World Academy of Science, Engineering and Technology
International Journal of Civil and Environmental Engineering
Vol:5, No:11, 2011

Investigating Daylight Quality In Malaysian Government Office Buildings Through Daylight Factor and Surface Luminance

Mohd Zin Kandar, Mohd Sabere Sulaiman, Yong Razidah Rashid, Dilshan Remaz Ossen, Aminatuzuhariah M Abdullah, Lim Yaik Wah and Mansour Nikpour

Abstract—In recent years, there has been an increasing interest in using daylight to save energy in buildings. In tropical regions, daylighting is always an energy saver. On the other hand, daylight provides visual comfort. According to standards, it shows that many criteria should be taken into consideration in order to have daylight utilization and visual comfort. The current standard in Malaysia, MS 1525 does not provide sufficient guideline. Hence, more research is needed on daylight performance. If architects do not consider daylight design, it not only causes inconvenience in working spaces but also causes more energy consumption as well as environmental pollution. This research had surveyed daylight performance in 5 selected office buildings from different area of Malaysian through experimental method. Several parameters of daylight quality such as daylight factor, surface luminance and surface luminance ratio were measured in different rooms in each building. The result of this research demonstrated that most of the buildings were not designed for daylight utilization. Therefore, it is very important that architects follow the daylight design recommendation to reduce consumption of electric power for artificial lighting while the sufficient quality of daylight is available.

Keywords—Daylight factor, Field measurement, Daylighting quality, Tropical

I. INTRODUCTION

DAYLIGHTING is one of main parameters for controlling building energy use.In recent years, there has been an increasing interest in using daylight to save energy in buildings[1].It has been pointed out that in tropical and subtropical regions, daylighting is always an energy saver[2].

Mohd Zin kandar is an Associate Professor at the Architecture Department , Faculty of Built Environment, Universiti Teknologi Malaysia, Skudai, 81300, Johor, Malaysia, e-mail: drzin2000@yahoo.com

Mohd Sabere Sulaiman is with Public Works Department Malaysia, Architectural Branch, Kuala Lumpur, e-mail:¡sabere@jkr.gov.my¿

Yong Razidah Rashid is with Public Works Department Malaysia, Architectural Branch, Kuala Lumpur, e-mail:yongr@jkr.gov.my

Dilshan Remaz Ossen is as senior lecturer at the Architecture Department , Faculty of Built Environment, Universiti Teknologi Malaysia, Skudai, 81300, Johor, Malaysia, e-mail:d_remaz@hotmail.com

Aminatuzuhariah M Abdullah is an Associate Professor at the Architecture Department , Faculty of Built Environment, Universiti Teknologi Malaysia, Skudai, 81300, Johor, Malaysia, e-mail:b-zuhariah@utm.my

Lim Yaik Wah is with the Architecture Department , Faculty of Built Environment, Universiti Teknologi Malaysia, Skudai, 81300, Johor, Malaysia, e-mail:limyaikwah@gmail.com

Mansour Nikpour is with the Architecture Department , Faculty of Built Environment, Universiti Teknologi Malaysia, Skudai, 81300, Johor, Malaysia and with the Architecture Department, Islamic Azad university, Bam Branch, Iran, e-mail:mnik56@gmail.com

Manuscript received July 30, 2011

Ibrahim and Zain-Ahmed (2006) studied to formulate a simple design tool to predict the impact of envelope design options on the potential of energy savings due to daylighting [3]. Zain-Ahmed et al. (2002) experimented the impact of windows geometry on daylighting for Malaysian tropical climate. The findings showed that the optimum opening for daylight was 25% of window-to-wall ratio (WWR)[4].

The optimum overhang geometry by considering the energy saving for building cooling and lighting in tropical climate was investigated by Ossen (2005).It had proven that extensive use of overhang will cause increasing energy consumption for electric lighting due to the lack of daylighting. This will further increase the cooling load due to the waste heat from electric lighting[5].

