DATABASE

Roof Daylight Systems
PV as art
Architectural Engineering
TU Delft . Studio 2016

tutors
Anne Snijders
Marcel Bilow

Frédérique Sanders
F.C.J.E.Sanders@student.tudelft.nl

references
The sections in this database are own illustrations
The photographs are extracted from http://www.archdaily.com
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sunshading system
classification
analysis method

11  rebound
Connecticut, United States
Madeira, Portugal
Paris, France
Riehen, Switzerland
Rotterdam, The Netherlands
Venice, Italy
Zamora, Spain
Zaragoza, Spain

45  reflection
Cascais, Portugal
Córdoba, Spain
Herning, Denmark
Medellín, Colombia
Munich, Germany
Nottingham, Great Britain
Paris, France
Santiago de Compostela, Spain
Texas, United States
Utrecht, The Netherlands
Venice, Italy
Venice, Italy

95  filtration
Bregenz, Austria
Davos, Austria
Giornico, Switzerland
Helsinki, Finland
Munich, Germany
Yokohama, Japan

121  conclusion
overview
comparison
conclusion
introduction
ADVANTAGES
roof daylight

- stimulate biorhythm of users
- decrease in lighting / electricity costs

DISADVANTAGES
roof daylight

- summer: overheated by greenhouse effect
- winter: high heat losses through glass
- sun glare on screens
SOLUTION

=  

ROOF DAYLIGHT SYSTEM

yes < diffuse radiation (D)  
no < beam/direct radiation (B)
rebound

reflection

filtration
CLASSIFICATION

Function of roof daylight / sunshading systems: transform beam/direct radiation (B) in diffuse radiation (D). The different projects in this database are arranged in three groups:

1. **Rebound**
   
   Direct light not admitted / openings towards the North

2. **Reflection**
   
   Direct light bounced back and forth

3. **Filtration**
   
   Direct light transmitted through different material layers
**VVVV-1 analysis software** < points

**VVVV-2 analysis software** < connections
ANALYSIS METHOD

In order to compare the 26 different daylight projects, of each project a representative interior photo will be subjected to the VVVV-1 and VVVV-2 analysis software. This is a computational reinterpretation program based on procedural digital workflows. With this software the light intensity in the building can be measured.

The VVVV-1 analysis software focuses on the points of lightness; the VVVV-2 analysis software on the connections in lightness. The higher the Threshold and lower the Tolerance of the output, the higher is the light intensity in the building.
1. rebound
Yale Center for British Art

Function: Museum / history institute
Architect: Louis Kahn
Connecticut, United States - 1974
Focused on Lightness
0.75 Threshold - 0.03 Tolerance
Centro das Artes Casa das Mudas

Function: Art centre
Architect: Paulo David
Madeira, Portugal - 2004

glass on North
white reflective
Focused on Lightness
0.93 Threshold - 0.07 Tolerance
Pajol Sports Centre

*Function: Sports centre*
Architect: Brisac Gonzalez
Paris, France - 2012
Focused on Lightness
0.74 Threshold - 0.08 Tolerance
Beyeler Foundation

Function: Museum
Architect: Renzo Piano
Riehen, Switzerland - 1982

- double-glass with operable louvers
- frosted glass panels on South
- perforated metal
Focused on Lightness
0.88 Threshold - 0.02 Tolerance
Rotterdam Central Station

*Function: Public transport station*

*Architect: Team CS (Benthem Crouwel Architects + MVSA Architects + West 8)*

Rotterdam, The Netherlands - 2014
Focused on Lightness
0.88 Threshold - 0.07 Tolerance
Museo dei Maestri IUAV . Sala Aldo Rossi

Function: Museum
Architect: own work
Venice, Italy - 2013 (unbuilt)
Focused on Lightness
0.89 Threshold - 0.05 Tolerance
Museo Provincial de Zamora

Function: Museum
Architect: Luis Moreno Mansilla and Emilio Tuñón
Zamora, Spain - 1996
Focused on Lightness
0.75 Threshold - 0.09 Tolerance
Congress Centre of Aragón . Expo 2008

Function: Congress centre / auditorium
Architect: Nieto Sobejano Arquitectos
Zaragoza, Spain - 2008
Focused on Lightness
0.82 Threshold - 0.06 Tolerance
2. reflection
Casa das Histórias Paula Rego

Function: Museum
Architect: Eduardo Souto de Moura
Cascais, Portugal - 2009

glass

white reflective
Focused on Lightness
0.86 Threshold - 0.04 Tolerance
Contemporary Art Centre

