Simplified Formula and Daylighting Performance of External Shading Device for Small Office Room

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Abstract: - Daylighting simplified formula or rules of thumb as an easier method to estimate daylight that penetrate into the room. However we first need to determine the amount of daylight by using shading device. The using of shading device was very much needed to overcome some problems such as reduce cooling load, solar radiation and glare. This study discuss the performance of different length of shading device of the simulated office room based on small size academic office room in public university in Malaysia. The chosen sky types was overcast sky and intermediate sky without sun. Model were then simulated and analyzed using an application of IES_VE software called RADIANCE. As the result, existing daylighting rules of thumb has been modified and new simplified formula was created.

Key-Words: -Daylighting, radiance, rules of thumb, shading devices

1 Introduction

Daylighting can replace artificial illumination, and thus save electricity [1]. The use of daylighting within a building creates a more pleasing and productive atmosphere for the people within. Daylight provides a direct link to the outdoor environment and natural light delivers a dynamic evolving distribution of light [2]. 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 [3]. The use of natural light has been seen as important in improving the environmental quality and energy efficiency of buildings [4].

According to [5], the daylight that enters a window can have several sources: direct sunlight, clear sky, clouds or reflections from the ground and nearby buildings. The lights come not only in quantity and heat content, but also in such qualities as color, diffuseness and efficacy as shown in Fig. 1.

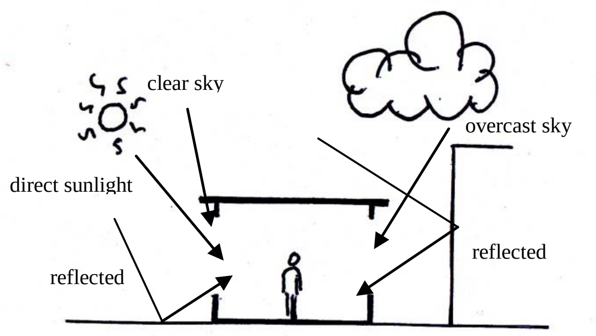

Fig.1: Various sources of daylight

2 Daylighting Rules of Thumb

According to [6], 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 [7]. This potential has been explored extensively in the previous work which range from the unconscious use of typology related to internal variables [8] to a formal typological approach which include external parameter variables such as external obstructions [9] and latitude angles [10].

Reference [11]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.

Morphological Diagram			
Level	Parameters	Var I	Var 2
I	A room layout	2 bilateral	1 unilateral/ 2
	B collector posn.	1 within plane	bilateral
	C collecting area	1 side light<15%	1 within
	D aperture shape	1 intermediate	plane/ 5
	E glare control	1 light filters	2 15-
II	F plan layout	5 atrium	30%/3>30%
	G wall/aperture	1 25%	1
	H aperture	1 symmetric	intermediate/
	distribution	4 other (louvres)	4
	I shading devices	5 screen glass	1 light filters/
III	J roof aperture	1 large blocks	2
	K urban layout		3 unilateral
	L facades		slabs
	reflactances		2 50%/ 3 75%
	M street top		2 solar
	lighting		asymmetric
			3 overhang
			6 other
			9 other

Table 1: Daylighting typology at room, building and town-planning levels

3 External Shading Devices

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 [12]. According to [1], the objectives of shading are to minimize the total solar energy entering a room and thereby reduce the average temperature of the room, prevent sunlight from falling directly onto occupants, reduce the local illuminance of surfaces that may present glare sources to the occupants and prevent the view of brightly lit outside surfaces, or clouds, or the sun itself. In another study by [13], 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. Reference [14] has 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. Also according to [1], irrespective of climate, there are advantages for the main facades of a building to face north and south, rather than east and west, even in the summer, which makes shading difficult, and impossible if a view is to be maintained. Refer Fig. 2.

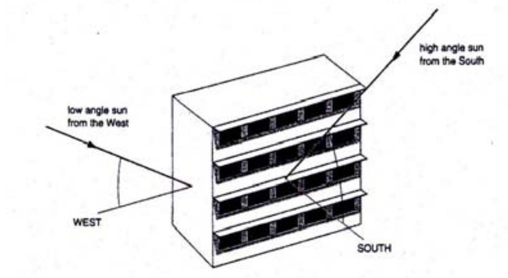

Fig.2: An orientation with the main facades of the building facing north and south is preferable

4 Daylight Factor

The use of the daylight factor has persisted to the present day. The daylight factor has an important characteristic; it is a good indicator of the overall appearance of a room. This is because the brightness appearance of a place depends at least as much on the relative luminance of surfaces within the field of vision as on absolute values. By definition, the daylight factor is a measure of the contrast between inside and outside [15].Daylight factor defined as the proportion of the unobstructed external daylight illuminance that reaches a point inside the room. That is, if the room is removed, the point of interest would receive all the available daylight. That point would be having the daylight factor of 100% [16].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 [17] alsooutlinesperformanceindicatorsfordaylightfactor, as shown in Table2.

