Passive Solar Design, Part 1

Introduction

Passive solar design is the process of creating a home that provides both shelter and comfort year-round while responding to regional climate conditions and minimizing dependence on energy-consuming mechanical systems. The goal is to build and occupy a home that (a) utilizes solar heat gain in the winter to warm the interior of a home, (b) controls solar heat gain in the summer, and (c) facilitates daylighting, natural ventilation, and nighttime cooling to keep a home comfortably cool in the summer. This fact sheet describes five steps in the first phase of designing the basic form and layout of a home:

Shape
Orientation
Location
Aperture
Roof overhangs

Green Building Benefits

Passive solar design saves energy by maximizing the home's natural heating, cooling, ventilation, and lighting options. Reduced energy consumption reduces utility bills for the owner or occupant, reduces air pollution from power plants, and reduces the environmental impacts of resource extraction associated with fossil fuels. Moreover, homes featuring good passive solar design are typically healthier and more comfortable.

Shape

S is for Shape: In a temperate climate, shape a home to be roughly rectangular.

An important factor in determining a home's thermal performance is its floor area-to-surface area (F/S) ratio. This is the ratio of the finished floor area of a home to the sum of all its exterior surfaces (the exterior walls and roof). The more living space enclosed per unit of exterior surface area the less heat gain and loss will occur through the building envelope. A home with a high F/S ratio is a more efficient design than one with a low F/S ratio.

The F/S ratio of a home should be as large as possible – but only up to a point. In order to minimize the heat gains and losses through the enclosure of a home, a compact shape is desirable. The most space-efficient orthogonal shape is a cube. This configuration for a home, however, may place a large portion of the floor area relatively far from the home's perimeter. Consequently, passive solar heating, daylighting and natural ventilation may be difficult to implement.

A house form that optimizes solar heat, daylight, and ventilation will be elongated in the east-west direction (see orientation below) so that more of the living area is closer to the perimeter and can take advantage of these passive options. While this may appear to compromise the thermal performance of the home, the heating and cooling load savings achieved by well-designed solar heating, daylighting, and natural ventilation techniques will more than compensate for the increased heat gains and losses through the building envelope.

In summary, a home located in a cold, cloudy climate with few opportunities for solar heating should have a high F/S ratio and a more cubical shape. For a cubical shape, all four walls are of equal length, and the ratio of length to width is 1.0. A home located in a hot, humid climate should have a lower F/S ratio and be more narrow and rectangular in shape to facilitate passive options such as daylighting and natural ventilation year-round.

For example, a narrow rectangle that is 48 feet long and 16 feet wide has a length to width ratio of 3.0. A home located in a temperate climate should have a shape somewhere in between a cube and a narrow rectangle. To achieve an optimum F/S ratio in temperate climates, some references indicate that a rectangular shape with a length to width ratio in the range of 1.25-1.50 is best. For example, a home with a rectangular footprint of 40'x32' or 48'x32' would fall within this ratio.

Orientation

O is for Orientation: Face the longer walls of a home to the south and north.

The orientation of a home on its site or lot is critical to achieving energy efficiency and thermal comfort. The ability of a home to properly utilize solar heat gain in the winter and mediate solar heat gain on walls, roofs, and windows in the summer depends a great deal on where and how the home is placed on the site and especially the direction the windows face.

Passive solar design includes the proper positioning of a home on its lot or site as well as proper window placement to make your house more comfortable year-round and save money on annual heating and cooling costs.

The first step is to find a true north-south line on the home's lot or site. When using a compass to find magnetic north, an adjustment must be made for finding true (solar) north-south. In the Bay Area, the magnetic declination (the direction the compass needle points to) is about 17° east of true north. This means that true north is 17° counter-clockwise of a compass needle pointing to magnetic north. Another way to find true south is to visit your lot or site on either the Vernal (Mar 21) or Autumnal (Sep 21) Equinox. On those two days of the year, the sun rises true east, is located at true south at solar noon (12:15PM PST in the Bay Area), and sets true west.

NORTH: The north side of a home is the coolest side because it receives very little direct sun. A north wall will receive sunlight only during the very early morning and very late afternoon hours of summer. At these times of day, the sun's vertical position in the sky (the solar altitude) is at its lowest, so trees and adjacent homes quite often shade north walls. North walls receive no direct sunlight during fall, winter, and spring.

