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ORIGINAL ARTICLE

Optimal of Daylighting Performance with Shading Device via Computer Simulation for Office Building in Malaysia

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ABSTRACT

Day lighting is an essential subject in modern architecture to improve occupant comfort and energy saving in office buildings. This study investigates to adequate the daylighting performance with shading device in terms of illuminance level and daylight factor in office building in tropical area. In this paper a survey of Climate Change Green Lab (C2GL) building in Malaysia is located in Universiti Kebangsaan Malaysia (UKM) and is targeted for composing in year 2013. The building is principally of three stories high. The building is rectangular in plan, glazed on the north, south, west, east side and a central courtyard through all three floors, supplying light to the center of building. All of the windows were included light shelves in C2GL building. Light shelves are good result to prevent direct light and reduce the amount of light into places. In this research, comparison is made between window with light shelves and without light shelves for C2GL building by computer simulation. The computer simulation software were performed using IES<VE> (integrated Environmental Solution <Virtual Environment>) to model daylighting analysis the effect of shading device to optimal illuminance. The location for IES<VE> simulation case studies is a geographical Kuala Lumpur in Malaysia location at latitude 3.12° North and longitude 101.55° east. The results have indicated the average illuminance in the C2GL office building without shading is higher than prescribed standard in Malaysia. The simulations were shown when shading device is used, the illuminance levels and daylight factor on the work plane obtained adequate the basic requirement of the CIBSE lighting guide and standard from Malaysia. Moreover, the average illuminance level in C2GL can be improved with shading devices according to standard in days.

Key words: light shelf, computer simulation, illuminance, day light factor

Introduction

Good day lighting is an essential element in architecture to improve visual comfort and reduce energy consumption in building and saving energy. The design of shading device should give an optimum solution to day lighting problems in terms of distribution and the principle of day lighting design is to maximize the utilization of day light, avoid glare problem (Hien *et al*,2003). The amount of daylight entering a building is mainly through window opening that provide the dual function not only for admitting light for indoor environment, but also allowing people to maintain visual contact with the outside world. People desire good natural lighting in their working environment (Li *et al*, 2008). Previous studies were conducted on these variables and their effect on day light as well. In fact, studies of day lighting accompanied with light shelf systems came up that control day light in buildings. In general, shading devices reduce the illuminance levels significantly; this is very beneficial in visual comfort. On the other hand, the illuminance distribution is much affected by the reflectance value of the surface (Alzoubi *et al*, 2010). Numerous day lighting algorithms have been developed and validated that explore different types of shading devices and illuminance predictions. The objective of study is to analysis the influence of light shelf device on the illuminance and daylight factor levels. Based on these facts, this study investigates to calculate design of light shelf in a Climate Change Green Lab (C2GL) building in Universiti Kebangsaan Malaysia. Generally, the function of light shelves performs as control of diffuse light, sun shading device, redirecting daylight into room. Every section of lightshelf device

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(i.e. interior, exterior) contributes in a particular method to mention one of the functions of above. Light shelves divided window into higher and lower sections for better daylight penetration. The section of light shelf that extends into room as well as reflect light from the higher section of the window deeper into room, while reducing the levels of light close to the window; hence, in the evening distribution of light in whole of the space (Brown, 2001). During the last 30 years, engineers and architects have increasingly relied on building energy simulation programs to design and retrofit buildings (Loutzenhiser *et al*, 2006). In computer related field, several studies utilized computation for problem solving in such kind of research. Coupling lighting and energy were among those problems solved by computer simulation (Alzoubi *et al*, 2010). Computational lighting simulation can predict indoor illuminance more accurately than manual methods even though computational methods have rarely been validated for real buildings with real occupancy (Hien *et al*, 2003; Baker *et al*, 1993). Generally, light shelf system can be improve visual comfort and reduce illuminance.

