Revisiting Daylight Shafts

An emerging technology that requires a smaller footprint within the building may also allow for higher levels of daylight

BY ANOTHAI THANACHAREONKIT AND KONSTANTINOS PAPAMICHAEL

The Net-Zero Energy (NZE) building vision—along with emerging knowledge about health and well-being effects of light, especially daylight—has increased interest in the expanded use of daylight into buildings' core spaces; that is, areas that are farther away from perimeter windows and skylights. The Canada-California Strategic Innovative Partnership (CCSIP)[1] currently is helping to develop strategies to turn off electric lights and use daylight in most commercial buildings in major cities in the world by 2030[2].

Light shafts have been a main architectural approach to bringing daylight into buildings' core spaces. They often are used in multi-story buildings, providing daylight to lower floors through windows facing the daylight shaft[3].

The use of traditional materials for interior surfaces of light shafts results in relatively large footprints competing for valuable floor space that could otherwise contribute to sales and lease prices. Today's technologies, such as those used in several emerging building core daylight systems, offer significantly increased potential for smaller footprints and higher daylight levels through new implementations of the light shaft strategy. The two most important technologies are very high-reflectance materials and sun tracking/redirecting/concentrating systems.

High-reflectance materials support daylight transfer through long distances and are widely used in tubular daylighting devices (TDDs) and many other emerging core sunlighting systems. Sun tracking/redirecting/concentrating technologies, such as those

All Graphs: CLTC

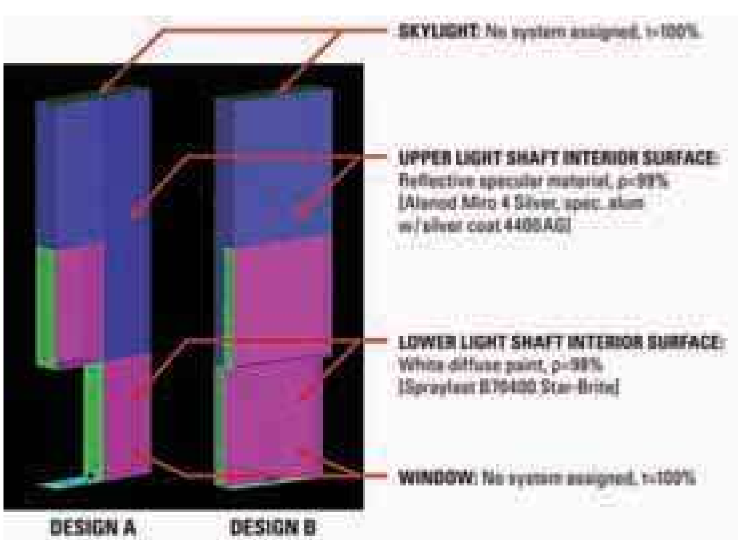

Figure 1. Schematics of two daylight shaft designs with separated light guides for each of the first and second floors and the materials used for the initial simulations.

used in some skylights[4] and most core sunlighting systems greatly increase the quantity and quality of daylight introduced in the daylight shaft. Light-redirecting technologies already are used with traditional light shafts[5].

GOING VERTICAL

The main difference between light shafts and other core daylight strategies is that light shafts employ vertical openings, such as a dedicated shaft integrated in the architectural design of the building, rather than ceiling mechanisms. Directing daylight through vertical rather than horizontal openings offers increased vertical-to-horizontal luminance ratios for luminous comfort, provides daylight directly to the eyes of occupants for circadian maintenance and connects occupants to the exterior daylight changes, just like perimeter windows.

The use of new core daylighting technologies for light shafts was considered in the design of a new, three-story UC Davis Medical Center building in Sacramento, CA, in collaboration with and support from CO Architects. The original building design includes extensive daylight considerations, successfully providing daylight in building perimeters with long south and north façades. However, the daylight levels at the core of the 60-ft-wide building are significantly lower than those in the perimeter. The use of small-footprint light shafts could greatly improve daylight balance and distributions.

