Interior shadings for office indoor visual comfort in humid climate region

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Abstract. As part of the fenestration system, the interior shadings have also a role to control the indoor environment to maintain indoor visual comfort. As the occupants have personal access to control these, their control behavior then, might enhance or even worsen indoor comfort performance. The controlling behavior might not only influence indoor comfort performance but can also indicate the success or failure of interior shading as a control device element. This paper is intended to report control behavior patterns, as represented by the variety of the slats’ openings of two types of interior shading i.e. Venetian and Vertical blinds and to analyze these on the concurrent impacts to indoor office building’s indoor illuminance and luminance distribution. The purpose of this research is to figure out the shading control patterns as well as to examine the effectiveness of these two types of interior shadings to control indoor visual environment. This study is a quantitative research using experimentation on the slats’ opening of two types of shadings at two identical office rooms. The research results suggested that both types of blinds seem unsuitable for gaining proper illumination values at work planes in humid tropical area. However, these shadings demonstrate good performance for luminance distribution except for that of the closed Venetian blinds.

1. Introduction

The fenestration system of commercial buildings is one of vital building elements that drives much on the building’s comfort and energy consumption. As part of the fenestration system, if the exterior shading is inadequate, the interior shading, which is one of adaptive type of fenestration systems, should take over the role to control comfort performance of the indoor environment [1][2]. In a humid tropical region like Indonesia, the role of shading as a device to modify indoor comfort is vivid. While the exterior shading’s role is much on the thermal control, the interior shading compliments that with its task as the visual control device.

In the other side, some studies concerning energy and buildings have also found that adaptive building elements and the occupants’ proper control behavior towards these, can significantly reduce the buildings’ energy consumption [3][4][5]. These studies have driven any advancement of technologies to allow architecture to become more adaptive towards its inhabitants’ requirements. Not only that, studies on control behavior of the adaptive building’s elements to control temperature, lighting and shading have reached the main stream. While technologies for office automation are becoming more widespread with considerable commercial interest [6][9], studies that on manual control technologies are also of interest [7][8]. These because the adaptive buildings’ elements have high opportunity to contribute to building energy saving [5].
Focusing on problem of office buildings with a large opening in humid tropics, empirical evidence and many studies [1][6][7] show that the occupants were rarely willing to operate the shadings as they need for modifying indoor comfort (figure 1). Mostly, they depend on the artificial lighting and air conditioning as these devices can instantly eliminate both thermal and visual problems. Other studies in the sub-tropic regions have also shown similar evidence [6]. The blinds were infrequently adjusted and always set into the worst conditions which resulted to inappropriate indoor comfort.

![Figure 1. The commonly used facades in a humid tropical region with solar protective glass and indoor shading device. Empirical evidence showed that the occupants rarely adjusted the blinds and depended mostly on the operation of artificial light.](image)

These evidences have indicated that as the occupants have personal access to operate the interior shadings, their control activities then, might enhance or even worsen indoor comfort performance. Or in other words, the control activity might not only influence indoor comfort performance but also indicate the success or the failure of interior shading as a control device.

Concerning the blinds influence on daylighting performance, some studies on sub-tropical region found that the Venetian blind type was superior in daylighting performance compared to the other types of interior shadings [9][10][11]. Also, only a few similar types of research in that topic had been done in other different climate characteristics such as humid tropics area [1]. Based on that, there is an opportunity to develop research in these issues.

This paper is intended to report comparison results of the control mechanism patterns, as representative of occupants’ behavior, over two types of interior shading devices i.e. Venetian and Vertical blind and these concurrent impacts into indoor office building’s visual comfort performance i.e. absolute illuminance and luminance distribution. The purpose of this research is to comprehend each shading mechanism in regulating light entering the room as well as to discuss the efficacy of these two types of shading by comparing indoor visual performances resulted due to the using of these two common types of interior shadings. Accordingly, this research will trace on the behavior of these shadings that might be suitable to be applied for the office building in humid climate region.

