LET THERE BE LIGHT – DAYLIGHT, GLARE AND THERMAL PERFORMANCE OF FACADES – CASE STUDIES

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ABSTRACT
Fundamental considerations of building design involve providing daylight, minimizing glare and optimizing the thermal performance of building facades. This paper investigates the timing, application, analysis, and outcomes from the simulation of daylight and glare in the development of the architecture of building facades.

The ability to optimise the design depends on when during the design process the simulation analysis occurs. This paper presents four (4) projects as case studies. Examination of these case studies highlights the most effective timing for achieving good outcomes in design of the façade.

Daylight, glare, and thermal performance of a façade system is most effectively analysed with full cooperation of the design team and involvement of the simulation expert early in the concept design phase.

INTRODUCTION
The design of building façades has a large influence on the indoor environment and is critical to the wellbeing of the occupants. The use of daylight (with glare reduction) and natural views in building design has been shown to improve human performance, health and learning; improve communication and a sense of belonging to a community or place; boost sales in retail shops; and positively impact on the energy efficiency of buildings.” (Cakir A., 2010) (Clearwater, et al., 1990), (Collins, et al., 1990), (Heerwagen, et al., 2005). Unfortunately, poor outcomes in building design often result from a lack of co-ordination between the design team and the simulation expert and an over emphasis on the simulation results. Analysing four case studies, this paper proposes that better outcomes could be achieved with good timing and communication between the design team and simulation expert, while focusing on the design intent instead of the simulation outputs.

DAYLIGHT AND GLARE SIMULATION
Key performance indicators (KPI) for assessment of daylight and glare used in the projects presented in these case studies are in accordance with the requirements of the Green Rating tools appropriate to each project.

The green rating tools used for these case studies are the Australia Green Building Council’s, Green Star tool and the United States Green Building Council’s Leadership in Energy and Environmental Design (LEED).

There is significant debate as to the validity of these KPI’s; however that debate is a paper in its own right. These projects used the KPI’s from each of the appropriate rating tools (Green Star or LEED) and these are presented below:-

KPI’s - Daylight:
For both rating tools, daylight is based on a CIE uniform overcast sky.

Under the Green Star hospital rating tool, the daylight factor is calculated using a uniform design sky, which is a CIE standard overcast sky, with an equivalent horizontal illuminance of 10K lux. The Green star Credit is summarized here:

- IEQ-4 Daylight
  One point is awarded for:
  Achieve a daylight factor of 3% for 30% of bedded areas and a daylight factor of 2.5% for 30% for all other occupied areas.
  Additional points are awarded for increases to the percentage floor area that receives the same daylight factors.

For the LEED assessment, the specified lux levels are analysed easily within IES-VE as the functionality is built into the FluxPro package.

The credit criteria are presented here the same as within the LEED manual, as it is an American rating tools, the equivalent International System of units have been provided for ease of understanding. The LEED credit is summarized here:

- IEQ-C8.1 – Daylight and Views – Daylight
  Demonstrate through simulation that 75% or more of all regularly occupied spaces achieve daylight illuminance levels between 269-5382 lux for a clear sky condition on September 21 at 9am and 3pm.
  269 lux = 25 footcandles
  5382 lux = 500 footcandles
- IEQ-C8.2 Daylight and Views – Views
 Achieve direct line of sight to outdoor environment via vision glazing between 30 inches and 90 inches above finished floor level (FFL) for 90% of building occupants of all regularly occupied areas.

**KPI’s - Glare:**

- CIE clear sky is the reference point for glare simulation for the Green Star rating tool.
  - IEQ-11 Daylight Glare Control
    - One point is awarded for:
      - The typical glazing configuration on each façade, fixed shading devices, shade the nominated plane 1.5m in from the centre of glazing line for 80% of the occupied hours.

**LEED**

The rating tool does not have a direct glare analysis requirement. This is possibly due to the debate about the validity of the measurement and analysis KPI’s currently used.

Within each project case study, the metrics above were used to assess the overall design of the building façade systems. Not all the projects were assessed with the exact same KPI’s; the Merck and MARS projects were targeting LEED requirements, while the other two targeted Australian Green Star.

**CASE STUDIES**

**Gold Coast University Hospital (GCUH)**

The Gold Coast University Hospital involved extensive simulation of different options for the façade shading to ensure optimal daylight penetration into the ward rooms, while minimizing the impact on the heat gain.

