Case Study 2: Studying Lighting Analysis Techniques

CASE STUDY 2
Carlson Education Building, Room 240
ABS 731: Lighting Design and Technology
Spring 2006
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Student: Daniel Overbey
Abstract

Introduction

The primary purpose of this investigation to simply for the author to familiarize himself with the fundamental approaches to daylight analysis:

1. Spatial monitorization and documentation
2. The Lumen Method
3. Daylighting simulation software (i.e. AGI32)

The author incurred innumerable lessons and gained invaluable experience. As a result of this investigation, the author is much more versed in discussing daylighting characteristics and is more analytically conscious of daylight distribution throughout a given space. The author has gained experiential knowledge as to what kind of impact sky conditions, materials’ attributes, and sky dome obstructions have on daylight quality. The author has also become familiar with the limitations of several daylight simulation techniques. The CEB 240 investigation was comprised of three essential components:

1. Documentation of both internal and external elements that influence daylight
2. Employment of the Lumen Method for predicting interior daylight illumination
3. Simulation of CEB 240’s interior daylight illumination via AGI32 lighting simulation software.

Key Lessons

Among other lessons, a thorough knowledge of the AGI32 daylight simulation performance and capabilities has prompted the author to alter the construction techniques for three-dimensional digital models in order to reduce a model’s number of irregularly-triangulated surfaces. This will both help the software calculate lighting more efficiently and make the program’s renderings more accurate.

The issue of non-clear sky conditions became a very valuable lesson. Much care should be given to properly documenting sky conditions during a “sweep” of a studied space. There are different degrees of overcast sky conditions, for instance. While distribution may be relatively identical, a heavy overcast condition versus a moderate overcast condition will produce very different levels of interior daylight illumination. This became evident during the 9:00am and 3:00pm sweeps of CEB 240. Several sky conditions had to be explored within AGI32 in order to determine a sky condition that most accurately reflected the actual conditions during those times.
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Conclusion

This investigation concludes that daylight alone will not suffice for proper interior illumination within CEB 240. Using daylight alone, glare would become very problematic.

It is actually unclear whether the designers of the CEB addition actually modeled it to utilize daylight. The exterior treatment of the CEB addition, while fundamentally responsive to regional daylight availability, is rather generic and is repeated on both the north and south sides of the building. Such a duplication undermines design credibility.

Exterior obstructions to solar access also negatively influences daylight availability for CEB 240. A further investigation should be to simulate interior daylight illumination under the physical context that existed when the 1970 addition was erected.

Additionally, one should investigate the performance of the space throughout an entire year. The different solar altitudes likely produce varying levels and distributions of daylight throughout the space.

It appears that the AGI32 software is very accurate for simulating spaces under clear sky conditions. Vague records with regard to the non-clear sky conditions during the documentation/monitorization phase of the project has kept the author from accurately comparing the model to the actual room during those conditions. The critical flaw of the Lumens Method is its inability to properly compensate for some of the unique characteristic of the space.

Above: A side-by-side comparison of a photograph from the actual CEB 240 and the AGI32 model under similar sky conditions.
Site Documentation

William D. Carlson Education Building

Summary

The William D. Carlson Education Building (CEB) faces 2 degrees west of solar south. Room 240 is located on the second floor as depicted on the floor plan on page 4. It is part of an addition to the original CEB that was built in 1970 by Jack Miller and Associates AIA Architects Engineers. From room 240's high south-facing glazing there are many obstructions to the sky dome (see the sun-path diagram on the page 6). These obstructions greatly reduce available daylight.
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Carlson Education Building Addition

Architect: Jack Miller and Associates AIA
Architects Engineers
Location: Las Vegas, Nevada
Client: University of Nevada, Las Vegas, Clark County, Nevada
Job number: 69-18
Date of construction drawings: March 1970

Above: Second floor plan of Carlson Education Building with RM 240 identified
Source: 2006 University of Nevada, Las Vegas
Site Documentation

William D. Carlson Education Building, Room 240

Daylighting

The south-facing exterior of room 240 features an interesting architectural treatment. An egg-crate shading strategy featuring a splayed surface below suggests that some architectural consideration was given to daylighting. While the vertical members block sever east and west direct sunlight, the horizontal member blocks high sun angles during the cooling season. All of the surfaces feature a reflectivity near 70%, thus the splayed surface may diffuse direct sunlight while the bottom of the horizontal overhang reflects diffused light into the classroom via the high window placement—which begins to function like a clearstory.
Solar Access Study Summary

From the sun-path diagram above, one may observe that there are many obstructions to the skydome from CEB 240. The Boyd Law School (BLS) building did not exist when the CEB addition was built. The BLS building is within very close proximity of the CEB and even though its surfaces are quite reflective, its proximity undermines any attempt by the CEB of utilizing daylighting for classroom functions during most non-clear sky conditions.
Room Documentation

