Daylight Distribution of a New Design for Future Commercial Office Building in Malaysia

Adel Mansour[1], Kamaruzzaman Sopian[1], Gregers Reimann [2] and Azni Zain Ahmed [3]
[1] Solar Energy Research Institute, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor.Malaysia.
[2] IEN Consultants Sdn. Bhd., 43300 Seri Kembangang, Malaysia. www.ien.com.my
[3] Institute of Research, Development and Commercialization,Universiti Teknologi MARA
40450 Shah Alam, Malaysia

Abstract

A new design for future commercial office building in Malaysia has been developed. A full scale test model has been constructed. Full scale models are generally believed to be a reliable tool for illumination modeling and are often used to predict daylight factors. The visual performance provided by daylight and the illuminance distribution inside the test cell have been studied. The daylight factor as an index for the distribution and level of daylight inside the test cell has been determined under constantly changing levels of illumination and sky distribution. Work plane illuminances and daylight factors were experimentally determined, according to the roof ceiling, light shelf and blind tilt variances which caused changing in the daylight factor. A horizontal and/or downward blind tilt yields the most daylight. However, these positions have glare problems with direct view to the sky. Hence, an upward blind tilt just blocking the sky view is the best option.

Keywords: Daylighting, illuminance, Daylight Factor, tropics

1. Introduction

Single measurements of daylight in a room are not sufficient to predict the amount of light available during different times of the day and of the year. Many and repeated measurements would be needed in order to arrive at a reasonable estimate.

However, every point within a room receives a certain fraction of the total amount of light emitted by the open sky (Koch et al. 1951).For the daylighting design of a room at a certain location, it is necessary to know the external daylight levels and to be able to estimate the corresponding internal levels (Oteiza et al. 1996).

The first step in evaluating the visual performance and energy efficiency provided by daylight requires an accurate estimation of the amount of daylight entering a building. The actual daylight illuminance of a room is mainly influenced by the luminance levels and patterns of the sky in the direction of view of the window at that time (Li et al. 2005).Predicting the distribution of daylight levels in an atrium and its adjoining spaces can be difficult. Three techniques namely model studies, computer simulation and analytical formulae can be used (Littlefair, 2002).

Manual methods and computational methods (simulation tools) are used to calculate the daylight factor. Although computer simulation tools can handle more complex room geometries and visualize the interior distribution of illuminances, the manual methods can be very useful in the preliminary design stage due to the simplicity of execution (Betman, 2003).

The daylight factor (D.F.) is defined as the illuminance received at a point indoors from a sky of an assumed luminance distribution and without direct sunlight, expressed as a percentage of the horizontal illuminance outdoors from an unobstructed hemisphere of the same sky (Betman, 2003). D.F. is expressed in percentage as;

$$D.F = \frac{E_{in}}{E_{ex}} \times 100 \qquad (1)$$

Where E_{in} and E_{ex} are respectively the internal and external diffuse illuminance on horizontal plane.
The method assessed in the present work measures the daylight factor at a reference point in the working plane inside a full scale test model.

2. Full Scale Model Setup

Physical models are commonly used to assess daylighting performance of building, several physical parameters affect on daylighting performance assessment. To accurately predict daylight levels and daylighting characteristics, and to develop the right design that will transmit daylight deep into the back of the façade, a full scale test model, 6×6 meters room, was constructed at Universiti Kebangsaan Malaysia (UKM) as shown in Figure 1.The overall experimentation was carried out in UKM solar campus, located in Bangi, Malaysia (N 2° 56' 35", E 101° 45'14").The test module is surrounded by an open plain and facing the west.

2.1 Criteria of Test Model;

To assess the performance of the light in any environment, typical full scale model will be the best option. In order of that, the daylight test cell is 6 x 6 x 3.6 meters and which also could be modified into 3 x 6 x 3.6 meters by using white curtain-wall inside the model as a partition. The daylight test cell was also provided with moveable light shelf and blind tilt; the ability to change the ceiling roof boards is possible.

