Conference Proceedings
July 2015

Hokkaido, Japan

ICEAS
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ISBN 978-986-90263-9-0

ICEAS
International Conference on Engineering and Applied Science
ISBN 978-986-87417-1-3

Fundamental and Applied Sciences 2

Michaelangelo

2015/07/22 Wednesday 10:45-12:15

Session Chair: ***Prof. Angsumalin Senjuntichai***

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ICEAS-3745
Experimental Study on Daylighting and Visual Glare in an Educational Building: A Case Study of Lai Sue Thai Building, Ramkhamhaeng University

Lerdlekha Tanachaikhan
Faculty of Engineering, Ramkhamhaeng University, Thailand
lerdlekha@hotmail.com

Abstract

Solar energy can be an important alternative as a primary source of light and heat for commercial and residential buildings. Daylighting can help reduce electric lighting requirement in buildings, such as offices, educational buildings, and factories. Moreover, daylighting provides more pleasant atmosphere and also allows people to have visual contact with the exterior view. This paper presents an experimental study on the potential of daylighting and visual glare in an education building namely Lai Sue Thai under tropical climate conditions of Bangkok. Interior illuminance measurement module was developed to collect the 15-minutes interval data for analysis of daylight availability. From study, it can be observed that daylighting can be effectively adopted to reduce electric lighting. Interior illuminance was found exceeding the illuminance standard level by up to 90% of experimental period while visual glare should be well controlled. For Lai Sue Thai Building, the visual glare index was acceptable. These experimental results agreed well to the simulation results from previous study. Therefore, daylighting in this building would be available and suitable not only for energy conservation but also for educational activities.

Keyword: Experimental study, Energy, Daylighting, Visual glare, Building

1. Introduction

Solar energy can be an important alternative as a primary source of light and heat for commercial and residential buildings. As a major source of light, passive solar exploitation or daylighting can help reducing electric lighting requirements in buildings, such as offices, educational buildings, and factories. In the tropics, daylighting using skylight has been shown to have a high potential in reducing electrical lighting energy and could provide a more pleasant atmosphere of daylit space [1, 2].

This study presents an experimental study on daylighting through clear glazing window, window with vertical blinds, and glazing window with low visible transmittance film to assess the potential of daylighting in reduction of electric lighting in office space of a lecturer's room during work hours (8 am to 5 pm) by using Lai Sue Thai Building as a case study. An ability to illuminate the daylit space at the required level by daylight alone was then estimated by cumulative frequency of daylight illuminance or daylight availability. Moreover, visual glare index was also examined to evaluate the visual discomfort condition of the occupants in this building.

2. Experimental Setup

2.1 Point Illuminance Measurement and Data Gathering Module

Point illuminance measurement and data gathering module consists of illuminance sensors, Analog to Digital Converter (ADC) for data gathering in the computer, and software developed for monitoring the measured results as shown in Figure 1.

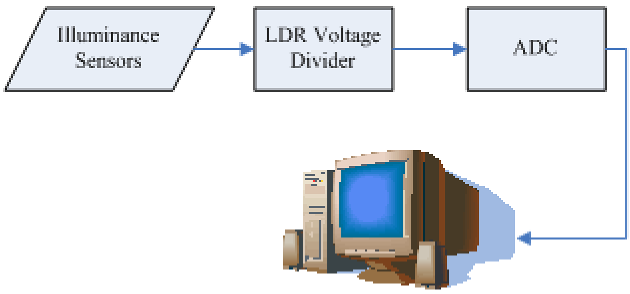

Figure 1 Point illuminance measurement and data gathering module

Figure 2 shows the illuminance sensor developed from Light Dependent Resister or LRD which is small and easy for installation. Each LDR was connected to the voltage divider and the output from this circuit was then transmitted to the ADC for gathering data in the computer. LDRs used in this study were initially calibrated with Lux meter (Technology Instruments model DK-200, ±3% of accuracy) to ensure the accurate digital output from the ADC. The measured results were then illustrated in the illuminance unit (Lux).

Figure 2 Illuminance sensor developed from LDR

The software used in this study was developed from package software. The collected data were from the ADC via RS-232 and the interface was Window program. The data could be collected in Text File for further application as well. Data gathering and monitoring program was controlled by user and the illuminance measured results were illustrated in real time as shown in Figure 3 [3].

