# The Effect of Light Shelf and Translucent Ceiling on Daylighting in Office Building in Thailand

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**Abstract**

Daylight control strategies were a challenge for a high-rise building in terms of saving energy consumption. Light shelf was one of the daylight control systems which was usually horizontal or inclined surfaces, placed on the inner and/or the outer side of windows to reflect sunlight to ceiling and distribute the light deeper into the room. This study aimed to investigate the performance of daylight control strategies in office rooms using a light-self with translucent ceiling. The light shelf, which is typically horizontal or inclined, was placed on the inner or outer side of windows to reflect sunlight and distribute it deeper into the room. The study investigated the effect of type of daylight techniques which are a combination of different light shelves and translucent ceiling on daylighting performance. The illuminance level in an office room was calculated using DIALux 4.13 and was performed for working hours in Bangkok, Thailand. The simulation was performed under clear sky conditions and using real climatic data from four orientations. Five types of daylight techniques, including the existing room, were investigated in terms of illuminance level and uniformity of daylight in the office room. The CIBSE (2015) and IESNA (2011) standards indicate that offices room should have uniformity of at least 0.8 and an illuminance level of 500 lux. Thus, the objective of this research was to determine the best combination of light shelves and translucent ceilings for achieving illuminance and uniformity standards. The results showed that the external light shelf with a translucent ceiling and static louver at 90o (option 4) was the best solution for office rooms, providing average illuminance level 776 lux (above the standard) and uniformity 0.4 (nearly the standard). This conclusion suggests that a light-shelf with a translucent ceiling guides daylight deep into the room but less uniformity.

**Keywords:** daylight, light shelf, translucent ceiling, illuminance, uniformity

## 1. Introduction

Daylighting in high-rise buildings is challenging due to the lack of standard requirements for illuminance, especially in office spaces. Daylight was revealed by many studies that it brings comfortable into indoor environment, provide a great chance for energy saving in building, decrease HVAC (Heating, Ventilation, Air-Conditioner) cost, protect user in building from eyestrain and reduce stress (Burmaka et al., 2020). Moreover, the human body synthesizes vitamin D from sunlight, therefore having access to daylight is also important for overall health and wellbeing (Wacker & Holick, 2013). The system to control daylight are light well, atrium, clear story, light shelf, roof monitor, external reflector, reflective louvers, and more (Peter Tregenza, 2011). Light shelves are control daylighting techniques that reflect sunlight to the ceiling, increasing daylighting and reducing heat (Mesloub et al., 2020). Thus, the light shelf provides uniform of light, increases daylighting to presentation in space and shades un-desirable heat from direct sunlight (Kontadakis et al., 2017). As the literature review of case study in Thailand, double cure light shelf can increase illuminance but low uniformity (Sok, 2018) while in Italy, light shelf can increase daylight illuminance back of the room (Berardi & Anaraki, 2015). In USA, Japan, and Korea, curve light shelf improve indoor uniformity (Lee et al., 2019). Also, in Malaysia, light shelf with horizontal light pipe system increases illuminance at the deep of the room (Sern et al., 2022). Moreover, in Poland, light shelf with translucent ceiling provides daylight going deep to the room, improves uniformity which bring a comfortable, and WELL standard to the employee (Brzezicki, 2021). As mentioned, not a few authors have researched the light shelf in Thailand. Moreover, a new method, light shelf with translucent ceiling, hasn't been inspected in Thailand yet, while it seems to be successful in Poland by author (Brzezicki, 2021).

From above reason, this research will explore the effect a light shelf with a drop-light translucent ceiling in an office building on daylighting performance with a real data climate in Bangkok. Five types of daylight techniques were explored in terms of illuminance level and uniformity of daylight in the office room in clear sky condition. The computer software DIALux 4.13 was used to simulate the illuminance and uniformity compared to standard daylighting requirements. The results of this study could serve as design guidelines for daylighting in office rooms and other buildings with similar characteristics such as their openings, room dimension and finishing, and furniture arrangement.

