Passive Solar Design Overview - Part 4: Controls

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Topic: Environment/Sustainability
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This is another guest post by Will Stewart.

In Parts 1, 2, and 3 of this Passive Solar Design Overview series, we looked at the three main architectural styles of passive solar design (Direct Gain, Indirect Gain, and Isolated Gain), as well as the first three of the five design aspects, *Aperture*, *Absorber*, and *Thermal Mass*. This article will address the design aspect *Controls* at an overview level. All of these aspects are important regardless of whether a new building is being designed or renovation of a current building is being considered.

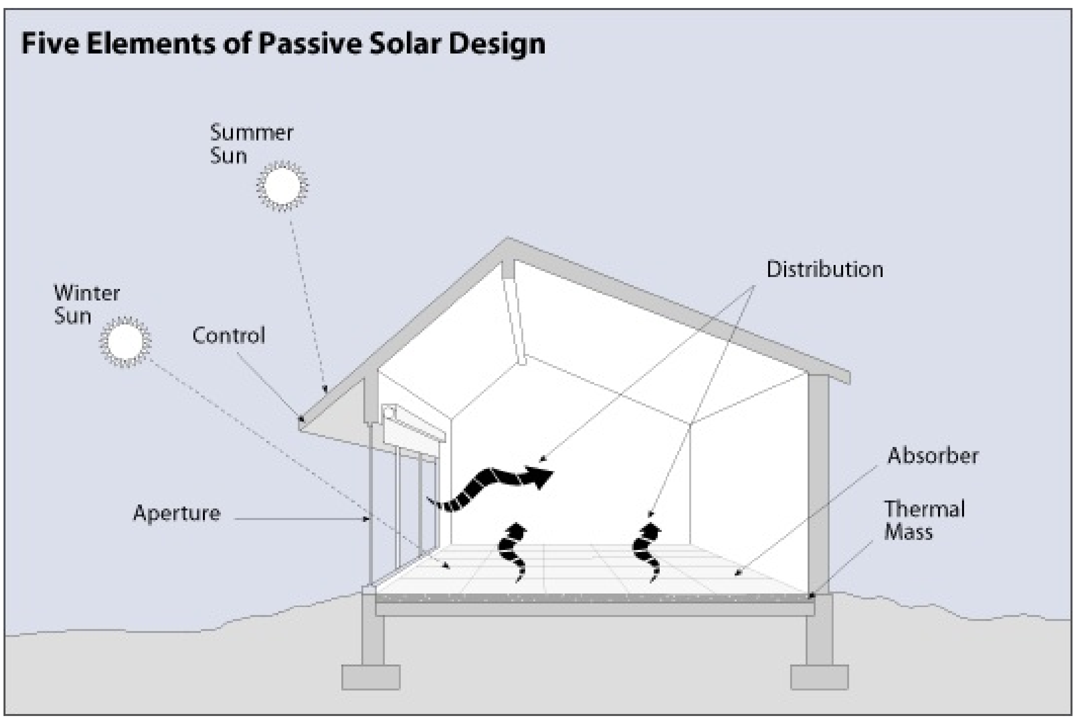

Figure 15 - Passive Solar Design Aspects

In passive solar design, the term *controls* stands for those aspects of the design that inhibit solar heat gain during non-heating seasons without precluding its desired collection during winter. These design components include overhangs (fixed, removable, louvered), light shelves, blinds, exterior louvers, awnings, landscape shading (deciduous trees or vines), etc. It also refers to quasi-active measures such as opening windows and raising/lowering insulating shades.

Sun Position

The first step in designing a solar shading control is to determine the seasonal sun angles at the building's location.

