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Daylighting Rules of Thumb and Performance of External Shading Devices for Clerestory Office Room in Kuala Lumpur

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ABSTRACT
Background: Malaysia has a hot and humid climate throughout the year. **Objective:** One of the advantages is consistent daylighting that can illuminate the internal spaces of buildings. Shading devices can significantly reduce building heat gains from solar radiation while maintaining opportunities for daylighting. They can reduce cooling load, solar access when desired and reduce glare. There have been debates on the maximum length of horizontal shading devices to achieve desirable results. This paper presents the impact of different length of shading devices on daylighting performance for simulated clerestory office room. **Results:** Several parameters other than shading devices such as floor depth, ceiling height, opening ratio, glass transmittance and material reflectance have been appointed. The chosen sky type was overcast sky. Models were then simulated and analyzed using an application of IES_VE software called RADIANCE. **Conclusion:** Existing daylighting rules of thumb has been modified and thus new formula has been created based on the medium size of academic office room in public university in Malaysia.

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INTRODUCTION

The use of natural light has been seen as important in improving the environmental quality and energy efficiency of buildings (Aghemo, C., 2008). The diversity of window designs help to optimize the ability of natural light entering the room. One of them is clerestories design as shown in Figure 1. It helps natural light penetrate deeper into the living room. Another advantage is the diffused nature of the light, which results because much of the entering light is reflected off the ceiling (Norbert, L., 2009). Also reduce intensity near the window.

However, solar radiation can become problem in this kind of climate. Thus shading devices were needed to reduce the undesirable penetration of solar radiation. In office buildings, an appropriate selection of solar shading devices can control indoor illumination from daylight, solar heat gains, and glare while maintaining view out through windows, thus saving lighting and thermal energy while maintaining visual comfort (Laouadi, A., A.D. Galasiu, 2009).

At the end of this research, rules of thumb or simplified formula will be produced. Rules of thumb in architectural daylighting are simple and comprehensive principles, which can be readily applied in the design process in order to predict or achieve daylight conditions deemed appropriate for an interior (Nik Ibrahim, N.L., 2002).

Experimental Procedure:

For the purpose of investigating the effects of external shading devices on daylighting and rules of thumb, this study use a series of simulations by an energy analysis program, IES_VE. A model designed based on the medium size academic office room taken from Prime Minister Department’s guideline (Jabatan Perdana Menteri, 2005) which was then simulated. The room size is approximately 5.0m in depth, 4.6m wide and 2.6m high with a clerestory design window facing north. The window glass transmittance is set at 0.9 (being a normal clear glazed window). The variable parameter in this experiment is the horizontal shading devices, which ranged from 0m to 2m with gradual 0.25m interval. Interior room surface reflectance in the simulation has been

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designated as 0.3, 0.6, and 0.8 for floor, wall and ceiling surface reflectance, consecutively (Flynn, J.E., 1992). Approximately, this is similar to reflectance criteria for best visual comfort in office interior proposed by Boylan (Boylan, B., 1987). The daylight illuminance was measured at the work plane 0.85m above the floor surface. Refer to Figure 2 for the section diagram.

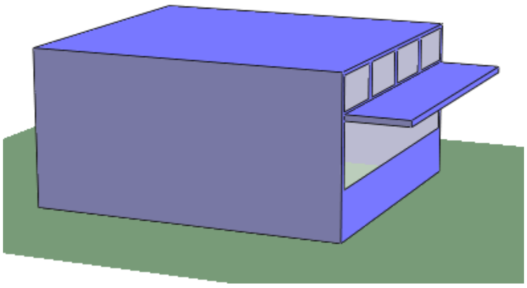

Fig. 1: Clerestory window design with shading device used in the experiment.

The original Littlefair's formula was used to calculate daylight factors which were then correlated to the simulation's daylight factors obtained under an overcast sky. The original Littlefair's daylight factor formula is shown below (Lynes, J.A., 1992):

$$DF_{avg} = \frac{\tau_w A_g \theta}{A_s\,(1-R^2)}$$

DF_{avg} average daylight factor
A_g window glazing area (m2)
τ_w transmission of window glazing
θ sky angle measured at the center of the window in degrees
A_s total area of the room surfaces ceiling, floor, walls and window (m2)
R the average reflectance. For fairly light colored rooms such as in the case studies, a value of 0.5 is normal

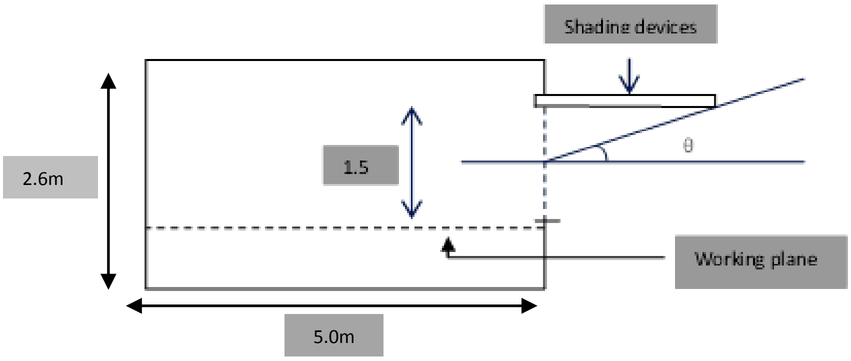

Fig. 2: Section diagram of the simulated room model.

