Comparing the occupants' comfort between perimeter zone and interior zone in Asian office.

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Abstract. Asian office buildings receive plenty of heat and daylight because of their glazing facades. They also allow the occupants to view outside. These effects depend on the seat position in different distance from the window. A study of building performance regarding these difference effects is required to clarify the occupants' comfort under contextual conditions. Therefore, this study aims to compare the impact of glazing facades on occupants’ comfort between the occupants in the perimeter zone and interior zone by analyzing the building performance in terms of thermal comfort and visual comfort. Measuring devices were installed to investigate temperature, humidity, and daylight in three office buildings in Thailand and three in Singapore. Simultaneously, occupants’ satisfaction were investigated using questionnaires during working hours. In total, 1,356 samples were surveyed. The questions were fixed for both thermal environment and visual environment in terms of sensation and satisfaction. Furthermore, the opening view and internal blind occlusion rate were noted by visual inspection. The results showed that the thermal environment and visual environment in the perimeter zone were affected by the outdoor environment more than the interior zone. However, most of the occupants were satisfied because they be able to adapt to a wide range of indoor environment conditions. The occupants in the perimeter zone were more satisfied in terms of temperature and view. On the contrary, occupants in the interior zone were more satisfied by the lighting environment. The dissatisfaction survey revealed that the thermal environment has the most influence on occupants’ comfort. However, daylight accessing was revealed to has the highest impact on occupants’ comfort in terms of building-facade effect. The results show that occupants’ comfort levels differed depending on the seat position in the current situation for Asian office buildings. The optimisation of building-facade performance considering its influence on occupants’ comfort is necessary.

1. Introduction

1.1 Green office building in Southeast Asia

Green buildings have been gaining popularity worldwide, especially in Southeast Asia, and the number of new buildings is predicted to increase because of economic growth. Most of these buildings are anticipated to obtain green building certification for contributing positively to the health and well-being of the occupants in terms of assessing the occupants’ comfort. However, it is difficult to do so. Because office buildings usually have facades made of glass, the associated transparency results in a large amount of heat gain and daylight entering. These two factors corresponding to the transmitted solar radiation affect the occupants’ comfort, especially for a person seated in the perimeter zone. The area within a radius of approximately 5 meters away from building facades should be investigated separately[1]. This area experiences the largest fluctuations in both the thermal and visual comfort. The thermal comfort index is mentioned in the green-building rating system based on ASHRAE
Standard 55, although only a few visual comfort criteria are specified. However, the effects of heat and light from solar radiation are experienced simultaneously by the occupants, and thus, it is necessary to consider both aspects to adopt steps to improve the occupants’ comfort.

1.2 Building facades’ effect

The function of windows was stated the criteria for window function as following: daylight, ventilation, sunlight, and view[2]. Based on the case study buildings, office buildings usually have facades made of glass. The associated transparency from these buildings can result in a large amount of solar heat gain, daylight, and an exterior view. Therefore, the impact of building facades on the indoor environment was studied based on temperature, lighting, and view.

The building facade is one of the most important elements and has a significant influence on comfort conditions with environmental impact[1]. Occupants situated near windows often experience thermal discomfort because of radiant temperature asymmetry and increased operative temperature[3]. In addition, solar radiation falling directly on the occupant can exacerbate visual discomfort[1].

The occupants in the perimeter zone experience stronger fluctuation of the indoor environment rather than those in the interior zone because of negative facade effects. Therefore, the satisfaction of the perimeters’ occupants should be treated separately from that of the interiors’ occupants to improve comfort conditions in both areas.

1.3 Internal blind usage

When a building is occupied, the occupants usually install blinds as internal shading devices to reduce the strong effect from the glass facade and allow themselves to maintain their own comfort[4]. The adjustment of internal blinds can result in different levels of indoor environment. Glass facades that are continually obstructed is no daylight use[5] and can also reduce the mean radiance temperature[6]. Thus, it has been shown that the way users interact with internal blinds can influence building performance. However, the occupants’ comfort in actual situations has not yet been studied. There is a consensus that disregarding the influence of user behavior in buildings may result in erroneous estimates, because users play a key role in the performance of buildings. As the trend toward highly glazed facades in office buildings keeps growing, it is important to study building performance and occupants’ behavior considering its influence on the occupants’ comfort.