Materials and Methods

2.1 Description of building:

The Climate Change Green Lab (C2GL) buildingin Malaysia is located in University Kebangsaan Malaysia (UKM). The building is principally of three stories high. The building is rectangular in plan with dimension 24 (m)length, 16(m)wide, 11.70 (m) height, the floor to floor height is 3.9 (m). The office building was varied glazed facing the four basic orientations (i.e. N, S, E and W) and a central courtyard through all three floors, supplying light to the center of building with transparent roof as shown in figure1, figure 2 and figure3. In the center of the building has a courtyard. The dimensions of courtyard were 8m (width), 6m (length), 1m (height). All of the windows were included light shelves inC2GL building. The dimension of those were set to be 0.8 (m) depth from external walls, 0.4 (m) depth from internal walls, 0.1 (m) the thickness of shading starting at 2.6 (m) from floors. (fig. 4) According to Bougdah *et al* (2009), Light shelves must be carefully positioned and sized if they are not to act as obstructions to light. They need to be placed above eye-level, both to preserve the view and so room heights must be greater than 3m to accommodate light shelves (Bougdah *et al*, 2009), therefore , the dimension of light shelf for C2GL is performance. In addition, the windows of building have conventional single glazing. Two utility rooms and function area in the ground floor. it is only the function area room in the C2GL building where the open spaces have not glazed. The most of the office rooms (i.e. director room, meeting room, office area,…) are on the first floor. The office area is part of the main office with open plan rooms on the first floor. The office room is open plan 140 m^2, 14 m long, 8 m wide and 3.75 heights, and also have window from north and open to courtyard. And also meeting room 48 m^2 have window from west and glass wall beside courtyard. The second floor consisted of student area and two utility rooms. The student area is part of the main office area on the second floor. It is 212 m^2 area, 20 m width, 16m depth, 3.9m height and about 7.8m above the ground. Day lighting for student area is provided from North, West, South oriented and also courtyard. The parameters for daylighting calculations are shown in Table 1.

Table 1: Parameters for daylighting calculation

Area	Area (m^2)	Width (m)	Depth (m)	Height (m)	Glass area in window (m^2)	Window area/floor area	Orientation of window wall
Ground floor							
Utility room 1	16	4	4	3.75	12.6	78%	North and East
Utility room 2	16	4	4	3.75	6.3	40%	EAST
Function area	240	20	16	3.75	73.35	30%	North, west and south
First floor							
Utility room 1	16	4	4	3.75	12.6	78%	North and East
Utility room 2	16	4	4	3.75	6.3	40%	EAST
Office area	140	14	8	3.75	38	48%	North
Pantry room	16	4	4	3.75	3.99	25%	North
Director room	16	4	4	3.75	9.87	60%	North and west
Meeting room	48	8	6	3.75	7.98	17%	West
Waiting area	12	4	3	3.75	7.98	65%	West and south
Reception area	20	5	4	3.75	3.99	20%	South
Walk way	60	10	6	3.75	28.02	45%	South
Second floor							
Utility room 1	16	4	4	3.75	12.6	78%	North and East
Utility room 2	16	4	4	3.75	6.3	40%	EAST
Student area	212	20	16	3.75	69.9	33%	North, west and south