## 2. Material and methods

### *2.1 Recommend illuminance and uniformity level for office room*

The office space is usually designed with the illuminance value of 300-500 lux. However, the modern technology office building with the computer and electronic equipment, the illuminance level increases from 300 lux to 500 lux (CIBSE, 2015 ; Issarasak, 2020). Moreover, according to CIBSE, minimum uniformity should not be less than 0.8. Therefore, the study used 500 lux as illuminance standard and 0.8 as uniformity standard. And if there are many options that pass the illuminance standard, the study will use the highest uniformity as a criterion for the best option.

**Table 1** Recommended light level from CIBSE (2015) and IESNA (2011)

| Areas | Recommended Lux Levels | |
|---|---|---|
| | CIBSE | IESNA |
| General | 500 | 500 |

### *2.2 Characteristics of office room*

The characteristic of the investigated office room is represented as a normal type office room located in Bangkok, Thailand. The office room has a size of 6 meters wide x 12 meters long and 4 meters high. This room has a glass façade made of transparent glass divided into parts. The bottom part is a window which its geometry is 9.6 meters long and 2 meters high and is located 0.85 meters above the floor level. The upper part has size 9.6 meters long and 1 meter high, located 3 meters above floor level. This room also has reflectance on wall of 80%, floor of 30%, and celling of 100% (represents a translucent ceiling). The reason of this because this is a characteristic of most office room in Thailand.

### *2.3 Simulation method*

This research utilized Dialux 4.13, a public domain program used by interior and exterior designers worldwide, to simulate indoor and outdoor illumination (Ciampi et al., 2015). Sketchup 2022 was used to design office room models with different light shelf characteristics. Five types of daylight techniques were explored: option 1 represents a base case (a glass façade without installing light shelf); option 2 is an office room with external light shelf with translucent ceiling; option 3 is an office room with curve external light shelf inclined 10o with translucent ceiling; option 4 is an office room with external light shelf with translucent ceiling and static

louver at 90°; and option 5 is an office room with curve external light shelf inclined 10° with translucent ceiling and static louver at 90°. Four orientations (east, west, south, and north) were investigated for each option. Three days were simulated, including the equinox, summer solstice, and winter solstice. The annual average illuminance was compared to the standard illuminance in office 500 lux. If multiple options provided the best results for the illuminance levels (above 500lux), the uniformity result was considered to find the best option.

### *2.4 Office room geometry for simulation*

The investigated office room in this study chose one office space and considered only staff working area, which has a width of 6 m., a length of 12 m., and a height of 4 m. as an investigated room. The layout of the room is presented below:

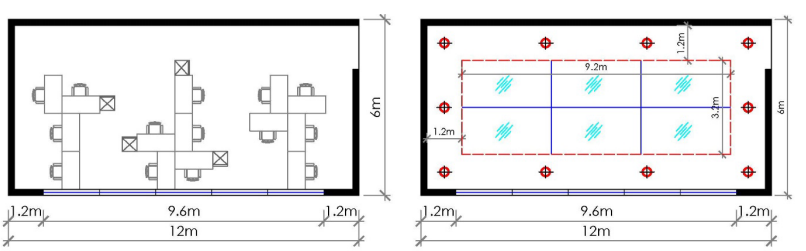
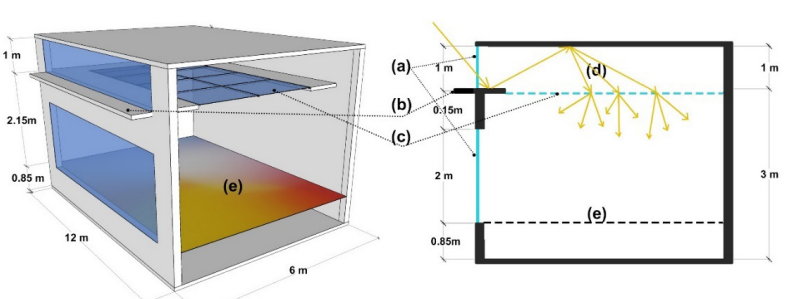