William D. Carlson Education Building, Room 240

Summary

On March 10, 2006, room 240 of the William D. Carlson Education Building (CEB 240) was monitored for this investigation. Room dimensions were carefully recorded as well as various furnishings within the room (see the axonometric diagram on the right). Illuminance meters were employed to document the reflectance values of significant indoor and outdoor elements. Where actual reflectance could not be recorded, standards from the IES Lighting Handbook were assumed. The transmittance of the classroom’s window could not be determined, but investigations with AGI32 suggest that the window indeed has a relatively large transmittance factor (perhaps over 75%). The documented reflectance values were applied to the AGI32 model. The glazing transmits 100% of the its luminance in the AGI32 model.
Other Reflectance Values

Interior
- Door: 21%
- Vertical blinds: 75%
- Black paper, billboard: 10%
- Slab table: 21%
- Ceiling prismatic panels: 70%

Exterior
- CEB exterior: 68%
- CEB glass: 25%, IES Lighting Handbook
- BLS bld. glass: 25%, IES Lighting Handbook
- Greenery: 6%, IES Lighting Handbook

- BLS building exterior: 69%

- CEB 240
  - Ceiling tile: 65%
  - Painted walls: 65%
  - Chalkboards, north: 16%
  - Billboard fabric: 30%
  - Chalkboards, east and west: 26%
  - Podium: 33%
  - Floor tiles: 53%
  - Red plastic furnishings: 15%
  - Table tops: 30%
  - Projector screen: 80%
Lumen Method

Applied “room with one window wall and roof overhang” method from Libbey-Owens-Ford Company

1. Available Daylight

Location: 36.11° N Latitude
           115.1° W Longitude
           2181 ft Elevation

Date: March 10
Time: 11:50 AM
Sky Condition: Clear

Illumination from the sky on window side of building (Ekw) is 1275 fc (see Figure 36C). The window is shaded from the direct light from the sun.
Illumination from the sky on the ground is 1100 fc and that from the sun is 0 fc.

The grass outside the window has a reflectance (Rg) of 11%.

Field proportion factor (assumed): 1%

$$\text{Egw} = (1100) \times 0.11 \times 0.5 = 60.5$$

Illumination from the ground on the window side of the building (Egw) is 60.5 footcandles.

Solar altitude: 49.97°
Window orientation: 2° Azimuth from sun (profile angle 50°)
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2. Room Conditions

Room length..................19 ft
Room width..................24.33 ft
Ceiling height...............10 ft
Sill height..................2.5 ft
Roof overhang...............8 ft

Ceiling reflectance..........65 %
Wall reflectance............65 %
Floor reflectance.............53 %

For the Lumens Method, it will be assumed that the entire wall above the sill. Frame and metalwork account for 10% of the area of the opening.

Glass type: Solar bronze
Glass transmittance: 77%

3. Equivalent Room

Since this room has an overhang, the dimensions of an "equivalent room" must be determined. The length of the equivalent room will be different for each prediction point.

For the MID opint, as shown in the diagram, the equivalent room length is 29'-11" (use 30' approximate). The width of the room is 32'-5" or 32.42'.
Lumen Method

Applied “room with one window wall and roof overhang” method from the Libbey-Owens-Ford Company

4. Window Transmittance Factors

Area = length x height x available portion

Ag = 19' x 7.5' x .90
Ag = 128.25' (for illumination from the sky)
Ag = 19' x 10' x .90
Ag = 171' (for illumination from the ground)
Tg = .77

Note: The effect of the normal sill height on illumination from the ground in the equivalent room is negligible, so the window transmittance area (Ag) is computed as though the window extends to the floor.

5. Coefficients of Utilization for Equivalent Room

Illumination from the sky

Ccs MAX: 0.0098    Kcs MAX: 0.125
MID: 0.0062       MID: 0.106
MIN: 0.0047       MIN: 0.0994

Illumination from the ground

Cug MAX: 0.0077    Kug MAX: 0.14
MID: 0.0062       MID: 0.0966
MIN: 0.0041       MIN: 0.0816

6. Calculations for Equivalent Room

Ccs, Kcs, Cug, and Kug values taken from LOF coefficients of utilization without window controls tables (see next page).