Function: Art centre
Architect: Nieto Sobejano Arquitectos
Córdoba, Spain - 2013

glassfibre reinforced concrete panels (GRC)
glass
Focused on Lightness
0.68 Threshold - 0.06 Tolerance
Herning Museum of Contemporary Art

Function: Art centre
Architect: Steven Holl
Herning, Denmark - 2009
Focused on Lightness
0.86 Threshold - 0.03 Tolerance
Fernando Botero Library Park

Function: Library / theatre
Architect: G Ateliers Architecture
Medellín, Colombia - 2009
Focused on Lightness
0.65 Threshold - 0.06 Tolerance
Herz Jesu Kirche

*Function: Church*

*Architect: Peter Zumthor*

*Munich, Germany - 1996 (unbuilt)*

![Diagram of Herz Jesu Kirche]

- **glass**
- **light well**
- **indigo blue absorbing**
Focused on Lightness
0.65 Threshold - 0.06 Tolerance
Nottingham Contemporary

Function: Museum
Architect: Caruso St. John Architects
Nottingham, Great Britain - 2009
Focused on Lightness
0.95 Threshold - 0.04 Tolerance
Musée de l’Orangerie

Function: Museum
Architect: Olivier Brochet
Paris, France - 2006 (renovation)
Focused on Lightness
0.95 Threshold - 0.04 Tolerance
CGAC . Centro Galego de Arte Contemporânea

Function: Museum
Architect: Álvaro Siza
Santiago de Compostela, Spain - 1993
Focused on Lightness
0.87 Threshold - 0.05 Tolerance
Kimbell Art Museum

Function: Museum
Architect: Louis Kahn
Texas, United States - 1972
Focused on Lightness
0.86 Threshold - 0.05 Tolerance
Gym Hall TNW

Function: Gymnastics hall
Architect: NL Architects
Utrecht, The Netherlands - 2011
Focused on Lightness
0.93 Threshold - 0.07 Tolerance
Nordic Pavilion Venice Biennale

Function: Pavilion Biennale
Architect: Sverre Fehn
Venice, Italy - 1962
Focused on Lightness
0.75 Threshold - 0.04 Tolerance
Museo dei Maestri IUAV . Sala Aldo Rossi

Function: Museum
Architect: Niki Maragkoudaki
Venice, Italy - 2013 (unbuilt)
Focused on Lightness
0.98 Threshold - 0.02 Tolerance
3. filtration
Kunsthaus Bregenz

*Function:* Museum
*Architect:* Peter Zumthor
*Bregenz, Austria - 1997*

[Diagram of etched, translucent glass shingles and frosted glass panels]

96
Focused on Lightness
0.75 Threshold - 0.06 Tolerance
Kirchner Museum Davos

*Function: Museum*
Architect: Annette Gigon and Mike Guyer
Davos, Austria - 1992

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translucent glass
frosted glass panels
Focused on Lightness
0.89 Threshold - 0.05 Tolerance
Museum La Congiunta

*Function:* Museum
*Architect:* Peter Märkli
*Giornico, Switzerland - 1992*
Focused on Lightness
0.70 Threshold - 0.04 Tolerance
Guggenheim Helsinki Design Competition

Function: Museum
Architect: Karol Zurawski
Helsinki, Finland - 2014 (unbuilt)

frosted glass
lightweight
bended wood
Focused on Lightness

0.78 Threshold - 0.04 Tolerance
Sammlung Goetz

*Function: Museum*
Architect: Herzog & de Meuron
Munich, Germany - 1992
Focused on Lightness
0.93 Threshold - 0.08 Tolerance
Daylight House

Function: Residential house
Architect: Takeshi Hosaka
Yokohama, Japan - 2011
Focused on Lightness
0.80 Threshold - 0.05 Tolerance
conclusion
1. Yale Center for British Art
   Connecticut, United States
   TH: 0.75 - TO: 0.03

