Daylight illuminance with prismatic film glazing in a factory building

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Abstract. Prismatic film glazing has the potential to improve indoor illuminance levels and uniformity. Indoor illuminance distributions with prismatic film glazing in a manufacture building were measured. The measured illuminance data with prismatic film glazing were compared to Radiance simulation results with conventional glazing. This study shows that using prismatic film glazing at side windows can improve indoor illuminance levels and illuminance uniformity for inner spaces. The technology can work effectively for large depth spaces under sunny sky but only has slightly better performance under overcast sky.

1. Side window daylight measures
In general, there are two methods for daylight: skylight daylight and side window daylight. While skylight daylight is mainly applied in atriums, lobbies and underground spaces, side window daylight has much wider applications. Daylight is an effective resource to improve indoor occupant health and energy savings [1]. Limited by the aperture parameter factors such as size, shape and position, providing good daylight for deep depth spaces such as manufacturing spaces through side-windows presents a challenge.

For side window daylighting, light shelves can refract light to the ceiling and then reflect to the inner spaces. Due to the dust accumulation on the panels, it is necessary to maintain routine housekeeping to clean the light shelf so that the light reflective system can work effectively. Meanwhile, adding the light shelf may bring hurdles to elevation maintenance.

Similar to light shelves, prismatic film glazing has can refract light to ceiling and then reflected to the inner spaces, thus providing the opportunities to improve indoor luminous environment. Due to the manufacture requirements, large factory buildings usually have deep depth and thus make daylighting difficult, especially for the spaces not located on the top floor. This makes the manufacture buildings a good fit for utilizing the prismatic film glazing.

2. Prismatic film application
The mechanism of prismatic film glazing is adding a saw-tooth prismatic film between double glazing or attached to the back of a glazing, so that the light passing through prismatic film will be majorly refracted upward to the ceiling (Figure 1) and then be reflected downward to the inner spaces. Some light will be diffused vertically after passing the prismatic film and this part of lights is different from lights reflected due to light shelves.

Prismatic film glazing has wide applications in factory buildings. It has been utilized in side windows or atrium space of factory buildings to increase daylit areas and spaces as well as to improve luminous comfort by illuminance uniformity (Figure 2).
As a new light directive guidance system, prismatic film glazing systems can reduce the excessive daylight close to the window areas by reflect light to the inner spaces and thus can improve the daylit area and illuminance uniformity. As light is refracted in the prismatic film, the appearance of prismatic glazing is translucent. Meanwhile, the indoor illuminance performance of prismatic film glazing is highly depending on the film properties, sun position, sky conditions as well as the altitude where the building is located on.

If we define the sky dome as 145 patches, each patch represents one part of the sky and the light coming out of prismatic film as the outcome dome, we can clearly see the different incoming lights affect the transmission light flux after prismatic film with the LBNL BSDFViewer (Figures 3 and 4) [2].

3. Factory building case study
The first floor of Sumin Decoration Company Office Building is a manufacturing with prismatic film glazing installed on the East, West and South facades (Figures 5 and 7). The floor plan and field measurement spots grid set according to Liu [3] and Standard GB/T5699 [4] are illustrated in Figure 6. Field measurements are conducted for a year. For simplification, the Spring Equinox, Summer Solstice, Autumn Equinox and Winter Solstice are the typical time for field measurement [5].

According to the LEED requirement [6], this paper presented field measurement results as 9AM, 12PM and 15PM for both sunny and overcast skies.

4. Field measurement results vs. simulation data
The field measurement results of illuminance levels within the first floor were compared to Radiance simulation results of conventional glazing with visible transmittance of 0.62. Summer season with sunny sky results and autumn overcast sky results were presented in this paper.
4.1. Summer sunny sky data

From Table 1, under sunny sky at 9:00, the exterior direct sunlight is majorly on the east side. The illuminance levels on the east and west side with conventional glazing are higher than that of prismatic film glazing; while the results are the opposite at the inner locations far from walls.

Table 1. Illuminance levels with prismatic and conventional glazing (sunny sky)

| Date  | Unit Points | W1 | W2 | W3 | W4 | W5 | W6 | W7 | W8 | W9 | W10 | E10 | E9 | E8 | E7 | E6 | E5 | E4 | E3 | E2 | E1 |
|-------|-------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
|       | (Lux) Distance | 2m | 4m | 6m | 8m | 10m | 12m | 14m | 16m | 18m | 20m | 20m | 18m | 16m | 14m | 12m | 10m | 8m | 6m | 4m | 2m |
| Prismatic Glazing (Mea.) | F | 1292 | 555 | 363 | 300 | 284 | 274 | 267 | 241 | 254 | 270 | 330 | 334 | 445 | 507 | 713 | 830 | 970 | 1106 | 1152 | 1209 |
| Conventional Glazing (Sim.) | E | 468 | 525 | 374 | 350 | 154 | 283 | 189 | 120 | 116 | 154 | 270 | 320 | 445 | 507 | 713 | 830 | 970 | 1106 | 1152 | 1209 |
| Prismatic Glazing (Mea.) | E | 951 | 898 | 567 | 388 | 327 | 254 | 237 | X | 161 | 164 | 251 | 236 | 434 | 464 | 515 | 752 | 1408 | 2141 | 2295 |
| Conventional Glazing (Sim.) | E | 1585 | 1334 | 860 | 524 | 467 | 401 | 333 | X | 221 | 200 | 248 | 242 | X | 383 | 417 | 593 | 758 | 980 | 1045 |

