Pilot project at Coloplast testing Daylight Redirecting Glass Lamellas

The Coloplast premises

The Coloplast premises are situated at 56.96°N, 12.49°E north of Copenhagen, Denmark. The office building used for the pilot project is lying opposite two other buildings. Right in front is another office building, to the left a glass cladded corridor building connecting the two buildings, see figure 1.

Figure 1. The office building used for the pilot project is lying opposite two other buildings.

The daylight redirecting glass lamellas are mounted outside one office module (the Test area) and the existing sun shading glass lamellas are mounted outside an adjacent office module (the Reference area), see figure 2 and 3.

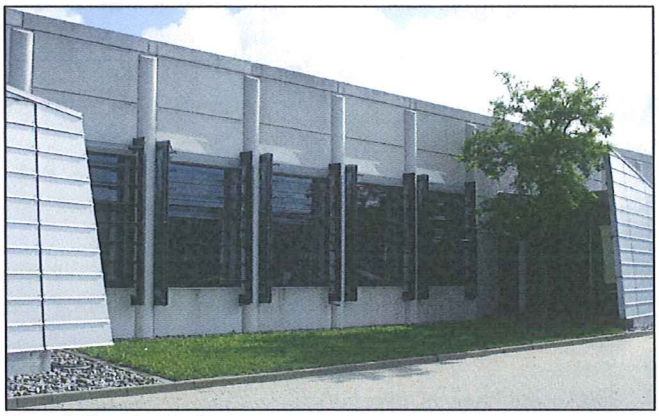

Figure 2. Façade of test area.

Figure 3. Façade of reference area.

The office modules share the same façade facing approximate 11° to the west of south. The layout of the office building housing the test and reference areas is shown in figure 4.

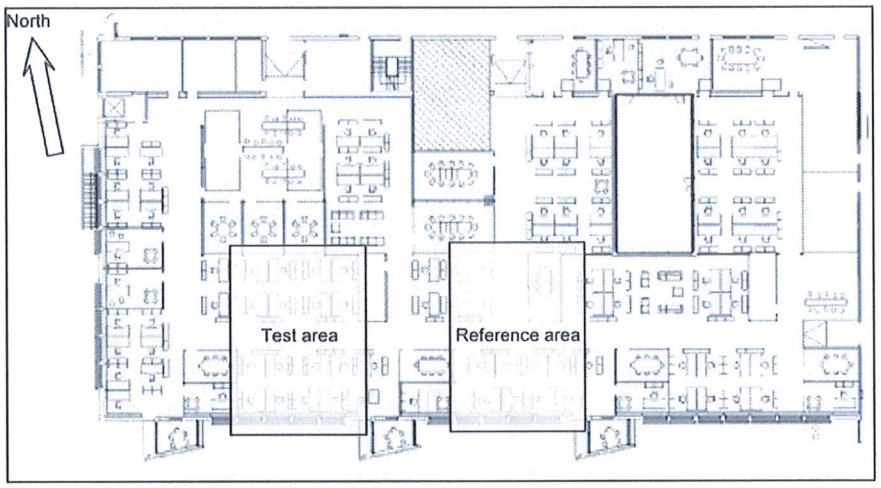

Figure 4. Layout of the office building marking the test and reference areas.

Properties of the daylight redirecting glass lamellas and the existing sun shading glass lamellas as well as a description of the set-up and functionality of the systems are listed in paragraph Shading control strategy*, likewise a description of interior surfaces are listed in paragraph Demonstration building*.

Luminaries were built into the ceiling in a regular pattern throughout the offices, see figure 5.


Figure 5. Built-in luminaries in the offices.

Background

Working with daylight redirecting glass lamellas will as a starting point have three different weather types:

- Overcast weather
- Intermediate weather
- Clear sky conditions

In this report only overcast weather and clear sky has been taken into consideration.

Overcast sky

In overcast weather the sky is assumed to be of the type CIE-Overcast Sky, an ideal sky type. In such a situation the ratio of the vertical illuminance to the horizontal illuminance E_v/E_h will be 0.396. In the reported case of overcast condition this ratio is monitored and depicted in figure 6. The chart shows data where E_v/E_h is within a limit of 10% of the ideal value. The limit of 10% has been chosen considering it impossible to get ideal conditions in nature.