Thermal performance assessment of the façade as well as daylight and glare analysis was performed early on in the design stages for the project. The advantages to the project, as noted below, were numerous and resulted in a balanced design.

- Thermal performance of the façade systems, including glazing and shading devices allowed input to the design team on where to apply different glass types and shading arrangements to minimize heat gain
- Further analysis of these arrangements allowed the design team to assess the impact on daylight and glare providing additional information to optimise the façade.
- Views from the wardroom, the impact of the glare from different shading arrangements and the bed location, resulted in the inclusion of internal blinds to assist in controlling glare.

The assessment of glare for this project occurred directly after the façade analysis and still within the Design Development phase. By considering the
shading system and bed location, the project the team was able to inform the client and the design team that even with optimised shading systems, glare would still be an issue for some of the wardrooms. Figure 3 shows the impact of a vertical fin shading system on the amount of glare sources produced. For the majority of wardrooms, horizontal shading systems reduce the number of glare sources.

An aspect of the simulation process that could have been improved was how the model was managed. The GCUH project involved a very large model that had to be separated into smaller models to allow computation times to be reduced. This was not the most efficient method of assessment. Using smaller models with short computational times allows for faster feedback to the design team and this improves the ability of the simulation expert to communicate the key performance aspects of the design.

Another aspect of the project that restricted the design teams’ scope for exploring different solutions was the façade system options. Façade options were reduced to a curtain wall system for the majority of the façade due to the early involvement of a managing contractor. The early involvement of a managing contractor can be beneficial or not depending on the attitude towards construction costs associated with the façade design.

The above figure shows the glare sources associated with the shading devices in relation to the bed orientation. The Visual Light Transmission (VLT) value shown above is the actual performance value of the glass used in the design of this building. The figure shows the maximum possible glare threshold in frame 3. This glare threshold value can be compared against the values shown in frames 1 and 4. Frame 2 shows the plan detail and location of the eye and focal points use for the simulation images in frames 1, 2, & 3.
Early involvement of the simulation process in design of the façade allowed for informative contributions to the design team on the minimum requirements to meet compliance while ensuring the energy efficiency, daylight and glare performance of the façade were optimised.

For this project, the façade design was considered from a thermal performance perspective and as a response to the climatic conditions of the location. Melbourne, Australia has a large number of overcast sky days and high daily and yearly temperature fluctuations. The design team considered the winter and summer solar gains and the daylight and glare aspects of the façade to ensure a balanced result was achieved for the occupants.

Many design iterations were considered on the PDI project. Each iteration was discussed with the design team before proceeding to the next simulation. This resulted in changes to both the west and east façade. For example, adding solid vertical constructions to these facades reduced the thermal gain, while still providing views and daylight. The main northern façade of the building involved an integral timber blind within the double glazed windows. Multiple iterations involving the size of the timber slats and their spacing were required to achieve a balance between the daylight, glare, and the thermal performance.

Meetings with the architectural design team, open discussion during the design process and a willingness by the simulation team to consider the many iterations has resulted in a façade solution that is both innovative and responsive to the location and function of the building.
The New China facility packaging and commercialization plant designed for Merck is a large site containing 3 major buildings. The focus of the design team was achieving LEED Silver compliance for the Administration building. This project received instruction to try for a LEED rating during the design development (DD). The confirmation that a LEED rating was required occurred at 50% of the Design Development stage and hence the majority of the architectural design decisions where already determined. At this stage of the project, modelling to determine the daylight and glare performance of the façade was locked in by the predetermined façade and building layout and was more focused on determination of whether the daylight or glare targets were achieved.

To reduce the amount of assessment required the area of the building that was determined to be most likely to achieve the requirements was the dining room/canteen area. Initial modelling of the dining room/canteen area of the building indicated the daylight penetration was not going to meet the LEED requirements. Table 1 shows the results for the internal zone of the dining area. As the design team had fully developed the facade solution, the only avenue for design change was in the glazing performance.

This is a very limited approach and not recommended, the façade design had very little room for design alteration and the daylight and glare modelling had no impact on the façade design.