Ekwp = Ekw x Ag x Tg x Ccs x Kcs
MAX = 1275 x 128.25 x 0.77 x 0.0098 x 0.125 = 154
MID = 1275 x 128.25 x 0.77 x 0.0062 x 0.106 = 83
MIN = 1275 x 128.25 x 0.77 x 0.0047 x 0.0994 = 59

Egwp = Egw x Ag x Tg x Cug x Kug
MAX = 60.5 x 171 x 0.77 x 0.0077 x 0.14 = 9
MID = 60.5 x 171 x 0.77 x 0.0062 x 0.0966 = 5
MIN = 60.5 x 171 x 0.77 x 0.0041 x 0.0816 = 3

7. Calculations for the Actual Room

(from plotting the values of the equivalent room)

Illumination from the sky        Illumination from the ground
MAX: 97 fc                      MAX: 6 fc
MID: 69 fc                      MID: 4 fc
MIN: 59 fc                      MIN: 3 fc
8. Compensation for Sun-lit Area Under Overhang

\[ A - B = X_e \]
\[ C + 20 \]

A = 8'
B = 0'

Cmax = 5.33'
Cmid = 12.33'
Cmin = 19.67'

<table>
<thead>
<tr>
<th>Reference</th>
<th>Xf</th>
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<tbody>
<tr>
<td>Fig. 37B</td>
<td>1.69</td>
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<tr>
<td>Fig. 37C</td>
<td>1.38</td>
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<tr>
<td>Fig. 37D</td>
<td>1.22</td>
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</tbody>
</table>

9. Multiply illumination from the ground by factor \( X_f \), and add to illumination from the sky

Total illumination on work surface

\[
\text{Total} = (E_{\text{gwp}} \times X_f) + E_{\text{kwp}}
\]

MAX = (9 x 1.69) + 154 = 168.7 fc
MID = (5 x 1.38) + 83 = 89.3 fc
MIN = (3 x 89.3) + 59 = 62.1 fc

From Libbey-Owens-Ford, How to Predict Interior Daylight Illumination
03.10.06 / 9:00 AM

Illuminance Summary

<table>
<thead>
<tr>
<th></th>
<th>AGI32</th>
<th>Actual</th>
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<tbody>
<tr>
<td>Average</td>
<td>49.90</td>
<td>27.47</td>
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<tr>
<td>Maximum</td>
<td>4506</td>
<td>70</td>
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<tr>
<td>Minimum</td>
<td>1.8</td>
<td>10</td>
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<tr>
<td>Avg./Min.</td>
<td>27.72</td>
<td>2.75</td>
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<td>Max./Min.</td>
<td>2503</td>
<td>7</td>
</tr>
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</table>

While it may initially appear that there is a large discrepancy between the AGI32 model and the actual values recorded within CEB 240, they are actually relatively similar in overall light distribution. A single, questionable, reading of 4506 footcandles within the AGI32 model totally changed the resulting values in the illuminance summary. By omitting this questionable value (see section below), one may observe the striking similarities between the recorded values and the computer simulation.
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Time: 9:00am (clock time)
Sky condition: Partly cloudy

Time: 9:00am (clock time)
Sky condition: AGI32 - Clear
Illuminance Summary

<table>
<thead>
<tr>
<th></th>
<th>AGI32</th>
<th>Actual</th>
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</thead>
<tbody>
<tr>
<td>Average</td>
<td>24.62</td>
<td>31.93</td>
</tr>
<tr>
<td>Maximum</td>
<td>94.3</td>
<td>91</td>
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<tr>
<td>Minimum</td>
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</tr>
<tr>
<td>Avg./Min.</td>
<td>12.31</td>
<td>2.66</td>
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<tr>
<td>Max./Min.</td>
<td>47.15</td>
<td>7.58</td>
</tr>
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</table>

Among the three times recorded/simulated, the 11:50 AM (11:59 AM solar time) comparison provided the most similar results. This may be due to the clear sky conditions. The morning and afternoon sweeps occurred during overcast/partly cloudy conditions under which there was a great deal of varying cloud coverage throughout the sky dome.

Under such stable clear sky conditions, this comparative analysis added much to the verisimilitude of the AGI32 software.
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Time:
11:59am (solar time)

Sky condition:
Mostly clear

Time:
11:59am (solar time)

Sky condition:
AGI32 - Clear
03.10.06 / 3:00 PM

Illuminance Summary

<table>
<thead>
<tr>
<th></th>
<th>AGI32</th>
<th>Actual</th>
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</thead>
<tbody>
<tr>
<td>Average</td>
<td>2.63</td>
<td>9.53</td>
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<tr>
<td>Maximum</td>
<td>7.0</td>
<td>21</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.3</td>
<td>3</td>
</tr>
<tr>
<td>Avg./Min.</td>
<td>8.77</td>
<td>3.18</td>
</tr>
<tr>
<td>Max./Min.</td>
<td>23.33</td>
<td>7</td>
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The 3:00 PM sweep occurred under a heavy overcast condition. The result was a severe drop in the average illuminance value within the classroom.

Consistent with the rest of the analysis, the illuminance values progressively decrease as one ventures away from the south-facing glazing.
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Time: 3:00pm (clock time)

Sky condition:
- Heavy overcast
- AGI32 - Clear