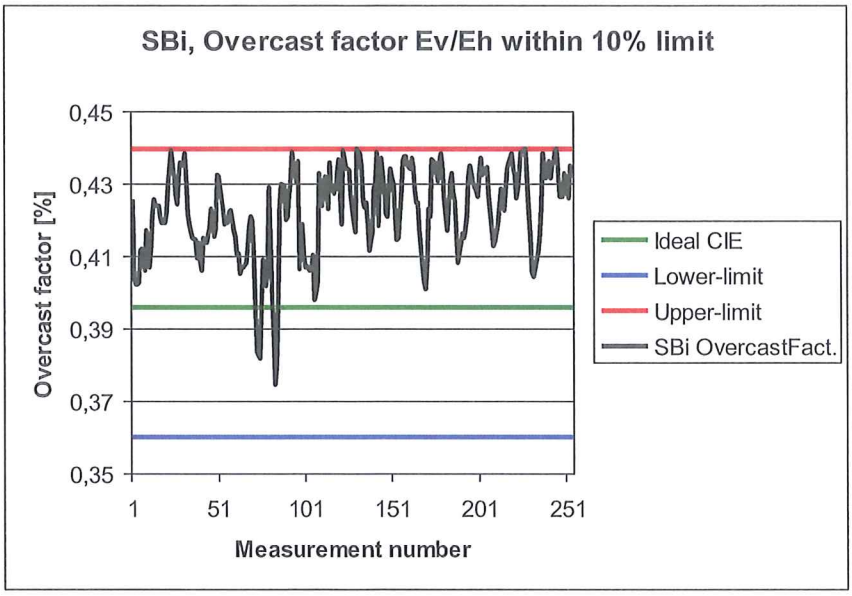

Figure 6. The ration Ev/Eh as for the reported overcast condition.

Clear Sky

In this project clear sky conditions are considered to be present when the horizontal (global) illuminance is greater than 25 Klux.

Test set-up

In the test area the top four existing sun shading glass lamellas were replaced by daylight redirecting glass lamellas. The new lamellas are produced by Saint Gobain Glass type Antelio Silver with a light reflection of 31%. The existing lamellas are also produced by Saint Gobain and are of type Parasol Green with a light reflection of 6% and with white frit covering 55% of the surface. Optical properties for both glass types are described in paragraph The shading system*. The facades of the test and reference areas are shown in figures 7 and 8.

The top four lamellas in the test area are operated by their own motor and will be adjusted according to a set of weather parameters independent of the behavior of the existing lamellas. Parameters for the new lamellas are described in paragraph The shading system*

Figure 7. Close-up of glass lamellas in test area. The top four lamellas are made of Antelio Sillver glass 10 mm thickness.

Figure 8. . Close-up of glass lamellas in reference area. The lamellas are made of Parasol Green glass 8 mm thickness.

Existing lamellas

In sunny conditions the existing lamellas were closed i.e. all lamellas were in a vertical position excluding as much sun light (and heat) as possible.

In overcast weather the lamellas were opened i.e. all lamellas were in a horizontal position letting as much light as possible into the office.

New lamellas

In sunny conditions the new lamellas were closed i.e. all lamellas were in a vertical position excluding as much sun light (and heat) as possible. This condition was met when the global illuminance exceeded 25 Klux for more than 10 minutes. The lamellas were turned back into redirecting position when the global illuminance became lower than 17.5 Klux for a period of at least 20 minutes.

In overcast weather the lamellas were opened and turned into the redirecting position. All new lamellas were turned to an angle of 30° towards the facade letting as much light as possible be redirected into the office. This condition was met when the global illuminance became lower than 25 Klux for more than 10 minutes.

In the months May and June the optimal redirecting position was calculated to be 25° towards the façade. The rest of the year the optimal redirecting angle was calculated to be 30° towards the facade.

The various thresholds were introduced to be sure that the lamellas would not be operated whenever the sun was hidden by a cloud for only a few minutes and to be sure that the sky was indeed overcast.

Instrumentation

To monitor illuminance levels inside the test and reference areas together with outside conditions a set of illuminance sensors were used. In both office areas the illuminance sensors were placed in measuring lines, see figure 9.