Shahriar and Mohit (2007) investigated the depth of daylight zone and Permanent Supplementary Artificial Lighting of Interiors (PSALI) in a generalized high-rise office space in Kuala Lumpur, Malaysia[6].

Lim et al. (2009) studied the relationship of solar shading geometry, window size and room geometry in achieving optimum energy saving for office buildings in tropical climate. The balance between the reduction of unwanted heat gain and daylight penetration was studied using computer simulation. The findings showed that the impacts of external overhang solar shading on energy saving increased when overhang ratio (OHR) or WWR increased; or room depth ratio (RDR) decreased. The optimum OHR increased when WWR increased or RDR decreased[7].

Ghisi and Tinker (2005) presented an Ideal Window Area concept when there is effective daylight integration with the artificial lighting system. Rooms of ten different dimensions and five different room ratios were employed to predict the potential for energy savings on lighting, which can up to 86.2%[8].

The impact of glazing area, shading device properties and shading control on building cooling and lighting demand using a coupled lighting and thermal simulation module was investigated[9]. Case study of 13 existing high rise office buildings in Johor Bahru, Malaysia was carried out to investigate the office luminous condition and users' response (Lim and Hamdan, 2010). In most of the cases, the overall luminous ambience was considered dark due to the low WPI and surface luminance. Although these offices were lit up by

electric light, many of them recorded mean WPI lower than minimum 300 lux recommendation. Most of the users closed up the window with blinds or curtain due to the unpredictable global illuminance and glare problem. Plan shape and window sizes did not show much impact on the luminous condition. This was due to the use of electric lighting. The important design criteria were ceiling height, surface reflectance and internal shading devices. Internal shading devices played the most important role in determining the daylight utilization and glare problem[10].
There are several standards used for electric lighting. In Malaysia, the Malaysian Standard 1525:2007 has outlined illuminance levels recommendations for various tasks and applications . The recommended daylight factor (DF) for an effective daylight-lit office space is 1.5% [11].

This standard should be employed as benchmark in lighting study in Malaysia. However, other criteria such as illuminance uniformity, luminance value, luminance ratio, etc. are not mentioned.Dubois (2001) had studied various lighting quality standards from different sources such as IES and CIE. A combination of these standards was used for daylight analysis as shown in Table 1[12]. Some of these recommendations were adapted from electric lighting standards. Therefore, daylight may give better tolerances. This study was carried out under temperate climate. Thus, the recommended daylight factor is considerably high for tropical climate in Malaysia.Daylight utilization is an effective strategy for energy saving as well as visual comfort. From the above mentioned standards, it shows that many criteria should be taken consideration in order to have daylight utilization and visual comfort. However, the current standards are adapted from electric lighting. Hence, more research is needed for daylight performance.

Daylight utilization is an effective strategy for energy saving as well as visual comfort. From the above mentioned standards, it shows that many criteria should be taken consideration in order to have daylight utilization and visual comfort. However, the current standards are adapted from electric lighting. Hence, more research is needed for daylight performance.

TABLE I
LIGHTING PERFORMANCE INDICATOR (DUBOIS, 2001)

Performance indicator	Interpretation
Abslute Luminance	
$> 2000 cd/m2$	Too bright,anywhere in the room
$> 1000 cd/m2$	Too bright, in the visual field
$< 500 cd/m2$	Preferable
$< 30 cd/m2$	Unacceptably dark
Luminance Ratios	
$L_{VDT}/L_{surroundings} < 0.1$ $or > 10$	Unacceptable within 60 cone of vision
$L_{VDT}/L_{surroundings} < 0.05$ $or > 20$	Unacceptable within 120 cone of vision
$L_{paper-task}/L_{VDT} < 0.33$ $or > 3$	Unacceptable within whole visual field
$L_{paper-task}/L_{surroundings} < 0.025$ $or > 40$	Unacceptable within 60 cone of vision
$L_{paper-task}/L_{surroundings} < 0.33$ $or > 3$	Unacceptable within 120 cone of vision
$L_{paper-task}/L_{surroundings} < 0.1$ $or > 10$	Unacceptable within whole visual field
$L_{paper-task}/L_{surroundings} < 0.05$ $or > 20$	Unacceptable
$L_{VDT}/L_{surroundings} < 0.33$ $or > 3$	Unacceptable between points anywhere in the visual field
Daylight Factor	
$< 1\%$	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 II
ROOM INDEX AND NO. MEASURING POSITIONS