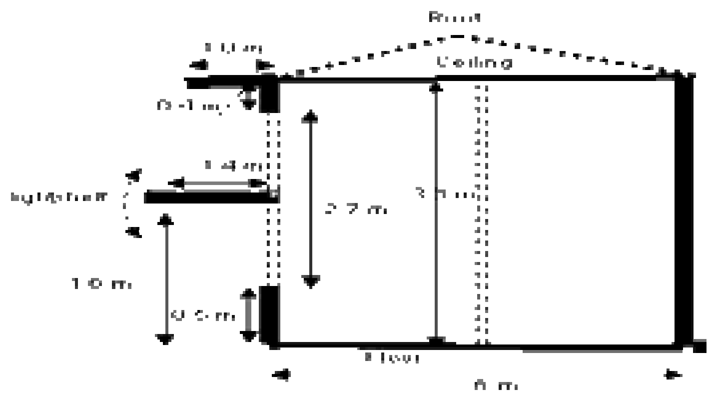

Figure 1 Daylight test cell Diagram

Figure 2 Daylight Test Cell in UKM

The light shelf height is 1.6 meters in vertical positions and 1.4 meters width,

Table 1 Glass performance

Parameter \ Glass Item	Upper window	Lower window
Thick(mm)	6	6
Visible light Tm%	70	51
Visible light Ref%	8	5

the upper side of the light shelf is a mirror as shown in Figure 2.

A main atrium characteristic is the roof;a careful design of the roof fenestration system limits glare, mitigates passive solar heating affects and supplies adequate daylighting and minimum sunlighting (Calcagni et al,2004).

The blind tilt was design to block the sky view from the upper window but also these blind tilts could change its tilted angel by six different aspects (figure 1).
These parameters were separately considered during experiment setups;
Outside vertical fins exist with width about two meters in the both side (left and right) of the test cell, the internal fins' reflectance about 0.9-1. A thick plastic layer was used as a carpet for the test cell ground floor, the ground floor material's reflectance assumed to be 60%.

Walls inside the test cell were painted by white color and its reflectance about 71%.The glass used for the upper and lower window of the test cell were chosen with consider to table 1.galzing area was chosen with care to admit enough daylight without excessive solar heat gain. Illuminance distribution or daylight factor change has been noticed within using white or mirror roof ceiling. In addition, reflective ceilings have been fixed on the roof of the test cell. The reflective ceiling surface properties has a total reflection about 85%-86% and diffused reflection about 30%.

2.2 Luxmeter

Tools used for all experiments are Testo 545 lux-meter. Five luxmeters are used in different experiments. Calibrations are considered in each test.
The lux-meter has two range measurements of resolutions in two different channels;
Resolution 0 – 3200 lux: 1 lux
Resolution 0 – 100000 lux: 10 lux .

3 Experimental Methodologies

The experiments were carried out for several days during morning hours and during working office noon-hours. The sensor of the luxmeter was placed at the height of the table(80cm), experiment readings were being taken in small time of intervals and range of the measurement was [1m, 6m] from the façade with one meter step. Splitting the Daylight test cell into two typical rooms with width 3 m in order to compare illuminance changes using different light shelf tilted angel, blind tilt or ceiling roof at the same time.

4 Experiments;

4.1 Light Coming from Windows

Light is coming into the test cell through both (upper and lower) window, in order to control the light coming into the test cell, it is primary to estimate the percentage of light from each window separately. Blocking once the lower window, and once the upper window in order to measure and study the light coming from windows. The measurements were performed each one meter step from the façade. Referring to figure 3, it is noticed that the upper window allow more light to inter the model.

4.2 Roof Ceiling Experiment

Test cell is split into two identical halves (3 x 6 meters).The right side of test cell, Reflective ceiling has been installed for the roof ceiling, while the other side white ceiling roof has been installed. All experiments were done without furniture.

Blinds in front of the upper daylighting windows were turned to block the view of the sky; and at the same time the light shelf was horizontal. Luxmeters are placed in different distances from the facade at height table and left in the room to measures the illuminance every 30 seconds as shown in figure 4.The illuminance ratio, at the distance between 1 m and 6m, has been determined as shown in Figure 5.

Illuminance measured from 8:00-12:39 time interval for three days, the result as shown in Figure 6.