2. Method
As this study aims at gathering information about the control mechanisms of the two interior shading devices, and the influence of these on indoor daylighting performance, a descriptive-explorative method is then used and considered as the category of the research explanation. Further, based on that objectives, since the inquiries are explored based on what and how questions, this research can be categorized as a quantitative research [13]. So that, it is essential for the research to have a clear view or picture of the phenomena before carrying out the data collection procedure.

2.1. Experimental rooms and interior shadings investigated
The study focused on two types of shadings (i.e., the Venetian and Vertical Blinds). These shadings were set at two identical office rooms which are functioned as lecturer rooms at the Department of Architecture, ITS (figure 2). Since illuminance and luminance performance are also highly influenced
by the rooms’ interior surface attributes, the optical characteristics these are also considered in the measurements and discussions.

![Figure 1](image1.png)

![Figure 2](image2.png)

**Figure 2.** The plan (1) and the sections i.e. A (2), B (3), C (4) respectfully of the office used as the experimental rooms.

| No. | Attributes                  | Properties (%)                      | Room 1                      | Room 2                      |
|-----|-----------------------------|-------------------------------------|-----------------------------|-----------------------------|
| 1.  | Window glass                | Clear glazing (VT=90, R=5)          | Clear glazing (VT=90, R=5)  |                             |
| 2.  | Floor                       | Grayish ceramic (T=0, R=40)         | Grayish ceramic (T=0, R=40) |                             |
| 3.  | Ceiling                     | White painted (R=80)                |                             | White painted (R=80)       |
| 4.  | Working plans               | Dark brown wood (T=0, R=5)          | Dark brown wood (T=0, R=5)  |                             |
| 5.  | Interior shading            | Cream/light brown Venetian blind (T=5, R=65) | Yellowish Vertical blinds. (T=70, R=10) |

Note: T= transmittance value; R=reflectance value; VT=visible transmittance (Source: measurement)

The independent variables of this study were two types of interior shadings. Table 1 indicates the rooms’ attributes as well as the properties of these independent variables. The capability of materials technology in transmitting the visible light will determine the amount of daylight entering the room.
The higher the transmittance value of the transparent material, the better it will transmit the light. As shown in table 1, the transmittance value of the shading system depended mostly on the transparency of the material.

2.2. Data collection methods
Data collection was mainly by using direct field measurements. Since this research is in the context of daylighting, the authors conducted measurements within the absence of artificial lights. Other than that, information from secondary sources such as building’s drawings, pictures, some product information, and from the building’s technical managers was also enrich the data. Important aspects and means of measurement for gathering the data are described as the followings:

Points of measurements were on three work planes (WP’s) located in zone 0-3 m from window perimeter (i.e. WP 1, WP 2, WP 3) from the nearest window distance (figure 3). The Illuminance values were measured at these three represented working plans and sitting positions. While for the luminance, the measurements were taken only at the working table 2 (WP 2) in which it has the sitting position against the window. This working table with its sitting position might have the most possibility experiencing glare due to veiling reflection and over-bright light captured at the computer’s display board.

Figure 3. The position of working plans (i.e. WP1, WP2, WP3) where the illuminance (the red and green points) and luminance (the blue arrow) values were recorded.

Illuminance and luminance measurements were taken during the months of June and July 2017. For measuring these, three lux-meters and a luminance meter data logger were used. They were set to record every hour from 8 AM to 3 PM. The lux-meters were set at every represented working tables, while the luminance photometer was held at 1.0 m high (the assumption of the height of the workers’ eyes when sitting on their work plane) and at their chair positions (figure 3). For measuring the luminance, the device was focused to approximately 40° in altitude and 90° in azimuth as the area of the human field of view (VOW). So that, it measured luminance at some points such as the table, the computer display (VDT), and its surrounding surfaces such as the door and its frames, the papers at the table and the wall. The measurements were conducted at the average outdoor illuminance of 4.000 – 80,000 Lux and under the average of partly cloudy and overcast sky.

Both illuminance and luminance measurements were taken when the window blinds were executed by tilting the slats so they were opened at 0°, slightly opened at 22.5°, 45°, 67.5° respectively and until
they were closed at 90° (figure 4 for the Venetian blind and figure 5 for the Vertical blinds’ execution scenarios).