2. Centro das Artes Casa das Mudas
   Madeira, Portugal
   TH: 0.93 - TO: 0.07

3. Pajol Sports Centre
   Paris, France
   TH: 0.74 - TO: 0.08

4. Beyeler Foundation
   Riehen, Switzerland
   TH: 0.88 - TO: 0.02

5. Rotterdam Central Station
   Rotterdam, The Netherlands
   TH: 0.88 - TO: 0.07

6. Museo dei Maestri IUAV Sala Aldo Rossi
   Venice, Italy
   TH: 0.89 - TO: 0.05

7. Museo Provincial de Zamora
   Zamora, Spain
   TH: 0.75 - TO: 0.09

8. Congress Centre of Aragón Expo 2008
   Zaragoza, Spain
   TH: 0.82 - TO: 0.06

9. Casa das Histórias Paula Rego
   Cascais, Portugal
   TH: 0.86 - TO: 0.04

10. Contemporary Art Centre
    Córdoba, Spain
    TH: 0.86 - TO: 0.06

11. Herning Museum of Contemporary Art
    Herning, Denmark
    TH: 0.86 - TO: 0.03

12. Fernando Botero Library Park
    Medellin, Colombia
    TH: 0.65 - TO: 0.06

13. Herz Jesu Kirche
    Munich, Germany
    TH: 0.65 - TO: 0.06

14. Nottingham Contemporary
    Nottingham, Great Britain
    TH: 0.95 - TO: 0.04

15. Musée de l’Orangerie
    Paris, France
    TH: 0.95 - TO: 0.04

16. CGAC. Centro Galego de Arte Contemporâne
    Santiago de Compostela, Spain
    TH: 0.87 - TO: 0.05

17. Kimbell Art Museum
    Texas, United States
    TH: 0.86 - TO: 0.05

18. Gym Hall TNW
    Utrecht, The Netherlands
    TH: 0.93 - TO: 0.07

19. Nordic Pavilion Venice Biennale
    Venice, Italy
    TH: 0.75 - TO: 0.04

20. Museo dei Maestri IUAV Sala Aldo Rossi
    Venice, Italy
    TH: 0.98 - TO: 0.02

21. Kunsthau Bregenz
    Bregenz, Austria
    TH: 0.75 - TO: 0.06

22. Kirchner Museum Davos
    Davos, Austria
    TH: 0.89 - TO: 0.05

23. Museum La Congiunta
    Giornico, Switzerland
    TH: 0.89 - TO: 0.05

24. Guggenheim Helsinki Design Competition
    Helsinki, Finland
    TH: 0.78 - TO: 0.04

25. Sammlung Goetz
    Munich, Germany
    TH: 0.93 - TO: 0.08

26. Daylight House
    Yokohama, Japan
    TH: 0.80 - TO: 0.05
**rebound**

1. **Yale Center for British Art**
   Connecticut, United States
   TH: 0.75 - TO: 0.03

2. **Centro das Artes Casa das Mudas**
   Madeira, Portugal
   TH: 0.93 - TO: 0.07

3. **Pajol Sports Centre**
   Paris, France
   TH: 0.74 - TO: 0.08

4. **Beyeler Foundation**
   Riehen, Switzerland
   TH: 0.88 - TO: 0.02

5. **Rotterdam Central Station**
   Rotterdam, The Netherlands
   TH: 0.88 - TO: 0.07

6. **Museo dei Maestri IUAV Sala Aldo Rossi**
   Venice, Italy
   TH: 0.89 - TO: 0.05

7. **Museo Provincial de Zamora**
   Zamora, Spain
   TH: 0.75 - TO: 0.09

8. **Congress Centre of Aragón Expo 2008**
   Zaragoza, Spain
   TH: 0.82 - TO: 0.06

**reflection**

9. **Casa das Histórias Paula Rego**
   Cascais, Portugal
   TH: 0.86 - TO: 0.04

10. **Contemporary Art Centre**
    Córdoba, Spain
    TH: 0.68 - TO: 0.06

11. **Herning Museum of Contemporary Art**
    Herning, Denmark
    TH: 0.86 - TO: 0.03

12. **Fernando Botero Library Park**
    Medellin, Colombia
    TH: 0.65 - TO: 0.06

13. **Herz Jesu Kirche**
    Munich, Germany
    TH: 0.65 - TO: 0.06

14. **Nottingham Contemporary**
    Nottingham, Great Britain
    TH: 0.95 - TO: 0.04

15. **Musée de l’Orangerie**
    Paris, France
    TH: 0.95 - TO: 0.04

16. **CGAC. Centro Galego de Arte Contemporâne**
    Santiago de Compostela, Spain
    TH: 0.87 - TO: 0.05

17. **Kimbell Art Museum**
    Texas, United States
    TH: 0.86 - TO: 0.05

18. **Gym Hall TNW**
    Utrecht, The Netherlands
    TH: 0.93 - TO: 0.07

19. **Nordic Pavilion Venice Biennale**
    Venice, Italy
    TH: 0.75 - TO: 0.04

20. **Museo dei Maestri IUAV Sala Aldo Rossi**
    Venice, Italy
    TH: 0.98 - TO: 0.02