**Figure 1.** Layout plan and celling plan of the office room

**Table 2** Glass geometry

| | Type | Size | Thickness | Transmission |
|---|---|---|---|---|
| **Glass facade** | Transparent glass | 2m x 9.6m | 10 mm | 100% |
| **Glass ceiling** | Translucent glass | 9.2m x 3.2m | 8 mm | 100% |

**Figure 2.** Staff working area room geometry




According to the CIBSE recommendation, room reflectance should be considered as follows: walls have reflectance of 80%, floors have reflectance of 30%, and ceilings have reflectance of 80%. However, this investigated office room chooses ceilings reflectance of 100% which represents a translucent ceiling.

This room geometry characteristics:
(a) transparent glass as the glass façade and clearest story window
(b) a light shelf
(c) a transparent ceiling
(d) a daylight distribution plenum and
(e) a working plan as shown in Figure 2.

Following the literature review, five options was created by two independent variables, which are 1) type of external light shelf (the investigated light shelfs was derived from those tested in previous studies) (Brzezicki, 2021; Sok, 2018; Lee et al., 2019) and 2) type of ceiling (opaque or translucent ceiling) for testing as shown in Table 2 below:

## 3. Results and discussion

### 3.1 Average annual illuminance and uniformity level in south orientation

Figure 2 shows the average annual illuminance for each option, including the base case (option 1), in the south orientation. The result reveals that illuminances from all options are higher than the office illuminance standard, 500 lux. For the base case, option 1 seems to affect the highest illuminance with a result of 2,017 lux, while options 4 has the lowest illuminance result, which are equal to 684 lux. Therefore, to find the best option for this south orientation, uniformity results need to be considered.

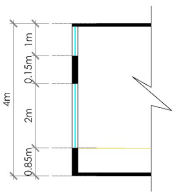
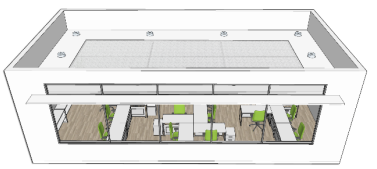
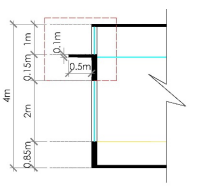
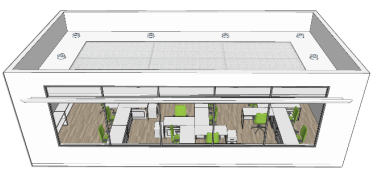
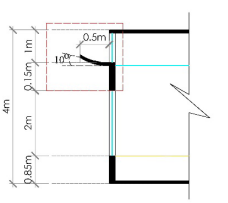
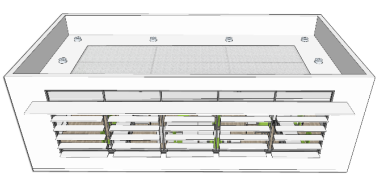
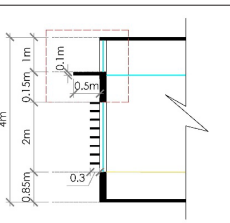
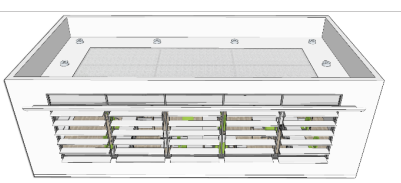
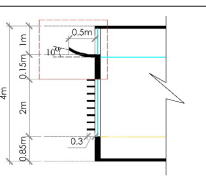
| Description | 3D View | 2D View |
|---|---|---|
| **Option1:** Existing room with glass façade |  |  |
| **Option 2:** External light shelf with translucent ceiling |  |  |
| **Option 3:** Curve external light shelf inclined 10° with translucent ceiling |  |  |
| **Option 4:** External light shelf with translucent ceiling and static louver at 90° |  |  |
| **Option 5:** Curve external light shelf inclined 10o with translucent ceiling and static louver at 90° |  |  |