SOUTH: The south is the sunniest side of a home since the sun's position for most of the day is in the southern sky. During the summer in the Bay Area (and other locations at 38°N latitude), the sun is very high in the sky at solar noon (about 1:15PM PDT). Consequently, overhangs or awnings can easily shade south walls and windows (see R is for Roof below). Properly sized overhangs also have the advantage in winter, when the sun is much lower in the sky, of allowing direct transmission of sunlight through south windows for passive solar heating.

EAST: The east side of a home will be exposed to solar heat gain in summer mornings. Careful placement of window area on the east side of a home is recommended. Overhangs on east walls do not perform well for shading because the sun is so low in the sky during the morning (close to the horizon) that it travels beneath the overhang.

WEST: The west side of a home will bear the brunt of the sun's heat. Therefore, minimize not only the window area, but also the total wall area facing west. In those parts of the Bay Area where air conditioning is common, the overheated period (the time when your air conditioner will run the most) occurs between 3PM and 5PM. Since the ambient heat of the day has built up (air temperature), the sun's added heat compounds the cooling problem. For this reason, the western exposure of a house should have as few windows as possible. If windows are required by the dictates of the site or design, protect them from solar heat gain with porches, trees, trellises, sunshades, carports, or out buildings.

California's 2005 Building Energy Standards (Title 24) limits the area of west-facing windows to a maximum of five percent of the conditioned floor area. This limitation applies to all residential projects except those in the coastal climate zones 1, 3, 5, and 6.

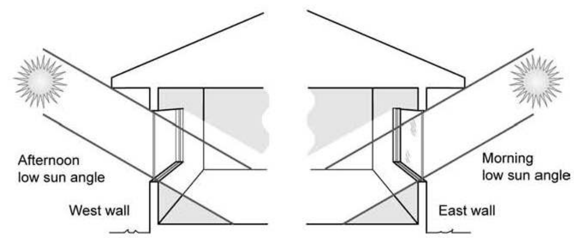

Figure 1. Difficulty of Shading East- and West-facing Windows[1]

To maximize the benefits of shape and orientation, a home in the Bay Area should be elongated in the east-west direction. This will increase the surface area of north and south walls and reduce the surface area of east and west walls. With proper window shading, solar heat gain potential in the winter will be maximized and unwanted solar heat gain during summer mornings and afternoons will be minimized. If facing a longer wall true south is not feasible, an orientation that is within 30° east or west of true south will result in only a minor decrease in annual passive solar heating and cooling performance.

In many Bay Area locations, the south, southeast, and southwest sides of a home also receive the prevailing summer breezes. Consequently, elongating the home in the east-west direction will also increase the wall area and potential window area for facilitating natural ventilation. By placing windows on opposite sides of the house, some on the windward side and some on the leeward side, the home can be designed to take advantage of natural ventilation in the spring, summer, and fall. Once the overall shape and orientation of a home has been determined, proper room location should be considered in order to take advantage of direct passive solar heating and cooling.

[1] California Energy Commission, 2005 Building Energy Efficiency Standards: Residential Compliance Manual, CEC-400-2005-005-CMF

Location

L is for Location: Locate major living spaces of a home on the south perimeter.

Allowing sunlight to enter directly into a living space is the most effective way of implementing passive solar heating. By doing so, the space can be warmed directly in the winter without having to rely on heat being transferred from one space to another. Additionally, this allows enough daylight to enter the room so that adequate illumination is provided for most daytime activities. Spaces that need warmth in winter, cool breezes in summer, and light year-round should be placed along the perimeter of the home near a south-facing wall. Those that don't require these conditions can be placed in the home's interior. Each of the rooms along the south-facing wall should have its own solar aperture.

Aperture

A is for Aperture: Design south-facing windows for solar gain and ventilation.

Winter sun angles are very low making vertical and steeply pitched glazing optimum for transmitting winter solar heat gain into a home. South-facing windows are the least costly, simplest, and easiest way to accomplish this. They gain more heat during a clear or partly cloudy winter day by transmitting solar radiation into the home than they lose at night. Thus, south-facing windows are a net energy gain in the heating season. Windows that don't face south typically lose more energy than they gain each day during the heating season and are therefore a net energy loss. South facing windows that are a net energy gain are called the home's solar aperture.

Some references give a rule of thumb that about half, or even a majority, of a home's windows should face south in most California climates. California's 2005 Building Energy Standards (Title 24) limits the area of all windows to a maximum of 20 percent of the conditioned floor area. Applying this rule of thumb, the south-facing window area will equal at least 10 percent of the home's floor area. For example, a 2,000 sq. ft. home will have about 200 sq. ft. of south-facing windows or solar aperture. After placing and sizing south-facing windows, design roof overhangs for shading the solar aperture.