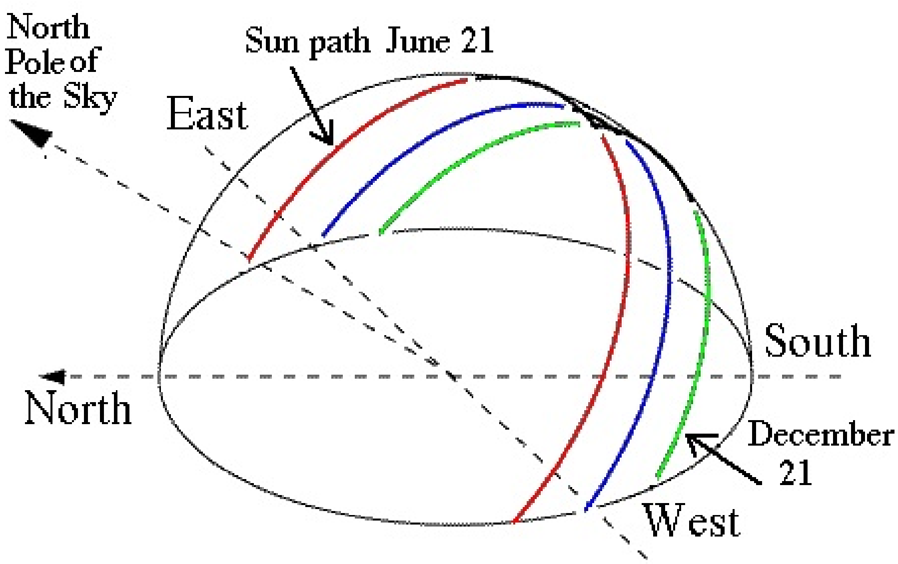

Figure 16 - An example of the Sun's inclination difference by season

You can obtain this information from a number of sites online (need to determine your latitude and longitude? Find it at WeatherUnderground after you enter your location) ;

- SolarPlots.info (US only, from TOD reader dallastx)
- SunPosition.info
- SunAngle

Overhangs

The most common controls include fixed roofline or pente eaves, louvered overhangs, and vegetative support structures (e.g, pergolas). In the winter, the sun's inclination is low in the sky, providing desired warmth; in the summer, the sun is (relatively) high in the sky at noon (see figure 13). Overhangs will help to block the direct insolation of the summer sun, though will not reduce ground reflection or the majority of diffuse sky radiation.

Note that there are many different types of overhangs:

- Fixed: Stays in place year around
- Removable: Removed during heating season
- Louvered: Blocks summer insolation, allowing most winter insolation through
- Vegetative: Supports deciduous foliage during growing season to block summer sun
- Daylighting shelves: While some are primarily interior, others are dual purpose, using an overhang to help capture more light

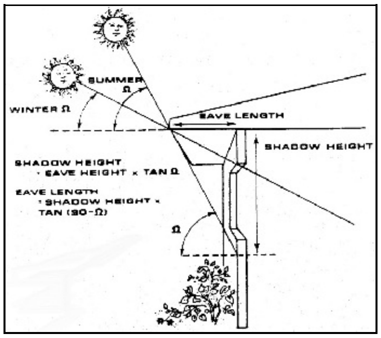

Figure 17 - Overhang considerations

Figure 18 - Renovation addition of pente eave over 1st floor to reduce summer solar gain

Figure 19 - Balconies and PV arrays can be overhangs

Figure 20 - Simple louvered overhang

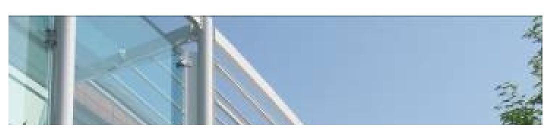

Figure 21 - Seasonal retractable overhangs

Figure 22 - Multi-story louvered overhangs

Figure 23 - Movable PV array overhangs (winter and summer configurations)

Three of the main criteria in fixed overhang design are;

- Window height
- Overhang extension length
- Offset of the overhang above the window

Some simple rules of thumb from the US DoE include (HDD and CDD data is available from local weather services);

- *Cold climates*: above 6,000 heating degree days (HDD)* (at base 65°F [18°C])
  Locate shadow line at mid-window using the June 21 (summer solstice) sun angle.