2. Methodology

2.1 Case study buildings

Six office buildings involving the operation of an air-conditioning system were selected. The specifications of the three buildings (Offices A, B, and C) located in Singapore and other three (Offices D, E, and F) located in Thailand are listed in Table 1. On-site measurements were performed within 3-5 days during working hours based on the collaboration from the occupants.

Table 1. Basic information of target office buildings

| Location | Office A | Office B | Office C | Office D | Office E | Office F |
|----------|----------|----------|----------|----------|----------|----------|
| Location | Singapore | Singapore | Singapore | Thailand | Thailand | Thailand |
| Construction year | 2014 | 2003 | 2014 | 2014 | 2008 | 2015 |
| Period | 03/18 | 03/18 | 05/18 | 05/18 | 09/18 | 09/18 |
| Total stories | 6 | 5 | 17 | 22 | 40 | 25 |
| Target story | 4 | 3 | 5 | 17 | 14 | 11 |
| Gross area[m²] | 18,591 | 7,094 | 31,360 | 30,060 | 89,029 | 56,400 |
| Target area[m²] | 512 | 1,241 | 2,425 | 1,320 | 3,250 | 1,400 |

2.2 Glass facades with internal blind performance

Building specification was inspected by using the building’s information specification sheet or documents from the building stakeholder to understand how glass performance can affect the indoor
environment and occupants’ comfort. The solar heat gain coefficient (SHGC) of glazing facades was used referring to the optical properties taking into account its influence on the thermal environment with thermal comfort. On the contrary, the visible light transmittance (VLT) resulted in a visual environment with visual comfort. Internal blind lowering/closing has an influence on the indoor environment and occupants’ comfort. The blind’s position or specification has a strong impact on the building-facade performance considering glazing facades combined with internal blinds as an effective layer inside the building. The users’ interaction with internal blinds was evaluated using visual inspection in the four buildings at 11:00 a.m. and 3:00 p.m. The blind occlusion level could be segmented into 10 different percentages from 0% (fully opened) to 100% (fully closed). Moreover, the rate of facing the opening-view area of different seat positions was measured individually in terms of projection factors in six-dimensional values (up-down, front-back, left-right). It was measured by a 360° spherical camera dividing the result by using SPCONV. When a building is occupied, the occupants usually install blinds as internal shading devices. Therefore, the actual facade performance becomes different from the design-phase performance referring to the occlusion of internal blind. The integrated performance of glass with an internal blind was inspected to clarify its actual performance in the holistic facade system. The SHGC was clarified by using WINDOW 7.4 software to simulate glass layers covered with an internal blind layer. Meanwhile, the VLT was clarified from on-site measurement by installation of two pyranometers with two illuminance sensors inside and outside the building at the same level to find out the difference of solar radiation and daylight entering between the outdoors and the indoors. Moreover, the interior surface temperature was measured from thermocouples installed to clarify the surface temperature of the glass and internal blind.

### 2.3 Indoor environment measurement

To understand the indoor environment, a set of measuring devices with a T&D TR-74, TR-52, and globe ball were installed inside the perimeter zone and interior zone on the working partition level to investigate air temperature, globe temperature, humidity, and work plane illuminance level all day long. The mean radiant temperature (MRT) that would result in the heat loss by radiation from a seated person as an enclosure accounted for the interior surface temperature and projection factors. A thermography camera evaluated the surface temperature, while projection factors in six-dimensional values (up-down, front-back, left-right) were measured by a 360° spherical camera dividing the result by using SPCONV software. It will be used not only for MRT calculation, but also for view analysis. The rate of 1 for project area factor means the total facing-surrounded environment of that seated position.