IESNA and CIBSE has recommended of 100 – 200 lux for minimum working space illuminance where visual tasks are only occasionally performed [18]. Furthermore, Building Research Station, BRS has outlined the illuminance of 100 – 150 lux is suitable for prolonged reading, school and office work [19].

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Daylight Factor	Interpretation
<1%	Unacceptably dark negligible potential for daylight utilization
1-2%	Acceptable small potential for daylight utilization
2.5%	Preferable large potential for daylight utilization
5%	Preferable Ideal for paper work too bright for computer work total daylight autonomy

Table 2: Lighting performance indicator [17]

4 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 small size academic office room in UKM, Bangi was simulated. The room size is approximately 4.0m in depth, 3.5m 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 [20]. 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 reflectance 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 [21], 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 [22]. The daylight illuminance was measured at the work plane 0.85m above the floor surface. Refer to Fig. 3 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 [23] 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)
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

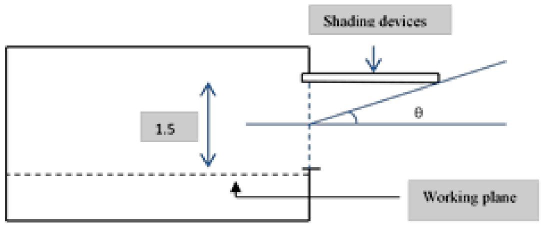

Fig.3: Section diagram of the simulated room model

4 Result and Discussion

Fig. 4(a) and 4(b) show that the centreline illuminance measured in the simulation decreased with increasing length of shading devices under the overcast sky and intermediate sky without sun. The illuminance range between the front and rear interior was larger with shorter or no shading devices. For overcast sky, the area 2 meter from the window wall still receives adequate daylight illuminance by using 2 meter shading device, meanwhile for intermediate sky without sun type, 1 meter shading device is the most suitable for 2 meter distance from the window. Increasing the length of shading devices for the large room with 20% window to floor area had a great impact on the centreline illuminance for both sky types. That intermediate sky without sun and 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.

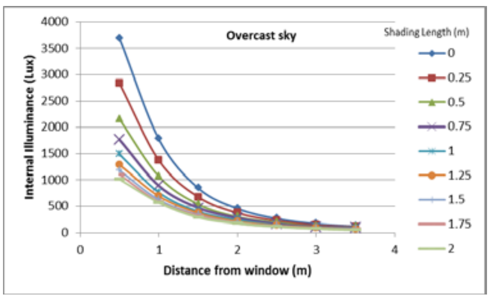

Fig. 4(a): Measurement of centerline illuminance under an overcast sky

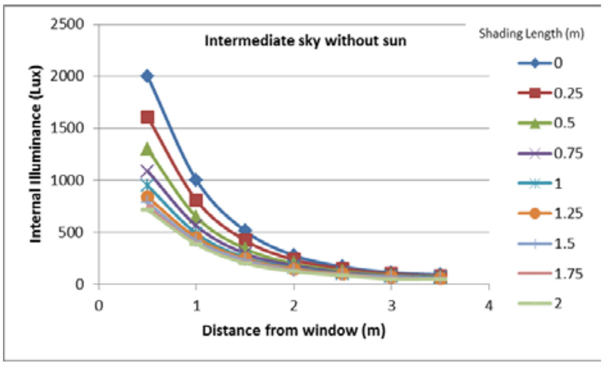

Fig. 4(b): Measurement of centerline illuminance under an intermediate sky without sun

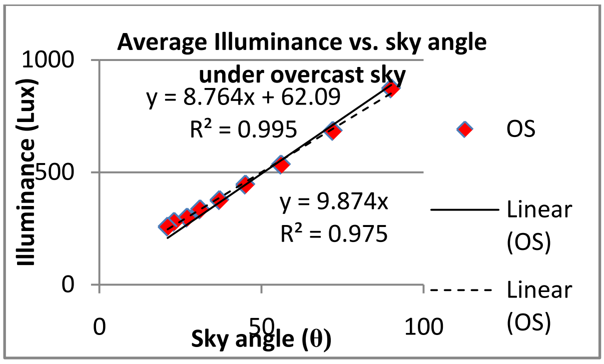

Fig. 5(a): Average illuminance vs sky angle under overcast sky

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} (%)	4.43	3.55	2.76	2.22	1.82	1.53	1.33	1.13	1.03

Table 3: Result of daylight factor, DF for different lengths of shading device

As shown in Table III, 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.