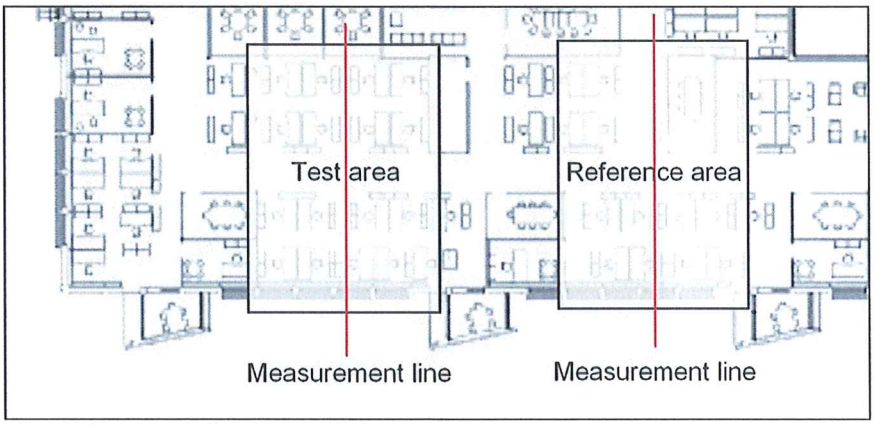

Figure 9. Measurement lines in test and reference area.

The sensors were placed at a height of 0.85 m above the floor and mounted at the ceiling, see figure 10.

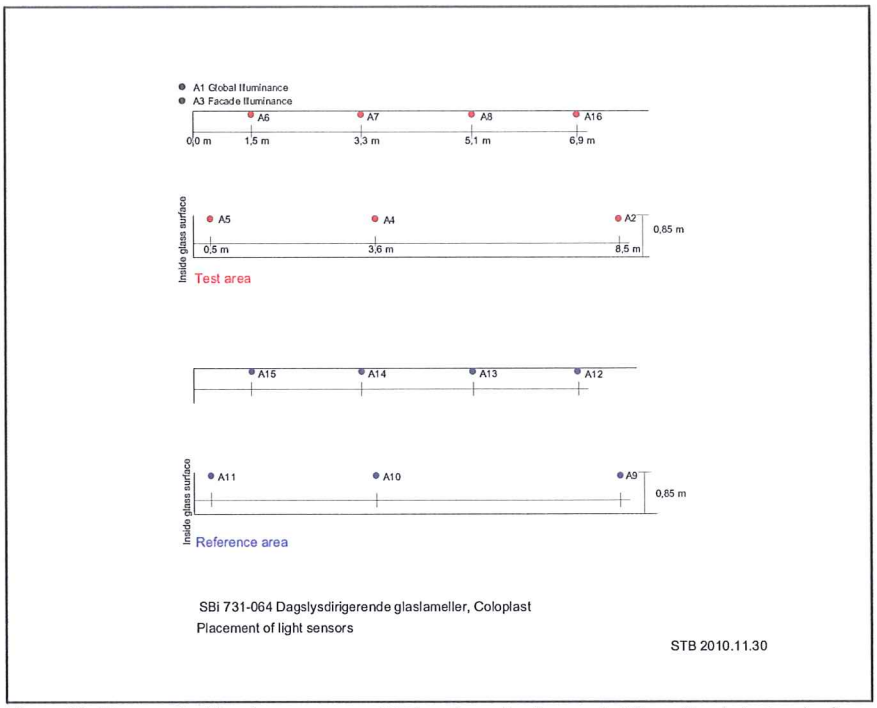

Figure 10. Placement of illuminance sensors 0.85 m above the floor and at the ceiling in test and reference areas.

Outside the office building, the horizontal and vertical illuminance was measured. At Coloplast no free horizon was available. Therefore, during the test period supplementing horizontal and vertical illuminance and irradiance levels were measured at the Daylight Laboratory at SBi where the sensors are facing a free horizon. The direct distance between Coloplast and SBi is approximate 11 km.

The measuring equipment used was manufactured by Hagner type MCA-1600 Multi-Channel Amplifier and 16 illuminance sensors type SD1. All illuminance measurements are in the unit lux.

Results

Results of the measurements for clear and overcast sky conditions are presented below.

Clear sky conditions

For clear sky conditions a rise in illuminance levels in the test area are seen compared to the reference area throughout the day, see tables 1 – 3 and figures 11 – 13. The illuminance is largest at the window position decreasing in through the room. At a distance of 8.5 m (furthest back in the office) the illuminance levels are 489 lux against 331 lux (morning), 488 lux against 429 lux (noon) and 366 lux against 260 lux (afternoon).