**Table 3** Independent variable

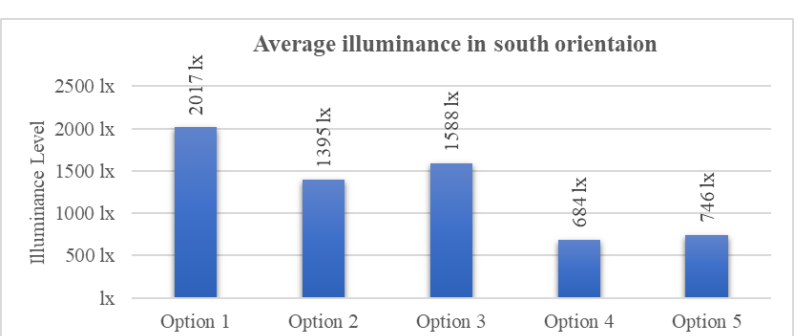



**Figure 3** Average annual illuminance for all options in south orientation

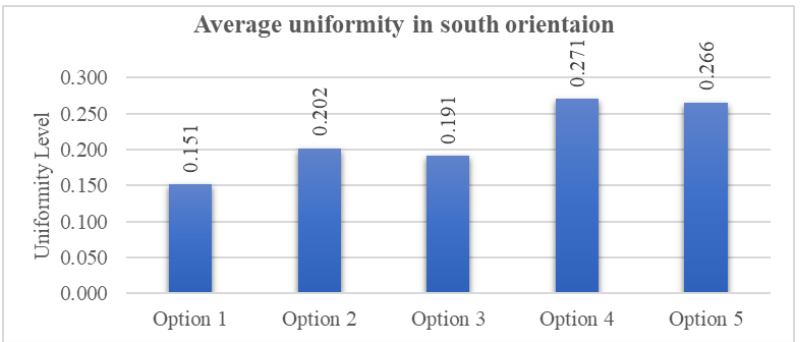



**Figure 4** Average annual uniformity for all options in south orientation

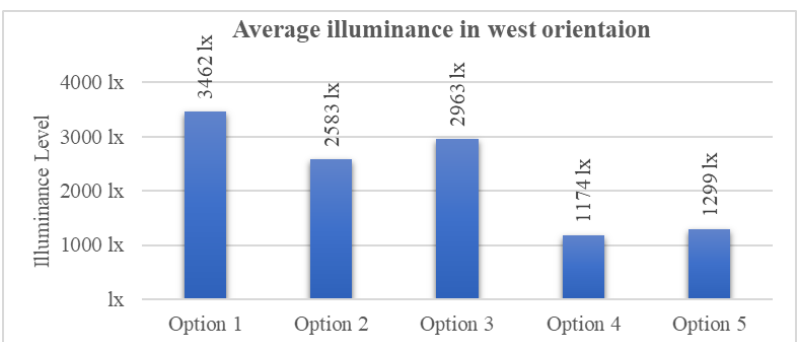



**Figure 5** Average annual illuminance for all options in west orientation

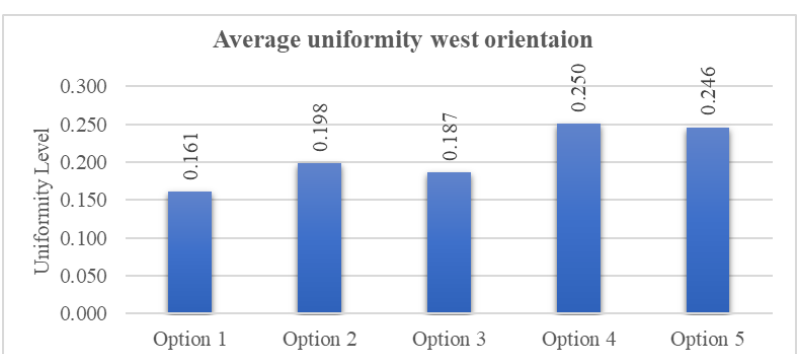



**Figure 6** Average annual uniformity for all options in west orientation

Figure 3 illustrates the average annual uniformity for each option in the south orientation. The result shows that for the base option (option 1) without an installed light shelf, the result was very low, 0.151. After the installation of a light shelf with a translucent ceiling, the result in uniformity increased. Compared to other options, option 4 brings the best uniformity with the result equal to 0.271. As mentioned above, all options have illuminance result pass through the illuminance office standard (500 lux). Uniformity result would be a criterion to conclude the best option. Thus, option 4 is the best option in this orientation.

