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ETIQA TOWER: Zero Cost Daylight Harvesting Strategy for a High Rise Office Tower

ABSTRACT

This paper review and discuss a simple daylight harvesting strategy that make use of existing building solution without increasing development cost to the building developer. This solution addresses the concern of speculative office building developers that is highly sensitive to additional cost required for green features in a building. The daylight harvesting strategy proposed was based on addressing glare from two distinct sources, glare due to direct sunlight and glare due to the bright tropical sky.

Although Malaysia has consistent daylight from the hours of 9am to 5pm every day of the year, most buildings failed to harness daylight use. Malaysian cloudy white tropical sky and bright sun causes significant glare issues in this climate. Building occupants simply choose to close the blind totally to avoid glare from the bright sky and sun, killing the daylight, and make use of glare free electrical lights instead.

The simulation studies conducted showed that it was possible to use existing building solutions with minor change in specifications and design to address the glare issues while harnessing daylight into the building without additional cost. This solution was proposed for an actual building development and is currently being implemented. This building is expected to be operational in 2018.

Keywords: High-performance building; Indoor Environmental Quality; Daylight Harvesting

1. INTRODUCTION

There are significant health and energy efficiency benefits to harvest daylight in office buildings. In a tropical climate like Malaysia, daylight is consistently available from the hours of 8am to 6pm daily for the entire year and matches the need of an office building perfectly.

Although the benefits of having daylight harvested in office building is very significant, most new and existing office buildings in Malaysia failed to harness it successfully. Fortunately, there are at least 3 completed office buildings in Malaysia that managed to harvest daylight successfully. Unfortunately, the daylight features provided by these buildings is rather extensive; using light reflection shelves, glare prevention blinds and split window design. These provisions increase the capital cost for a building project. Additional cost is a major deterrence for new building design to incorporate daylight harvesting in buildings. While an owner occupied buildings may be keen to invest in a better environment for own use, a speculative building that is built to be rented out or sold are not keen in any additional cost because it will reduce the financial feasibility of a project.

An attempt is made on an actual speculative (for rental return) multi-tenanted office building project located in Kuala Lumpur, Malaysia; to harvest daylight without any additional cost to the developer. The strategies implemented on this building are presented in this paper.

2. TROPICAL CLIMATE AND DAYLIGHT HARVESTING

The average cloud cover in Malaysia is consistently ~7 oktas (where 8 oktas is the maximum cloud cover) during all hours of the day, daily [1]. Due to the high cloud cover, the entire sky dome is usually brightly lit during daytime. This is advantageous for harnessing daylight, because the cloud diffuses the direct sun causing the light to come from the entire sky dome instead of just from the direction of the sun.

Diffused daylight offers a more consistent source of light as compared to direct sunlight in this region. Direct sunlight is inconsistent because of the cloud conditions. I.e. the sun can hide behind, and appear from a cloud easily, causing drastic changes in lighting level.

3. GLARE

Glare discomfort is a central cause of buildings not harvesting daylight in tropical climate. Glare in an office environment is caused by a significant difference in the ratio of luminance between the task and the source of light. In the case of harvesting daylight for an office space, the glare source is the window itself. Inadequate protection from glare, will lead to building occupant fatigue and headache, causing dissatisfaction at workplace. Exposing building occupants to glare will cause blinds to be used, fully closed, killing daylight opportunities.

In tropical climate; glare from daylight is found to be caused by two (2) distinct sources - the direct sunlight and a bright sky.

4. EXAMPLES OF DAYLIGHT HARVESTING IN MALAYSIA

There are 3 completed office buildings that harvested daylight successfully in Malaysia. These buildings have a minimum of 50% of its electrical lights switched off for more than 80% of the working hours. The experience gained from these buildings indicates that the prevention of glare in the office space is the top most priority that determine the success of a daylight harvesting in an office building.

The successful design implemented by these 3 buildings require additional development cost on the daylight harvesting features; to provide glare protection while offering deep and uniform throw of daylight into the building. A quick review of these 3 buildings’ daylight harvesting systems are provided in the subsections below:

4.1. Energy Commission Building, Putrajaya

This building was designed to be 50% day lit with an internal light shelve. During operation, more than 70% of the electrical lights in the office were switched off when daylight is available. The internal light shelf and venetian blind are mirrored to deflect the harvested daylight onto the ceiling. The bottom of the horizontal venetian blind was painted with white matt and designed as a glare protection device. A harvested daylight depth of 5 meters was achieved using this daylight harvesting system.

