Innovative Daylight Systems for the Tropics

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- Daylight is
  - desirable
  - cool
  - green

- Daylight design & lighting controls

- Case studies
  - MOE (built)
  - ST Diamond building (built)
  - MMK (daylight concept)
  - ADB atrium (built)
  - GEO building (built)
### What are the Climatic Design Issues?

<table>
<thead>
<tr>
<th>Climatic parameter</th>
<th>In a cold/temperate climate</th>
<th>In a tropical climate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sun</td>
<td>Our friend</td>
<td>Our enemy</td>
</tr>
<tr>
<td>Wind</td>
<td>Our enemy</td>
<td>Our friend</td>
</tr>
<tr>
<td>Daylight</td>
<td>Our friend</td>
<td>Our enemy (perceived to be hot, glary and give unwanted solar tan)</td>
</tr>
</tbody>
</table>

**EXAMPLE: Air movement**

- less than 0.15 m/s (cold climate)
- higher than 0.15 m/s (tropic climate)
  - *Recommended range: 0.15 – 0.50 m/s*
  - *Do not exceed: 0.70 m/s*

**EXAMPLE: Sun light / Daylight**

- Cold climate: “Solar canopy” advertisement
- Tropic climate: Skin whitening advertisement
DAYLIGHT SURVEY RESULTS
Among 46 building professionals in Singapore

Suppose daylight can be controlled just like electrical lighting. If this is the case, please indicate how you believe a **typical office worker** would prefer to have his workplace lit:

- **Offices preferred to be mostly daylit**
- Fully lit with electric light
- Mean vote
- Fully lit with daylight
DAYLIGHT SURVEY RESULTS
Among 569 office building occupants in Manila, Philippines

"Regarding the balance between electrical and natural light, which do you prefer?"

- Total reliance on electrical light: 4%
- Predominant reliance on electrical light with supporting daylight: 13%
- Equal reliance on daylight and electrical light: 46%
- Predominant reliance on daylight with supporting electrical light: 31%
- Total reliance on daylight: 6%

Offices preferred to be mostly daylit
DAYLIGHT SURVEY RESULTS
Among 46 building professionals in Singapore

Misconception:
Daylight was thought to be 2.6 times hotter than it is
Daylight is ‘Cool’

Luminous Efficacy

- **Incandescent**: 15
- **Low voltage halogen**: 18
- **Fluorescent lamp**: 65
- **Direct Sunshine**: 100
- **Clear sky daylight**: 130
- **"Cool Daylight"**: 200

Less Heat & More Light!
Different Glazing Performances

Examples

a) Suncool HP Brilliant 50
   - VLT: 51%
   - SHGC: 26%
   - VLT/SHGC ratio: 1.96
   NB. Spectrally selective, allowing light, blocking heat

b) Optifloat Clear
   - VLT: 81%
   - SHGC: 73%
   - VLT/SHGC ratio: 1.11
   NB. Only slightly spectrally selective
Orientation for Daylighting

North & South windows can easily be shaded by horizontal overhang
Daylighting Design Strategies

- Control solar heat gain
- Control glare from clear sky and direct sun
- Make daylight factor more uniform
- Increase daylight factor deep in building

Malaysian MS1525 requires 300 lux for offices.

Most people can work down to 100 lux with daylight before switching on lights.
Case study

MOE BUILDING
(MINISTRY OF EDUCATION, SINGAPORE)
LESSON

Glare from overcast sky may inhibit daylight system

NB: Building by others, not by IEN Consultants
Daylight design but
- blinds down
- lights on

• Split window design

• Slanting ceiling

But glary, so top-window blinds always down

Other observations
• High cubicles inhibit daylight and views
• Light circuiting can be improved
Case study

ST DIAMOND BUILDING
(ENERGY COMMISSION OF MALAYSIA)
Self-shading facades
Atrium Daylight Design

The atrium has been carefully designed to optimize daylight utilization for each floor employing the combination of the following three strategies:

1. Automated blind with six different configurations to maintain the appropriate daylighting levels at all times. The blinds with 30% light transmittance are adjusted every 15 minutes and follow three different control strategies for morning, mid-day, and evening.

2. The windows size becomes larger deeper into the atrium to cater for lower daylight levels.

3. A band of Tannenbaum reflector panels are applied to 4th and 5th floor to deflect daylight across the atrium to 1st and 2nd floor where daylight levels are the lowest. The 'christmas tree' profile reflectors have an inclination of 10° and reflect about 85% of the light in a semi-diffuse manner, hence, avoiding visual glare issues for the building occupants.
Façade Daylight Design

The building is 50% daylit. The façade daylighting system consists of a mirror lightshelf and a white painted window sill. Both deflect daylight onto the white ceiling for improved daylight distribution until 5 meters from the façade + 2 additional meters of corridor space. Installed office lighting is 8.4 W/m², but 1-year measurements show consumption of only 4 W/m² showing 50% reliance on daylighting.
Typical Cross Section - Day-Lighting - Office

- Mirror lightshelf
- Fixed blinds for glare control
- Daylight reflected onto ceiling
Daylight Skylight through Roof
Take in diffuse light only
## Lighting Control Strategy

