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**MARK THROWER** MANAGING EDITOR

SERIES **13** | MODULE **06** | **SHADING SYSTEMS**

# Retrofitting Solar Shading

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There are many different reasons to want to control the amount of sunlight that is admitted into a building. In warm, sunny climates excess solar gain may result in high cooling energy consumption. In cold and temperate climates winter sun entering south-facing windows can positively contribute to passive solar heating. But in nearly all climates controlling and diffusing natural illumination will improve daylighting.

Well-designed sun control and shading devices can dramatically reduce building peak heat gain and cooling requirements and improve the natural lighting quality of building interiors. Depending on the amount and location of fenestration, reductions in annual cooling energy consumption of 5 per cent to 15 per cent have been reported. Sun control and shading devices can also improve user visual comfort by controlling glare and reducing contrast ratios. This often leads to increased satisfaction and productivity. Shading devices offer the opportunity of differentiating one building facade from another. This can provide interest and human scale to an otherwise undistinguished design.

The use of sun control and shading devices is an important aspect of many energy-efficient building design strategies. In particular, buildings that employ passive solar heating or daylighting often depend on well-designed sun control and shading devices.

During cooling seasons, external window shading is an excellent way to prevent unwanted solar heat gain from entering a conditioned space. Shading can be provided by natural landscaping or by building elements such as awnings, overhangs, and trellises. Some shading devices can also function as reflectors, called light shelves, which bounce natural light for daylighting deep into building interiors.

The design of effective shading devices will depend on the solar orientation of a particular building facade. For example, simple fixed overhangs are very effective at shading south-facing windows in the summer when sun angles are high. However, the same horizontal device is ineffective at blocking low afternoon sun from entering west-facing windows during peak heat gain periods in the summer.

## Clear glass facades

Exterior shading devices are particularly effective in conjunction with clear glass facades. However, high-performance glazing systems are now available that have very low shading coefficients (SC). When specified, these new glass products reduce the need for exterior shading devices.

Solar control and shading can be provided by a wide range of building components including:

- landscape features such as mature trees or hedge rows;
- exterior elements such as overhangs or vertical fins;
- horizontal reflecting surfaces called light shelves;
- low shading coefficient (SC) glass; and,
- interior glare control devices such as Venetian blinds or adjustable louvers.

To choose a solar control device we need to consider:

- the site latitude;
- the orientation of the façade;
- the orientation of the openings (vertical or horizontal) The aesthetic of the façade;
- the glazing type of the window;
- the need for daylight;
- the need to get a completely opaque solution or not;
- the need to have air passing through it;
- the performance of the solar control device itself; and
- the control of the solar shading if movable.

The overall thermal and optical performance of a solar control device in respect to solar radiation impinging on it is based on the phenomena:

- primary transmission: beam solar

radiation passes directly through the shading assembly Reflected transmission: beam solar transmission passes through the shading assembly by multiple reflection on the slats and/or the set-back (belonging to the building);

• diffuse transmission: diffuse solar radiation passes through the shading assembly directly and by multiple reflection; and

• solar absorption: solar radiation is absorbed by the shading assembly and may in turn be transmitted via:

• conduction within the shading assembly;

• convection to the surrounding air; and

• longwave radiation towards the glazing, set-back; outdoor or indoor environment (depending on the location of the device) or another part of the shading assembly at a different temperature.

The global shading efficiency of a device is the result of all these direct and indirect transmission processes. Two parameters are commonly used to characterise the device performance:

Solar gain factor or solar factor (SF) defined as the fraction of the incident solar energy which passes through the device

Shading coefficient (SC) defined as the ratio between the solar factor of the assembly and the solar factor of the reference opening made of a single pane clear glass (table 5.1).

**Table 1. Example of shading coefficient given by manufacturers for some shading devices**

| Type of shading device | Shading Coefficient | Daylight Transmittance |
|---|---|---|
| Screens (outside position)<br>(ref: Hexcel Lyverscreen Satin 525) | 0.14 grey<br>0.20 yellow<br>0.26 white | 5 per cent grey<br>18 per cent yellow<br>25 per cent white |
| Screens (inside position)<br>(ref: Hexcel Lyverscreen Satin 525) | 0.48 grey<br>0.36 yellow<br>0.37 white | 5 per cent grey<br>18 per cent yellow<br>25 per cent white |
| Reflective film inside<br>(ref DTI reflective with a 4 mm clear glass) | 0.26 argent 20<br>0.42 argent 35 | 20 per cent argent 20<br>35 per cent argent 35 |
| Ionised film inside<br>(ref DTI Sputter with a 4 mm clear glass) | 0.67 inox 50<br>0.41 inox 75<br>0.46 bronze 50<br>0.26 bronze 75<br>0.49 XH50 | 50 per cent inox 50<br>23 per cent inox 75<br>45 per cent bronze 50<br>22 per cent bronze 75<br>45 per cent XH50 |
| Sealed blinds (for a chosen blades tilt) | Depends on sun elevation, no data | No data |

## Luminous transmittance

Shading devices are also essential to avoid glare situations. If their luminous transmittance is too high (above 10 per cent in general), the risk of glare is significant, with luminance reaching more than 1 000 cd/m2 for an illuminance on the awning of 40 000 lux [2]. So, screens with transmission factors lower than 10 per cent are sufficient to avoid glare from the sky.