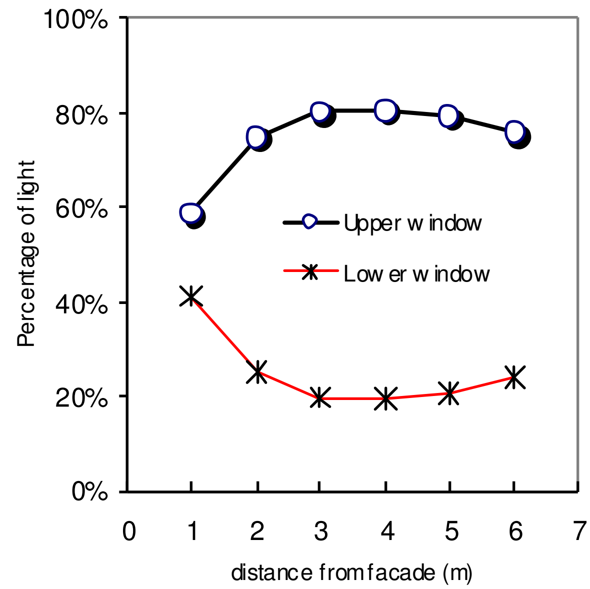

Figure 3 Percentage of light coming from windows

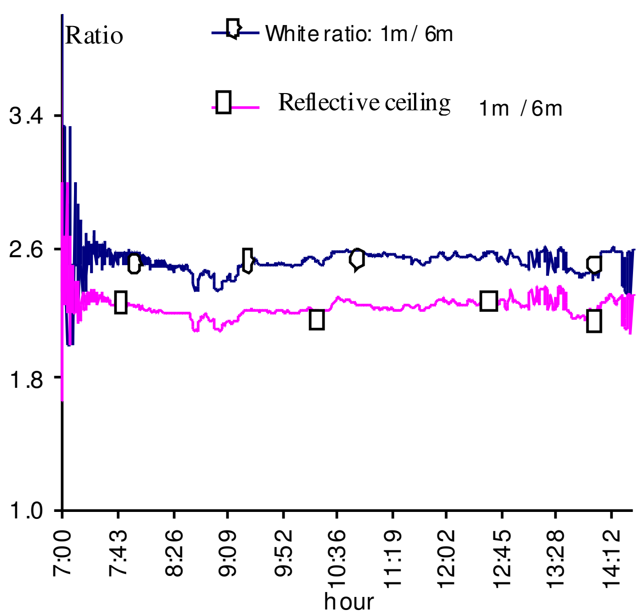

Figure 5 Illuminance Ratio 1m/6m

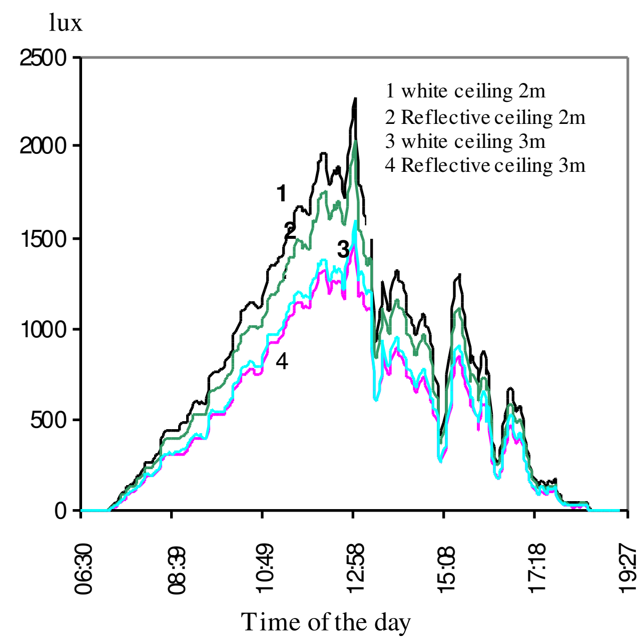

Figure 4 Illuminance inside test

4.3 Light Shelf Tilt Experiment

Test cell was split again into 3 m width again, white ceiling roof had been installed and Blinds turned to block view to the sky; light shelf horizontal. Luxmeter is placed at height table .Daylight Factor changes were observed as shown in Figure 7.

4.4 Blind Tilt Experiment

Six different positions for the Blind Tilt has been taken in consider in order to study the impact of the blinds to the daylight factor inside the test cell, same parameters used in the light shelf experiment applied also in this experiment. Changing in the daylight factor have been noticed and observed as shown in Figure 8.