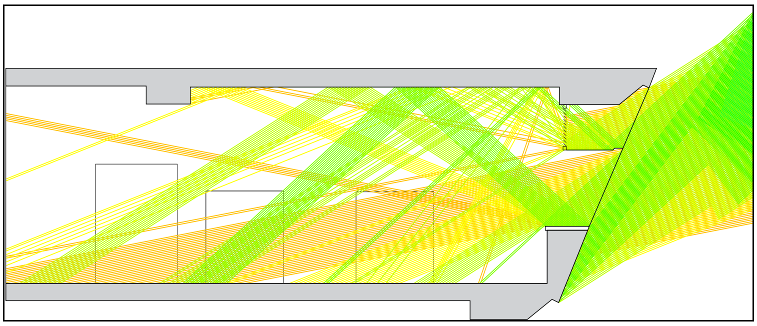

Figure 1. Typical Section of Daylight Distribution– Diamond Building

4.2. Green Energy Office (GEO) Building, Bangi

Daylight harvesting system implemented in GEO building consist of venetian blind and external light shelf. A daylight depth of 6 meter was achieved by this design. A “Tannenbaum’s Christmas tree” profiled ceiling reflector was provided on the 2nd floor to deflect daylight deeper (up to 7-meter depth). The daylight harvested in this building reduces the average operating lighting power density of this office building down to 0.56 W/m² (Reimann 2007). This is a 95% reduction of lighting power from Ashrae 90.1 limit of 11 W/m² for office spaces.

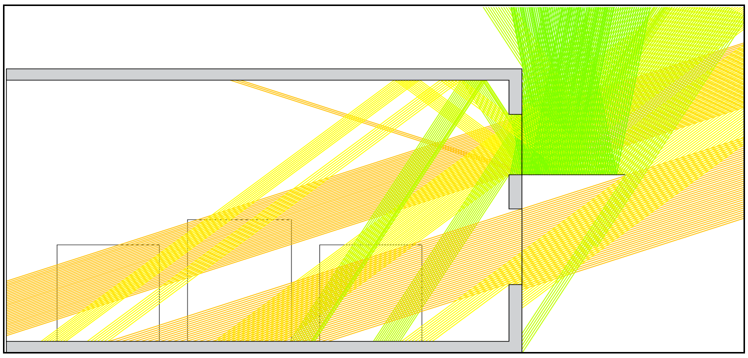

Figure 2. Typical Section of Daylight Distribution - GEO Building

4.3. Sarawak Energy Berhad, Kuching

Daylight harvesting system implemented in SEB Building is shown in Figure 3. It consist of venetian blind, external light shelf and external shade. A daylight depth of 5 meter was achieved. During operation more than 50% of electrical lights in this building are off.

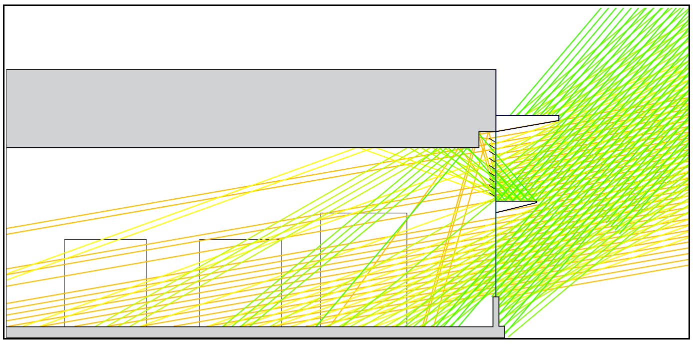

Figure 3. Typical Section of Daylight Distribution– SEB Building

5. PROPOSED ZERO COST SOLUTION

The proposed zero cost daylight harvesting solution rely on the use of conventional vertical blind system together with the selection of glazing visible light transmission properties. The project client and design team were consulted to ensure that the proposed daylight harvesting strategy is not adding addition capital cost to the building construction. The vertical blinds were considered as base building cost and the selection of glazing visible light transmission does not increase capital cost.