The principle of an 'ideal' screen is to reflect the maximum amount of solar rays from its external surface and to reduce transmission to ensure optimum control of glare phenomena. From the table above, we can observe the performance for example of the grey screen, in outside position (ref: Hexcel Lyverscreen Satin 525). With this screen, we obtain a shading coefficient of 0.14, this signifies that the reduction of the thermal contribution of the window is significant since the screen eliminates around 80 per cent of the thermal contribution of the window (the same screen placed inside eliminates around 50 per cent of the thermal contribution of the window). The daylight transmittance equal to 5 per cent is sufficient to avoid glare from the sky.

The choice of shading device is influenced by the site latitude and façade orientation. The choice of the screen fabric best adapted for each façade is defined by the trajectory of the sun or its absence on the façade concerned. In fact, in Northern European countries the sun is low over the horizon for most of the day, lighting south oriented façades. Therefore a screen with a very low transmission rate must be installed (3 per cent for example). On the contrary, north facing facades need to optimise the sky's luminance, as there is no direct exposure to the sun. In this case, there is no point in using a screen with a low transmission rate, as this would considerably reduce the contribution of natural light inside the office. A screen with 10 per cent daylight transmittance will manage this level of external luminance.

These parameters are based on the boundary conditions assumed in the ISO/DIS 9050 for glass tests. Designers and decision makers must be conscious that the performance of the shading assembly might be different in the actual application conditions. Main reasons are:

• only the direct solar radiation and a fixed solar incidence angle are considered in the standard tests, although some experiments have shown that the shading device performance is strongly dependent on the ratio direct/diffuse.

• the distance between the shading device and the glazing is ignored. As far as the size of slats is small this distance can be disregarded but the fraction of sunlit device for medium/large slats can be influenced by this distance.

It also has to be considered that the terminology itself is misleading as Shading Factor should consider the reduction of heat gain achieved by the shading device.

Photovoltaics (PV) are solid-state, semiconductor type devices that produce electricity when exposed to light. Electrons in the photovoltaic material are knocked free by light to flow out of the device as an electric current. The more intense the sunlight, the stronger the electric current.

This phenomenon was discovered in the mid-1800s, yet important applications followed much later—for satellites and applications where extending the electric grid is cost prohibitive. Architectural applications have only recently become prominent. With Building Integrated Photovoltaics (BIPV), for instance, photovoltaics are integral to the building skin: the walls, roof, and vision glass. The envelope produces electricity, which flows through power conversion equipment and into the building's electrical system.

## Commercial solar panels

Today's commercial solar panels are, for the most part, composed of wafer-based crystalline silicon solar cells which are quite efficient in converting solar radiation into electrical power (approximately 15 per cent conversion efficiency), but with several important obstacles standing in the way of maximum exploitation. To begin, they must be precisely oriented to receive direct sunlight and even then are limited in their ability to absorb diffused light. In addition, they are heavy, opaque, and take up a great deal of space.

Organic solar cell technology has been around for about thirty years, however nowadays it is starting to attract substantial interest due to its low production cost. While organic cells have not yet reached the efficiency values of silicon-based cells, these Organic Photovoltaic (OPV) cells have proven to be lighter in weight, more flexible (they are capable of adapting to curved surfaces), and even more sensitive to low light levels as well as indirect sun light, making them one of the most appealing photovoltaic technologies for many everyday applications. Among such advantages, a property that makes them even more interesting is their potential to be implemented as a semi-transparent device.

Photovoltaic vision glass integrates a thin-film, semi-transparent photovoltaic panel with an exterior glass panel in an otherwise traditional double-pane window or skylight. All the PV types can be integrated and/or laminated in glass, but only thin-film photovoltaics will be translucent. Electric wires extend from the sides of each glass unit and are connected to wires from other windows, linking up the entire system. If the PV cells are part of the vision glass, various degrees of transparency are possible—as in frit glass—since the PV cells offer shade and produce electricity. In some cases, the PV panels are placed in spandrel panels, rather than the vision glass. Smaller PV systems can be used to power facade equipment directly instead of being connected to the electrical grid in

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the building. Vertically oriented PV panels are optimally not positioned toward the sun. One approach to position the PV panels more perpendicular to the sun is to place them into fixed shading devices on the facade or on movable shading panels, using the generated power to track the shades to the optimal solar angle.