After initial decisions were made on the light shafts' location and footprint, based on aesthetic appeal and building codes, several light shaft designs were developed and evaluated in terms of daylight levels on the work plane, poten-

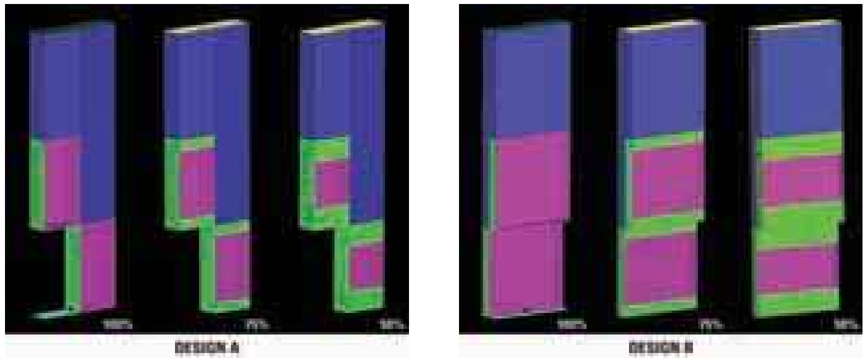

Figure 2. Window area options considered in parametric simulations.

Figure 3. Daylight lumen output through 50 %, 75%, and 100% shaft windows on June 21 at solar noon.

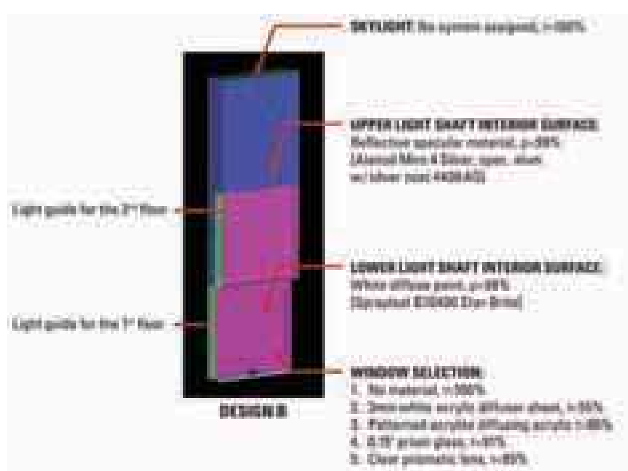

Figure 4. Different glazing materials considered for the daylight shaft windows.

tial glare and economics. The intent was to use light shafts to illuminate the core spaces on the first and second floors and use skylights to illuminate the third floor.

Two main designs were selected for daylight performance evaluation using Photopia lighting simulation software[6]. Both designs have a 14-ft-wide and 3.5-ft-deep footprint and run the whole building height of 45 ft using two separate light guides, one for each of the first and second floors. Design A has two separated light guides along its width, and Design B has two separated light guides along its depth (**Figure 1**).

Initially, both designs were evaluated with respect to the total lumens through parametric simulations varying the size of the shaft windows for the two floors, at 100 percent, 75 percent and 50 percent of shaft wall area for each of the two floors (**Figure 2**).

Initial simulations were performed without any glazing material in the daylight shaft windows to determine total lumen output for each daylight shaft window (**Figure 3**).

Design B was further evaluated considering a variety of different diffuse glazing materials for the daylight shaft windows (**Figure 4**).

Simulations were performed to determine horizontal work plane illuminance at 2.5 ft above the floor (**Figure 5**) and candlepower distributions for evaluation of glare potential (**Figure 6**).

Finally, a parametric evaluation was performed considering different reflectance values for the materials covering the interior surfaces of the light guides (**Figure 7**).