As shown in Fig. 5(a) and 5(b), average illuminance increased with the increase of sky angle under the overcast sky and intermediate sky without sun. The linear correlation is obtained between the average illuminance and the sky angle which can be represented by the following simple equation.

$E_{avg} = 10\,\theta$ (overcast sky)
[E_{avg} average illuminance]

$E_{avg} = 6\,\theta$ (intermediate sky without sun)
[E_{avg} average illuminance]

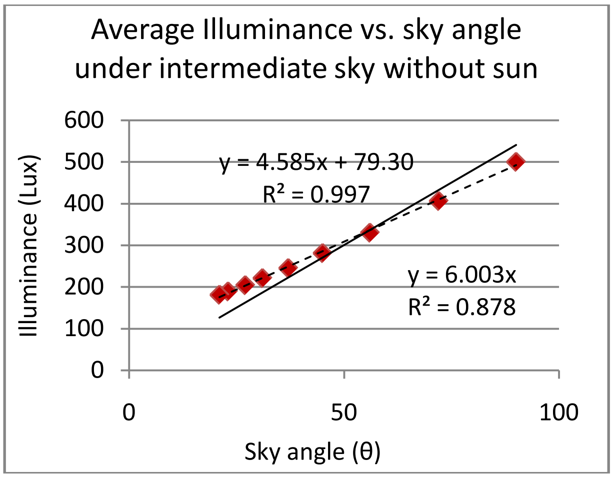

Fig. 5(a): Average illuminance vs sky angle under intermediate sky without sun

Average daylight factors obtained from the simulations and from the calculations made using the Littlefair formula are correlated in Fig. 6(a) and (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.

$$DF_{avg} = \frac{6\theta}{100}\,\% \quad \text{(intermediate sky without sun)}$$

There is no equation for an overcast sky because the graphic below shown that the linear corelation proved that DF simulation is equal to DF Littlefair.

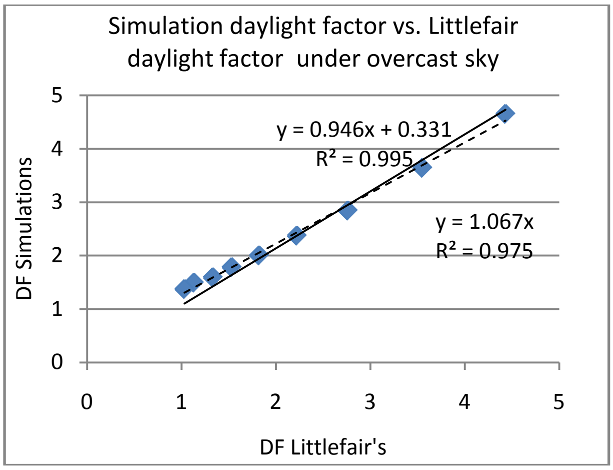

Fig. 6(a): Simulation daylight factor vs Littlefair daylight factor under overcast sky

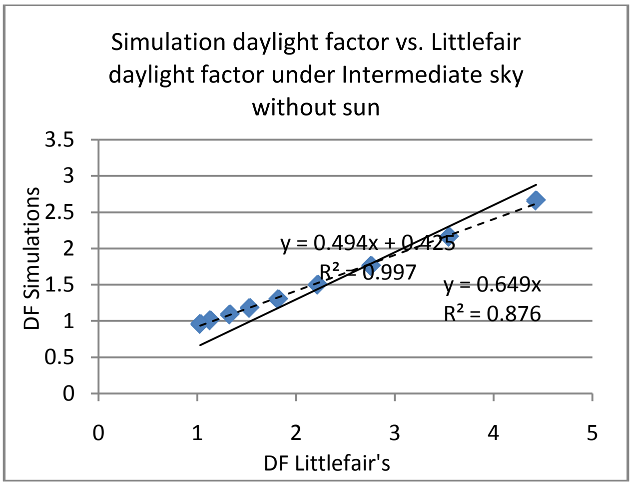

Fig. 6(b): Simulation daylight factor vs Littlefair daylight factor under intermediate sky without sun

4 Conclusion

The equations or rules of thumb were produced in this article are only applicable for the small size 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 concluded that approximately 1-2% daylight factor can still be achieved even with the application of 2m long shading device under both sky. This shows that the usage of shading devices is pretty suitable for buildings in Kuala Lumpur.

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