylighting without glare. The PSF was positioned 0.5 m away from the side window. Figure 2 and Figure 3 illustrate the elevation and perspective views of the office building, showing the side window and inclined PSF, respectively.

The study was conducted in Surabaya (latitude 7.38° S, longitude 112.79° E), a city in the tropics. The sky condition in Surabaya is classified as intermediate [14]. Climate data from Surabaya-Juanda International Airport was used for this simulation.

Figure 4 shows the placement of sensor grids inside the office building. The sensor grids were positioned 0.5 m apart and set 0.5 m from the wall. The sensor grid height for the daylight availability simulation, including useful daylight illuminance and mean illuminance, was set at 0.8 m above the floor. Meanwhile, the sensor grid height for spatial disturbing glare (sDG) was set at 1.2 m above the floor, corresponding to the eye level of a seated person. The sDG simulation results included analyses for eight different viewing directions at each sensor point (Figure 5). The colours correspond with the frequency from 0 to 5% of the occupied hours. The simulation period covered office building occupancy hours from 8:00 am to 6:00 pm.

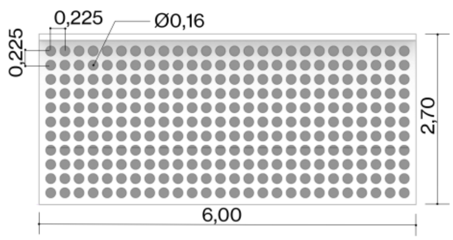


Figure 2. Elevation of the Office Building with Inclined Perforated Screen Facade

Table 2. The Material Characteristics of the Office Building

Room elements	Material	Reflectance (%)	Transmittance
wall	white painted	70	N/A
floor	ceramic tile	39	N/A
ceiling	white ceiling	86	N/A
side window	clear glass	15	77
perforated screen facade	white painted	90	N/A

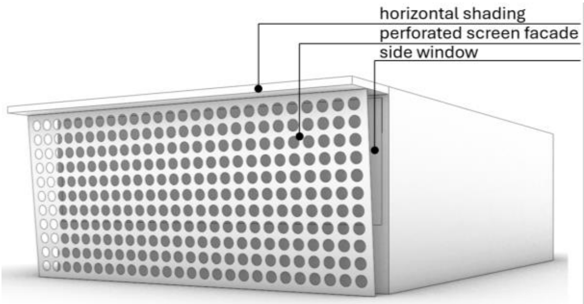


Figure 3. Perspective of Office Building with Side Window and Inclined Perforated Screen Facade

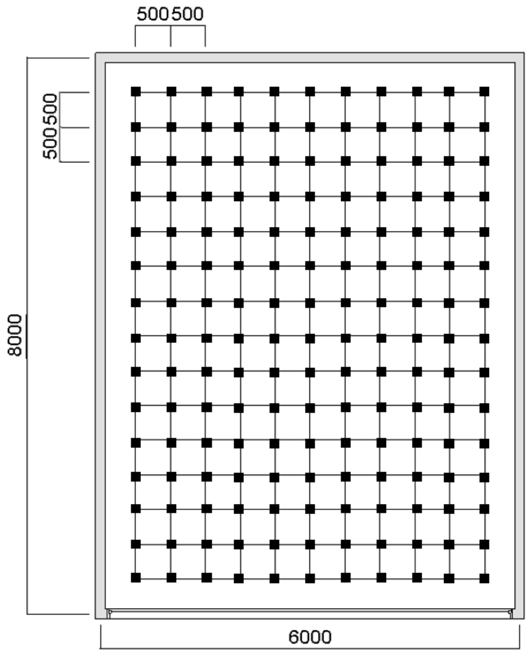


Figure 4. The Sensor Points Placement in the Office Building Plan

Perforated Screen Facade Inclination Angle

Table 3 presents a sectional view of the office building facade in three scenarios: the base case (without PSF), the facade with a vertical PSF (0°), and the facade with an inclined PSF. The base case represented an office building with a side window and 1 m horizontal shading. The base case's daylight availability and visual comfort were compared with those of the vertical and inclined PSFs.