The cost for specific materials also was considered for materials with higher than 90 percent reflectance. The highest reflectance (99.6 percent) materials are the most

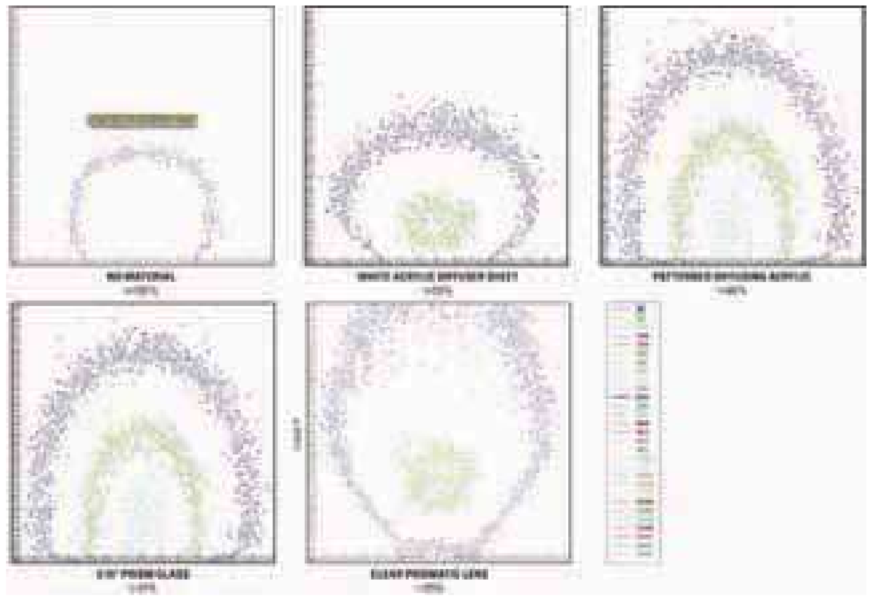

Figure 5. Work plane illuminance distributions for December 21 at solar noon for different glazing materials in the daylight shaft windows.

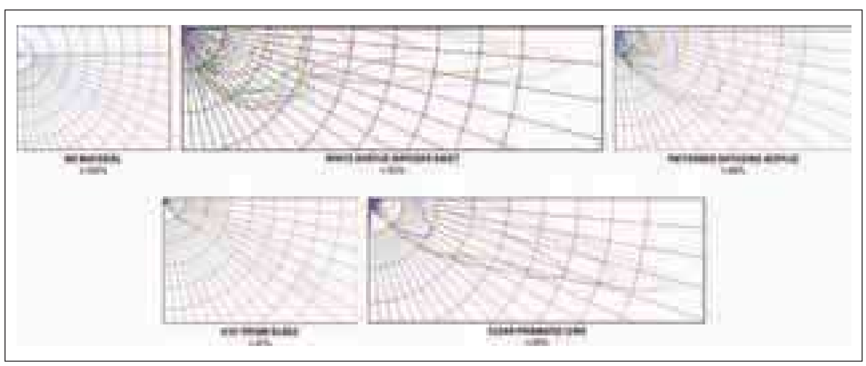

Figure 6. Candlepower distributions for December 21 at solar noon for different glazing materials in the daylight shaft windows.

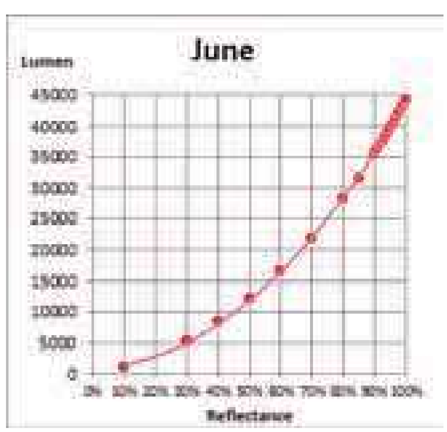

Figure 7. Lumen output for different reflectance values of the interior surfaces of the light shaft.

expensive ($15 per sq ft). Materials with 98 percent reflectance range from $1.75 per sq ft to $2.25 per sq ft, which correspond to totals of $3,500 and $4,500, respectively, for all surfaces of the daylight shaft. Materials with 90 percent reflectance are available for $0.05 per sq ft, bringing the cost down to $600 for all surfaces of the three-story daylight shaft.