Daylight glare index such as daylight glare probability (DGP) was evaluated in daylit spaces using Evalglare software by using high-dynamic-range photos (HDR) taken from digital single lens reflex camera (DSLR) at 11:00 a.m. and then again at 3:00 p.m. The camera was set at eye-level of seated-person around 1.20 meters. The appropriate range of the DGP was 0.35–0.40[7].

### 2.4 Occupants satisfaction

Paper questionnaires were given to 1,356 samples in the perimeter zone and interior zone. The data survey was divided into subjective and objective variables. The objective variables measured include gender, age group, clothing, and various types of behavior inside the workspace environment. The subjective variables measured is satisfaction levels. The occupants were asked to answer or rate the level for the same questions at 11:00 a.m. and then again at 3:00 p.m. Occupants’ comfort was measured in terms sensation and satisfaction for temperature, lighting, and exterior view. The satisfaction questions used a five-point semantic differential scale with endpoints “dissatisfied” and “satisfied.” For the purposes of comparison, it was assumed that the scale was roughly linear, and ordinal values were assigned to each point along the scale, from −2 (dissatisfied) to +2 (satisfied), with 0 as the moderate midpoint. In the event that respondents indicated dissatisfaction with a survey topic, they were given sensation questions by rating the level of the surrounded environment within a nine-point semantic differential scale with endpoints of extreme conditions, such as “extremely dark” and “extremely bright” for the lighting environment.

This study focused on occupant satisfaction with thermal comfort, lighting comfort, and view comfort. In a given building, the satisfaction score was derived from the mean of all occupants’ votes.
on satisfaction questions in that category. Similarly, the mean satisfaction scores in each zoning of the building layout were computed through a “one zoning, one vote” method to give zonings of various occupant population numbers equal weight in the analysis.

3. Building-facade performance

3.1 Internal blind usage

The inspection results showed that most of the internal blinds were closed all the time during the investigation. The average blind occlusion rates of Offices A, B, C, D, E, and F were 72.57, 80.75, 85.61, 72.75, 76.36, and 92.71, respectively. The orientation is one of the most influential factors for user interaction with internal blinds; different orientations receive different rates of direct solar radiation, and this could influence the way in which the users adapt to their surroundings by opening or closing the blinds. The average blind occlusion rate for the six buildings was 81.73%. The occlusion rates in the east, northwest, west, southwest, south, southeast, northeast, and north orientations were 87.56%, 85.33%, 80.06%, 75.55%, 75.01%, 72.86, 70.12%, and 66.77%, respectively. The east-oriented office and the west-oriented office had a high internal blind occlusion rate, referring to the strong effect from negative solar radiation.

Table 2. Basic information of building facades performance in target buildings

|                      | Office A | Office B | Office C | Office D | Office E | Office F |
|----------------------|----------|----------|----------|----------|----------|----------|
| WWR(%)               | 62.08    | 62.06    | 65.41    | 72.54    | 75.86    | 100      |
| Glass specification  | IGU      | IGU      | IGU      | Heat-Lay reflecting | Low-E IGU | Low-E IGU |
| SHGC(SC)             | N/A      | N/A      | N/A      | 0.51     | N/A      | 0.34     |
| U-factor(W/m² · k)   | N/A      | N/A      | N/A      | 1.78     | 1.81     | 1.56     |
| VLT                  | N/A      | N/A      | N/A      | 0.79     | 0.74     | 0.58     |
| Internal blind       | Roller blind | Roller blind | Roller blind | Roller blind | Roller blind | Roller blind |

The reasons for closing the blinds were evaluated using questionnaires. These reasons can be inferred considering the negative solar effects of the external environment. The prominent negative factors noted in this study were solar heat gain and overbrightness from solar radiation. The reasons for closing internal blinds were primarily to reduce solar heat gain (58%), control overbrightness (25%), cut off the connection between outdoors and indoors for privacy (10%), and avoid an unpleasant window view (7%). It can be concluded that the impact of solar heat gain has the most influence on internal blind adjustment by the occupants.