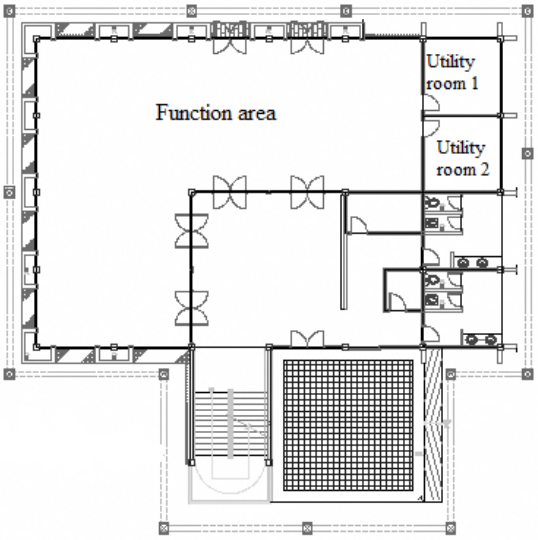

Fig. 1: Ground Floor Plan

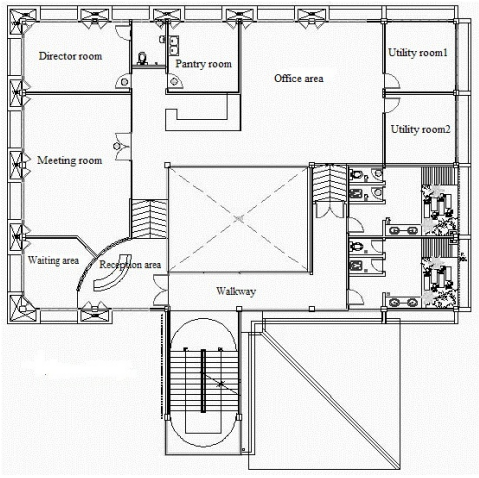

Fig. 2: First Floor Plan

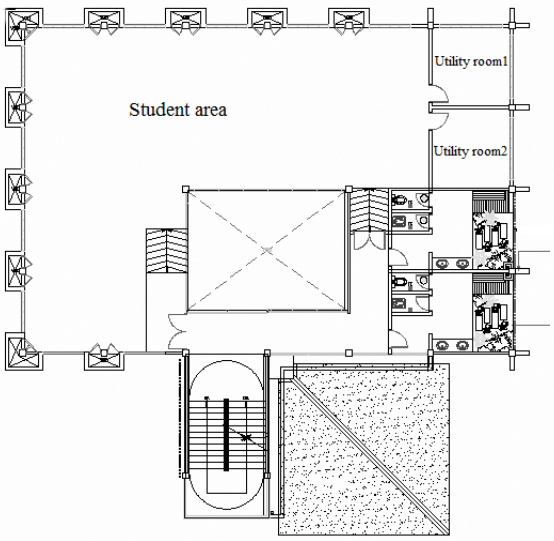

Fig. 3: Second Floor Plan

Fig. 4: Perspective View

Fig. 5: Perspective View

The simulation study:

Computer simulation strategy was followed to fulfill the objectives of the undertaken system of inquiry. The method focused on simulation lighting in a Climate Change Green Lab (C2GL) office in Malaysia. Computer simulation techniques were used in the present study to predict the average day light factor and illuminance over the work plane in office spaces for the purpose of investigating the effect of external shading devices on day lighting. Based on the parametric computer simulation studies, easy to use charts that correlate average day light factor (DF_{ave}) and illuminance were developed by Radiance in IES<VE> (Integrated Environmental Solutions<Virtual Environment>) software used to simulate for lighting analyses a typical office building located in the city of Kuala Lumpur which is situated at 3.12° North and 101.55° East longitude and 22.0 altitude. Researchers have indicated the result of Radiance valid with system performance in internal daylighting (Ng *et al*, 2001*)*. The time and date of simulation were set on July 21st at 12 noon. The sky condition was assumed to be standard CIE overcast sky. (Table. 2) For the purpose of examining light distribution, horizontally work-plane in the office (85 cm) above floor level was developed (Neufert, 2000). Therefore, the reference point was set at 0.85m from the floor level. All together, for simulation runs were conducted. The reflectance of walls, floors and ceilings was assumed to be 0.5, 0.2 and 0.8 respectively according to IES standards, which are regular values for an office spaces. The transmittance of the window in the simulation was 0.8. (table. 3) These are close to standard reflectance values recommended in most day lighting literature. For example, standard floor surface reflectance in schools and offices is around 0.2 and 0.3 with wall surface reflectance usually between 0.4 and 0.6. A standard ceiling is usually light-colored for consistent day light appearance and reflection of shadow-free or diffused light, and therefore has a higher surface reflectance than other surfaces (Ibrahim, 2009)

Table 2: Information to the computer simulation

Related information to the computer simulation	
Date of simulation	July 21 st
Time of simulation	12 pm
Location	Kuala Lumpur- Subang
Latitude	3.12° North
Longitude	101.55° East
Sky condition	CIE standard overcast sky

Table 3: Parameters used for C2GL simulation

The parameters of a CGLB office used for computer simulation.	
Office parameter	Average reflectance value
Walls	50%
Floor	20%
Ceiling	80%
Transmittance of the window	80%

Finding and discussion:

3.1 The effect of light shelves on illuminance:

The result of simulation focused on the illuminance work plane for C2GL office building. Comparative analyses were done to identify which rooms behavior adequate daylight after using light shelve according to literature. Malaysian standard code was used to analysis the illuminance level of office task. It can be seen in Table 4. The lower value of illuminance were 300 Lux and 500 Lux which are taken from standards.