Note: the cells marked as “X” mean there are columns and no measurements were conducted at these points.
At 12:00, the illuminance levels with conventional glazing on the west side are overwhelmingly higher than measured data.

At 15:00, the illuminance levels on the west side with conventional glazing are significantly higher than prismatic film glazing. Simulated data showed that the illuminance may reach 6000 Lux with direct sunlight and strong solar radiation at the space 4m from west side windows, while only around 156 Lux at the space 20 m from windows. This may cause luminous discomfort and glare issues. In the field measurement, the corresponding illuminance levels are 1612 Lux and 510 Lux.

In Table 1, the values in red color are the locations where the illuminance levels with prismatic film glazing are higher than that of conventional glazing. It is obvious that prismatic film can improve inner spaces illuminance levels.

4.2 Autumn overcast sky data

The data of autumn season overcast sky are presented in Table 2.

### Table 2. Illuminance levels with prismatic and conventional glazing (overcast sky)

| Date       | Unit Points | W1 | W2 | W3 | W4 | W5 | W6 | W7 | W8 | W9 | W10 | E10 | E9 | E8 | E7 | E6 | E5 | E4 | E3 | E2 | E1 |
|------------|-------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 9:00       | Prismatic F | 918 | 305 | 215 | 170 | 172 | 148 | 157 | 139 | 152 | 136 | 111 | 121 | X 180 | 187 | 196 | 225 | 274 | 370 | 432 |
|            | Glazing (Mea.) E | 814 | 605 | 368 | 231 | 182 | 143 | 125 | 110 | 103 | 93 | 126 | 110 | 156 | 168 | 197 | 312 | 376 | 520 | 724 |
| 12:00      | Prismatic F | 878 | 548 | 325 | 268 | 233 | 241 | 231 | 198 | 199 | 214 | 233 | 230 | 258 | 326 | 317 | 326 | 350 | 550 | 689 |
|            | Glazing (Mea.) E | 565 | 585 | 442 | 380 | 326 | 290 | 255 | X 184 | 192 | 202 | 209 | X 276 | 274 | 318 | 327 | 340 | 485 | 445 |
| 15:00      | Prismatic F | 665 | 548 | 340 | 288 | 245 | 220 | 182 | 137 | 122 | 142 | 127 | 143 | 154 | 151 | 184 | 219 | 223 | 203 | 231 |
|            | Glazing (Mea.) E | 448 | 362 | 307 | 255 | 217 | 179 | 185 | X 117 | 120 | 114 | 123 | X 156 | 159 | 167 | 200 | 180 | 200 | 259 |

Note: the cells marked as “X” mean there are columns and no measurements were conducted at these points.

At 9:00, the illuminance levels with prismatic glazing are lower than the data with corresponding conventional glazing at the locations close to the east and west walls but higher than that with conventional glazing at the inner space spots.

At 12:00, the illuminance levels with conventional glazing are overwhelmingly lower than prismatic film glazing except in few inner space locations.

At 15:00, the illuminance difference is similar to the 9:00 conditions. Although the illuminance with prismatic glazing at spaces within 10 m to window are lower than the data with conventional glazing, at the inner space 12-20m from windows, the illuminance levels are still higher than the illuminance with conventional glazing. Tables 1 and 2 indicate that prismatic film glazing systems have better luminous performance on illuminance level and illuminance uniformity improvement on the inner spaces of large depth buildings than conventional glazing under sunny sky. The system still work effectively at the inner spaces under overcast sky.
5. Conclusions
This paper introduced the properties and advantages of prismatic film glazing system. By comparing the indoor illuminance levels measurement with prismatic glazing to Radiance simulation results with conventional glazing, the paper summarized the following features with prismatic glazing:

1) Prismatic glazing can provide better illuminance levels and illuminance uniformity for inner spaces in large depth buildings such as factories under sunny sky.
2) Prismatic film glazing can avoid direct sunlight with conventional glazing under sunny sky by refracting light into inner spaces and thus can provide better luminous comfort environment for building occupants.
3) Both the incident light angle and intensity will affect the performance of prismatic film glazing system for side window daylight.
4) Side window prismatic film glazing systems can significantly improve the illuminance levels for spaces over 10 m from windows (inner spaces of large depth buildings).

Compared with conventional glazing, prismatic film glazing works less effectively under overcast sky as the average illuminance levels are lower.

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