According to the high rate of blind occlusion, the opening view area was reduced drastically in every building orientation. For the glass facade area, 83.25% was covered with internal blind lowering or closing by the occupants. Only 16.75% of the glass area still opened to connect indoors and outdoors. The projected area factor of the window area for the occupants in the perimeter zone was 0.32, while 0.11 for those in the interior zone. On the contrary, if focusing on only the glass surface area without internal blind covered, the projected area factor of the opening area for the occupants in the perimeter zone was 0.06, while it was 0.02 for those in the interior zone, as shown in Figure 1.

3.2 Optical properties

The way users interact with internal blinds can influence building performance. In the field investigation of glass facade performance, the occupants usually installed internal blinds as internal shading devices to reduce the strong effect from the glass facade and allow themselves to maintain their own comfort. The glass facades that are continually obstruct daylight use and can also reduce heat transmittance.

Of the blinds, 81.73% were closed or lowered all day long during the investigation. In terms of thermal performance, the on-site measurement by thermocouples installation showed that the glass facades’ interior surface was mainly affected by the internal blind surface as the high occlusion rate
shown in Figure 1. Comparing the interior internal blind surface with the interior glass surface, it was 0.18% to 9.24% lower, as shown Figure 2. Moreover, the glass facades with internal blind simulation in WINDOW 7.4 (Office D and Office F) in Figure 3 show that the SHGC is 5.88% to 7.68 % lower. The internal blind was considered an effective additional layer of the whole facade system that can lower heat transmittance from transmitted solar radiation.

In terms of visual performance, the high occlusion rate of the internal blind revealed the lower opening view of the projected area factor at 81.25% in the perimeter zone and 81.81% in the interior zone, as shown in Figure 1. The occupants in the perimeter zone hardly experienced the exterior view, especially the occupants seated in the inner interior zone. Furthermore, the internal blind also obstructed daylight utilization. The illuminance level on the work plane level can be drastically lower from 0.08% to 5,145.77% with blind covering[8] because the VLT of the facade system was reduced for 55.17 % to 73.41%, as shown in Figure4. Its transparency was incapable by internal blind lowering.

4. Indoor environment in perimeter one and interior zone

4.1 Thermal environment
To understand the actual thermal environment performance in the case study office buildings, on-site measurement of operative temperature was conducted. The results in Figure 5. show that the mean operative temperature of the case studies ranged between 21.25 °C and 23.76 °C . The operative temperature for occupants in the perimeter zone ranged from 22.48 °C to 23.76 °C but 21.25 °C to
23.51 °C for those in the interior zone. The operative temperature in the perimeter zone was 1.23% to 5.46% higher than in the interior zone because of the strong effect from the external heat load referring to transmitted solar radiation. The closer a seat position is to a window, the greater the impact. The thermal environment inside the perimeter zone usually fluctuated in terms of solar heat gain as the air temperature measurement shown that perimeter zone was 0.41% to 4.85% higher than the interior zone. Meanwhile, the mean radiant temperature revealed the same trend that the perimeter zone was 0.31% to 7.14% higher than interior zone, as shown in Figure 6.

In addition, the mean radiant temperature accounted for the effect of the surround-surface temperature. Comparing the same seat position near the glass facades with blinds controlled by the occupants and without blinds, the mean radiant temperature was 0.61% to 2.63% lower [8]. This is because the internal blind temperature was 1.66% to 13.24% lower than the internal blind surface temperature, as shown in Figure 2. The impact of the external heat load from glass facades on the mean radiant temperature mainly arises from the internal blind surface temperature.

### 4.2 Visual environment

In this study, on-site measurement was conducted inside daylit space by analyzing the daylight glare probability, which is commonly used for evaluation of the daylight discomfort glare for a source with non-uniform levels of luminance. The results in Figure 7. stated that the mean daylight glare probability of the case studies ranged between 0.01 and 0.31. The daylight glare probability for occupants in the perimeter zone ranged from 0.12 to 0.31, while it was 0.01 to 0.18 for those in the interior zone. The perimeter zone value was 1.23% to 5.46% higher than that of the interior zone because of the impact of daylight entering.