The vertical PSF was tilted on the inclined PSF, and its rotation point was located at mid-height of the PSF. The inclination angle was adjusted in 5° intervals, with a maximum angle 20°. As a shading device, the PSF was inclined to reduce direct solar radiation while enhancing daylight performance.

Daylight performance metrics

This study evaluated the daylight performance of inclined perforated screen facades (PSF), focusing on daylight availability and visual comfort. Daylight availability was measured using annual mean illuminance and useful daylight illuminance (UDI). Visual comfort was analyzed through spatial disturbing glare (sDG).

Mean illuminance is the average illuminance across the occupied floor area during all occupied hours. The recommendation of illuminance level for office tasks is 500 lx [27]. According to Leadership in Energy and Environmental Design (LEED) v4.1 [28], illuminance levels must fall between 300 and 3000 lux from 9 a.m. to 3 p.m. for 55% and 75% of the occupied floor area to earn 1 or 2 points respectively.

Useful daylight illuminance (UDI) measures the percentage of occupied hours during which illuminance levels on the work plane fall within ranges considered "useful" by building occupants [26]. The range of UDI is 100-3000 lux (Equation 1). UDI values greater than 3000 lux (UDI-e) indicate occupied times when an oversupply of daylight may cause visual or thermal discomfort or both [21]. Conversely, UDI values less than 100 lux represent times when daylight level is insufficient to serve as the primary illumination source or contribute significantly to artificial lighting [21]

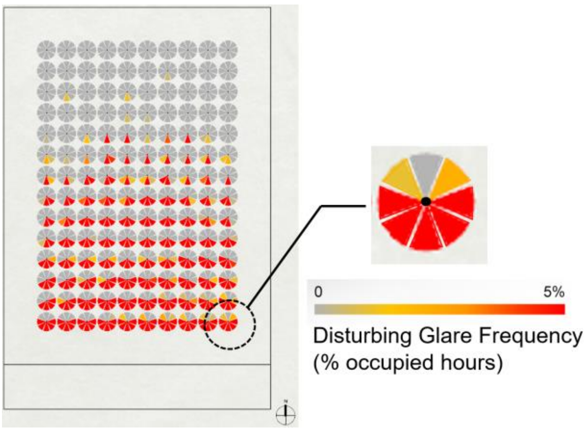
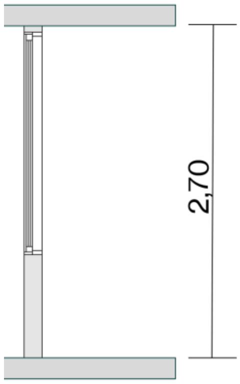
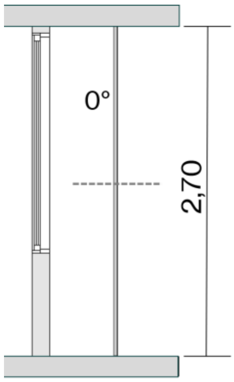
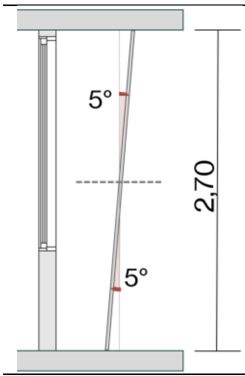
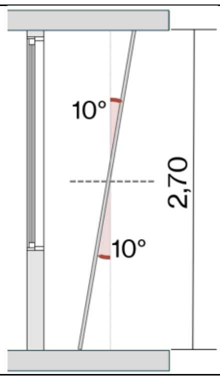
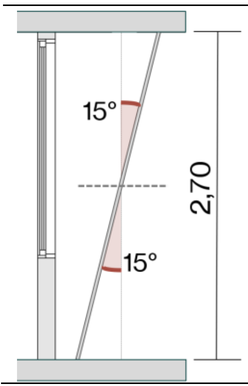
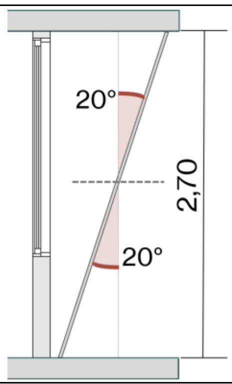