**Figure 4.** (1) The section of the room with the Venetian blind; (2) Venetian blind’s position opened at 0°; and (3) closed at 90°

**Figure 5.** (1) The section of the room with the Vertical blind; (2) Vertical blinds’ position opened at 0°, and (3) closed at 90°
2.3. Method of analysis
After the all illuminance and luminance values of points was gathered, the visual performance analysis was conducted by comparing those average values at each work-planes using standard parameters as well as looking at the trends of the values of each shading types. Standard used combined from several international standards [14][15][16] since the Indonesian National Standard (SNI) for daylighting design had not established luminance values as standards for evaluating luminance distribution (table 2).

| No. | Performance Indicator and interpretation |
|-----|------------------------------------------|
| 1.  | Illuminance                              |
|     | E<200 lux                                |
|     | Not adequately lit – **too dark** for paper and computer work. |
|     | E average of 200 lux or above             |
|     | Adequately lit – **sufficient** for both paper (sedentary) and computer (detail) works. Maximum of 300 lux is for avoiding glare for these two types of work |
|     | More than 300 lux                        |
|     | Over lit – **too bright** and causing glare for both paper and computer works. |
| 2.  | Luminance Ratio                          |
|     | For the surfaces ratios within a cone of 60° centered about the line of sight (ergorama): |
|     | Task (VDT screen) to adjacent surroundings(e.g. table, divider) max 3:1 or 1:3. (L_{VDT}/L_{surroundings}>0.33 or<3). |
|     | Task (VDT screen) and adjacent paper max 3:1 or 1:3. (L_{VDT}/L_{paper}>0.33 or<3). |
|     | Acceptable Luminance ratio within a cone of ergorama and panorama |
|     | For the surfaces ratios within a cone of 120° centered about the line of sight (panorama): |
|     | Task (VDT screen) and immediate surroundings (Windows, window frame, and blinds) max 10:1. (L_{VDT}/L_{surroundings}>0.1 or<10). |

3. Results and Discussions
3.1. Illuminance performance
The following presents the results of the measurement of each type of interior shading at various degrees of slats executions:
Figure 6. Trend lines of illumination performance due to various blinds’ slat angle operation: (1) at 90° – fully closed; (2) at 67.5°; (3) at 45°; (4) at 22.5°; and (5) at 0°. Recorded hourly at various time scheduled (x axis): 1 (at 8 AM), 2 (at 9 AM), 3 (at 10 AM), 4 (at 11 AM), 5 (at 12 PM), 6 (at 1 PM), 7 (at 2 PM), and 8 (at 3 PM) respectively.

Figure 6 above shows that both blinds provide different illuminance behavior received at the working planes. When these were closed at 90°, the Vertical type provided more superior performance compared to that of the Venetian. It could also reach more than the standard of 200 Lux when it was at 8-9 AM. This behavior was constantly changing concurrently with the blinds slats operation. At the opening of all degrees of slats (i.e. 67.5°; 45°; and 22.5°), the performance behavior of these two types of blinds were almost the same. They almost reached more than 50% of illuminance above standard at the opening of 66.5°, while almost reached 100% of illuminance above standard at the opening of 45° and 22.5°. Even, at the opening of 0°, they both provided 100% fulfilled the standard. However, at the opening of 22.5° and 0°, both the shading exceeded the maximum acceptable standard of 500 Lux, particularly in the morning between 8-10 AM. This phenomenon gave an alert that excessive bright light will occur due to the application of both types of shading, particularly in the morning. However, it can interestingly be noted, that the operation of slat angle of both shadings when it was nearly and totally opened (i.e. at 22.5° and 0°) provided too much light entering the room, especially for the
vertical blind type. This happened might be due to every sun’s angle incident and daylight from the sky-vault can be more freely regulated to enter the room by the Vertical blind compared to this by the Venetian blind. This findings imply that both the Vertical and Venetian blinds have potentially contributed to over bright light received at the work plane in the morning, particularly at the opening of 22.5° and 0°. However, the Vertical blind, due to its higher transmissivity value, compared to the other counterpart, contributes to better illuminance performance even if the blind is entirely closed. This type of blind with its control mechanism would be very beneficial to be applied in region with the thermal problem like Indonesia. The blinds would have dual functions. These are to reject heat while still allowing sufficient daylight entering the room.