Table 4: Malaysian standard office illuminance levels (MS1525, 2007)

Illuminance type	Task	Illumination (Lux)
Working interiors	General offices, reading and writing	300-400
	Drawing offices	300-400
Exacting task	Proof reading	500
	Exacting drawing	1000
	Detailed and precise work	2000

The simulation result showed a great instance of correlation between the shading device position and the light distribution in spaces. Day light design is impractical for tropical area with no shading devices concern to resist the penetration of direct solar radiation. In other words, the influence of shading devices in day lighting performance of buildings' perimeter area is very important for fenestration design (Chou, 2004). Figure 3, 4, 5 presents the result of simulated illuminance between light shelves and without light shelves design in C2GL building under an overcast sky. The value comparison of average illuminance on workplane for office building in different floors (i.e. ground, 1st, 2nd floor) with and without shading devices were simulated using Radiance of IES<VE> for lighting analysis. It is observed that the average illuminance working plan values without shading are higher than the standard of 500 lux in office building in Malaysia. Hence, it is apparent that the shading design benefits the illuminance standard in specific of office in tropical area to achieve the required average illuminance working plan between 300-500 lux. As shown in fig. 3 , the daylight average illuminance in utility room 1 was simulated with two windows in the east and west 2045 lux without light shelf and 700 lux with shading and the result average illuminance of utility room 2 was 980, 360 lux with and without shading respectively. In the function room in ground floor is only a place open to the outdoor, therefore there are not any glazing in the hole area. Fig.4 indicates that the amount of average illuminance level on horizontal workplane in office area, director area and meeting room is 630, 850 , 360lux without shading where as 470, 360 , 373 lux with shading respectively in the first floor of C2GL building. The lighting levels required within offices spaces are relatively high. Most international standard specify a minimum design illuminance of 300-500 lux depending on specific tasks. However this is not enough to guarantee good lighting conditions (Capeluto, 2003). It can be seen that the average illuminance level for student area in second floor around 1300 lux without shading; whereas, 1100 Lux with shading on horizontal workplane. It can be observed that around 200 Lux decreased the amount of average illuminance with shading device. For large, open plan spaces the condition that useful daylight illuminance is achieved simultaneously across the workplane is too restrictive. For these spaces, especially when they are deep plan, illuminances will rarely be in the range 100-2000 lux across all the work plane at any one instant. It was noted that the daylight illuminance range of 700-1800 lx appeared to be acceptable for both computer and paper oriented tasks (Nabil *et al*, 2006). As a result, the amount of illuminance for student area and office area in first and second floor respectively are acceptable. The comparison of the light sheves on illuminance of the rooms in second floor presented in Fig. 5. Consequently, every office spaces of C2GL building with light shelves admit illuminance on working plan according to recommended level.