- *Moderate climates*: below 6,000 heating degree days (HDD)* (at base 65°F [18°C]) and below 2,600 cooling degree days (CDD)* (at base 75°F [22°C])
  Locate shadow line at window sill using the June 21 (summer solstice) sun angle.
- *Hot climates*: above 2,600 cooling degree days (CDD)* (base 75°F [22°C])
  Locate shadow line at window sill using the March 21 (vernal equinox) sun angle.

One quick way to gauge the design of an overhang is to model it. We can use an online overhang modeling program to trial various configurations of

Fins

Fins complement overhangs by using vertical surfaces to block undesirable solar insolation on the East and West side of equatorial-facing windows.

Figure 24 - Fins combined with overhangs

Daylighting

Passive solar controls can be designed to enable *daylighting*, which is the use of natural light in a manner that reduces the energy required for artificial lighting. Overhangs can be combined with *light shelf* techniques to capture light above the overhang to reflect into the building space along the ceiling.

Figure 25 - Overhangs doubling as light shelves

Figure 26 - Light distribution from light shelves

External Shade Control

Another way to keep the sun out during non-heating seasons is to place external blinds on the outside, a technique that may sound bizarre to some until one realizes that most old-fashion shutters were louvered to provide external shading in the summer while also allowing natural ventilation and daylighting. These remain a viable way to accomplish all three, though are not as easy to find these days in their traditional configurations. Note that external shades, unlike most overhangs, have the added benefit of reducing diffuse and reflected solar radiation.

Figure 26 - Traditional shutters **Figure 27 - Bahama shades**

Figure 29 - Motorized external shades

Internal Shade Control

Internal solar shading control fall into two broad categories; *blinds* and *shades* (or curtains). Most people are familiar with venetian blinds and typical decorative curtains. Both have the issue of the heat gain associated with sunlight entering the window, a portion reflecting off the surface, and then some portion re-exiting the window; hence, external measures are superior, though internal shades can be helpful in controlling diffuse and reflective radiation that an overhang does not. At each step, a portion of the sunlight is absorbed by these surfaces or reflected into the conditioned space. For more northerly locations, this may not be an issue, though for the rest it can result in less than desirable heat gain. Insulating shades will be covered in a energy efficiency article.

There are other shades that are intended to reject solar insolation; some with a full reflective block, and others block primarily UV, providing a daylighting effect. One must ensure that the blocking is primarily reflective, with as little absorption as possible (for summer heat control).

Figure 30 - Partially reflective shades

Figure 31 - White insulated shades reflect most of the sun's energy while providing additional r-value

Exercise

It's one thing to understand the basics, and another thing altogether to have 'hands-on' experience. To gain a better sense of how overhangs (and fins) can help prevent undesirable summer solar gain while still allowing winter solar heat gain, let's examine "what-if" designs at your location. Try many different combinations, and optimize for best winter exposure and most summer shading. You'll see that late summer is the biggest challenge (for those areas with hot summers). Below are two simple (and free) modeling tools to use to accomplish this;

- **Overhang Annual Analysis**: Simple online overhang calculator from *sustainable by design* that shows the shading % by month for given window heights, overhang height (offset above window), and overhang depth.
- **Solar-2**: A legacy Windows-95 program (part of a suite of building design tools from UCLA) that will accept simple building designs, focusing on equatorial-facing walls and windows, and other structures that can block solar insolation access. Enter your location, window sizes and placement, overhang and fin design information, and you will be able to see month by month hourly shading percentages and solar gains in BTUs. An animation of the solar insolation penetration of the building provides an interesting show for friends and family you want to educate.

One more passive solar design aspect article is next in the series (Distribution), with other articles on building energy efficieny renovations, passive solar renovations, case studies, and building energy design tool examples.

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