**filtration**

21. **Kunsthalle Bregenz**
    Bregenz, Austria
    TH: 0.75 - TO: 0.06

22. **Kirchner Museum Davos**
    Davos, Austria
    TH: 0.89 - TO: 0.05

23. **Museum La Congiunta**
    Giorno, Switzerland
    TH: 0.86 - TO: 0.03

24. **Guggenheim Helsinki Design Competition**
    Helsinki, Finland
    TH: 0.78 - TO: 0.04

25. **Sammlung Goetz**
    Munich, Germany
    TH: 0.93 - TO: 0.08

26. **Daylight House**
    Yokohama, Japan
    TH: 0.80 - TO: 0.05
<table>
<thead>
<tr>
<th>No.</th>
<th>Location</th>
<th>Reflective Areas</th>
<th>TH: Low [0.60 - 0.75]</th>
<th>TO: High [High-Low]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Yale Center for British Art</td>
<td>Reflective Ceiling + Walls</td>
<td>0.75 - 0.03</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Centro das Artes Casa das Mudas</td>
<td>Reflective Ceiling + Walls + Floor</td>
<td>0.93 - 0.07</td>
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<tr>
<td>3</td>
<td>Pajol Sports Centre</td>
<td>Reflective Ceiling + Walls + Floor</td>
<td>0.74 - 0.08</td>
<td></td>
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<tr>
<td>4</td>
<td>Beyeler Foundation</td>
<td>Reflective Ceiling + Walls + Floor</td>
<td>0.88 - 0.02</td>
<td></td>
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<tr>
<td>5</td>
<td>Rotterdam Central Station</td>
<td>Reflective Ceiling + Walls + Floor</td>
<td>0.88 - 0.07</td>
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</tr>
<tr>
<td>6</td>
<td>Museo dei Maestri IUAV Sala Aldo Rossi</td>
<td>Reflective Ceiling + Walls + Floor</td>
<td>0.89 - 0.05</td>
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<tr>
<td>7</td>
<td>Museo Provincial de Zamora</td>
<td>Reflective Ceiling + Walls + Floor</td>
<td>0.75 - 0.09</td>
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<tr>
<td>8</td>
<td>Congress Centre of Aragón Expo 2008</td>
<td>Reflective Ceiling + Walls + Floor</td>
<td>0.82 - 0.06</td>
<td></td>
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<tr>
<td>9</td>
<td>Casa das Histórias Paula Rego</td>
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<td></td>
</tr>
<tr>
<td>10</td>
<td>Contemporary Art Centre</td>
<td>Reflective Ceiling + Walls + Floor</td>
<td>0.68 - 0.06</td>
<td></td>
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<tr>
<td>11</td>
<td>Herning Museum of Contemporary Art</td>
<td>Reflective Ceiling + Walls + Floor</td>
<td>0.86 - 0.03</td>
<td></td>
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<tr>
<td>12</td>
<td>Fernando Botero Library Park</td>
<td>Reflective Ceiling + Walls + Floor</td>
<td>0.65 - 0.06</td>
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<tr>
<td>13</td>
<td>Herz Jesu Kirche</td>
<td>Reflective Ceiling + Walls + Floor</td>
<td>0.65 - 0.06</td>
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<tr>
<td>14</td>
<td>Nottingham Contemporary</td>
<td>Reflective Ceiling + Walls + Floor</td>
<td>0.95 - 0.04</td>
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<tr>
<td>15</td>
<td>Musée de l’Orangerie</td>
<td>Reflective Ceiling + Walls + Floor</td>
<td>0.95 - 0.04</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>CGAC, Centro Galego de Arte Contemporâne</td>
<td>Reflective Ceiling + Walls + Floor</td>
<td>0.87 - 0.05</td>
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</tr>
<tr>
<td>17</td>
<td>Kimbell Art Museum</td>
<td>Reflective Ceiling + Walls + Floor</td>
<td>0.86 - 0.05</td>
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<tr>
<td>18</td>
<td>Gym Hall TNW</td>
<td>Reflective Ceiling + Walls + Floor</td>
<td>0.75 - 0.04</td>
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<tr>
<td>19</td>
<td>Nordic Pavilion Venice Biennale</td>
<td>Reflective Ceiling + Walls + Floor</td>
<td>0.93 - 0.07</td>
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<tr>
<td>20</td>
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<td>Reflective Ceiling + Walls + Floor</td>
<td>0.98 - 0.02</td>
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<td>21</td>
<td>Kunsthau Bregenz</td>
<td>Reflective Ceiling + Walls + Floor</td>
<td>0.75 - 0.06</td>
<td></td>
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<tr>
<td>22</td>
<td>Kirchner Museum Davos</td>
<td>Reflective Ceiling + Walls + Floor</td>
<td>0.89 - 0.05</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Museum La Congiunta</td>
<td>Reflective Ceiling + Walls + Floor</td>
<td>0.78 - 0.04</td>
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<td>24</td>
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<td>0.70 - 0.04</td>
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<td>25</td>
<td>Sammlung Goetz</td>
<td>Reflective Ceiling + Walls + Floor</td>
<td>0.93 - 0.08</td>
<td></td>
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<tr>
<td>26</td>
<td>Daylight House</td>
<td>Reflective Ceiling + Walls + Floor</td>
<td>0.80 - 0.05</td>
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<tr>
<td></td>
<td>TH LOW TO HIGH</td>
<td>TH MEDIUM TO MEDIUM</td>
<td>TH HIGH TO LOW</td>
<td></td>
</tr>
<tr>
<td>------------------</td>
<td>----------------</td>
<td>---------------------</td>
<td>----------------</td>
<td></td>
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<tr>
<td><strong>REBOUND</strong></td>
<td>3/8 - 9/24</td>
<td>1/8 - 3/24</td>
<td>4/8 - 12/24</td>
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<tr>
<td><strong>REFLECTION</strong></td>
<td>4/12 - 8/24</td>
<td>3/12 - 6/24</td>
<td>5/12 - 10/24</td>
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<tr>
<td><strong>FILTRATION</strong></td>
<td>2/6 - 8/24</td>
<td>2/6 - 8/24</td>
<td>2/6 - 8/24</td>
<td></td>
</tr>
</tbody>
</table>