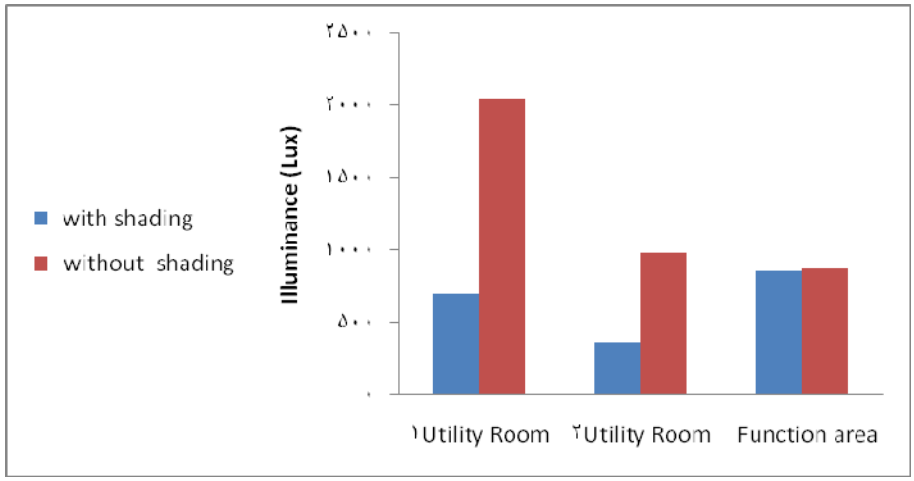

Fig. 3: Comparison average illuminance with and without shading in the ground floor under an overcast sky

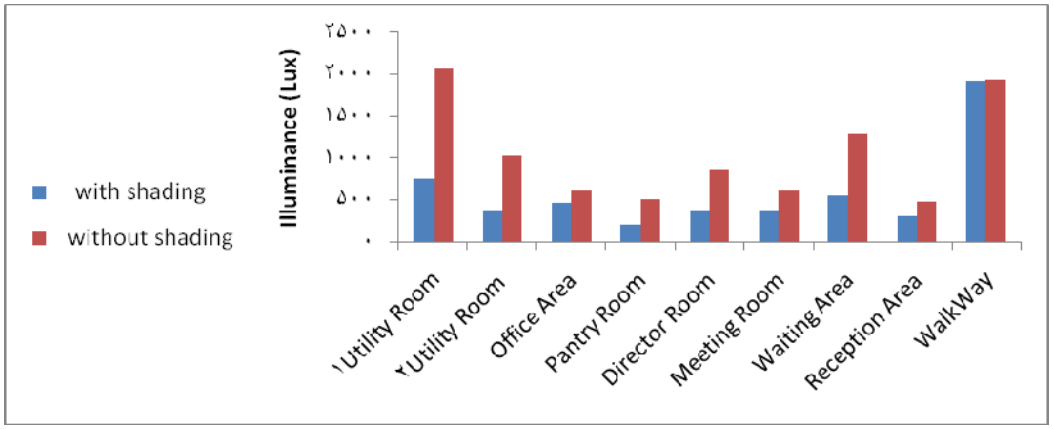

Fig. 4: Comparison average illuminance with and without shading in the first floor

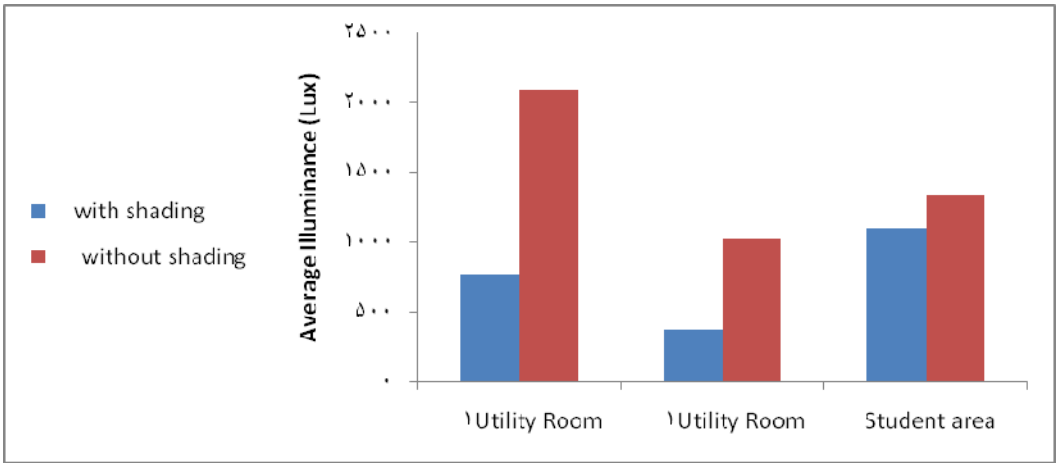

Fig. 5: Comparison average illuminance with and without shading in the second floor