3.2. Luminance distribution performance

Figure 7 shows that almost all the two shadings applied to contribute to the acceptable luminance distribution. Nearly all the opening scenarios of the two interior shadings contributed to 50% of acceptable luminance distribution value except the closed Venetian blind. This good performance might be due to the execution of closed blinds that had made the luminance of far surrounding surfaces of the VDT were far lower than that of the VDT’s luminance itself. Although the slats of the Venetian blind were closed, there was still small fissure among slats. This small opening together with highly reflective material of the blind, contributed to high luminance at the window perimeter area. The opaque material character of closed Venetian blinds’ metal slats, though could transmit a small amount of light through its fissures between slats, had deterred the light penetrated deep into the room. Contradiction with that phenomenon, the Vertical blinds due to its better transmittance performance could maintain considerably good performance of luminance distribution.

![Figure 7. Percentage of luminance distribution that fulfills the standards due to various blinds types and slat angles (i.e. at 90° – fully closed; at 67.5°; at 45°; at 22.5°; and at 0°).](image)

These findings are in line with the concept stated that interior shadings could be used to eliminate excessive bright spots in the rooms since it can reflect and diffuse the bright light spot [16]. But, the in the case of a high reflective blind type such as the Venetian, it does not eliminate the upcoming daylight. Inversely, it will significantly attenuate the amount of light emitted. This result also does not in line with the findings from the study by Dubois [10][11]. She asserted that the best performance for redirecting and diffusing daylight was the Venetian shading since it has better capability to reflect as well as redirect the incoming daylight from the low altitude of the sun compared to the other shadings. This difference of finding is interesting. The difference occurred might be caused by different climate
characteristic. The study by Dubois was conducted in a moderate climate that has the majority of low sun angles from low altitude of the sun in which it has low intensity of horizontal sky luminance. In this kind of climate, the daylighting can be attenuated and redirected very well using Venetian blind. This result also indicates that the horizontal slats of the venetian might also become a better device to reflect much light at the highest sun angle from the high sun altitude in the tropics. However, this will cause problem of very high luminance of the window surface and will at the end be a glare source. Further, the finding also implies that both shading devices contribute to acceptable luminance ratio. Compared to its counterpart, the Venetian blinds seem to be the best one for controlling glare since it could successfully reach more than 80% of points measured fulfilled standard. The slats can reflect the incoming light and better distribute it until deep into the room so that there are only small differences of luminance between area at the perimeter and deepest area. This balance luminance values between perimeter and deepest area reduce the potential of glare. However, if thermal problem forced the blinds to be closed for entire the time, the Venetian blind is not a good device. In that case, the Vertical blind would be the best one.

4. Conclusions
This paper has discussed visual performance due to the application of two types of interior shading devices (i.e. Venetian and Vertical blinds). Results show that both shading devices transmit daylight higher than standard particularly at some low angle slats. But in case that the blinds should be closed due to the thermal problem, the Vertical blind shows to be as a better device for maintaining indoor illuminance compared to the Venetian blind. Further, in terms of providing good performance of luminance distribution, both shadings type can be considered included in that criteria. However, if thermal problem forced the blinds to be closed for the entire working time, the Venetian blind is not a good device. As this blind has the characteristic of an opaque material that can deter the daylight penetrate into the room, the application of this blind can cause bad luminance distribution across the room.

The study implies that the use of both blinds seems unsuitable for gaining proper illumination values at work planes in humid tropics area. However, these shadings demonstrate good performance for luminance distribution except for the Venetian blinds if it is closed. The results then, force for further more detail research of the efficacy of other interior shadings such as the roller blinds as one of devices to control the upcoming daylight that determines the visual quality of office rooms particularly for the office buildings in humid tropics climate. Further, it is recommended to do more researches in the view on the occupant behavior in operating the devices to know in detail the most expected of interior shading tasks to regulate indoor environment well as to study underlying environmental aspects influencing that behavior within the context of humid tropics region.

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