Roof Overhangs

R is for Roof Overhangs: Size roof overhangs to shade south-facing windows.

The sun is very high in the sky at solar noon during the summer. As a result, small overhangs or awnings can easily shade south walls and windows. Shading windows from the summer sun can help maintain comfortable conditions inside your home as well as considerably lower annual cooling costs. Properly sized overhangs and other shading devices such as awnings can provide plenty of shade for south-facing windows all summer while allowing solar gain to be transmitted through the windows in winter.

Use Figure 2 for south-facing roof overhang sizing. A correctly sized roof overhang will completely shade a window at solar noon on August 21st (the warmest and sunniest month of the year). The minimum overhang depth is given as a fraction of the window height plus header height (the space between the top of the window and the roof overhang) for various California latitudes. Windows that do not face directly south will require larger overhangs for complete shading.

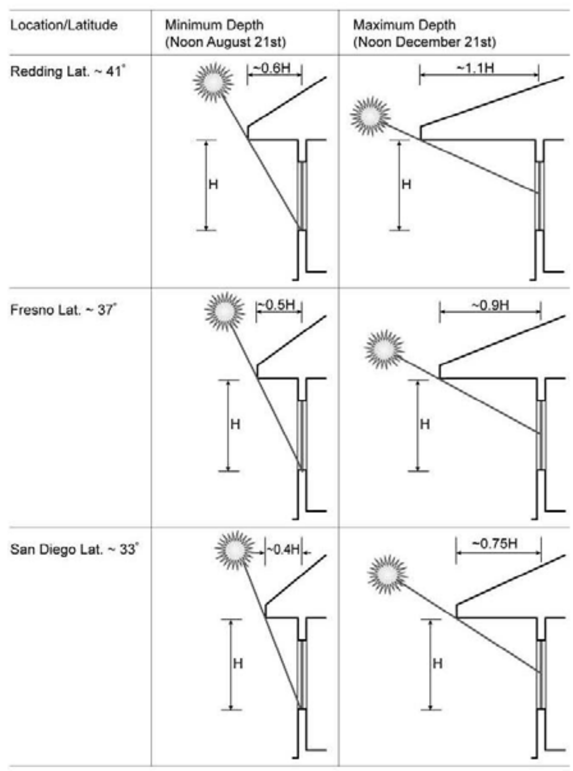

Figure 2. South-facing Roof Overhang Dimensions for Title 24 Prescriptive Compliance[2]

As indicated in Figure 2 for Fresno (37° LatN), a south-facing window that is 48" high and is located 12" directly below the roof overhang (i.e., in the first floor of a one story house and the second floor of a two story house) requires a 30" deep roof overhang

[2] Ibid.

[(48”+12”) x 0.50] to provide total shading at solar noon on August 21st. Most of the Bay Area is located at roughly 38° LatN so the overhang size for Fresno can also be applied there. For larger windows and patio doors that are 6-7 feet in height, using the same equation indicates that a roof overhang or other shading device that is 42-48” deep will be required. From Figure 2 we can see that in Fresno even a 24” wide overhang, a more conventional size, will shade all south facing windows 36” in height or less.

In addition to protecting the south walls, preventing solar gain on the west side of a home should also be considered. The western exposure of a home should have as few windows as possible. Moreover, if feasible, minimize not only the window area, but also the total wall area facing west as explained above. If windows are required by the dictates of the site or design, protect them from solar heat gain with porches, trellises, sunshades, or carports.

For more information

- *Energy Savers: Five Elements of Passive Solar Design*; U.S. DOE, Energy Efficiency and Renewable Energy Program, www.eere.energy.gov/consumerinfo/factsheets/five_elements.html
- *Man, Climate, and Architecture*; Baruch Givoni, Van Nostrand Reinhold Co., 1981.
- *Passive Solar Design*; Consumer Energy Center, California Energy Commission, www.consumerenergycenter.org/homeandwork/homes/construction/solardesign.html
- *Passive Solar House, The*; James Kachadorian, Chelsea Green Publishing, 1997.
- *Sun, Wind, and Light*; G. Z. Brown and M. DeKay, John Wiley & Sons, Inc., 2001

- For more information about the Coalition, visit our website at www.greenaffordablehousing.org or call Bruce Mast at 510-271-4785.