Figure 5. Example of Sensor Points with Eight Views for Spatial Disturbing Glare

Table 3. The Section of the Office Building Facade with an Inclined Perforated Screen Facade

Base case No PSF	PSF inclined 0º (vertical)
	
PSF inclined 5º	**PSF inclined 10º**
	
PSF inclined 15º	**PSF inclined 20º**
	

$$\mathrm{UDI100-3000lx} = \frac{\mathrm{t100lx \le E \le 3000lx}}{\mathrm{T}}\mathrm{x100\%} \quad (1)$$

Where t represents the duration of illuminance (E) within the range of 100-3000lx, and T denotes the total occupied hours throughout the year.

Useful daylight illuminance (UDI) is subdivided into UDI-autonomous (300-3000lx) and UDI-supplementary (100-300lx). For UDI-autonomous (UDI-a), additional electric lighting is most likely not needed, while for UDI-supplementary (UDI-s), additional electric lighting may be required [21]. High values of UDI are often associated with low energy usage for electric lighting [21]. The recommended target for $UDI_{100-3000lx}$ is ≥ 80% [29].

Spatial disturbing glare (sDG) quantifies the percentage of total views within the occupied floor area affected by disturbing or intolerable glare for at least 5% of occupied hours [30]. sDG is a statistical metric based on the Daylight Glare Probability (DGP) [17]. The computation of sDG is based on DGP hourly values for eight distinct viewing directions at each location within space [20]. Levels of DGP are classified as follows [17]: imperceptible glare (DGP ≤0.34), perceptible glare (0.34<DGP≤0.38), disturbing glare (0.38<DGP≤0.45), and intolerable glare (DGP>0.45)

RESULTS AND DISCUSSION

Daylight Performance of Inclined Perforated Screen Facade

The daylight availability and visual comfort of the building with an inclined Perforated Screen Façade (PSF) are shown in Table 4. The following section will discuss the daylighting performance of the inclined PSF, including mean illuminance, useful daylight illuminance (UDI), and spatial disturbing glare (sDG).

Mean Illuminance

Figure 6 shows the mean illuminance of the base case and office buildings with different inclination angles of the perforated screen facade (PSF). The base case, an office building with a side window and 1 m depth horizontal shading, had the highest mean illuminance level, reaching 1889lx. The mean illuminance level was in the range of 300 to 3000lx. However, 17.14% of the 140 sensor points recorded an illuminance level exceeding 3000 lx. As shown in Table 4, the sensor points with illuminance levels above 3000lx, marked in red, were located near the side window. An illuminance level above 3000 lx indicates an oversupply of daylight, which may lead to visual discomfort, thermal discomfort, or both.

Implementing a vertical perforated screen facade (0º) as a shading device resulted in a significantly lower mean illuminance, reaching 1060 lx. No sensor points recorded an illuminance level exceeding 3000 lx in office buildings with a vertical PSF. An illuminance level between 300-3000 lx across all sensor points is crucial to support building users in performing visual tasks.