The proposed strategy uses a conventional vertical blinds to provide glare protection from the direct sunlight, while leaving the blinds partially open for daylight to be harvested. As the vertical blinds are left partially open, glare protection from the bright sky is required to be addressed by the glazing properties.

Glare protection from the view of the bright sky is achieved via selection of the glazing visible light transmission to be dark enough to provide glare protection while keeping it transparent at the same time for daylight to be harvested.

Studies were conducted to optimize the vertical blinds with the highest possible visible light transmission while being low enough to prevent glare from direct sunlight. This strategy maximises daylight potential, while providing glare protection. In short, the selection of the vertical blind has to be matched with the selection of glazing visible light transmission for an optimized solution.

In summary, 4 distinct studies were carried out to investigate this solution. The 1st study is to address the possibility of glare from a bright sky, allowing us to specify the glazing visible light transmission for this project. The 2nd study is to optimise the opening angle of the vertical blind, to provide total glare protection from the direct sunlight for the entire year without requiring any manual adjustment for the full year. The 3rd study is to select the highest possible visible light transmission of the vertical blinds based on the selected glazing properties adequate to prevent glare from direct sunlight. The 4th study is to test the depth of daylight available based on all the selections made. An in-house developed raytracing software, SketchUp, IES<VE> SunCast and Radiance simulation software were used for these studies.

Glare evaluations were based on Radiance simulation of luminance outputs. The luminance intensity in candela per meter square (cd/m^2) is used as the primary indicator of visual comfort. For an office environment, this simple indicator is acceptable because the required illuminance level in an office space is consistently in the range of 300 to 500 lux level. In addition, this glare evaluation method was applied successfully on all 3 office building examples provided in section 4.

The luminance intensity criteria used for an office environment were as follows; a value below 1000 cd/m² is deem acceptable for all building occupants, while a value exceeding 2000 cd/m², is deemed unacceptable for most building occupant. There is an indication from the 3 completed buildings in Malaysia with successful daylight harvesting that tropical climate occupants may have a higher tolerance of luminance intensity. Building Sector Energy Efficiency Project (BSEEP) has approved a grant in 2014 to test this hypothesis on actual building scenarios.

5.1. Glare Prevention from the View of a Bright Sky

Simulation studies were conducted to test the maximum allowable glazing visible light transmission (VLT) under a bright diffuse sky condition. The brightest diffuse sky condition from Radiance (Uniform Cloudy Sky) was used for this study.

Table 1. Maximum Luminance Intensity at various Visible Light Transmission

Visible Light Transmission of Glazing	Maximum Luminance Intensity (cd/m²)
15%	664
20%	888
25%	1118
30%	1335
35%	1573
40%	1797
45%	2007
50%	2242

The result of this study, shown in Table 1, indicates that a glazing with VLT of 40% is the maximum allowable for this project. Ideally, the selected glazing should have a VLT below 30% to ensure comfort for a majority of building occupants.