### *3.2 Average annual illuminance and uniformity level in west orientation*

Figure 4 shows the average annual illuminance for all options in west orientation. Result reveals that all options have illuminance result pass through the standard. Option 1 (without installing a light shelf) has the highest illuminance result of 3,462 lux. After installation of the light shelf method, the results reveal that options 4 comes up with the lowest results equal, 1,174 lux. The reason might be because there are static louvers in option 4 underside the light shelf members Thus, they would protect against sunlight to entering the room.

Figure 5 shows the average annual uniformity of all variables in the west orientation. Option 1 is still the option that has the lowest result of uniformity over 0.161. Notice that on option 4, we can assume that this option has the best result of uniformity over 0.250, which is a better result compared to the other 5 options. It could be concluded that option 4 is the best option in this orientation.

### *3.3 Average annual illuminance and uniformity level in east orientation*

Figure 6 summarizes the average annual illuminance in east orientation for all options. Result reveals that all options have

the highest illuminance over the standard (the highest value is 2,546 lux (option 1) and the lowest value is 793 lux (option 4).

Since all options have the result of illuminance pass through the illuminance office standard (500 lux) so uniformity result will show which option would be the best in this orientation. Figure 7 shows the average uniformity for all options in east orientation. The result shows that all options have uniformity result under 0.3. Option 1, the existing room, has a uniformity result equal to 0.172. However, option 4 brings the best result of uniformity, equal to 0.292. It could be concluded that option 4 is the best option in this orientation.

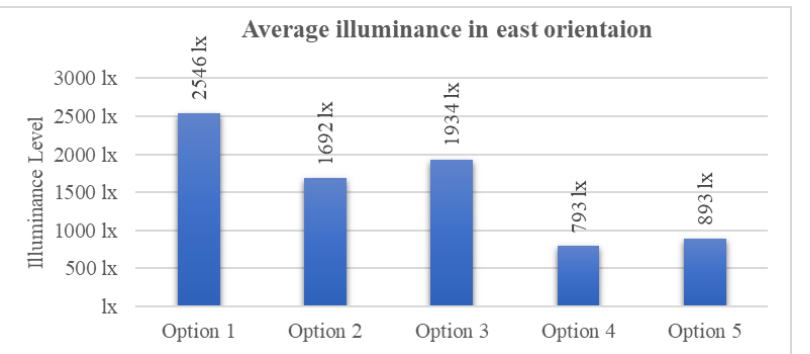



**Figure 7** Average annual illuminance for all options in east orientation

### *3.4 Average annual illuminance and uniformity level in north orientation*

Figure 8 displays average illuminance in north orientation for all options. Compared to the standard illuminance in an office room (500 lux), option 1, 2 and 3 have the illuminance result achieved the standard while option 4 and 5 are lower than the standard.

Average uniformity results is still the criteria to consider which option is the best in this orientation. Figure 9 shows the average annual uniformity in the north orientation. Only option 4, an external light shelf with translucent ceiling and static louver can increase the amount of uniformity which achieve a best result than other options (equal 0.322). Even though option 4 cannot achieve the illuminance standard (500 lux), the result is not much different. Moreover, this option brings a better result uniformity, so this option is still the best option for this north orientation.