The emerging concept for the window of the future is more as a multifunctional "appliance-in-the-wall" rather than simply a static piece of coated glass. These facade systems include switchable windows and shading systems such as motorized shades, switchable electrochromic or gasochromic window coatings, and double-envelope window-wall systems that have variable optical and thermal properties that can be changed in response to climate, occupant preferences and building system requirements. By actively managing lighting and cooling, smart windows could reduce peak electric loads by 20–30 per cent in many commercial buildings, increase daylighting benefits throughout the United States, improve comfort, and potentially enhance productivity in homes and offices. These technologies can provide maximum flexibility in aggressively managing demand and energy use in buildings in the emerging deregulated utility environment. They can also move the building community towards a goal of producing advanced buildings with minimal impact on the nation's energy resources.

The ideal window would be one with optical properties that could readily adapt in response to changing climatic conditions or occupant preferences. Researchers have been hard at work on new glazing technologies for the next generation of smart windows. After many years of development, various switchable window technologies are now in prototype testing phases and should be commercially available in the near future. As with other window technologies, the architect will need to understand these new systems in order to specify them properly.

### Switchable windows

There are two basic types of switchable windows—passive devices that respond directly to a single environmental variable such as light level or temperature, and active devices that can be directly controlled in response to any variable such as occupant preferences or heating and cooling system requirements. The main passive devices are photochromics and thermochromics; active devices include liquid crystal, suspended particle, and electrochromics.

Automated shading systems have significant potential to reduce energy use and improve environmental quality. For buildings with low-performance glass (e.g., single-pane clear), automated (and manual) shades can also increase thermal comfort by raising or lowering the effective surface temperature of the window wall during the winter or summer, respectively. The higher initial price of automated shades can be partially offset by these performance benefits as well as the reductions in HVAC installed capacity and ongoing HVAC maintenance costs, and decreased cost for furnishings replacement due to UV fading and degradation.

The shade material and location of the shade in the window wall dictates the degree of daylight transmission and solar heat gain rejection. Exterior shades reject more heat than interior shades. Between-pane shades perform somewhere between exterior and interior shades depending on the size of the glazing cavity and whether it is ventilated. For roller shades, daylight, solar heat gain transmission, view, and privacy can be controlled by the perforation of the shade, shade weave, changes in material over the height of the shade, and differences in shade material on the front and back surfaces. View is possible through a roller shade with an openness factor as low as 2 per cent. The venetian blind has a second option for movement—tilt angle—that enables it to control daylight and allow partial view while fully blocking direct sun.

Automated systems often have wall switches or hand-held remote controllers so that individual shades can be controlled. Automated controls feature scheduling, direct sun control or depth of sun penetration, solar heating, glare control, daylighting, occupancy, response to HVAC operations, and limits on exterior shade operations, in the case of high winds, snow, or ice.

International studies have evaluated the economic feasibility and the effect of window shading retrofits on the heating and cooling energy requirement of housing stock based on detailed energy simulation.

They found, for example that adding 15mm light aluminium shading on the indoor side of windows with automatic control based on zone temperature would result in substantial reduction in energy and GHG emissions. It was also found that other types of window shading devices may be effective in reducing the cooling energy consumption, but they can result in an increase in overall energy consumption when both heating and cooling season performance is taken into consideration.

The economic feasibility of solar shading depends largely on the fuel mix and cost of fuels used as well as the tolerable payback period and expected fuel cost escalation rate. Thus, the economic feasibility is different for each type of system and country location.

Current PV production technologies, pricing structure, and energy rates limit BIPV use to prominent, prestige buildings (although PV-integrated cladding costs are comparable to marble). Of course, as these factors are in constant flux, BIPVs are receiving increased attention that is justified by the promise of a future building envelope that can generate energy in addition to providing shelter.

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Please mark your answers on the sheet below by placing a cross in the box next to the correct answer. Only mark one box for each question. You may find it helpful to mark the answers in pencil first before filling in the final answers in ink. Once you have completed the answer sheet in ink, return it to the address below. Photocopies are acceptable.

### QUESTIONS

1. **What are the potential percentage range of annual cooling energy savings from the retrofitting of shading measures**
   ☐ 20% to 30% ☐ 15% to 30% ☐ 5% to 15%

2. **What will be improved from the diffusion of natural light?**
   ..............................................................................................................

3. **Which two types of flux must be used to establish a solar factor for use in shading design?**
   ..............................................................................................................

4. **What is the definition of solar gain factor or solar factor (SF)?**
   ..............................................................................................................

5. **What is the shading coefficient of a simple grey screen?**
   ..............................................................................................................

6. **Are transmission factors lower than 10 per cent sufficient to avoid glare from the sky**
   ☐ Yes ☐ No

7. **What is the approximate conversion factor for solar radiation into electrical power for present PV cells?**
   ☐ 30% ☐ 50% ☐ 15%

8. **When were the phenomenon of photovoltaics first discovered?**
   ☐ mid-1800s ☐ mid-2000s ☐ mid-1900s

9. **What is the minimum openness factor to permit viewing through a roller shade?**
   ☐ 2% ☐ 5% ☐ 15%

10. **What are the two basic types of switchable windows?**
    ..............................................................................................................

Please complete your details below in block capitals

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