Room index	minimum number of measuring positions
Less than 1	4
1 to below 2	9
2to below 3	16
3 or greater	25

II. METHODOLOGY

For this research,5 government office buildings were selected from different states of Malaysia: 1. Wisma Persekutuan (WP)Kuala Lumpur, 2. WP Taiping, 3. WP Temerloh, 4. WP Gua Musang and 5. WP Pinang. Around eight to nine different rooms with different characteristics such as room type, geometry, floor area, window orientation and number of occupants were chosen for survey. Windows glazing of these rooms were clear or tinted. External and internal shading devices were used in some of the rooms. Types of partitions were glass, dry wall or dry wall with glass. Totally 41rooms were selected in different buildings. For each room, different parameters of daylighting performance were calculated. The same method was used for all the buildings and rooms. The method was as follows: First a luxmeter with a data logger was installed at the roof top of buildings. The data logger had been set to record exterior illuminance for every ten minutes, from start until the end of the measurement. Concurrently, the research team measured the illuminance and luminance of interior spaces. For calculating surface reflectance, research group used luxmeter positioned facing and vice versa with respect to each surface (wall, floor and ceiling) of each room. Also the distance of sensor of luxmeter should be 2.3 inch for both facing and vice versa condition with respect to each surface to get the percentage of surface reflectance for each surface. For measuring work plan illuminance, the room index must be calculated.

$RoomIndex = (lengths \times width)/[Mountingheight \times (length + width)]$

The room index is needed to know the minimum number of measuring positions from which average illuminance may be calculated.

Then according to the room index equation and table 2,

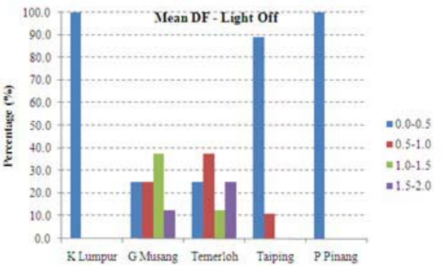

Fig. 1. Percentage of mean daylight factor achieving various ranges when electric lights off

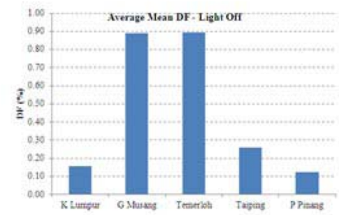

Fig. 2. Comparison of average mean daylight factor when electric lights off

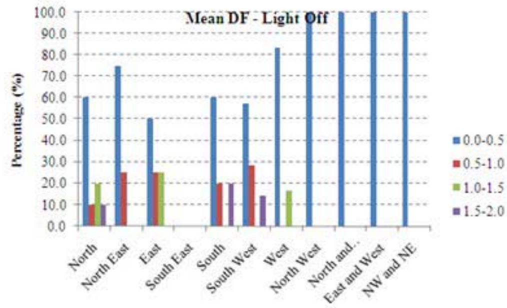

Fig. 3. Percentage of mean daylight factor achieving various ranges when electric lights off according to window orientation

minimum number of measuring points were calculated for each room. The area of each room should be divided into the minimum number of measuring points. According to the minimum number of measuring positions four or nine percent of research group were incumbency to locate illuminance sensor at the middle of each divided area on the work plane 75cm above the floor and They should record illuminance rate at the same time in two conditions (lights on and lights off). For measuring luminance for each surfaces of room the amount of luminance were recorded from the middle of each surfaces of room as well as middle of aperture in two conditions lights on and lights off.