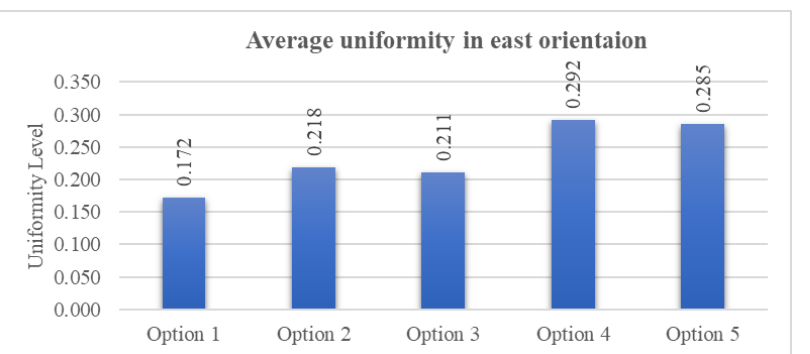



**Figure 8** Average annual uniformity for all options in east orientation

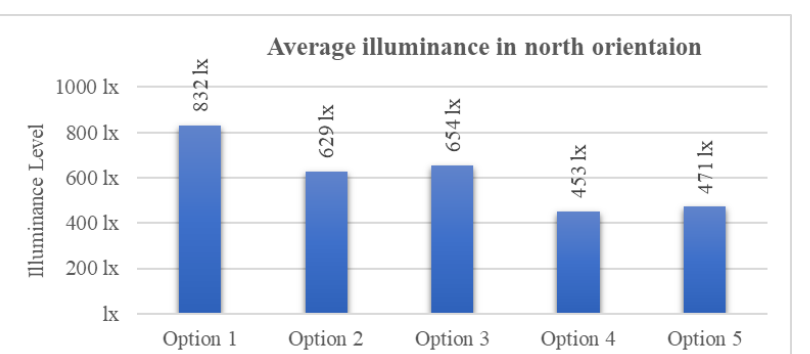



**Figure 9** Average annual illuminance for all options in north orientation

## 4. Conclusion and discussion

In conclusion, the results revealed that option without install any light shelf (option 1) gets the highest illuminance and less uniformity. After installation of light shelf and translucent ceiling method, the results in west, south, east, and north

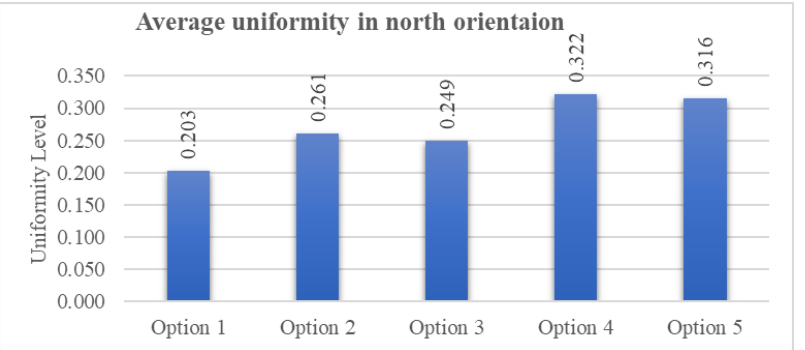
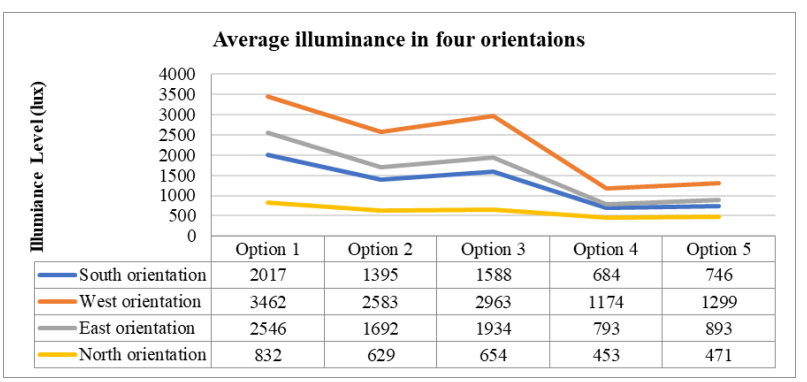
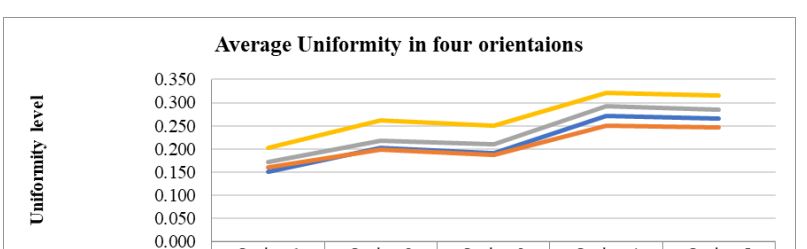