The daylight glare probability inside the Southeast Asia office buildings revealed a low rate in every situation. The international standards mentioned a comfortable range within 0.35–0.40. However, most of the daylight condition distributed at 0.01–0.31. This is because 81.73% of the internal blinds were lowered or closed. Opening-glass area was drastically low as shown in Figure1. And this obstructed condition can lower the VLT of the whole facade as shown in Figure 4.

In addition, the high internal blind occlusion rate resulted in not only less daylight entering, but also a lower projected area factor for the opening area. The opening rate of the perimeter zone was 9.87% to 71.15% higher than that of the interior zone, as shown in Figure 8. However, if one focuses on only the actual opening area without internal blind covering, the glass-opening area was 12.36% to 77.13% lower than the whole window area. The opening rate in the interior zone was 8.45% to 64.36% lower than that of the perimeter zone, as shown in Figure 9. Therefore, The occupants in the interior zone had a smaller projected area factor for the opening-view area compare to perimeters’ people so that they rarely had a window view.

![Figure 5. Frequency distribution of operative temp.](image)

![Figure 6. Frequency distribution of MRT.](image)

![Figure 7. Frequency distribution of daylight glare probability](image)
5. Occupants satisfaction in perimeter zone and interior zone

In the questionnaire survey, the occupants were asked to rate the level of satisfaction for the indoor environment in terms of temperature, lighting, and view. The mean of occupant satisfaction between the perimeter zone and interior zone is plotted in Figures 10. The mean of these two zones is marked by the horizontal dash lines, which show the range of the overall mean satisfaction inside the grey area. The results show that, on average, occupants in the perimeter zone were more satisfied in terms of temperature and view. However, occupants in the interior zone were more satisfied for lighting, because the mean score was higher.

For thermal satisfaction, most of the mean satisfaction score of each building (Offices A, B, C, E, and F) in the perimeter zone was 9.21% to 33.41% higher than in the interior zone. The results indicate that satisfaction scores present positive mean values except for thermal satisfaction inside the interior zone of Office F. When occupants expressed dissatisfaction with a survey category, their sensations were asked simultaneously. The sensation question results show that most of the interior occupants in Office F were dissatisfied because of the cooling environment. Of them, 92.34% felt slightly cool, cool, and cold. Moreover, the satisfaction score of the occupants inside the interior zone in four buildings (Offices A, C, E, and F) was rated lower than those in the perimeter zone because of the dissatisfaction answer concerning the cooling environment.

Not only were the occupants in the interior zone dissatisfied with the cooling environment, but 72.63% of the occupants in the perimeter zone were also dissatisfied with the cooling environment. Even though the air temperature, operative temperature, and mean radiant temperature inside this area were higher than in the interior zone because of the heat gain effect from transmitted solar radiation. The thermal environment inside the perimeter zone mainly resulted in cooling answers from dissatisfied occupants. It can be concluded that negative effect of solar heat gain has a less effect in terms of thermal comfort because of the high rate of internal blind occlusion, which can lower the SHGC and interior surface temperature of the window.

Figure 8. Frequency distribution of Projected area factor of window area

Figure 9. Frequency distribution of Projected area factor of opening-glass area

Figure 10. The mean thermal satisfaction score of temperature, light and view, respectively
The primary reason, based on the questionnaire result, for lowering/closing internal blinds was to reduce the solar heat gain. However, the sensation survey showed that most of the occupants were dissatisfied by the cooling environment rather than the warming environment. Only the occupants seated very close to building facades answered slightly warm, warm, or hot for the sensation questions. Closing the internal blind may originate from heat-reducing reasons. However, when the internal blinds were closed all day long, the environment cooled, so that the occupants were dissatisfied with cooling environment in terms of the thermal comfort.