Table 1. Measurements at workplane (0.85 m above floor) in sunny conditions, morning.

2010.09.23 10:44		
Distance from window	Illuminance, [lux]	Illuminance, [lux]
[m]	Reference area	Test area
0.5	1,911	3,259
3.6	870	1,010
8.5	331	489

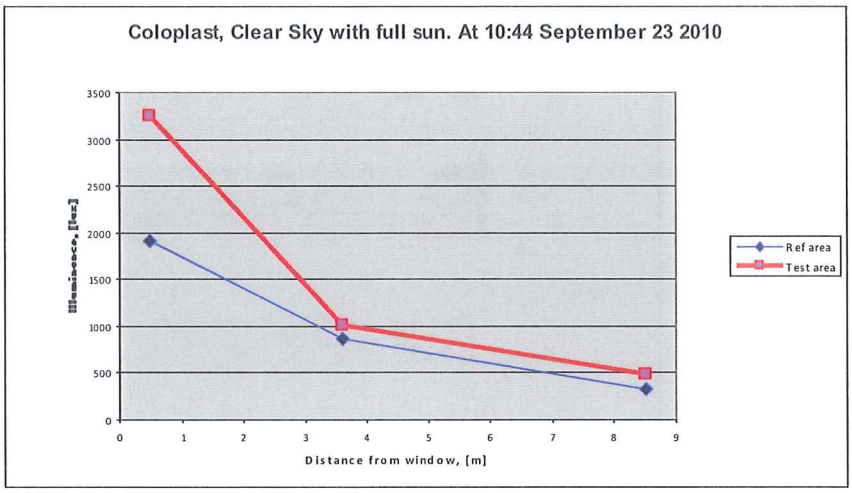

Figure 11. Illuminance level at workplane, clear sky, 10:44 September 23 2010, morning.

Table 2. Measurements at workplane (0.85 m above floor) in sunny conditions, noon.

2010.09.23 13:44		
Distance from window	Illuminance, [lux]	Illuminance, [lux]
[m]	Reference area	Test area
0.5	11,308	24,281
3.6	1,373	1,990
8.5	429	488

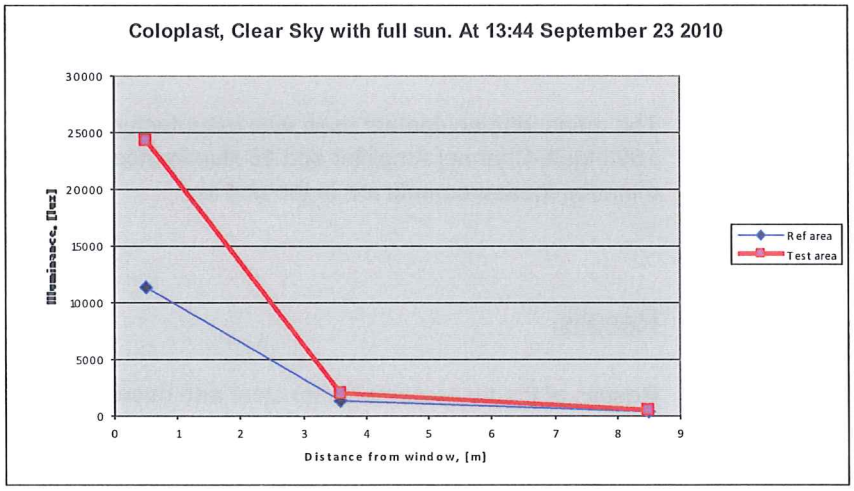

Figure 12. Illuminance level at workplane, clear sky, 13:44 September 23 2010, noon.

Table 3. Measurements at workplane (0.85 m above floor) in sunny conditions, afternoon.