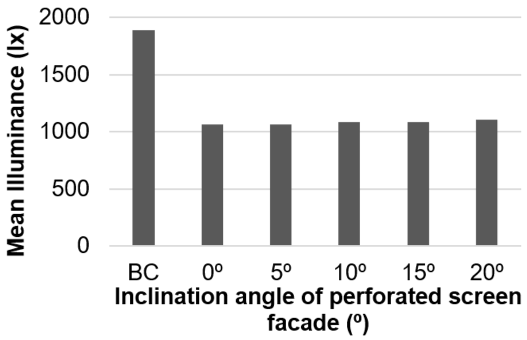


Figure 6. The Mean Illuminance of Base Case and Office Buildings with Different Perforated Screen Facade Inclination Angle

Office buildings incorporating an inclined PSF with angles ranging from 5º to 20º exhibited mean illuminance levels between 1065 lx and 1105 lx. All cases adhered to the recommended illuminance thresholds established by LEED v4.1. Furthermore, no sensor points recorded illuminance levels surpassing 3000 lx in office environments employing PSFs with inclined angles.

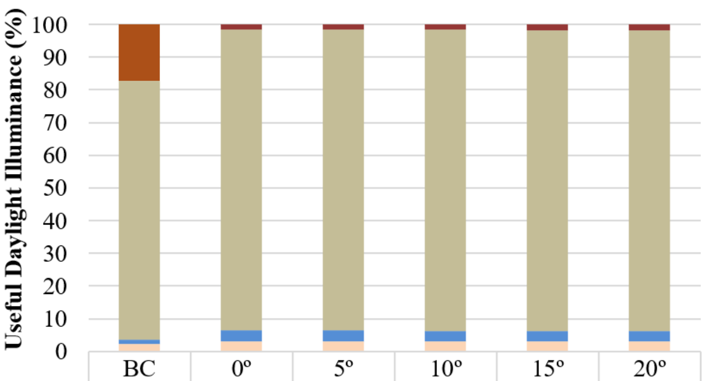
Compared to the base case, integrating a vertical perforated screen façade (0º) in the building façade reduced the mean illuminance by up to 43.9%. Similarly, implementing an inclined PSF reduced the mean illuminance by 41.5% to 43.5%, with inclination angles of 20º and 5º, respectively. These findings demonstrate the effectiveness of PSF as a shading system in tropical climates for reducing mean illuminance. Furthermore, these results align with previous research on integrating PSF in tropical regions [23] and extend the understanding of how inclination angles contribute to mean illuminance reduction.

Useful Daylight Illuminance

Figure 7 illustrates the useful daylight illuminance (UDI) for various inclination angles of the perforated screen facade. The base case, an office building with a side window and horizontal shading of 1-meter depth, recorded the lowest useful daylight illuminance ($UDI_{100\text{-}3000lx}$), occurring for 80.54% of the occupied time. Additionally, the base case exhibited a UDI-exceed (>3000lx) value as high as 17.2%. UDI-exceed (>3000lx) signifies periods during which an oversupply of daylight may result in visual discomfort, thermal discomfort, or both [21]. Furthermore, the base case recorded the lowest UDI-autonomous (300-3000lx), reaching 79.3%.

The implementation of vertical PSF (0º) in office buildings significantly reduced the UDI-exceed value (>3000 lx), reaching 91.51%. In office buildings with vertical PSF, the $UDI_{100\text{-}3000lx}$ reached 95.51%, representing an 18.6% improvement compared to the base case. These results highlight the effectiveness of PSF in reducing high illuminance levels, particularly in areas near side windows, and enhancing $UDI_{100\text{-}3000lx}$.

The $UDI_{100\text{-}3000lx}$ of inclined PSF ranged from 95.55% for an inclination angle of 5º to 95.08% for an inclination angle of 20º. Office buildings with a PSF inclination angle of 5º achieved the highest $UDI_{100\text{-}3000lx}$. Office buildings with PSF, both vertical and inclined, maintained $UDI_{100\text{-}3000lx}$ values of at least 80%, meeting the recommended target for $UDI_{100\text{-}3000lx}$.