III. Finding and Discussion

A. Daylight Factor

The ratio of relative daylight factor is equal to the internal illuminance divide by external illuminance at the same time. According to MS1525, daylight factor of 1.5% is potential for daylight utilization in general office spaces. The percentage of mean daylight factor achieving various ranges when electric lights off is shown in figure 1,

Figure 1 Percentage of mean daylight factor achieving various ranges when electric lights off When lights were off, hundred percent of surveyed area in WP Kuala Lumpur and WP Pulau Pinang had less than 0.5% daylight factor. Only 10% of surveyed area in WP Taiping achieved daylight factor between 0.5% to 1.0%. Most of the surveyed area of WP Temerloh obtained daylight factor between 0.5% to 1.0%. Most of the surveyed area of office WP Pulau Pinang achieved daylight factor between 1.0% and 1.5%. The average mean daylight factors for all the buildings when electric lights off are shown in figure 2. This graph shows none of the buildings could achieve mean daylight factor over 1.0%.

Daylight factor depends on different parameters. Therefore the relation between daylight factor and some parameters such as window orientation, room plan shape, room type and internal shading devices were investigated.

Figure 3 shows the percentage of mean daylight factor achieving various ranges when electric lights off according to window orientation. Hundred percent of surveyed area which have windows that face to these orientation such as North and south, East and West and NW and NE could not gain mean daylight factor over 0.5%. The percentage of surveyed area which have window facing South, South West and North were 20%, 14% and 10% that could achieve daylight factor between 1.5% to 2%. Besides 24% of the surveyed area that have window facing East gained daylight factor between 1% and 1.5%. Apart from that the percentage of the surveyed area which have window facing North and west and achieved daylight factor between 1% to 1.5% were 20% and 15% . The overall finding of this graph shows that the rooms with window facing south have better potential to get more daylight factor

Figure 4 demonstrates that percent of odd rooms could not achieve mean daylight factor more than 0.5%. Besides more than 90% of deep rooms could not obtain mean daylight factor above 0.5%. In addition, 28% of square rooms could gain mean daylight factor between 1.5% and 2%. The percentages of linear rooms that achieved various range of mean daylight factor such as between 0% to 0.5% ,0.5% to 1%,1% to 1.5%and 1.5% to 2% were 38%, 31% ,25% and 7% respectively. Therefore, square plan shape rooms have ability to achieve more daylight factor in comparison with the other plan shape rooms.

Figure 5 reveals that all executive and sharing room could not obtain mean daylight factor above 0.5%. Hundred percent of meeting rooms have mean daylight factor between 0.5 % to 1% . Eighty percent of open plan rooms could not obtain mean daylight factor higher than 0.5% and 18% of open plan rooms could achieve mean daylight factor between 0,5% to1%. Fifty eight percent of individual rooms could not achieve mean daylight factor more than 0.5% but around 13% of individual rooms could obtain mean daylight factor both two various ranges between 0.5% to 1% and between 1.5% to 2%.In addition around 16% of individual rooms gain mean daylight

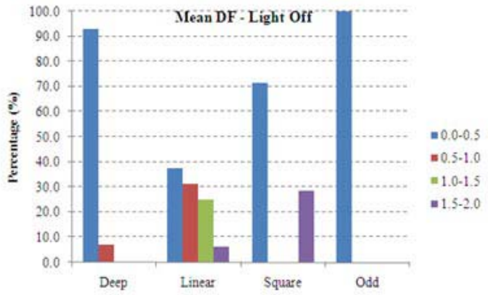

Fig. 4. Percentage of mean daylight factor achieving various ranges when electric lights off according to room plan shape

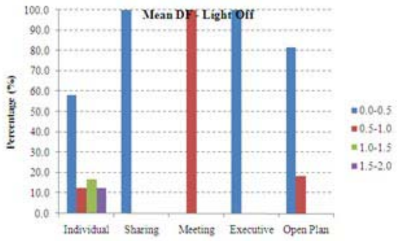

Fig. 5. Percentage of mean daylight factor achieving various ranges when electric lights off according to room type

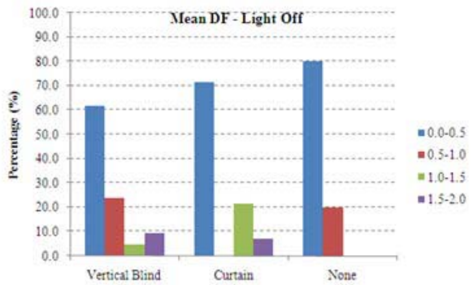

Fig. 6. Percentage of mean daylight factor achieving various ranges when electric lights off according to internal shading devices

factor between 1% to 1.5%. Therefore from the view point of daylight quality, individual rooms performed better comparing to the other types of the rooms.