- **Reflection Floor**: most rebound
- **Reflection Ceiling + Walls**: most filtration
- **Reflection Ceiling**: most rebound

<table>
<thead>
<tr>
<th></th>
<th>TH LOW TO HIGH</th>
<th>TH MEDIUM TO MEDIUM</th>
<th>TH HIGH TO LOW</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>REFLECTIVE CEILING</strong></td>
<td>5/5 - 20/20</td>
<td>0/5 - 0/20</td>
<td>0/5 - 0/20</td>
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<tr>
<td><strong>REFLECTIVE FLOOR</strong></td>
<td>4/5 - 16/20</td>
<td>1/5 - 4/20</td>
<td>0/5 - 0/20</td>
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<tr>
<td><strong>REFLECTIVE WALLS</strong></td>
<td>0/2 - 0/20</td>
<td>2/2 - 20/20</td>
<td>0/2 - 0/20</td>
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<tr>
<td><strong>REFLECTIVE CEILING + WALLS</strong></td>
<td>0/10 - 0/20</td>
<td>2/10 - 4/20</td>
<td>8/10 - 16/20</td>
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<tr>
<td><strong>REFLECTIVE CEILING + WALLS + FLOOR</strong></td>
<td>0/4 - 0/20</td>
<td>1/4 - 5/20</td>
<td>3/4 - 15/20</td>
</tr>
</tbody>
</table>

- **Reflection Ceiling**: most reflection ceiling
- **Reflection Walls**: most reflection walls
- **Reflection Ceiling + Walls**: most reflection ceiling + walls
CONCLUSION

The different sunshading projects are placed in order of the intensity of light in the building (based on an interior photograph representing the project). The light intensity is higher when the Threshold is higher and the Tolerance lower.

Linking this order to the characteristics of the different projects, it becomes visible that it doesn’t matter if the sunshading system is based on a rebound, reflection or filtration system. The filtration system is with the same number (8/24) represented in the “TH low - TO high”, “TH medium - TO medium” and “TH high - TO low” groups. The differences of amount in these groups of the rebound and reflection systems are negligible.

By contrast the effects of various reflective surfaces in the projects are much more noticeable. The table shows that the combination of reflective ceiling, walls and floor, is the most important in controlling the daylight coming into the space. Beside the table shows that reflective walls have more effect on the light intensity than a reflective floor.

Three important design recommendations can be extracted from this database:

1. The difference in reflective surfaces has more influence on the light intensity in the building, than the difference in type of sunshading system (rebound, reflection or filtration);

2. Reflective walls have more effect on the light intensity than a reflective floor. This indicates to the designer: keep the walls as light in color as possible and use the floor surface for deep colors or character-giving patterns;

3. To create an interesting interior with a pleasant light intensity, the sunshading system has to be composed of several different layers.