	BC	0º	5º	10º	15º	20º
UDI-e(>3000lx)	17,2	1,46	1,43	1,58	1,69	1,92
UDI-a(300-3000lx)	79,3	92,09	92,09	92,1	92,12	91,94
UDI-s(100-300lx)	1,24	3,42	3,46	3,31	3,2	3,14
UDI<100lx	2,27	3,03	3,02	3,01	2,99	3

PSF inclination angle (º)

UDI<100lx UDI-s(100-300lx) UDI-a(300-3000lx) UDI-e(>3000lx)

Figure 7. The Useful Daylight Illuminance from Different Inclination Angle of Perforated Screen Facade

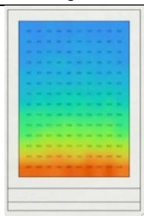
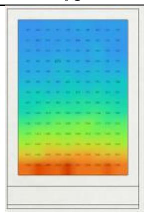
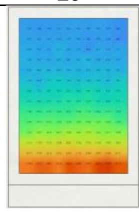
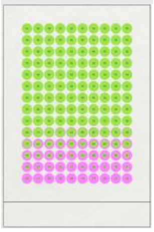
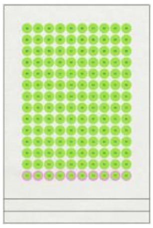
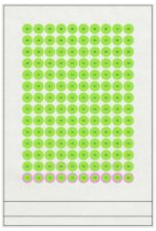
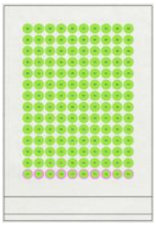
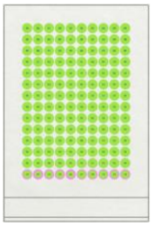
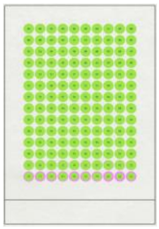
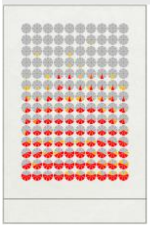
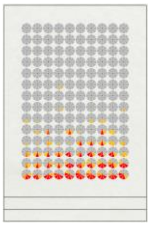
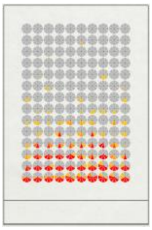
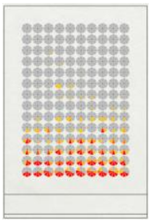
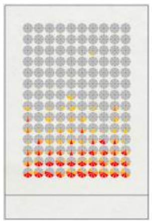
Similar to vertical PSF, the implementation of inclined PSF significantly reduced UDI-exceed values (>3000 lx), ranging from 88.84% to 91.69%. Table 4 shows that the position of sensor points with $UDI_{>3000lx}$, marked by violet colour, was near the side window. This reduction highlighted the effectiveness of inclined PSF in mitigating excessive illuminance levels and enhancing daylight performance in office buildings.

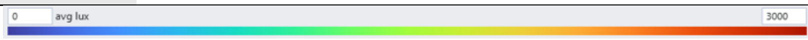
Spatial Disturbing Glare

The base case had the highest spatial disturbing glare (sDG) level, reaching 23.7. Even with horizontal shading of 1 meter in width, an office building with a side window still had a high percentage of total views across the occupied floor area affected by disturbing or intolerable glare for at least 5% of occupied hours. Table 4 presents a comparison of the sDG plot, showing that sensor points near the side window and the central area of the office building are marked in red, indicating exposure to disturbing glare. Figure 8 compares the annual daylight glare probability simulation, showing that the base case still recorded 7% disturbing glare and 4% intolerable glare. This result was consistent with previous research [16][17] which underscored that office buildings face high daylight levels and glare issues in the absence of proper external shading.