Figure 6 shows the percentage of mean daylight factor achieving various ranges according to internal shading devices. This figure shows 9% of rooms which have vertical blind achieved mean daylight factor between 1.5% to 2%. The percentage for rooms that have curtain was 7%. On the other hand, 80% of room which have no internal shading devices could not achieve mean Daylight factor over 0.5%. The percentage for rooms that have curtain and vertical blind were 71 % and 61% respectively.therefore this issue can be concluded that rooms with vertical blind can be more appropriate to use daylighting.

B. Surface Luminance

Mean internal surface luminance shows the brightness of surfaces. Benchmark of 30 cd/m^2 for surface luminance is

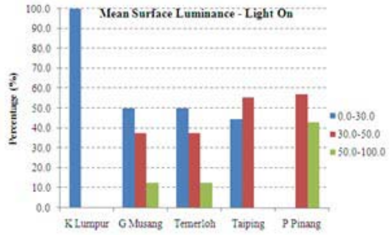

Fig. 7. Percentage of mean internal surface luminance achieving various ranges when electric lights on

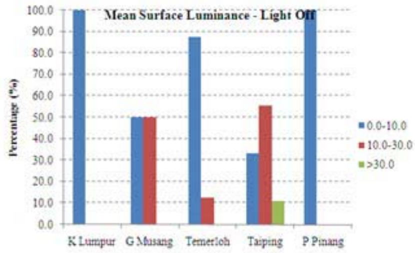

Fig. 8. Percentage of mean internal surface luminance achieving various ranges when electric lights off

acceptable and above this range is preferable. The percentages of mean internal surface luminance achieving various ranges when electric lights on and off are shown in Figure 7 and 8. Hundred percent of surveyed area in office building in WP Kuala Lumpur had mean surface luminance between 0 to 30 cd/m^2 when lights were on. The percentage of surveyed area that achieved acceptable mean surface luminance for WP Taiping, WP Temerlol and WP Gua Musang were 54%, 38% and 38% respectively when lights were on. The percentages of surveyed area in office buildings in WP Pulau Pinang and WP Gua Musang that gained preferable mean surface luminance were 42%, 12% and 12% respectively when lights were on.

Figure 8 shows that when lights were off all spaces of WP Kuala lumpure and WP Pulau Pinang had mean surface luminance between 0 to 10 cd/m^2. The percentage of surveyed area of office buildings in WP Temerloh, WP Gua Musang and WP Taiping that achieved mean surface luminance 0 to 10 cd/m^2 were 88%, 50% and 32% respectively ,when lights were off. Only 10% of surveyed area in WP Taiping achieved mean surface luminance more than 30 cd/m^2 when lights were off.

In addition the comparison of average means internal surface luminance when lights on and off is shown in Figure 9. This figure demonstrates that the average mean luminance when lights were on for buildings in WP Temerloh, WP Taiping and WP Pulau Pinang reached the acceptable range but when lights were off none of the buildings could achieve acceptable range for average mean luminance.