For view satisfaction, most of the mean satisfaction scores of each building (Offices B, C, D, E, and F) in the perimeter zone was 4.27% to 57.68% higher than in the interior zone. Only Office A was view satisfaction in the perimeter zone lower than in the interior zone. This was because its working space layout was small and narrow. Therefore, the view satisfaction votes of the occupants in those two zones were not drastically different. The results indicate that the satisfaction scores present positive mean values. All the occupants were satisfied with the view category. The opening-view area based on the projected area factors of each seat position inside the perimeter zone were 8.45% to 64.36% higher than those inside the interior zone as shown in Figure 8-9. It can be concluded that a higher degree of view facing in the perimeter zone resulted in a higher view satisfaction score for the perimeter occupants. However, the actual opening-glass area score was super low considering the high rate of blind occlusion. Only the occupants in the perimeter zone had a chance to experience a window view, whereas the occupants inside the interior zone hardly saw the outside view, even though the actual opening-glass area was small. The mean view satisfaction score of each building presented positive mean values for the satisfied mode.

For lighting satisfaction, most of the mean satisfaction scores of each building (Offices A, B, C, and F) in the interior zone were 9.21% to 33.41% higher than in the perimeter zone. The results indicate that satisfaction scores present positive mean values for the satisfied mode. The satisfaction score of the occupants inside the perimeter zone in four buildings (Offices A, C, E, and F) was lower than those in the interior zone because of the dissatisfaction with the brighten environment. The questionnaire result revealed that 84.14% of the occupants in the perimeter zone and 50.47% of the occupants in the interior zone were dissatisfied and felt into too-bright mode.

The questionnaire answer of the satisfied-occupants who answered their satisfactions’ score during 0-2(moderate-satisfied) were clarified with the indoor conditions from the measuring devices in their area, as shown in Figure 11-13. The result revealed a different comfortable range of indoor environment between the occupants in perimeter zone and interior zone. The satisfied-occupants mainly maintain their own thermal comfort and visual comfort under the condition of the area within their seat position. The mean operative temperature for the occupants in perimeter zone was 23.06°C to 23.95°C, while it was 22.13°C to 23.71°C for those in interior zone referring to the thermal satisfaction, as shown in Figure 11. Meanwhile for the visual satisfaction, The mean daylight glare probability for the perimeter zone was 0.17 to 0.26 but 0.03 to 0.14 for the interior zone as shown in Figure 12, and the opening-view based on projected area factor for the perimeter zone was 0.13 to 0.16 but 0.03 to 0.10 for the interior zone, as shown in Figure 13. This means that the occupants be able to adapt to and accept a wide range of indoor conditions base on their surrounded-environment. Moreover, the occupants in perimeter zone seem to have a wider comfortable range than those in interior zone because they always experience more fluctuated condition from building-facade effect.

![Figure 11. Frequency distribution of operative temperature](image1.png)

![Figure 12. Frequency distribution of daylight glare probability](image2.png)
Coming back to the overall-satisfaction analysis, it can be seen that, on average, as shown in Figure 14., the mean thermal satisfaction votes were the lowest compared with those for lighting and view. Thermal comfort has the most influence on occupants’ dissatisfaction. However, the questionnaire result revealed that 68.45% of the occupants in the perimeter zone and 88.54% of them in the interior zone were dissatisfied when answering the sensation questions about the cooling side. This was because of low operative temperature based on the low air temperature and low heat transmission of the building facade considering the high rate of internal blind occlusion. The impact of solar heat gain was not the main distribution from the building-facade effect.

View satisfaction had a higher score than lighting satisfaction. It can be seen that lighting comfort has the higher impact on occupants’ satisfaction. Considering only dissatisfied occupants in both the perimeter zone and the interior zone, most of them were dissatisfied with overbrightness from the sensation question. The brightness in the perimeter zone can be extremely high, especially for a seat position close to the building facade. But the high rate of internal blind occlusion results in a lower daylight glare index for both the perimeter zone and the interior zone. The DGP index was distributed in the range 7.19% to 13.26% lower than the comfortable level at 0.35 to 0.40 based on the international standard. However, the questionnaire result revealed most of the occupants in the perimeter zone and interior zone were dissatisfied and answered the sensation questions in the too-bright mode, even though the daylight index was small because of the high blind occlusion. It can be concluded that the occupants were highly sensitive to the lighting environment. Lighting comfort has the most influence on occupants’ satisfaction in terms of the building-facade effect.