2010.09.23 16:41		
Distance from window	Illuminance, [lux]	Illuminance, [lux]
[m]	Reference area	Test area
0.5	2,233	3,928
3.6	548	975
8.5	260	366

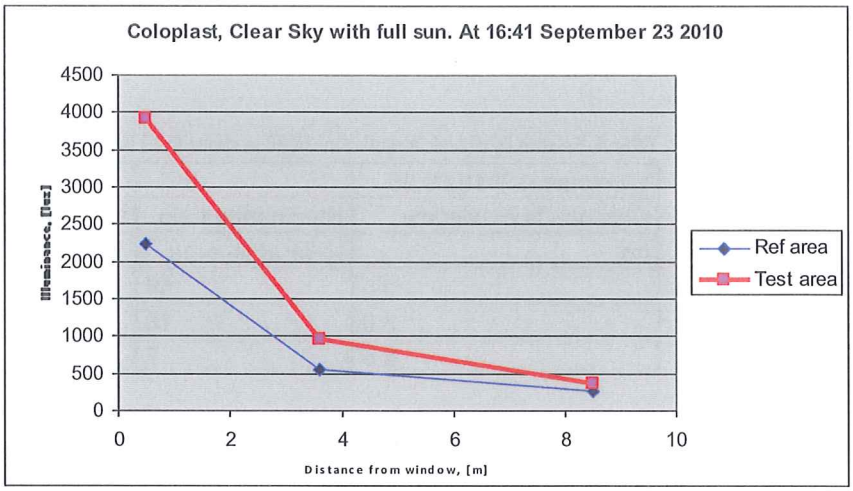

Figure 13. Illuminance level at workplane, clear sky, 16:41 September 23 2010, afternoon.

Overcast sky

Above it is pointed out that it was not possible to obtain a free horizon at the Coloplast premises. To remedy this it was decided to use equivalent measurements from the Daylight Laboratory at SBi for an overcast condition.

To be sure that an overcast condition was present at SBi the ratio of the vertical illuminance to the horizontal illuminance E_v/E_h was calculated for every measurement from 8:00 in the morning until 17:00 in the afternoon on a day with overcast conditions, 2010.09.26. Measurements where the ratios were between 0.36 and 0.44 were considered being an overcast condition, see figure 6.

To be able to relate the SBi and Coloplast measurements against each other it was necessary to evaluate the match of "pattern" of the horizontal illuminance at both places. To do this, the ratios between the horizontal illuminances $E_{SBi}/E_{Coloplast}$ were calculated f_{Match}. An average ratio f_{avg} of these ratios was then calculated.

As Sbi and Coloplast are approximate 11 km apart a match criteria was set up. The match criteria was that if the horizontal illuminance at Coloplast $E_{Coloplast} * f_{avg}$ was within 10% of the global illuminance at SBi at a given time then a CIE Overcast condition was present at Coloplast. Using this assumption a "pseudo" Daylight Factor can be calculated for the Coloplast conditions i.e. $DF_{Coloplast} = E_{Coloplast, sensor}/E_{SBi, global}$.

As $DF_{Coloplast}$ is not a real Daylight Factor for the Coloplast conditions, calculating DF for the overcast conditions at Coloplast was not appropriate. Instead the $DF_{Coloplast, sensor}$ for the actual sensor was rated against the highest $DF_{Coloplast, sensor\ max}$, which will give $DF_{sensor\ rated}$. With these assumptions the following results are calculated.

At overcast sky conditions a rise in illuminance levels in the test area compared to the reference area are seen, see tables 4 – 5 and figures 14 – 15. The $DF_{sensor\ rated}$ is largest at the window position decreasing in through the room. At the workplane and at a distance of 8.5 m the $DF_{sensor\ rated}$ are 10 against 7. At the ceiling and at a distance of 6.9 m the $DF_{sensor\ rated}$ are 13 against 10.

Table 4. Relative light levels at workplane (0.85 m above floor) in overcast condition.

Workplane, 2010.09.26		
Distance from window	Illuminance ratio	Illuminance ratio
[m]	Reference area	Test area
0,5	54	100
3,6	18	24
8,5	7	10