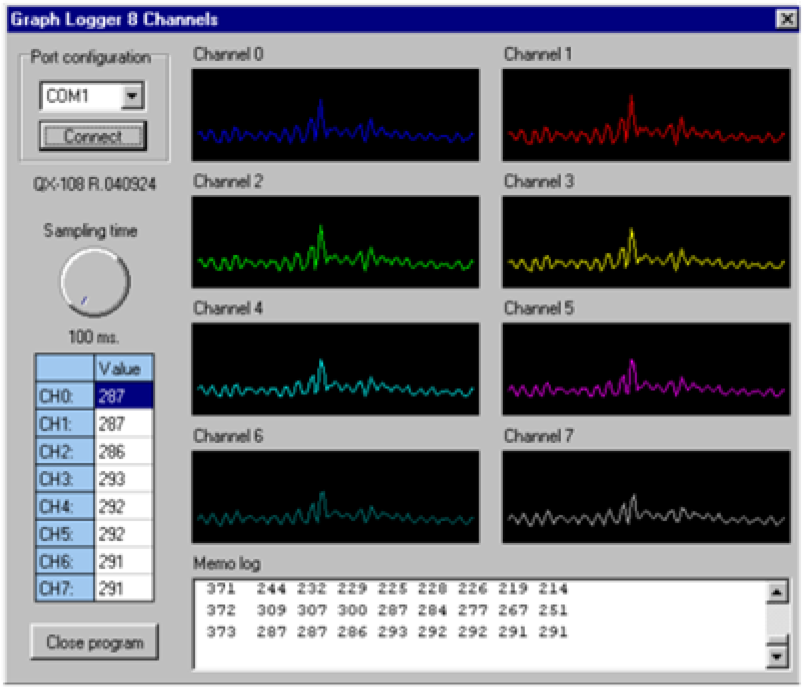

Figure 3 Data Gathering and Monitoring Program

2.2 Experimental Study on Daylight Availability

Lai Sue Thai building is a 5-stories concrete building which consists of lecture rooms and office spaces. For rooms exposing to exterior environment, only one fenestration per room is placed lengthwise along the façade facing east, west, north, or south direction while other walls are opaque and painted white. The Fenestrations are 6 mm-clear glazing, 1.5 m high, and placed 1.65 m above floor level. Very large size overhangs (2.8 m in width) are constructed at each story around the building. Overhang is a primary method to control direct solar radiation and generally used in tropical buildings. The appropriate depth of overhang calculating from extreme solar angles for Bangkok is about 1.2 m for 1.5 m high window [4]. High rise buildings are also located on east and west directions of the building. Therefore, direct and strong sunlight can be effectively controlled throughout the year for this building.

All lecturers' rooms are located on second floor with identical size and configuration. The occupants in the room are engaged with normal office activities. Air conditioning system used is split type and electric lighting is fully equipped during work hours. Lecturers' rooms with single fenestration are on east and west directions of the building. Window-to-Wall ratio (the ratio of the transparent area on one façade and the overall façade area or WWR) of the lecturer's rooms is 44%. From previous study, variations of daylight illuminance on vertical planes of east and west façade are symmetrical [5]. Therefore, a lecturer's room facing east direction was chosen for this study. Layout of the room is as shown in Figure 4.

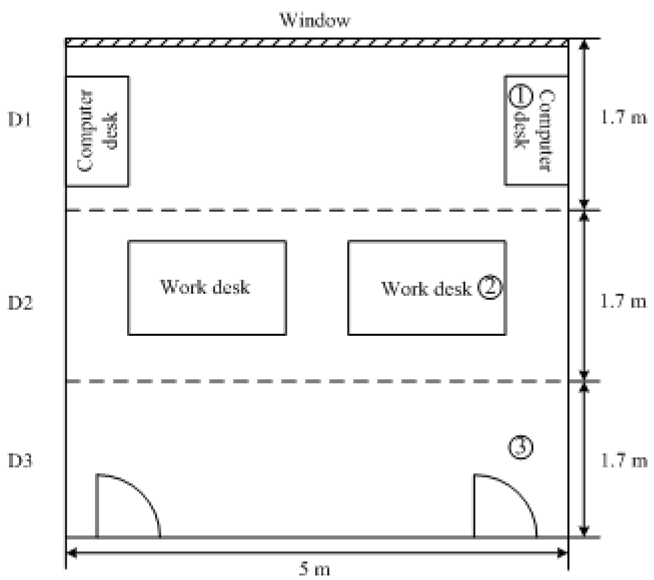

Figure 4 Layout of a selected lecturer's room

In this study, there were 3 cases considered:

1. Initial room with clear glazing window (Visible transmittance = 0.88)
2. Window with vertical blinds (10 cm width, 1.5 m length, 45 degree tilted angel)
3. Window with low solar transmittance film (Visible transmittance = 0.3)

In general, daylight illuminance is exponentially penetrated into deep space area. The room was therefore divided into 3 subsections from the windows (D1, D2, and D3) to measure point illuminances and to assess the variation of daylight illuminance on work plane (80 cm above floor level) at the computer desk, the work desk, and the door according to Figure 4. Data were collected every 15 minutes interval during work hours for 30 days. Exterior daylight conditions were referred to Asian Institute of Technology (AIT) Meteorological station.

An ability to illuminate the daylit space at the required level by daylight alone during work hours was estimated by cumulative frequency of daylight illuminance or daylight availability (f_i) which is defined as the percentage of occurrence during experimental period when the point illuminance (E) reaches a prescribed minimum (E_{STD}) [6]. In this study, E_{STD} was assigned by 500 Lux based on the maximum standard of the office space with normal activities [7].

$$f_i = \frac{number\ of\ occurences\ where\ E \geq E_{STD}}{total\ number\ of\ samples} \times 100\% \qquad (1)$$

2.3 Measurement of Visual Glare Index

Visual Glare index is directly related to the material reflectance. If glare index is low, the contrast between work plane and the material is also low that also implies to the visual comfort of the occupant. Glare index (C) can be calculated by [8]:

$$C = \left(\frac{\rho_{max} - \rho_{min}}{\rho_{max} + \rho_{min}}\right) \qquad (2)$$

where ρ_{max} is the reflectance of material

ρ_{min} is the reflectance of work plane

The reflectance can be calculated from the ratio of the illuminance reflected from material (E_1) and the illuminance of the material (E_2). Measurement of E_1 and E_2 can be performed using lux meter (Technology Instruments model DK-200) as shown in Figure 5.

$$\rho = \frac{E_1}{E_2} \qquad (3)$$

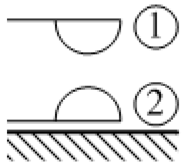

Figure 5 Reflectance Measurement

3. Experimental Results

3.1 Daylight Availability

The daily average values of exterior daylight illuminance data measured during experimental period are as shown in Figure 6 and can be divided into 3 parts: global, beam, and diffuse illuminances. The sky conditions can be explicitly categorized by using Sky Ratio based on Illumination Engineering Society of North America (IESNA). It was observed that the occurrence frequencies of partly cloudy sky, clear sky, and cloudy sky during experimental period were about 82%, 15%, and 3%, respectively. These conditions were directly related to the study on Bangkok sky conditions that the occurrence frequencies of partly cloudy sky, clear sky, and cloudy sky in annual basis were about 80%, 15%, and 5%, respectively [3].