C. Surface Luminance Ratio

Luminance ratio is equal to window luminance divide by average internal surface luminance. This ratio shows how

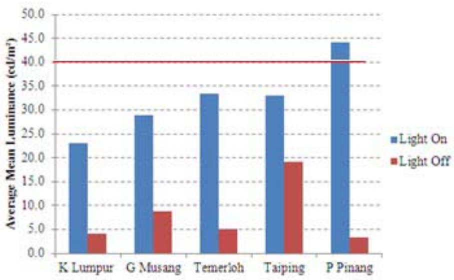

Fig. 9. Comparison of average mean internal surface luminance when electric lights on and off

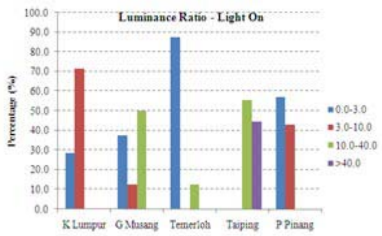

Fig. 10. Percentage of luminance ratio (window/average internal surfaces) achieving various ranges when electric lights on

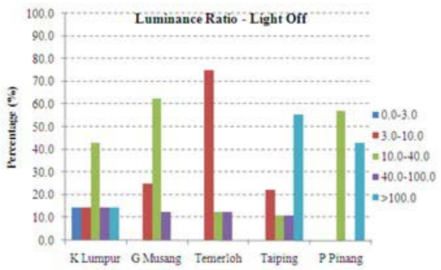

Fig. 11. Percentage of luminance ratio (window/average internal surfaces) achieving various ranges when electric lights off

much the windows were brighter than the internal surfaces. If this ratio remained below 40, it will be acceptable. The percentages of luminance ratio achieving various ranges when electrics lights on and off are shown in figure 10 and 11.

Figure 10 shows that only WP Taiping had 54% of surveyed area recorded surface luminance ratio more than 40 when lights were on. The other office buildings had acceptable surface luminance ratio when lights were on. Therefore the window brightness for most of the office buildings showed acceptable condition when lights on.

figure 11 shows that 54% of surveyed area in WP Taiping and 42% of surveyed area in WP Pulau Pinang and 13% of surveyed area in WP Kuala lumpur achieved surface luminance ratio above 100 which is unacceptable range when lights were off. In addition, 13%, 12%,12% and 10% of surveyed area of office buildings in WP Kuala Lumpur, WP Gua Musang, WP Temerloh and WP Taiping achieved surface luminance ratio between 40 and 100. WP Temerloh had the highest percentage

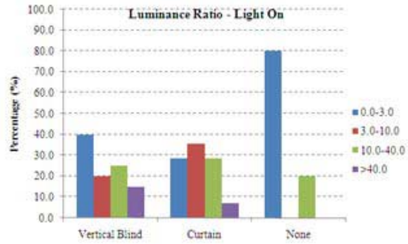

Fig. 12. Percentage of luminance ratio (window/average internal surfaces) achieving various ranges when electric lights on according to internal shading devices

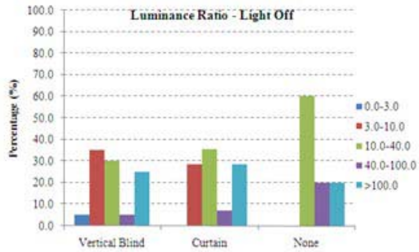

Fig. 13. Percentage of luminance ratio (window/average internal surfaces) achieving various ranges when electric lights off according to internal shading devices

of surveyed area which recorded surface luminance ratio between 3 and 10 with 74%. also 62% of surveyed area in WP Gua Musang achieved surface luminance ratio between 10 and 40 when lights were off. Therefore when lights were off, none of the buildings can achieve acceptable surface luminance ratio completely. The percentage of luminance ratio achieving various ranges when electric light on and off according to internal shading devices are shown in Figure 12 and 13. When lights were on, all rooms without internal shading devices had surface luminance ratio below 40. Just 8% of rooms with curtain and 14% of rooms with vertical blind had unacceptable luminance ratio when lights were on.

Whereas Figure 13 shows 20% of rooms without internal shading devices and 28% of rooms with curtain and 26% of rooms with vertical blind had surface luminance ratio above 100. In addition, 20% of rooms without internal shading devices and 8% of rooms with curtain and 6% of rooms with vertical blind had surface luminance ratio between 40 and 100 when lights were off. Overall 60 % of all rooms with different types of internal shading devices achieved acceptable range of surface luminance ratio(less than 40) when lights were off.