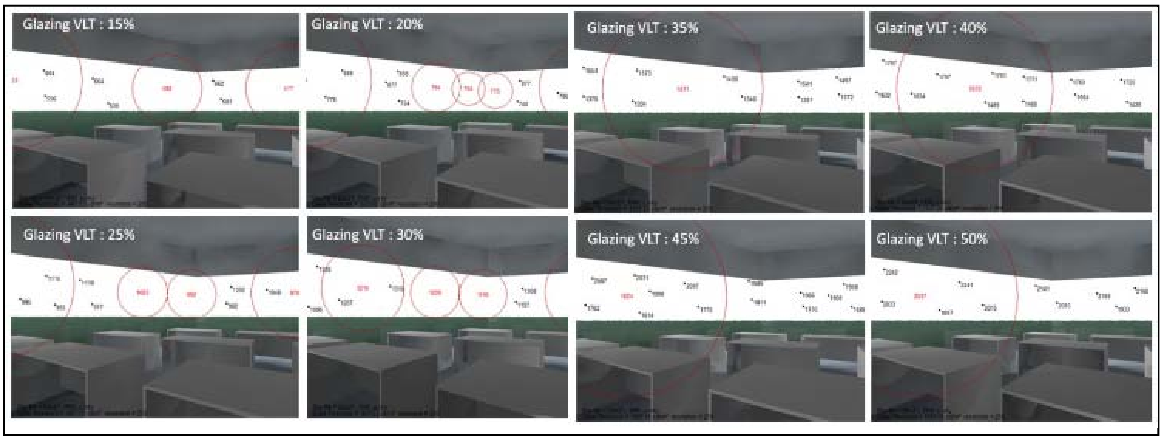

Figure 4. Radiance Simulation Results on Glazing Visible Light Transmission

7.2. Glare Prevention from Direct View of the Sun

Glare prevention from the direct view of sun is controlled via the design of vertical blind opening angles. The opening angle of the vertical blind were carefully designed to prevent any direct line of sight with the sun, while keeping it as open as possible for harvesting daylight. The blind opening angle is designed to be at a fixed position for the entire year. This is possible because Kuala Lumpur is location at 3° north of the equator. The position of the sun is fairly consistent as shown by the sun-path diagram in Figure 5. The building occupants are not required to make any adjustment to the blind at all ensuring simplicity of operation during use.

All possible extreme angles of direct sunlight were tested to ensure the success of this design. Figure 6 shows the angles of direct sunlight at extreme angles at:

1) June 21, 8am and 6pm
2) December 21, 8 am and 6 pm

Simulation studies were then conducted to select the highest possible VLT of the vertical blind while providing adequate glare protection from a direct view of the sun. A high VLT value will allow more daylight to be harvested, and at the same time, the VLT need to be low enough to provide glare protection from the direct sun. Radiance sunny sky condition with direct view of the sun was simulated with various blind VLT against a glazing VLT of 40% (worst possible case scenario).

The results from Radiance simulation indicates that a maximum allowable vertical blind VLT of 30% in combination with a glazing VLT of 40% should be adequate to provide glare protection from the view of direct sun.

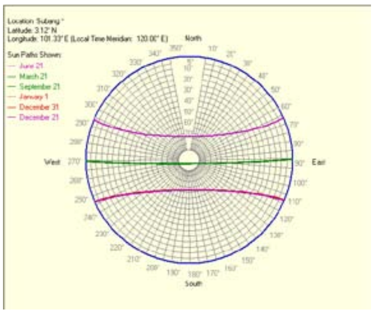

Figure 5. Sun Path of Kuala Lumpur

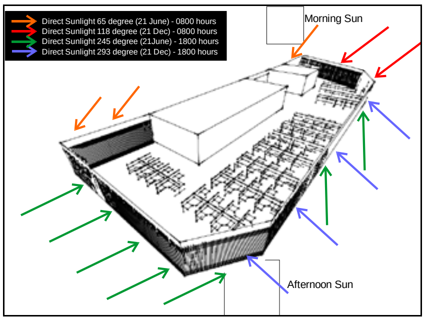

Figure 6. Extreme Direct Sun Angle

The worst case scenario on each façade was selected for further studies to ensure that the luminance intensity is kept below 2000 cd/m² while maintaining an illumination level not more than 2000 lux on the working level with the direct sun on the façade.