Two more parametric simulations were performed to explore light shafts serving up to 10 floors (**Figures 8** and **9**) and different sizes for the daylight shaft and window, considering values from 100 percent to 4 percent of initial window and daylight shaft dimensions (**Figures 10** and **11**).

These preliminary analyses demonstrate significant potential for effective application of daylight shafts integrated in the architectural design of buildings. The results are impressive, even without the use of sun tracking/redirecting/concentrating technologies. Daylight shafts can greatly contribute to the realization of the NZE buildings vision and the support of the circadian rhythms of building occupants. ■

Figure 8. Light shaft heights were considered from 1st to 10th floor.

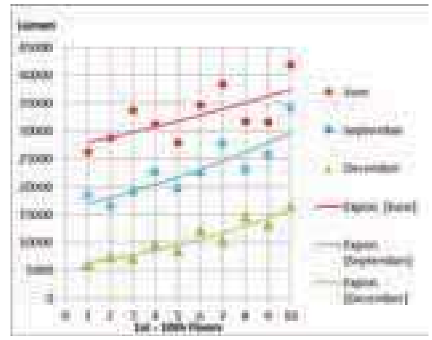

Figure 9. Lumen output as a function of light shaft height for summer, winter and spring/fall days at solar noon.

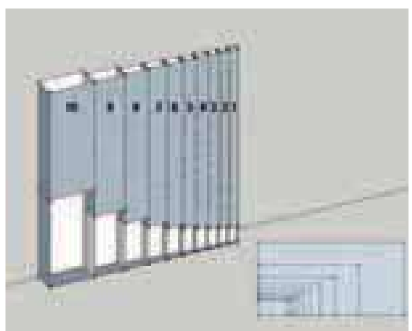

Figure 10. Different size of daylight shafts and windows ranging from initial size (100%) (No. 10) to 4% of the initial size (No. 1).

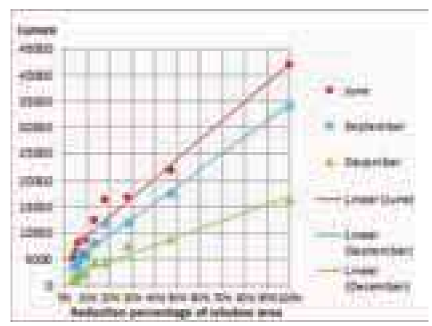

Figure 11. Lumen output as function of daylight shaft and window sizes.

THE AUTHORS

Anothai Thanachareonkit, Ph.D., is a post-doctorate researcher at CLTC, working on daylighting.

Konstantinos Papamichael, Member IES (2006), is co-director at the California Lighting Technology Center, UC Davis.

REFERENCES

1 CCSIP. "Collaborative Event: Developing Canada-California Sunlighting Solutions that generate clean, natural and sustainable energy for buildings." Web. 23 May 2010. http://www.ccsip.org/documents/events/CCSIP_Event_Core_Sunlighting_Solutions_English_Jan10_2010.pdf

2 Luis Fernandes and Michele Mossman, Core Concepts, *LD+A*, May 2011, 94-96.

3 Additional figures of daylight shafts can be found at CASA Batllo, Barcelona: http://stuckincustoms.smugmug.com/Portfolio-The-Best/your-favorites/10668747_AuyBk#1209596719_cph5i-A-LB

Mandarin Oriental, Barcelona: http://www.trivago.co.uk/barcelona-31965/hotel/mandarin-oriental-barcelona-1319782/picture-i5943826

4 http://www.howgreenworks.com/sun-tracker-skylights/

5 http://espaciosolar.com/preguntas_patios.html

6 http://www.ltioptics.com/Photopia/overview.html