RESULT AND DISCUSSION

Figure 3 shows that the centreline illuminance measured in the simulation decreased with increasing length of shading devices under the overcast sky. The illuminance range between the front and rear interior was larger with shorter or no shading devices. The 3m distance from window is the area with good potential for daylight utilization according to Dubois [9] and this seems to coincide with simulation result. Increasing the length of shading devices had a great impact on the centreline illuminance under the overcast sky but the area of 4.5 meter from the window wall still receives adequate daylight illuminance of not less than 150 lux. The overcast sky in Kuala Lumpur as tested in RADIANCE, IES_VE simulation could provide 18,782 lux on the horizontal plane outdoor free from any obstruction.

Table 1: Results of Daylight Factor, DF for different lengths of shading device under overcast sky.

Shading Length (m)	0	0.25	0.5	0.75	1.0	1.25	1.5	1.75	2.0
Clear Sky angle (θ)	90^0	72^0	56^0	45^0	37^0	31^0	27^0	23^0	21^0
DF_{avg} (%)	6.3	5.1	4.0	3.2	2.6	2.2	1.9	1.6	1.5

As shown in table 1, the angle of visible sky, θ is the angle subtended, in the vertical plane normal to the window, by the visible sky from the center of the window. It shows that the longer shading devices, the narrowed sky angle will become. The length of shading devices need to be converted into a θ in order to get a daylight factor using existing Littlefair's daylight factor formula as shown in the experiment procedure.

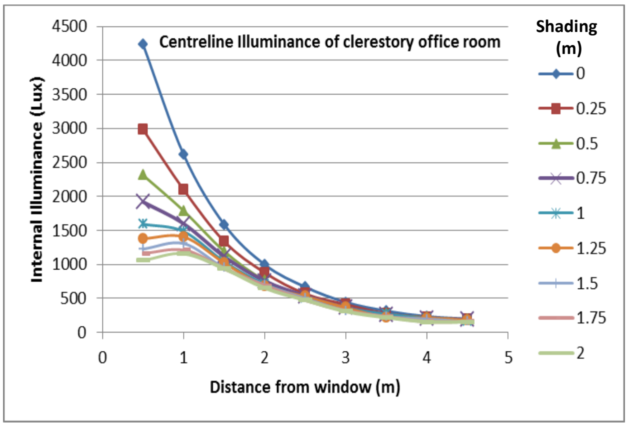

Fig. 3: Measurement of centreline illuminance under an overcast sky.

Figure 4 (a) showed that the average illuminance increment with the increase of sky angle under the overcast sky. The linear correlation is obtained between the average illuminance and the sky angle which can be represented by the following simple equation:

$$E_{avg} = 9\theta + 350 \quad \text{(overcast sky)} \qquad (1)$$

[E_{avg} average illuminance]

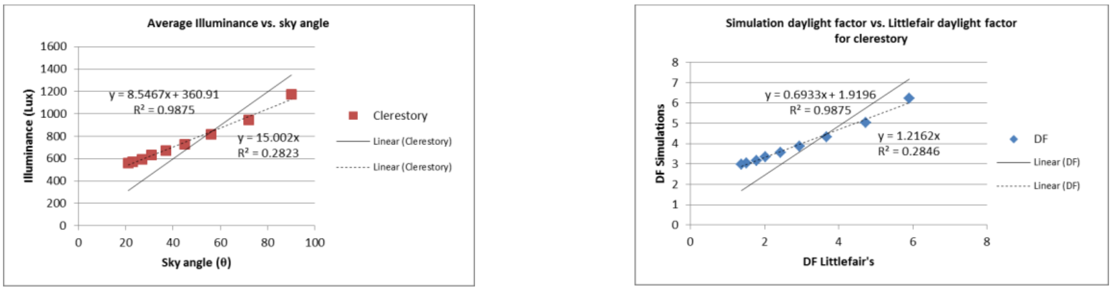

Fig. 4: (a) Average illuminance versus sky angle under an overcast sky (b) Simulation daylight factor versus Littlefair daylight factor under an overcast sky.

Average daylight factors obtained from the simulations and from the calculations made using the Littlefair formula are correlated in Figure 4(b). Based on the linear correlation shown, modification on the Littlefair's formula is necessary to describe the average daylight factors obtained from the simulation. This is shown in the following equation:

$$DF_{avg} = \frac{7\theta + 2}{100} \; \% \qquad (2)$$

Conclusion:

The equations or rules of thumb produced in this article are applicable for the medium size office rooms for public university in Kuala Lumpur with standard glazing transmittance, standard ceiling high, clerestory design window and under an overcast sky. Both these equations can be considered as simple formulas that can ease architects or designers to estimate daylighting based on parameters shown above. From the experiment, it can be

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conclude that average illuminance of not less than 150 lux or approximately 1.5% daylight factor can still be achieved even with the application of 2m long shading device. However, 1m length shading device is the most suitable choice that meets the distance criteria stated by Dubois (Dubois, M.C., 2001).

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