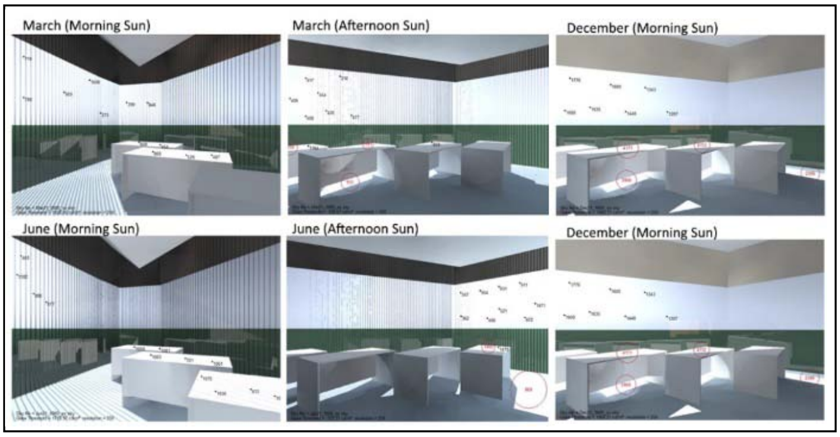

Figure 7. Radiance Simulation with Vertical Blind and Direct Sun

7.3. Depth of Daylight Available

The Passive Design Guideline recommended a minimum daylight factor (DF) of 1% be used for office spaces in Malaysia [1]. At 1% DF and the hours of 9am to 5pm, a lux level of 300 can be achieved ~70% of the time; while a lux level of 100 can be achieved ~100% of the time [1].

The result from Radiance based on the selected VLTs and blind angles, indicates that ~50% of the building office area can achieve a minimum DF of 1%.

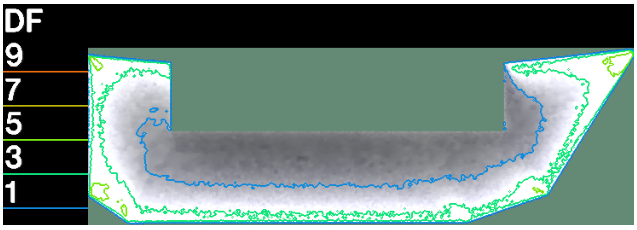

Figure 8. Simulated plan View showing daylight factor in contour line.

6. SOLAR HEAT MINIMIZATION

A double glazing with Low-E property was selected for this building. It has a low Solar Heat Gain Coefficient (SHGC) of 0.25, while allowing a visible light transmission of 32%. In addition, light coloured blinds were specified to allow part of the solar transmitted heat to be reflected out, increasing the performance of the façade to minimise heat gain.

7. DESIGN RISK

A number of design risks were found during the design. Studies made found that direct sunlight will penetrate the building façade up to 1-meter depth from the hours of 12:30pm to 1:30pm every day. It was found that a vertical blind system is not able to block off direct sunlight when the sun angle is vertically high up.

The façade affected with the direct sunlight penetration is dependent on the month of the year and orientation of the façade. Direct sunlight on the desk will cause an illumination level that is unacceptable for the visual comfort of the occupants. However, this situation only occurs over a period of 1 hour each day at 1-meter depth. Moreover, the hours of 12:30pm to 1:30pm is typical lunch hour in Malaysia.

It was also analysed that this situation occurs up to 4 months for each façade orientation. It is largely dependent on the sun position at different time of the year. An installation of a horizontal blind or short external horizontal shading devices would have been able to resolve this issue. However, such as horizontal shade would destroy the architectural intent for this building and it was not incorporated. Another potential solution is to recommend tenants not use place their desk right next to the façade, leaving a narrow walkway for plants or low cabinets space.

Another potential risk is that Malaysian tenants are generally not aware of the benefit of daylight in buildings. A tenant manual is proposed to be provided to educate the tenant on the benefit of daylight and how daylight is being harvested in this building. It is hoped that these guides will encourage the tenants to utilize daylight in this building.

Another potential risk in this design proposal is the reduction of uniformity of daylight provided for the office space. The use of internal light shelves would have reduced the intensity of daylight near to the façade while increasing the daylight deeper in the building space. However, due to the lack of funds for such design implementation, a decision is made to address only the core reason that daylight harvesting fail in this climatic zone – glare.

8. SUMMARY

A zero additional cost daylight harvesting system was proposed for a multi-tenanted office building. The proposed solution utilizes typical vertical blinds to provide glare protection from direct sunlight. In order to harvest daylight, the vertical blinds are left partially opened. A partially open vertical blind will expose part of the building occupants to the view of a bright tropical sky. To prevent glare from the view of the sky, the glazing visible light transmission was carefully selected to provide glare protection while allowing a reasonable amount of daylight to be harvested into the building. Simulation studies were conducted to test the proposed solution. Results indicates that it was possible to day lit 50% of the office building, while ensuring that all the building occupants are protected reasonably well from glare.

Finally, it is envisioned that the proposed solution for this building will enable building to be fairly transparent looking during operation. This aspect of the building is expected to increase the building aesthetic value.

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