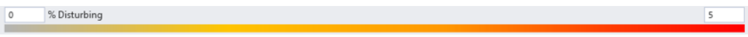
Implementing vertical PSF (0º) as a shading device significantly reduced spatial disturbing glare (sDG), achieving a reduction of 80.2%. An office building with a vertical PSF exhibited an sDG level as high as 4.7%, with no intolerable glare recorded (Figure 8). This result aligns with previous research on Daylight Glare Probability (DGP) reduction achieved through PSF in office rooms in the tropics [22]. Based on DGP, the

Table 4. The Mean illuminance, Useful Daylight Illuminance-a, and Spatial Disturbing Glare of Different Perforated Screen Facade Inclination Angle

	Base case	0º	5º	10º	15º	20º
Mean illuminance (lx)						
	1889	1060	1065	1084	1087	1105
Percentage of decrement (%)		43.9	43.6	42.6	42.5	41.5
Useful daylight illuminance-a (UDI-a) (%)						
	79.3	92.1	92.1	92.1	92.1	91.9
Percentage of improvement (%)		16.1	16.1	16.1	16.2	15.9
Spatial disturbing glare (%)						
	23.7	4.7	5.1	5.2	5.6	6.5
Percentage of decrement (%)		80.2	78.5	78.1	76.4	72.6

Mean illuminance: 

Useful daylight illuminance: 

Spatial disturbing glare: 

spatial disturbing glare metric used in this study provides a broader understanding of the visual performance of PSF, considering total views across the occupied floor.

An office building with an inclined PSF exhibited an sDG as high as 5.1% and 6.5% for inclination angles of 5º and 20º, respectively. No intolerable glare was recorded in office buildings with inclined PSF (Figure 8). The implementation of inclined PSF also reduced sDG compared to the base case, achieving reductions of 72.6% and 78.5% for inclination angles of 20º and 5º, respectively. Although inclined PSF resulted in a slightly higher sDG than vertical PSF, it effectively mitigates glare issues in tropical regions.

The reduction of sDG by both vertical and inclined PSF is crucial, as glare problems in tropical climates often lead building users to avoid natural daylight and instead rely on electric lighting as their primary illumination source. These findings align with previous research on PSF in tropical environments [22] while also contributing to a deeper understanding of the role of PSF with specific inclination angles in glare reduction.

The Impact of Inclination Angle of Perforated Screen Facade on Daylight Performance

Regression analysis was employed to evaluate the impact of the inclination angle of the perforated screen facade (PSF) on mean illuminance, useful daylight illuminance, and spatial disturbing glare. Figures 9, 10, and 11 present regression analysis plots examining the relationship between the inclination angle of the perforated screen facade (PSF) and various daylight performance metrics. Figure 9 illustrates the regression analysis between the PSF inclination angle and mean illuminance, while Figure 10 examines its correlation with useful daylight illuminance. Meanwhile, Figure 11 displays the regression analysis plot of the PSF inclination angle and spatial disturbing glare.

The regression analysis demonstrated that the PSF inclination angle significantly influenced the mean illuminance, with a coefficient of determination reaching 0.9541. Additionally, a linear relationship between the PSF inclination angle and mean illuminance can be defined as follows:

$$\text{Mean illuminance} = 2{,}24x + 1057{,}8 \qquad (2)$$

Any increase of 1 degree at the PSF inclination angle is expected to increase the mean illuminance by 2.24 lx. However, this equation exclusively applies to the case of office buildings incorporating inclined PSF in the tropics.

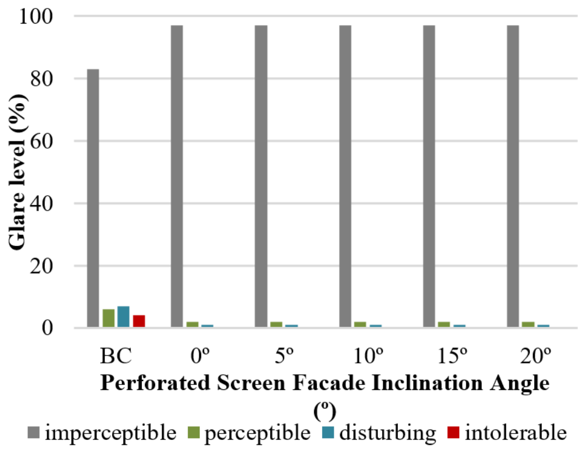


Figure 8. The Glare Level from Different Inclination Angles of Perforated Screen Facade