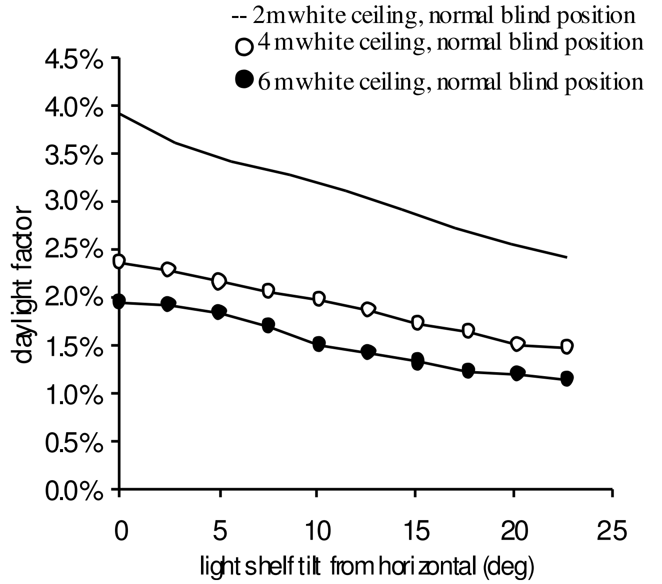

Figure 7 Light Shelf tilted angel Vs. daylight factor

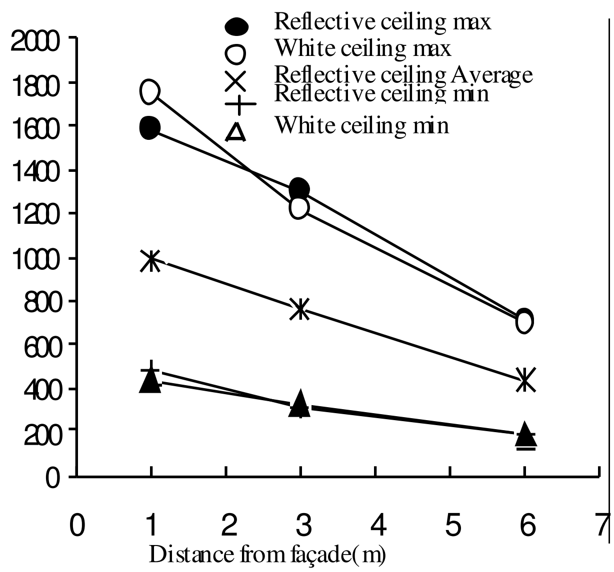

Figure 6 Average Illuminance measured 9:00 :2:39 over 3 days

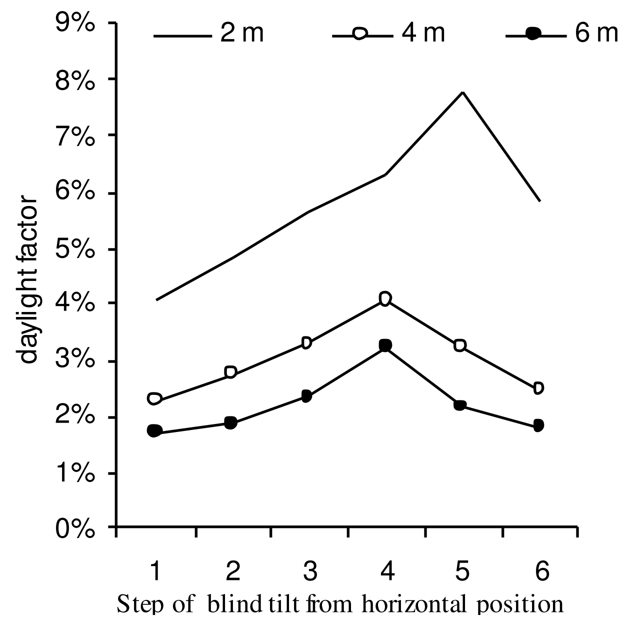

Figure 8 Step of blind tilt Vs. D.F

5 Conclusions

This experiment is an attempt to determine the right design for possible future office in Malaysia. The analysis provides an experimental investigation on the performance of light inside full scale test model represent one single office for future office in Malaysia. investigate the internal daylight illuminance with regards to the impacts of the ceiling roof properties, blind tilt and the light shelf in order to install the suitable choice. The reflective ceiling roof was the best option for the daylight test cell. A slightly more uniform indoor light distribution was observed which provide illuminance levels sufficient for good visual performance inside by using the reflective ceiling roof. In addition, it is found that the closer the light shelf is to horizontal, the more light enters the daylight test cell. Moreover, a horizontal and/or downward blind tilt yields the most daylight. However, these positions have glare problems with direct view to the sky. Excessive brightness contrast within the field of view could be controlled by an upward blind tilt just blocking the sky view as a best option. This blind orientation gives a satisfactory light distribution in the 6 meter deep test cell. As well as, the adequate orientation of the test cell is advised to face north or south regarding to location of the test cell in order to avoid direct incident sunlight.

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