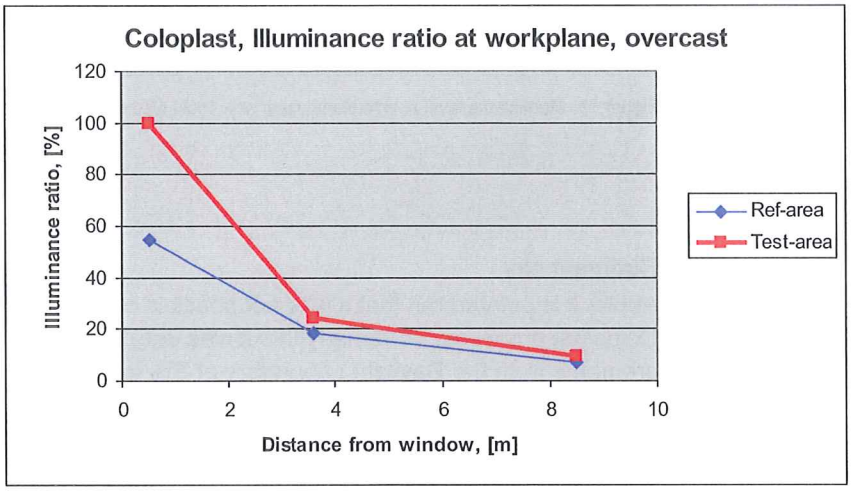

Figure 14. Illuminance ratios at workplane (0.85 m above floor), overcast condition.

Table 5. Relative light levels at ceiling in overcast condition.

Ceiling, 2010.09.26		
Distance from window	Illuminance ratio	Illuminance ratio
[m]	Reference area	Test area
1.5	77	100
3.3	28	35
5.1	16	20
6.9	10	13

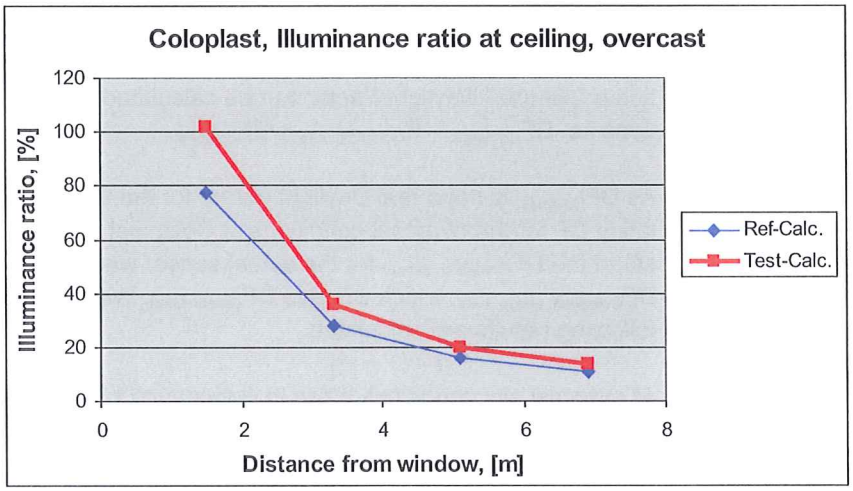

Figure 15. Illuminance ratios at ceiling, overcast condition.

Discussion

Doing experiments in a real working environment includes a lot of uncertainties. Contrary to working in a laboratory, employees are coming and going in a real environment, drawing curtains when too much light is coming into the office, moving furniture etc. Such actions influence measurements carried out in situ.

At Coloplast the following were considered obstacles against measurements:

- Employees were coming and going all day
- Curtains were manually drawn occasionally and not withdrawn when light became low outside
- Sensors at workplane were occasionally covered up
- Power supply was cut off without notice
- No information was available on how and at which criteria the artificial light was operated
- Apparently no information was available on how and at which criteria the existing glass lamellas were operated
- No free horizon was available at the premises

Conclusions

Considering all these uncertainties still some conclusions can be drawn:

- Apparently both in sunny and overcast weather, light conditions are better in the test area compared to the reference area on the assumption that the contribution of light from the artificial lighting system is equal in both areas
- Assuming the artificial light is turned on at 100% in both areas (and therefore contribute equally to a "base" light level) at overcast weather conditions a significant increase in light level throughout the test area is seen. Specifically light levels at the ceiling are higher in the test area compared to the reference area giving rise to higher light levels at the workplane
- At random interviews with employees at Coloplast no specific conclusion can be drawn considering the benefit of using the daylight redirecting glass lamellas
- In certain circumstances some employees situated in the test area have experienced glare problems looking out the windows
- At intermediate weather conditions when the daylight redirecting glass lamellas are changing position either from closed to redirecting position or vice versa a moving and confusing pattern of very bright spots are noticed at the ceiling. This is of course reflections from the lamellas and considered disturbing
- At the façade of the test area, see figure 2, noticeable bright spots are visible above the windows. It might indicate that a repositioning of the lamellas is necessary in future installations.

* D. Appelfeld, S. Svendsen. S. Traberg-Borup, Visual performance of a daylight redirecting glass shading system demonstration in an office building