The findings showed that the higher the inclination angle of PSF, the greater the mean illuminance (Figure 9). The amount of light the north or south facade receives varies throughout the seasons. In office buildings facing south, a higher PSF inclination angle increases the portion of the PSF area receiving daylight, particularly in the upper section of the PSF surface. Additionally, ground reflection can contribute to a higher amount of light entering the space, increasing mean illuminance.

Figure 10 shows a regression analysis plot of PSF inclination angle and useful daylight illuminance. The regression analysis indicated that the PSF inclination angle significantly influences $UDI_{100\text{-}3000lx}$, with a coefficient of determination reaching 0.8479. A linear relationship between PSF inclination angle and useful daylight illuminance is outlined in the following equation.

$$\text{Useful daylight illuminance} = -0{,}0218x + 95{,}592 \qquad (3)$$

Any increase of 1 degree at the PSF inclination angle is expected to decrease the useful daylight illuminance by 0.0218%. This equation is valid only for office buildings with inclined PSF in the tropics.

The findings showed that the higher the inclination angle of PSF, the smaller the useful daylight illuminance (Figure 10). Increased mean illuminance, along with the increase in PSF inclination angle, also correlates with an increase in UDI-exceed (>3000 lx) values, which in turn causes a decrease in UDI (100-3000 lx). Meanwhile, the $UDI_{<100lx}$ values tend to remain constant, as the modifications were applied only to the shading element, specifically the inclination angle of the PSF.

Figure 11 presents a regression analysis plot illustrating the relationship between the PSF inclination angle and spatial disturbing glare (sDG). The analysis confirmed that the PSF inclination angle strongly influences the spatial disturbing glare (sDG), with a high coefficient of determination of 0.8999. Additionally, a linear relationship between the PSF inclination angle and useful daylight illuminance can be defined as follows:

$$\text{Spatial disturbing glare} = 0{,}082x + 4{,}6 \quad (4)$$

Any increase of 1 degree at the PSF inclination angle is expected to increase the spatial disturbing glare by 0.082%. This equation is valid only in the case of office buildings with inclined PSF in the Tropics.

The higher the PSF inclination angle, the greater the spatial disturbing glare. Consistent with the results of daylight level analysis, an increase in the PSF inclination angle leads to higher daylight levels received by the building, as indicated by the rise in UDI-exceed (>3000 lx) levels. According to Chi et al. [21] the presence of $UDI_{>3000lx}$ in a building signifies periods during which excessive daylight potentially leads to visual and thermal discomfort, or both, which, in this case, is marked by an increase in spatial disturbing glare.

Vertical and inclined PSF implementation generally enhanced daylight availability and visual comfort compared to the base case. Vertical and inclined PSF integration significantly reduced mean illuminance and spatial disturbing glare in office buildings. Additionally, the use of PSF improved $UDI_{100–3000lx}$. These results align with previous research on PSF implementation in tropical regions [22] while contributing to knowledge about the role of PSF with specific inclinations in glare reduction.

Compared to vertical PSF, inclined PSF increased mean illuminance and spatial disturbing glare while decreasing $UDI_{100–3000lx}$ values. However, considering its ability to reduce mean illuminance, increase UDI, and decrease spatial disturbing glare compared to the base case, and noting that although the SDG value for inclined PSF is slightly higher, it remains significantly lower than that of the base case, these findings suggest that the inclination angle of PSF can be applied as an alternative PSF design for office buildings in the tropics.

