The Performance of External Shading Devices and Daylighting Rule of Thumb for a Tropical Climate

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Abstract: Malaysia has a hot and humid climate throughout the year. One of the advantages is consistent daylighting that can illuminate the internal spaces of buildings. However at the same time, solar radiation and glare problems do exist. The usages of shading devices are necessary to overcome these problems. There have been debates on the maximum length of shading devices to achieve desirable results. This paper presents the impact of different length of shading devices on daylighting performance of the simulated office room. Several parameters other than shading devices such as floor depth, ceiling height, opening ratio and material reflectance have been appointed. Overcast sky was chosen as tropical-compatible sky types. Models then were simulated and analyzed using an application of IES_VE software called RADIANCE. Existing daylighting rules of thumb has been modified and thus create new formula for Kuala Lumpur sky based on the largest academic office room in public university.

Key-Words: daylighting; shading devices; radiance; rules of thumb

1 Introduction
Daylighting should be adopted to overcome the excessive use of electrical energy in office space. There are many benefits for using natural light, for examples reduction in electrical energy consumption and a better indoor quality as often been quoted in the literature.

Based on some case studies done in Malaysia, the use of artificial lighting not only consumed energy but also produced waste heat inside the building that eventually contributed to the heating or cooling load [1]. The use of natural light has been seen as important in improving the environmental quality and energy efficiency of buildings [2].

2 Daylighting Rules of Thumb and the Limited Typologies
According to [3], Rules of thumb have been regarded by some authors as a form of knowledge which has no theoretical reasoning and is therefore unreliable. This perception can be dispelled by adapting a typological approach in dealing with rules of thumb in daylighting. Daylighting rules of thumb can be scientifically examined if their typological limitations are determined and addressed [4]. This potential has been explored extensively in the previous work which range from the unconscious use of typology related to internal variables [5] to a formal typological approach which include external parameter variables such as external obstructions [6] and latitude angles [7].

[8] highlight that a room consists of a set of planes including the floor, walls with apertures and ceiling. They developed a ‘morphological box,’ which recognizes the interdependence between various elements contributing to daylighting performance which occur at room, building and site levels (Table 1). These elements are some of the parameters which have to be specified or framed before any rules of thumb in daylighting can be tested and proposed.
### 3 Benefits of External Shading Devices

[9] have studied the usage of external shading devices for residential buildings in tropical countries. The shading devices were to reduce the undesirable penetration of solar radiation. In this study, a total of six types of external shading devices had been tested by means of LIGHTSCAPE software for daylighting simulation. Generally, most of the shading devices admit illuminance higher than the recommended level.

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 [10]. In another study by [11], it was discovered that an effective passive design strategy to control solar heat gain in buildings is the application of external shading devices, which can reduce solar heat gain more effectively than interior devices.

### 4 Daylighting Standards

According to the [12], shading coefficient, or SC is a percentage of average total heat recovery from the sun that is received through a window in a year. A restriction on the windows that bring value to SC, 0.8 or 80% only block 20% of the sunlight it receives in a year while the barrier that bring value to SC, 0.6 or 60% were blocking 40% of the sun. The standard also outlined illuminance levels recommendations for various applications and the recommended daylight factor (DF) for an effective daylight-lit office space is 1.5%. Studies have been done by [13] also outlines performance indicators for daylight factor, as shown in Table 2.

IESNA and CIBSE has recommended of 100 – 200 lux for minimum working space illuminance where visual tasks are only occasionally performed [14]. Furthermore, Building Research Station, BRS has outlined the illuminance of 100 – 150 lux is suitable for prolonged reading, school and office work [15].

<table>
<thead>
<tr>
<th>Daylight Factor</th>
<th>Interpretation</th>
</tr>
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<tbody>
<tr>
<td>&lt;1%</td>
<td>Unacceptably dark negligible potential for daylight utilization</td>
</tr>
<tr>
<td>1-2%</td>
<td>Acceptable small potential for daylight utilization</td>
</tr>
<tr>
<td>2.5%</td>
<td>Preferable large potential for daylight utilization</td>
</tr>
<tr>
<td>5%</td>
<td>Preferable Ideal for paper work too bright for computer work total daylight autonomy</td>
</tr>
</tbody>
</table>

Table 2: Lighting Performance Indicator [13]

### 5 The Experiment Procedure

For the purpose of investigating the effects of external shading devices on daylighting and rules of thumb, this study use a series or simulations by an energy analysis program, IES_VE. A model designed based on the largest academic office room in UKM, Bangi was simulated. The room size is approximately 6.7m in depth, 5.5m wide and 2.6m high with a full width window facing north. The window glass transmittance is set at 0.9 (being a normal clear glazed window). The ratio of window area to floor area is set at approximately 20%. This is twice larger than the minimum standard for 10% window area to floor area ratio for daylighting [16]. The variable parameter in this experiment is the horizontal shading devices, which ranged from 0m to 2m with gradual 0.25m interval. Interior room surfaces reflectances in the simulation has been designated as 0.3 for floor surface reflectance, 0.6 for wall surface reflectance and 0.8 for ceiling surface reflectance. This is based on [17], the reflection surface recommended for...
general systems are from 0.7 to 0.9 for ceiling finishes, from 0.4 to 0.7 for wall finishes and from 0.1 to 0.4 for floor finishes. Approximately, this is similar to reflectance criteria for best visual comfort in office interior proposed by [18]. The daylight illuminance was measured at the work plane 0.85m above the floor surface. Refer to Figure 1 for the section diagram.

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 [19] is shown below:

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

\(DF_{avg}\) average daylight factor  
\(A_g\) window glazing area (m²)  
\(\tau_w\) transmission of window glazing  
\(\theta\) 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. 1: Section diagram of the simulated room model

6 Results and Discussions

Figure 2 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 distance of 3m from window is the area with good potential for daylight utilization according to Dubois (2001) and this seems to coincide with simulation result. Increasing the length of shading devices for the large room with 20% window to floor area had a great impact on the centreline illuminance under the overcast sky but the area 3-3.5 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 10,000 lux on the horizontal plane outdoor free from any obstruction.

As shown in table 3, the angle of visible sky, \(\theta\) 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 \(\theta\) in order to get a daylight factor using existing Littlefair’s daylight factor formula as shown in the experiment procedure.

As shown in Figure 3, average illuminance increased 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.

\[
E_{avg} = 10 \theta \quad \text{(overcast sky)}
\]

\([E_{avg}\) average illuminance\]
7 Conclusions

The equations or rules of thumb were produced in this article are only applicable for the largest academic office rooms in Kuala Lumpur with approximately 20% window area to floor area ratio, standard glazing transmittance, standard ceiling high, full width window and under an overcast sky. Both these equations can be considered as simple formulas that can ease everybody to estimate daylighting based on parameters shown above. From the experiment, it can be conclude that average illuminance of between 200-250 lux or approximately 1.5% daylight factor can still be achieved even with the application of 2m long shading device. This shows that the usage of shading devices is pretty suitable for buildings in Kuala Lumpur.

References:


