A STUDY OF VERTICAL SHADING DEVICES FOR DAYLIGHTING THROUGH WINDOW IN THE TROPICS

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ABSTRACT

This paper reports simulation of the vertical shading device application for daylighting in the tropical region. The eastern façade exposure was taken as the consideration. BESim was used in this study to quantify the illuminance on the workplane and cooling energy consumption. The use of vertical shading devices combined with horizontal reflector has been sufficient to penetrate until 50% of the large room at window size 40 % relatives to the total wall area. It was found by that configuration, the energy consumption, combination of lighting and air conditioner could be saved 32 %. Simple payback period has shown that the incremental cost would recover less than 2.5 years.

1. INTRODUCTION

A daylighting system is the use of natural light from the sun to substitute the artificial light in the building for energy saving. In the tropics, the daylight is abundant (Chirarattananon, et al., 2005). However, the light will always come with heat. In the air conditioning building, the heat gain from the solar radiation is the main source of cooling load (Chirarattanon, et al., 2010). The proper strategy must be applied so that the natural light can be introduced with the allowable heat.

Shading is used to block the heat and direct light from the sun while allowing light from the sky and surroundings. The external shading is better than the internal one for tropical regions. It is because once the solar radiation pass through the glass, it will be in the building for good. It is really undesirable for the air-conditioning building, contrary to the high-latitude countries which need the intense solar radiation for heating.

Daylight through window is the common strategy. However, the consideration to shade the direct solar radiation has limited the daylight penetration depth. The wide area of window surely delivers the deeper daylight than the smaller one but it could increase the heat gain also, because the glass has the lower U-value than the opaque wall. There is a condition though there was increasing certain value of WWR, the useful daylight entering the room would not increase significantly (Tzempelikos, et al., 2006). It is called the daylight saturation region.

Another issue is the daylight management from the east or west façade. Since the façade facing the sun on the low-altitude angle, the main task of the vertical shading is to block the beam solar radiation in the morning or afternoon. In another hand, the daylight penetration depth will be decrease much more.

The main objective of this study is to quantify the energy saving as the benefit of lamp reduction by the application of vertical shading devices. There are two type of shading devices. First is the vertical shading devices and the last one is the vertical shading combined with the reflector.

2. METHODS

The calculation of daylighting and heat transfer was taken account by BESim simulation program. The scheme was an office building with the general lighting 300 lux. The working hour was 2340 hours/year started from 08.00 – 17.00. Thus, BESim was set from 08.00 – 16.00 since the energy is calculated one hour forward. The building was located in Bangkhuntien, Bangkok, Thailand, 13.7^0 N of latitude and 100.5^{0}E. BESim used metereological data on 19th, 20th, and 21st of March, June, September, and December 2000. The east façade was used for the scheme in this study.

2.1 Room Model

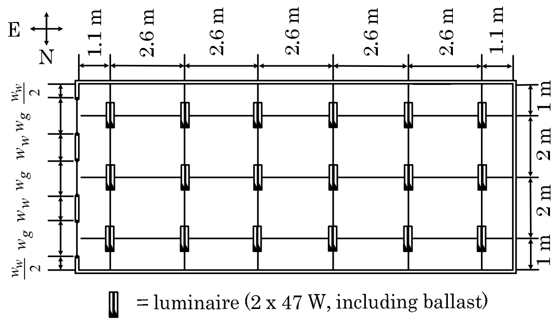

Fig. 1 Room model.

The room model was 6 m x 15.2 m x 2.65 m high. The window width w_g and wall intersperse w_w could be adjusted so that it was fulfill several scenarios by using different window to wall ratio. Window to wall ratio (WWR) is the ratio of the area of window with respect to the area of wall including the window itself.

The wall consisted of brick and cement with thickness 0.075 m. The eastern façade of the room comprised a glazed window that extends 0.85 m from the floor by 1.8 m to reach the ceiling. The glazing with thickness 12.38 mm comprised two layer of clear glass which was laminated.

The room was modeled with 30 points of illuminance point on the workplane. First point was at 0.5 meter from the window. The other point was 0.5 meters each other. The workplane height was 0.75 m from the floor.

Table 1 Properties of glazing.

Properties		Value
Emissivity		0.82
Conductivity		1.053 W/mK
Density		2512 kg/m^3
Spesific heat capacity		880 J/kgK
Daylight	Reflectance	0.07
	Transmittance	0.85
Solar	Reflectance	0.06
radiation	Transmittance	0.62

2.2 Shading Devices

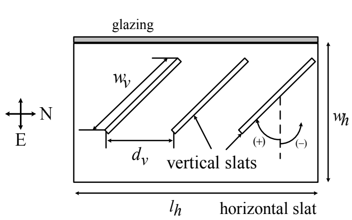

Fig. 2 Horizontal cross-section of shading devices.

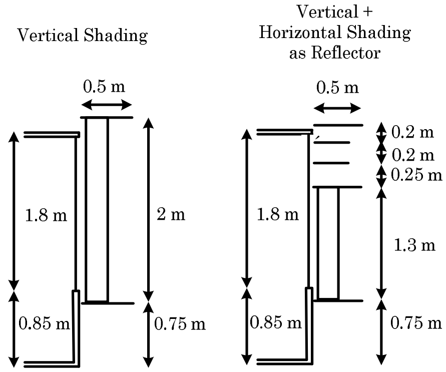

Fig. 3 Side-view of shading devices.

The vertical slats were varied. For March, September, and December, the slat angle 45^0 was applied. Meanwhile, 45^0 was for June. For each window size, the number of vertical slats was varied too. For WWR 0.2, 0.4, and 0.68, it used 15, 21, and 31 vertical slats respectively. The ratio of width to the distance between two slats w_v/d_v was 1.5 where the width of vertical slats w_v was 0.3 m.

2.3 Daylight Penetration Depth and Required Lamp

The illuminance on the workplane was obtained by using ray tracing and flux transfer methods. The calculation method can be found in Chirarattananon (2005).

Each row of luminaries represents one zone. If the border line occurred on the certain zone, starting from that zone until the latest row, the lamp will be turned on. Border line is the line where the illuminance is less than approximately 125 lux. The daylight penetration depth is the distance from the window to the border line.

2.4 Energy Consumption

The energy consumption was only the air conditioner *(AC)* and lighting. Equation (1) and (2) represents the calculation of annual electrical energy consumption and cooling coil load respectively. The coefficient of performance *(COP)* exhibits how much the heat can be extracted from the interior to exterior by 1 unit of electrical energy consumption. The coefficient of AC performance in this study is 2.5. E_a (kWh) is the annual energy consumption, CCL (kWth) is the cooling coil load, LL (kW) is lighting load, n_h (hour) is nominal working hour.

$$E_a = [(CCL \div COP) + LL]\, n_h \quad (1)$$

$$CCL = CCL_{external} + CCL_{internal} \quad (2)$$

2.5 Payback Period and Net Present Value

Payback period *(PP)* and Net Present Value *(NPV)* was employed to analyze the financial issue. The following equations describe *PP* and *NPV* mathematically. *P* (THB or Thai Bhat) is the total present value of the cost or revenue in certain year *n* with certain discount rate *i*. *A* (THB) is the annual cost or revenue. *IC* (THB) is the incremental cost and CS_a (THB) is the annual cost saving. The discount rate *i* was 8 % and the life time of the shading devices *n* was 20 years.

$$P \quad = \{[(1 + i)^n - 1] \div [\, i(1 + i)^n]\}A \qquad (3)$$

$$PP \quad = IC \div CS_a \qquad (4)$$

Table 1 Incremental cost

Item	Price
Shading material	688 THB/m²
Aluminum reflector	211.24 THB/m²
Self-cleaning coating	1,286.6 THB/L

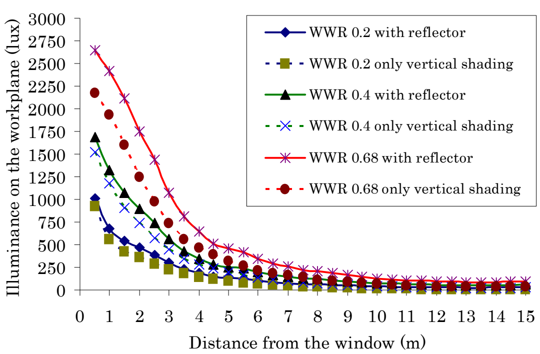

Fig. 4 Illuminance as function of distance from the window at 08:00 on 21st March 2000

3. RESULTS AND DISCUSSION

Figure 4 illustrates the relationship between the illuminance on the workplane with the distance from the window and the window size. By applying the wide window, the illuminance reduction will be less near the window whereas it will be huge by the increasing of the depth. Meanwhile, the application of the reflector is more superior than that of without reflector. More illuminance difference between these configurations occurs by the increasing of window size.

Table 2 Daylight penetration depth and supplemented luminaries

Case	Period	Parameter	WWR			
			0	0.2	0.4	0.68
A	1	DP (%)	0	26	39	49
		Lum (%)	100	83	67	67
	2	DP (%)	0	16	23	36
		Lum (%)	100	83	83	67
B	1	DP (%)	0	36	53	66
		Lum (%)	100	67	50	50
	2	DP (%)	0	16	26	36
		Lum (%)	100	83	83	67

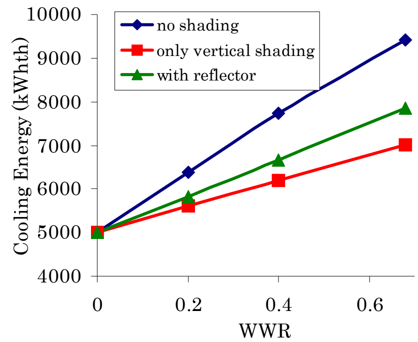

Fig. 5 Annual cooling energy consumption of external cooling load as function of WWR.

The daylight penetration depth *DP* with the border line approximately 125 lux is shown in Table 2. The maximum distance of daylight penetration occurs on WWR 0.68 by applying reflector. It is 10 m, 66% of the room depth. Despite the increasing of window size, the daylight penetration depth is not too much increasing. For WWR 0.4 and 0.68 on the period 1, the amount of supplement luminaries *Lum* is the same.

The data in Table 2 are classified into the case and period of the simulation results. Case A is the room with vertical shading devices whereas case B is that of with horizontal shading devices

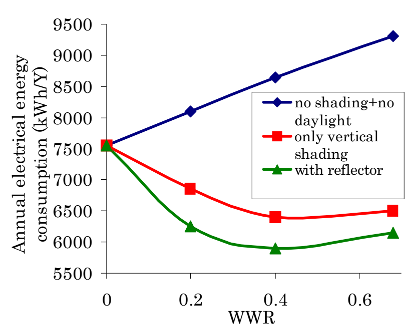

Fig. 6 Annual electrical energy consumption as function of WWR.

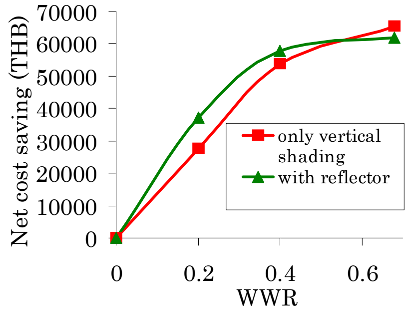

Fig. 7 Net Present Value of cost saving of two shading configurations due to WWR.

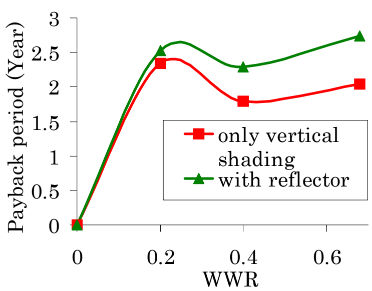

Fig. 8 Payback period as function of WWR.

combined with horizontal reflector. Due to the significant illuminance difference, the period of each case is consisted of 2 periods. The first period is March, June, and September. Meanwhile, December is the second one.

Figure 7 shows that the use of shading devices with reflector will reach the maximum benefit if it is applied on WWR 0.68 which is almost similar to WWR 0.4. Meanwhile, the investment will be returned less than 2.5 years for WWR 0.4 shown in Figure 8.

CONCLUSION

The use of shading devices has sufficiently introduce the daylighting while keep maintaining the heat gain from the solar radiation. The application of vertical shading devices combined with the horizontal reflector has increased the daylight penetration depth compared with the conventional vertical shading devices. It has made the daylight introduce to 50% of the room. It has been leading the building reaching the minimum energy consumption by saving 32 % from the AC and artificial lighting at WWR 0.4. This configuration is also beneficial in finance.

REFERENCES

Chirarattananon, S., Chaiwiwatworakul, P., Hien, V. D., Rakkwamsuk, P., and Kubaha, K., Assessment of energy savings from the revised building energy code of Thailand, *Energy*, vol. 35, no. 4, pp. 1741-1753, 2010.

Franzetti, C., Fraisse, G., and Achard, G., Influence of the coupling between daylight and rtificial lighting on thermal loads in office buildings, *Energy and Buildings*, vol. 36, no. 2, pp. 117-126, 2004.

Tzempelikos, Athanassios and K, Athienitis Andreas, The impact of shading design and control on building cooling and lighting demand, *Solar Energy*, vol. 81, no. 3, pp. 369-382, 2006.

Alzoubi, H. H. and Al-zoubi, A. H., Assessment of building façade performance in terms of daylighting and the associated energy consumption in architectural spaces: Vertical and horizontal shading devices for southern exposure facades, *Energy Conversion and Management*, vol. 51, no. 8, pp. 1592-1599, 2009.

Chirarattananon, Surapong, *Building for Energy Efficiency*. Asian Institute of Technology, Pathum Thani, Thailand, 2005.

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