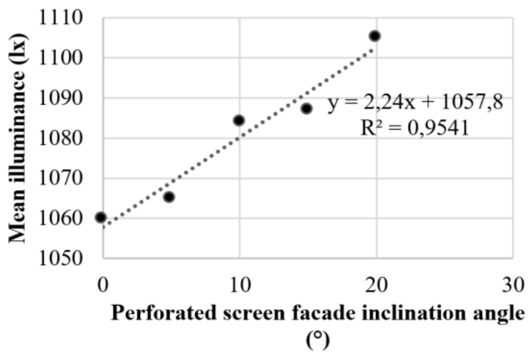


Figure 9. The Relationship Between Perforated Screen Facade Inclination Angle and Mean Illuminance

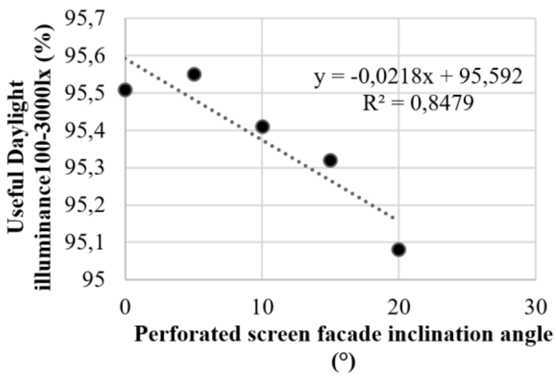


Figure 10. The Relationship between Perforated Screen Facade Inclination Angle and Useful Daylight Illuminance

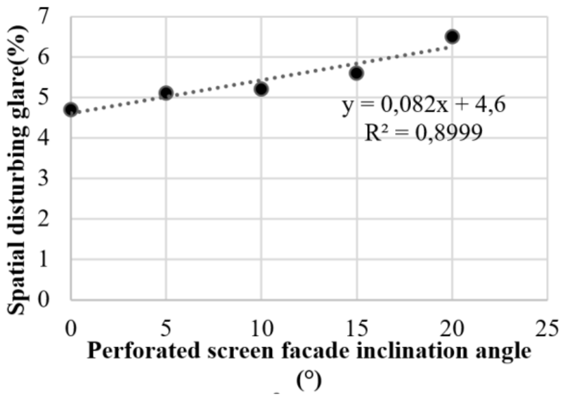


Figure 11. The Relationship between Perforated Screen Facade Inclination Angle and Spatial Disturbing Glare

CONCLUSION

This research evaluated the daylight performance of different inclination angles of perforated screen facade (PSF) in the tropics. Implementing vertical and inclined PSF significantly reduced the spatial disturbing glare (sDG) in office buildings. Vertical and inclined PSF as a shading device is an important consideration in tropical regions, where excessive glare often leads occupants to rely on electric lighting instead of daylight.

The study showed that vertical and inclined PSF improved daylight availability and visual comfort in office buildings. The vertical PSF achieved the highest glare reduction by lowering sDG by 80.2%, while the inclined PSF also contributed to mitigating glare at varying angles, achieving 72.6-78.5%. Additionally, PSF integration enhanced daylight availability by decreasing mean illuminance and increasing useful daylight illuminance ($UDI_{100\text{-}3000lx}$). These findings align with previous research on PSF in tropical climates and expand the understanding of how inclination angles of PSF influence glare reduction, offering valuable insights for sustainable building design. PSF can be applied with an inclination angle to buildings in the tropics, allowing for broader possibilities in facade design exploration.

The research introduced and focused on one of the PSF design variables, the inclination angle of PSF. The subsequent investigation should consider other variables such as perforated percentage, orientation, distance between PSF and side window, and external reflectance. This study also focused on daylighting performance only. Future research will focus on the energy performance of inclined PSF integration in buildings within tropical climates. The involvement of user aspects, specifically studies on user perception in buildings with inclined PSF implementation, needs to be explored.

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