3.2 The effect of light shelves on daylight factor:

The performance of building for daylighting is commonly evaluated regarding to daylight factor (DF), through themethod of daylight factor accepted several years ago by the Commission International de l'Eclairage. (Li , 2008) the ratio of indoor to outdoor illumination under an overcast sky is called the "daylight factor" (DF) (Lechner, 2001). Several parameters such as orientation of window, the shape of plan, room type and interior and exterior shading device have influenced on day lighting (Kandar *et al*, 2011*)*. Hence, there is a relationship between light shelves and daylight factor. Table 5 presented the standards of daylight factor analysis for working place from sources such as CIE and IES by Dubois (2001). According to Malaysian standard (MS 1525, 2007), the recommendation of daylight factor for utilization of daylighting in general office space is 1.5%, thus is acceptable (MS1525:2007). Christoffersen *et al*. (1999) achieved that the analysis of the evaluation of satisfaction between the measurement the level of daylighting for 20 office building and more than 1800 office workers indicated that the people preferred the level of light greater than normal (Dubois, 2001).

Table 5: Lighting performance indicator (DUBOIS, 2001)

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

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The simulated average daylight factor value under an overcast sky for C2GL office building were analyzed and fig.6.7.8 show the comparison result of DF_{avg} using light shelves and without light shelf for C2GL building set 0.85 (m) work plane at different floors. The simulation results of Ground floor indicates in fig.6 that DF_{avg} for utility room1, utility room2 and function area reduced significantly with light shelves. It is observed that without shading were higher than standard levels. Day light factor for utility room1 from 12% to 4%, utility room2 from 6% to 2% improved according to recommendation IES by using light shelves because, the photocopies machines and printers require 5% average daylight factor according to CIBSE (CIBSE, 1999). Figure 7 show the comparison of DF_{avg} in the 1st floor between windows facing light shelves and without light shelves were reduced around from 4% to 3%, 5% to 2% and 4% to 2% for office area, director area and meeting area respectively. it is observed that light shelves decrease percentage of DF_{avg} for each room. Fig.8 illustrates the DF_{avg} values obtained for the 2nd floor. As can be seen from this figure, The percentage of DF_{avg} in the office rooms without light shelves were much higher than the standard levels. Furthermore, the DF_{avg} for student area from 8% to 5%, utility room1 representing an improvement with using light shelves from 12.5% to 4% and utility room2 from 6 to 2%. Therefore, the result show that DF_{avg} between 2% to 5% when using light shelves according to standards.

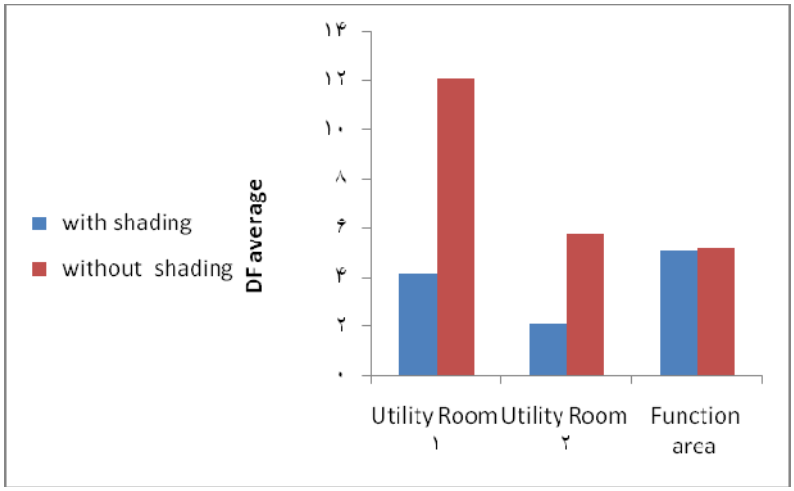

Fig. 6: Comparison DF_{avg} with and without shading in the ground floor under an overcast sky