**Figure 10** Average annual uniformity for all options in north orientation




| | Option 1 | Option 2 | Option 3 | Option 4 | Option 5 |
|---|---|---|---|---|---|
| South orientation | 2017 | 1395 | 1588 | 684 | 746 |
| West orientation | 3462 | 2583 | 2963 | 1174 | 1299 |
| East orientation | 2546 | 1692 | 1934 | 793 | 893 |
| North orientation | 832 | 629 | 654 | 453 | 471 |

**Figure 11** Average illuminance in four orientations




| | Option 1 | Option 2 | Option 3 | Option 4 | Option 5 |
|---|---|---|---|---|---|
| South orientation | 0.151 | 0.202 | 0.191 | 0.271 | 0.266 |
| West orientation | 0.161 | 0.198 | 0.187 | 0.250 | 0.246 |
| East orientation | 0.172 | 0.218 | 0.211 | 0.292 | 0.285 |
| North orientation | 0.203 | 0.261 | 0.249 | 0.322 | 0.316 |

**Figure 12** Average uniformity in four orientations

orientation showed that illuminance of all options pass through the standard of 500 lux. It also shows that option 1 gets the highest result and option 4 has the lowest results.

Although the uniformity value of the option 4 still do not reach the standard yet (0.8), the uniformity of this option 4 has a better result than the other options (over 0.3). The finding of this study, thus, yielded the conclusion that option 4 (an external light shelf with translucent ceiling and static louver 90o) is the best option for all orientations. This option has a better result than other options and can bring a good result illuminance and uniformity.

It should be stated that the option 4 is the best solution for this study, where there are static louvers underside the light shelf. Thus, the illuminance nearby the window is not very high. In the practical use of the office room, there should be an installation of artificial lighting at the back of the room to improve the uniformity. Regarding all orientations, Figures 11 and 12 show the average illuminance and uniformity for all options in four orientations. On the west orientation, this room gets a lot more direct sunlight spread into the room than other orientations, but less uniformity. On the contrary, in the north orientation, all options bring the lowest illuminance result, but they provide a better uniformity result than other orientations.

The result of this study correlated to other previous studies (Brzezicki, 2021), which has shown that the combination between external light shelf and translucent ceiling can give a better performance in daylighting in an office room than that without light shelf and having the opaque ceiling. However, the result of this study is contrast to some previous studies in Thailand, which has shown that curve light shelf can give a better daylighting performance than the flat one (Sok, 2018). The reason might be due to the fact that the previous study investigated the

daylighting performance in different context (classroom) and used an opaque ceiling. Therefore, this condition give rise to the lower uniformity result than our study (translucent ceiling may diffuse daylight evenly into the office room space).

To sum up, from the finding of this study and literature review (Brzezicki, 2021; Sok, 2018), external flat light shelf with translucent ceiling design in office room (a size of 72 $m^2$ and 100% transmission on glass façade and glass ceiling located in Thailand) can provide a good daylighting but less uniformity. Thus, for practical use, this method should combine with designed artificial lighting to increase the uniformity.