<table>
<thead>
<tr>
<th>No.</th>
<th>Lux sensor</th>
<th>Switch</th>
<th>Electric light</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Above setpoint</td>
<td>Off</td>
<td>Off</td>
<td>If necessary, use task light</td>
</tr>
<tr>
<td>2</td>
<td>Above setpoint</td>
<td>On</td>
<td>Off</td>
<td>If necessary, use task light</td>
</tr>
<tr>
<td>3</td>
<td>Below setpoint</td>
<td>Off</td>
<td>Off</td>
<td>If necessary, use wall switch or task light</td>
</tr>
<tr>
<td>4</td>
<td>Below setpoint</td>
<td>On</td>
<td>On</td>
<td>If nobody around, switch off switch</td>
</tr>
</tbody>
</table>

### Note:
- Task Lights to be distributed

### Location Setpoint (current) | Setpoint (with task lights)
--- | ---
Office | 300 lux | 120 lux
Corridors | 100 lux | 40 lux

NB. The same principle applies for first row of lighting for workstations along the atrium.
Lighting Levels

Office (lux)

- Singapore (common practise): 500 lux
- Malaysia (code): 350 lux
- Daylight level still comfortable to most people: 100 lux
- ST staff. Lowest measurement, lights still off: 33 lux

No need to switch on lights automatically: Save energy
YouTube video

Sustainable Features of ST Diamond Building
http://www.youtube.com/watch?v=3H_sXCtDayc
Case study

MMK
(DAYLIGHT DESIGN CONCEPTS)
Daylight Trough
(Design Concept by IEN and A61)
Daylight Factor
Floor Plan Daylight Simulation

Daylight troughs
Case study

ADB ATRIUM
(ASIAN DEVELOPMENT BANK)
Before & After Daylight Retrofit

- Cutting of eaves
- Installation of anidolic light scoop
Atrium Daylight Retrofit

- Daylight level increased 6-fold without glare
- 92% of occupants preferred atrium after retrofit
Comment: Significant increase in atrium light level by a factor 6 at sunny conditions
Measured daylight in Atrium

Good daylight levels in 100 – 2000 lux range
Case study

GEO BUILDING
(GREEN ENERGY OFFICE BUILDING)
Split Window Design
Daylight Responsive Lighting
Daylight Measurements

- Lighting consumption: 0.56 W/m²
- Code requirement: 15 W/m²

25 times more efficient
Daylight Responsive Lighting

Lighting Control
- Automatic off (light sensor and/or occupancy sensor)
- Manual on (people press the wall switch)
- Use task light (table lamp)

Measured lighting: 0.56 W/m²
(factor 25 below building code)
Light levels (lux) measured in GEO Building, 9 April 2012, 4:30 pm on rainy and gloomy afternoon. None of the general lighting had been switched on by the staff.

- Office design in Singapore and the US
- Office design code in Malaysia (MS1525:2007)
- GEO Building, desk near window (no lights on)
- GEO Building, desk away from window (no lights on)
- GEO Building, desk with 6.2 Watt LED task light
- GEO Building, library (no lights on)
- GEO Building, 2nd floor meeting room (no lights on)
- GEO Building, 2nd floor meeting room (lights on)
- GEO Building, atrium

![Graph showing light levels in different locations]
Conclusions

• Daylighting is big untapped renewable energy source in the tropics

• Daylit office spaces are preferred, when glare and heat is controlled

• Daylight is cool & free

• Most people work comfortably in daylight levels that are substantially lower than the code requirement. Supplementary task helps to ensure efficient use of electric lighting.

"Thank you"
Appendix
Speaker: Gregers Reimann

• **Education**
  
  M.Sc. In Energy Engineering from DTU (Technical University of Denmark)
  
  • Building energy simulation
  • Building daylight simulation
  • Thermal comfort (under Prof. Fanger)
  • Renewable energy for buildings (solar thermal, PV)

  Studies at: DTU (Denmark), UCLA (USA), UPM (Malaysia) and NUS (Singapore)

• **Working in different climates**
  
  • Greenland (low energy building, solar thermal)
  • Burkina Faso & Ghana (energy efficient building retrofitting; PV fridges)
  • Botswana (improve building code)
  • Philippines, Indonesia & Thailand (daylight and energy retrofits)
  • Malaysia & Singapore (energy efficiency, daylighting, sustainable buildings)
Daylighting in Tropical Climate
CASE: Light scoop for "Urban Canyon" (in narrow streets)

*Ray Tracing is done in "Raytrace" inhouse software. Daylight Factor is simulated in "Radiance" for a standard CIE overcast sky.

On an average day: Daylight Factor of 1.0% = more than 300 lux from 11am to 4pm
Daylight Factor of 0.5% = more than 200 lux from Noon to 3pm
Glare made easy
(Interesting correlation in Evalglare study)

- Total responses: 349
- Number of responses per illuminance-class: 29
- $R^2 = 0.77$
- Vertical Eye Illuminance [lux]
- ± Standard deviation

Percentage of disturbed persons

0% 20% 40% 60% 80% 100%

0 2000 4000 6000 8000 10000