**Table 1**  
Merck Daylight Report table for Compliance with LEED

<table>
<thead>
<tr>
<th>Current Results</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LEED requirement &gt; 75% floor area above threshold</strong></td>
<td>FAIL</td>
</tr>
<tr>
<td><strong>LEED NC 2.2 EQ Credit 8.1 Daylight &amp; Views:</strong></td>
<td></td>
</tr>
<tr>
<td>Total floor area (m²)</td>
<td>79.438</td>
</tr>
<tr>
<td>Total floor area above threshold (m²)</td>
<td>49.176</td>
</tr>
<tr>
<td>% floor area above threshold (%)</td>
<td>61.9</td>
</tr>
</tbody>
</table>
The Mars Petcare project is a small laboratory for the testing and development of pet foods. The building concept design stage involved assessing the building concepts to be able to meet LEED requirements.

Concept design started with the knowledge of the requirements of meeting a LEED rating for daylight and glare. This combined with the requirements of laboratory space resulted in the innovative design approach taken by the team. A laboratory is required to restrict direct sunlight from hitting the working surface of the benches, as direct sunlight will alter the results of some experiments. The early concept involved a floating roof that allowed light to enter at a high level above the working spaces within the laboratory; large overhangs on the roof to restrict any direct sunlight; and continuous windows around the perimeter of the building.

The resulting design was targeted to meet the LEED daylight and glare requirements while still providing sky views for the occupants. Using a basic model from Sketchup and importing this to IES-VE, preliminary assessment of the daylight performance of the design indicated the LEED requirements were easily meet. The design team for this project focused on the ability of the building to achieve a possible LEED Gold rating, while staying focused on the requirements of laboratory space. The use of large amounts of glass area with large roof overhangs enhanced the design while providing excellent access to daylight.

For this project, daylight penetration was a major focus during the conceptual design. A design that would allow a lot of high-level light into the building was simulated to determine the compliance with the LEED requirements for daylight. Successful early integration of simulation runs and feedback to the design team allowed this design to easily meet the LEED requirements while staying within the design brief and requirements of the client.

The resulting design for this laboratory resolved all issues concerning daylight penetration and laboratory code requirements for restriction of daylight to bench tops. A co-ordinated team approach and good communication between the simulation expert and the design team has resulted in a cost effective approach with maximum daylight and good external views, with minimal thermal impact.
CONCLUSION

Table 2
Summary of the timing and outcomes from the case studies

<table>
<thead>
<tr>
<th>PROJECT</th>
<th>MODELLING INITIATED DURING</th>
<th>INTERACTION BETWEEN MODELLER AND DESIGN TEAM</th>
<th>OUTCOMES</th>
</tr>
</thead>
<tbody>
<tr>
<td>GCUH</td>
<td>Late Schematic Design - Early Developed Design</td>
<td>Good</td>
<td>Façade design concept locked in but modelling results were able to impact on glazing and shading selections</td>
</tr>
<tr>
<td>PDI</td>
<td>Early Schematic Design</td>
<td>Good</td>
<td>Façade options, including form, glazing and shading were impacted by the modelling results</td>
</tr>
<tr>
<td>MERCK</td>
<td>Middle of Developed Design</td>
<td>Poor</td>
<td>modelling had no impact on façade form and shading options - modelling used to verify the design only - resulted in failing to meet LEED requirements</td>
</tr>
<tr>
<td>MARS</td>
<td>Start of Concept Design</td>
<td>Excellent</td>
<td>Modelling occurred during concept design - modelling results were able to impact building form, glazing, shading and façade.</td>
</tr>
</tbody>
</table>

The table above summarises the case study information presented in the case studies. The lessons learnt from the summarised outcomes are as follows:

- Get your team organized early – concept design stage is not too early to start simulations.
- Ensure all stakeholders are aware of the importance of daylight and glare on the human condition.
- Be flexible in your approach to the design team.
- Use simple models that focus on the facade design process.
- Have options for the analysis and simulations, one size does not fit all buildings or design teams.
- Present the simulation results in a graphical format that is easy for the design team to understand.

Daylight and glare are critical aspects of the design for an effective building. To optimise the facade system the design team must consider these amongst the many other design issues of good facade design. Buildings are for the people using them so the facade system should enhance the human experience. Simulations are a method to assist the design team with verification of their assumptions or to present alternatives. They are also a method of assisting us in understanding the impact of the environmental effects on the human condition. However, daylight and glare simulation does not account for the personal response of the building occupant as each person can have an individual experience.

The presented project case studies highlight lessons learnt. The increasing awareness of ‘green design principles’ results in designers being required to provide proof of concept as early in the design process as feasible. This paper presents the idea that early involvement, good teamwork and a committed design team can achieve a positive impact on the occupants comfort within the built environment.

ACKNOWLEDGEMENT

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