6. Conclusion

As the trend toward highly glazed facades for commercial buildings continues to grow, it is becoming increasingly important to be able to design facades taking into account the influence on occupants’ comfort, especially for occupants inside perimeter zones, who usually experience the largest fluctuation conditions compared with those in the interior zone. Therefore, the occupants usually close/lower internal blinds to reduce solar heat gain and control excessive brightness from...
solar radiation. These negative effects from glass facades cause the occupants to adapt by closing internal blinds to maintain their own comfort.

When a building is occupied with a high rate of internal blind occlusion, a building facades’ performance considering the blind-covering impact is different from that of the design-phase building. Therefore, The opening-view area, the visible light transmittance (VLT) and the solar heat gain coefficient (SHGC) were lowered. However, Thermal environment and visual environment inside the perimeter zone was distributed in a wider range and at a higher level than in the interior zone because of the strong effect from the transmitted solar radiation.

The satisfaction questionnaire result shows that the occupants in those two zone be able to adapt to a wide range of indoor conditions base on their surrounded-environment. On average, occupants in the perimeter zone were more satisfied in terms of the temperature and view. On the contrary, occupants in the interior zone were more satisfied by lighting, with the mean satisfaction score at a higher level. In the overall-satisfaction analysis, the thermal environment has the most influence on occupants’ dissatisfaction based on the lowest mean satisfaction score. However, occupants were dissatisfied because of the cooling environment, even though they were seated inside the perimeter zone that was affected by the strong solar radiation. Because the operative temperature was low. Moreover, the internal blind covering can reduce the negative effect with a lower SHGC and lower window interior surface account to a wide range of indoor conditions. These negative effects from glass facades cause the occupants to adapt by closing internal blinds to maintain their own comfort.

Overbrightness from daylight entering has the most influence on occupants’ satisfaction in terms of the building-facade effect. Most dissatisfied occupants in the perimeter zone and interior zone felt it was too bright, even though the daylight was blocked by the high occlusion rate of the internal blinds and the discomfort glare index was distributed lower than the international standard. The optimisation of lighting comfort is necessary with internal shading devices usage in order to provide a comfortable visual environment for assessing the occupants’ comfort.

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8. Reference

[1] Tzempelikos A, Bessoudo M, Athienitis R, and Zmeureanu R 2007 The impact of shading on thermal comfort conditions in perimeter zones with glass facades. Journal of 2nd PALENC Conference pp 1072-1077
[2] Markus A 1967 The function of windows — A reappraisal Building Science 2 Issue 2 pp 97-121
[3] Huizenga C, Zhang H, Mattelaer P, Yu E, and Arens E 2006 Window Performance for Human Thermal Comfort Final report to the National Fenestration Rating Council
[4] Khamporn N, and Chaiyapinunt S 2014 Effect of installing a venetian blind to a glass window on human thermal comfort Journal of Energy & Buildings 166 pp 538–549
[5] Gago E,J, Muneer T, Knez M and Köster H 2015 Natural light controls and guides in buildings : Energy saving for electrical lighting, reduction of cooling load Renewable Sustain Energy 41 pp 1–13
[6] Khamporn N and Chaiyapinunt S, 2014 An analysis of variables that effect on human thermal comfort from installing a venetian blind to the glass window The 25th conference of the mechanical engineering network of Thailand
[7] McNeil A and Burrell G 2016 Applicability of DGP and DGI for Evaluating Glare in a Brightly Daylit Space. ASHRAE and IBPSA-USA SimBuild 2016 Building Performance Modeling Conference pp 57-64
[8] Chaloeytoy K 2018 Field Investigation on occupants’ comfort considering the effects of glass facades in office buildings in Southeast asia Proceedings of the 12th ISAIA pp 1379-1383
[9] Fanger P.O and Toftum J 2002 Extension of the PMV model to non-air-conditioned buildings in the warm climates Energy Build 34 pp 533-536