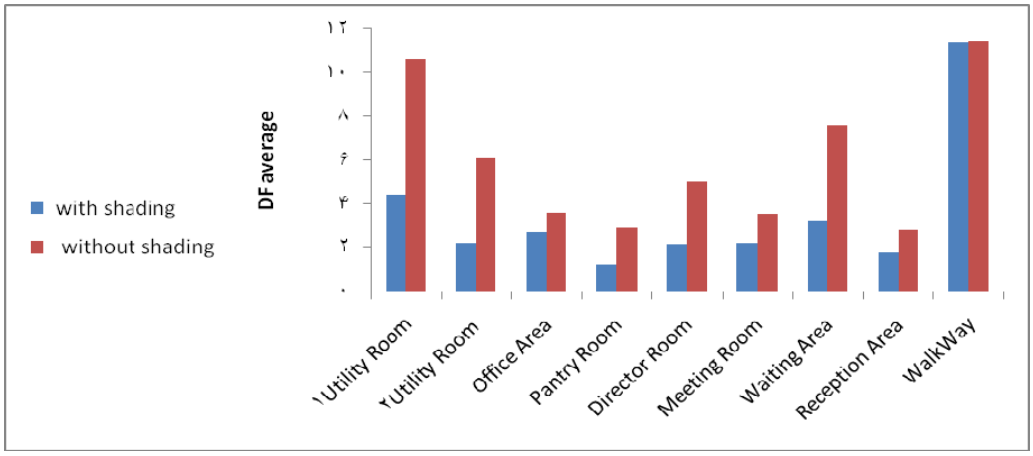

Fig. 7: Comparison DF_{avg} with and without shading in the first floor under an overcast sky

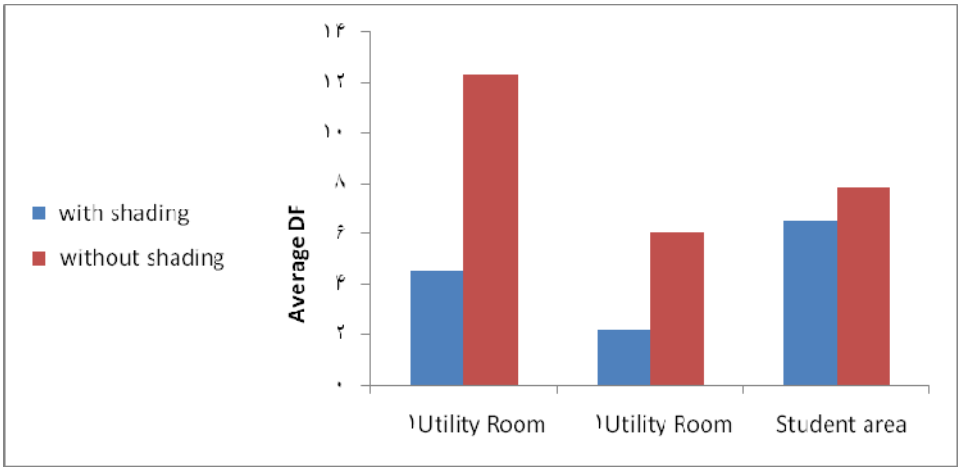

Fig. 8: Comparison DF_{avg} with and without shading in the second floor under an overcast sky

Conclusion:

This study examined the simulation results of the effect of shading devices on day lighting performance for a office building in Malaysia. The result of analyses obtained that most of the rooms after introducing shading device were improved to adequate daylighting except pantry room due to using for a short time. It also shows that shading devices with a 0.8 m from window wall and 2.5 m height to be reached to acceptable illuminance in office building. Thus, the design of external shading demands a comprehensive solution which includes admitting sufficient day light into the space, reducing the direct view of the sky, and providing a suitable interior design. Shading devices can simultaneously provide good day lighting in spaces. It is recommended that architectural designers be aware of this fact. Shading devices should help designers create pleasant places with optimal situations in terms of lighting. As shown, the average illuminance in the office building without shading is higher than that standard in Malaysia. Consequently, the average illuminance level in C2GL can be improved with shading devices according to standard except pantry room due to using for short time in days.

Acknowledgment

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