## 5. Limitation and Suggestion for Further study

Due to the limitation of time and suggestion of further study as follows:

Firstly, the result shows a better option for daylighting in an office room in Thailand, but illuminance still much higher than the standard (500 lux). There are two possible reasons, which are 1) glass transmission of ceiling and 2) size of the translucent ceiling. Therefore, to make a better daylight illuminance level in the office room, the next study should be investigate the effect of a decrease in glass transmission façade (from 100% to 80%, 60%, 40%, 20%). Moreover, the next study could be an investigation of the effect of a decrease in size of the translucent ceiling on daylighting level.

Secondly, due to time limitation, this study explored the effect on daylighting in a clear sky only. Thus, the next study would be investigate daylighting performance in other sky conditions.

Lastly, according to (Wolska & Sawicki, 2020) , since the illuminance nearby the window would be glaring, there should be further studies to investigate how to improve the glaring effect from the finding of this study.

## 6. Conflict of Interest

The authors declare that there are no conflicts of interest.

## 7. Acknowledgements

The authors would like to thank the Faculty of Architecture, Kasetsart University for supporting this research.

## References

Berardi, U., & Anaraki, H. K. (2015). Analysis of the impacts of light shelves on the useful daylight illuminance in office buildings in Toronto. *Energy Procedia, 78,* 1793-1798. https://doi.org/10.1016/j.egypro.2015.11.310

Brzezicki, M. (2021). An evaluation of useful daylight illuminance in an office room with a light shelf and translucent ceiling at 51° N. *Buildings, 11*(11). https://doi.org/10.3390/buildings11110494

Burmaka, V., Tarasenko, M., Kozak, K., Omeiza, L. A., & Sabat, N. (2020). Effective use of daylight in office rooms. *Journal of Daylighting, 7*(2), 154-166. https://doi.org/10.15627/jd.2020.15

Ciampi, G., Rosato, A., Scorpio, M., & Sibilio, S. (2015). Daylighting contribution for energy saving in a historical building. *Energy Procedia, 78*, 1257-1262. https://doi.org/10.1016/j.egypro.2015.11.270

Issarasak, S. (2020). *Characteristic of office's operation expense (OPEX): A study of grade a office building in Bangkok*. https://www.researchgate.net/publication/347443086_Characteristic_of_office's_Operation_Expense_OPEX_A_study_of_Grade_A_office_building_in_Bangkok

Kontadakis, A., Tsangrassoulis, A., Doulos, L., & Zerefos, S. (2017). A review of light shelf designs for daylit environments. *Sustainability, 10*(2). https://doi.org/10.3390/su10010071

Lee, H., Seo, J., & Choi, C.-h. (2019). Preliminary study on the performance evaluation of a light shelf based on reflector curvature. Energies, 12(22). https://doi.org/10.3390/en12224295

Mesloub, A., Ghosh, A., Albaqawy, G. A., Noaime, E., Alsolami, B. M., & Zhao, D. (2020). Energy and daylighting evaluation of integrated semitransparent photovoltaic windows with internal light shelves in open-office buildings. *Advances in Civil Engineering, 2020*, 1-21. https://doi.org/10.1155/2020/8867558

Peter Tregenza, M. W. (2011). Daylighting Architecture and Lightning Design. *Routledge*. https://doi.org/https://doi.org/10.4324/9780203724613

Sern, C. H. Y., Liou, L. T. K., & Fadzil, S. F. S. (2022). Daylighting performance of integrated light shelf with horizontal light pipe system for deep plan high-rise office in tropical climate. *Journal of Daylighting, 9*(1), 83-96. https://doi.org/10.15627/jd.2022.6

Sok, T. (2018). *A Study of the effect of characteristic of multiple curve light shelf on daylighting in university classroom* [Master's thesis, Kasetsart University]. Kasetsart University.

Wacker, M., & Holick, M. F. (2013). Sunlight and vitamin D: A global perspective for health. *Dermatoendocrinol, 5*(1), 51-108. https://doi.org/10.4161/derm.24494

Wolska, A., & Sawicki, D. (2020). Practical application of HDRI for discomfort glare assessment at indoor workplaces. *Measurement, 151*. https://doi.org/10.1016/j.measurement.2019.107179