IV. CONCLUSION

Hundred percent of surveyed office buildings in Malaysia have had dependency on electric lighting although there is sufficient external daylight availability in the tropical region. The findings demonstrate that when electric lights were off, all the buildings failed to meet the daylighting recommendation. All office buildings were not designed for daylight utilization, with average daylight factor lower than 1.5%.

Among the surveyed office buildings, WP Gua Musang and

WP Temerloh showed better daylight factor performance (0.89%) comparing to the others. When the electric lights were off, all the internal surfaces were considerably dark (luminance $< 30cd/m^2$). The contrast between the window and internal surfaces brightness was considerably too high (average luminance ratio window/average internal surfaces > 40 when light off). This will cause glare problem to the office users. Besides, the findings also show that individual rooms with smaller room depths recorded better daylight performances in comparison with open plan offices. Thus, deep planning was not appropriate for daylighting design, especially for open plan office. Proper daylighting design recommendation is needed for energy saving and visual comfort in Malaysian government office buildings.

ACKNOWLEDGMENT

The authors would like to acknowledge the Public Works Department Malaysia (JKR) for the research grant for this project and Universiti Teknologi Malaysia (UTM) for contributing to this research.

REFERENCES

[1] D.H.W Li and J.C. Lam and S.L.Wong,*Daylighting and its implications to overall thermal transfer value (OTTV) determinations* , Energy, vol.27 , 2002, pp 991-1008.

[2] YJ. Huang,B. Thom,B. Ramadan, *A daylighting design tool for Singapore based on DOE-2.1C simulations*, Proceedings of the ASHRAE Far East Conference on Air-conditioning in Hot Climates, Kuala Lumpur; 1989, pp 2027.

[3] N. Ibrahim and A. Zain Ahmed,*A Simple Prediction Tool for Energy Savings due to Daylighting in Malaysia*, ISESCO Science and Technology Vision. 2(1),2006, pp 25-29.

[4] A. Zain-Ahmed and k. Sopian and M.Y.H. Othman and Abidin, Z. Zainol,*The Availability of Daylight from Tropical Skies: A Case Study of Malaysia*, Renewable Energy,vol.25, 2002, pp 21-30.

[5] D.R. Ossen,*Optimum Overhang Geometry for High Rise Office Building Energy Saving in Tropical Climates*, Ph.D., Faculty of Built Environment, Universiti Teknologi Malaysia,2005.

[6] A.N.M. Shahriar andM.A. Mohit, *Estimating depth of daylight zone and PSALI for side lit office spaces using the CIE Standard General Sky*, Building and Environment,Vol. 42,2007,pp 2850-2859.

[7] Y.W. Lim and M.H. Ahmad and D.R.Ossen, *Effect of solar shading, fenestration and room geometry on office building energy efficiency in hot humid tropic*, 3rd International Conference on Built Environment in Developing Countries. 2-3 December. Universiti Sains Malaysia, USM, Penang, Malaysia,2009,pp 174-185.

[8] E. Ghisi and J.A. Tinker, *An Ideal Window Area concept for energy efficient integration of daylight and artificial light in buildings*, Building and Environment, Vol.40,2005, pp 51-61.

[9] A. Tzempelikos and A.K. Athienitis and P. Karava, *Simulation of faade and envelope design options for a new institutional building*, Solar Energy, 81(9),2007,pp 1088-1103.

[10] Y.W. Lim and M.A.Hamdan, *Daylight and Users' Response in High Rise Open Plan Office: A case study of Malaysia*, 3rd International Graduate Conference on Engineering, Science, and Humanities,2010, Universiti Teknologi Malaysia, UTM, Malaysia.

[11] Department of Standards Malaysia,*Malaysian Standard: Code of Practice on Energy efficiency and Use of Renewable Energy for Non-Residential Buildings (1st Revision)*, Malaysia, MS 1525:2007.

[12] M.C. Dubois, *Impact of Solar Shading Devices on Daylight Quality: Measurements in Experimental Office Rooms*, Research Report,2001, Lund, Sweden, Lund University.