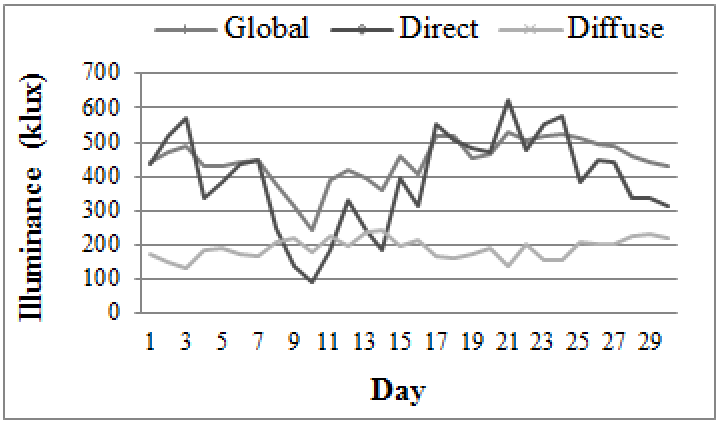

Figure 6 Exterior daylight illuminance during experimental period

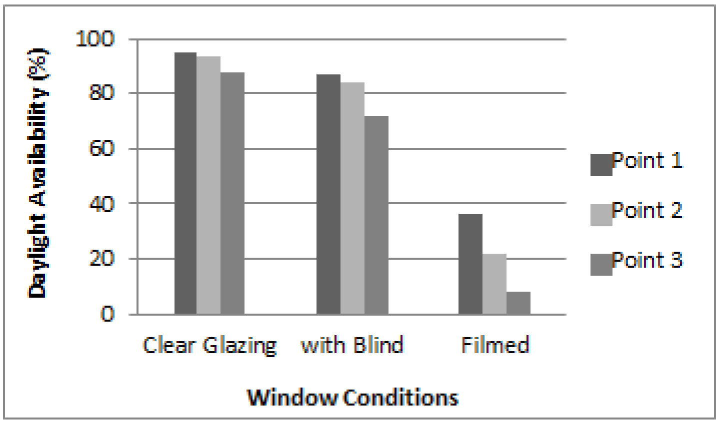

Figure 7 Daylight availability at the standard illuminance of 500 lux

From analysis of daylight availability, the results of 3 considered cases are as shown in Figure 7. It can be noted that the room with clear glazing window can exhibit high daylight availability by 95%, 93%, and 88% for Point 1, 2, and 3, respectively. These results imply the high potential of daylight that can enlighten the room at the requirement of 500 Lux by more than 90% of experimental time without supplementary of electric lighting due to the contribution of large window area and high visible transmittance of glazing. For window with vertical blinds, daylight availability would be slightly decreased to about 85%, 82%, and 70% for Point 1, 2, and 3, respectively due to the influences of tilted angle of blinds (45 degree). Although the availability was slightly decreased, the exterior view was half obstructed. Moreover, it is noted that solar heat gain cannot be shaded as vertical blinds were internally installed behind the window pane. For a room with low visible transmittance or filmed window, daylight availability was significantly decreased to about 36%, 22%, and 6% for Point 1, Point 2, and Point 3, respectively. However, solar heat gain can be effectively shaded due to low solar transmittance of filmed window.

It should be noticed that the interplay between the reduction of solar heat gain as heat load to air conditioning system and the increase of electric lighting requirement and also heat load generated by electric lighting that can raise cooling load by 20% should be well balanced for energy conservation in this case.

These experimental results of daylight availability agreed well to the simulation results analyzed in annual basis [4]. However, the simulation results were shown the slightly higher availability (about 5% - 8%) over the experimental ones as the influences of high rise buildings nearby were not taken into consideration. For further analysis, daylight availability of these 3 considered cases can be applied in estimation of electric lighting requirement of this room as well.

3.2 Visual Glare Index

Analysis of visual glare index was performed by measuring the maximum reflectance of material (ρ_{max}) and the minimum reflectance of work plane (ρ_{min}). The material with maximum reflectance was the white paper (ρ_{max} = 0.9) and the reflectance of work plane was considered in 2 cases:

1. Work desk: Work desk was made by wood. The average reflectance of work desk was about 0.4 due to dark color painted.
2. Computer desk: Computer desk was painted light color and polished. The average reflectance of computer desk was about 0.6.

From analysis, visual glare index of work desk and computer desk were about 0.38 and 0.2, respectively that indicate the low visual glare or high visual comfort for the occupants in this room. It is noted that visual discomfort condition would be occurred if the difference of material and work plane reflectance or so called the contrast is high.

4. Conclusion

Solar radiation is a renewable energy which is a primary source of light and heat. Passive solar exploitation or daylighting can be effectively used to reduce electric lighting requirement in daytime as well as to create the pleasant atmosphere for the occupants in the building. This paper presents an experimental study of daylighting and visual glare in Lai Sue Thai Building under tropical climate condition. Interior illuminance data were measured during work hours for 30 days at 3 points in a selected lecturer's room with a clear glazing window (WWR = 44%) facing east orientation. Daylight availability during experimental period was then assessed for those 3 points. From experimental results, it can be observed the high potential of daylighting of this room with about 90% of availability at the standard illuminance of 500 Lux.

However, shaded window (window with vertical blinds) and filmed window could reduce the potential of daylight which in turn can increase both electric lighting requirement and heat load generated by electric lighting to air conditioning system. From analysis of visual glare index, it was observed about 0.2 – 0.38 which implies low contrast or low visual discomfort condition in the selected work space.

5. Acknowledgement

Lerdlekha T. wishes to thank Research and Development Institute, Ramkhamhaeng University for the support of this research.

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