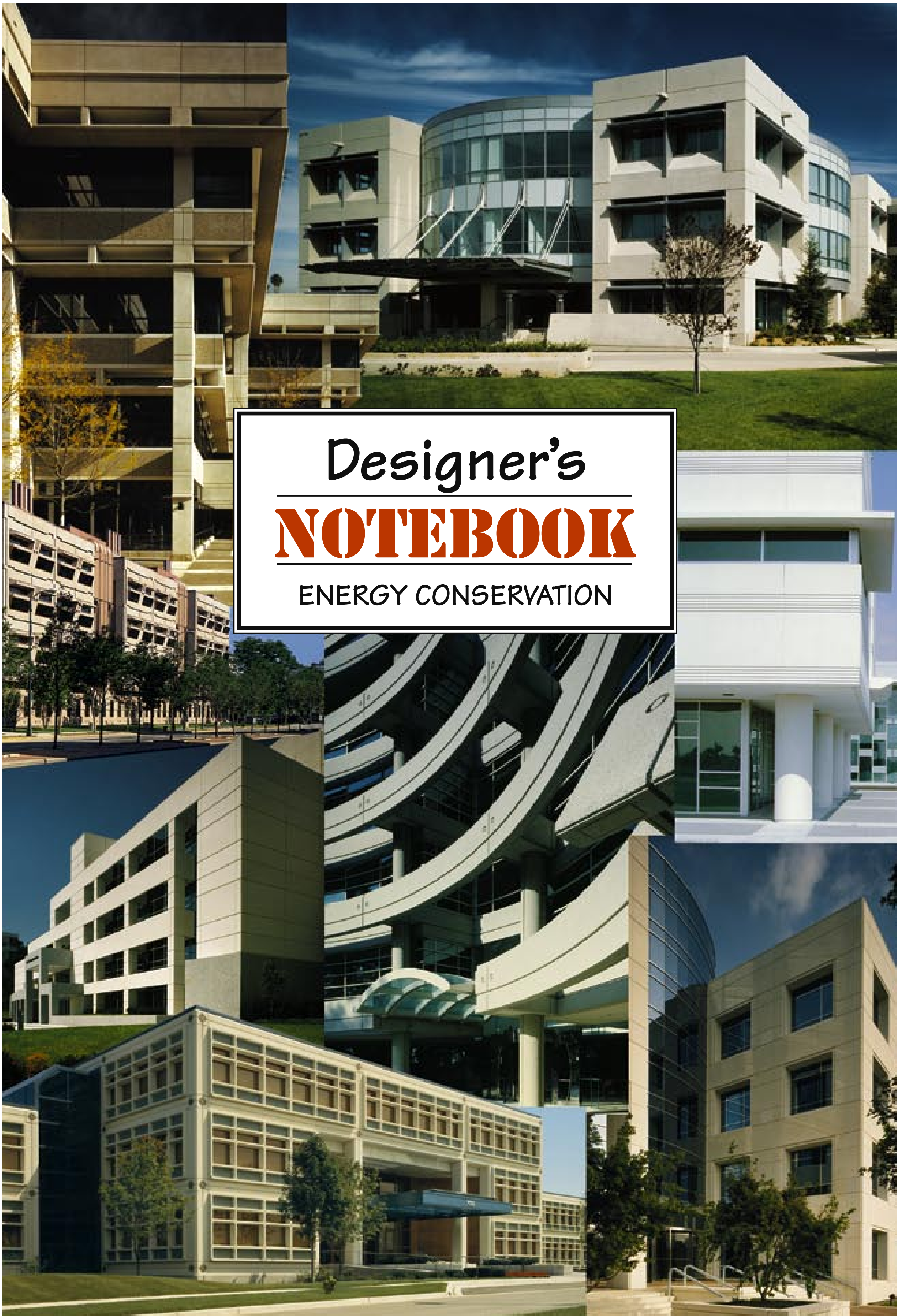
Designer's

NOTEBOOK

ENERGY CONSERVATION



Energy Conservation and Condensation Control – Part 1

Energy Conservation

Americans spend almost 90% of their time inside buildings. More than 2/3rds of the electricity generated and 1/3rd of the total energy (including fossil fuels and electricity) in the U.S. are used to heat, cool and operate buildings. Significant energy could be saved if buildings were built to or exceeded minimum national energy code standards. Saving energy will result in fewer power plants and natural resources being used to provide electricity and natural gas. It also means fewer emissions to the atmosphere. Emissions have been attributed to smog, acid rain, and global climate change.

Energy codes provide minimum building requirements that are cost effective in saving energy. The U.S. Energy Conservation and Production Act (ECPA) requires that each state certify that it has a commercial building code that meets or exceeds *ANSI/ASHRAE/IESNA Standard 90.1*[1]. In this sense, "commercial" means all buildings that are not low-rise residential (three stories or less above grade). This includes office, industrial, warehouse, school, religious, dormitories, and high-rise residential buildings. Some states implement codes similar to *ASHRAE Standard 90.1* and some have other codes or no codes. The status of energy codes by states is available from the Building Codes Assistance Project (BCAP) (*www.bcap-energy.org/backissues.html*). Building to minimum energy codes is a cost-effective method of saving energy. The designer is not constrained in aesthetic expression in applying the range of available high performance building systems to meet the performance criteria of ASHRAE 90.1.

Sustainability or green building programs such as LEED™[2] or EnergyStar[3] encourage energy savings beyond minimum code requirements. The energy saved is a cost savings to the building owner through lower monthly utility bills, and smaller and thus less expensive heating, ventilating and air-conditioning (HVAC) equipment. Less energy use also means fewer emissions to the atmosphere from fossil fuel power plants. Some government programs offer tax incentives for energy saving features. Other programs offer reduced mortgage rates. The EnergyStar program offers simple computer programs to determine the utility savings and lease upgrades associated with energy saving upgrades. Sustainable buildings often have features that have been shown to increase worker productivity, decrease absenteeism, and increase student test scores in schools.

The planned design of an energy-conserving or sustainable building requires the architect's understanding of the effects of design decisions on energy performance. More than half of the true total costs incurred during the economic life of a building may be attributable to operating and energy costs. An integrated design approach considers how the walls interact with the building and its HVAC system. Using this approach early in the design phase helps optimize initial building costs and reduce long-term heating and cooling energy costs. This integrated design approach is recommended for cost-effective, energy efficient, sustainable buildings.

Precast concrete panels have many built-in advantages when it comes to saving energy and protecting the building from the environment. Their versatility leads to unique solutions for many energy conservation problems. The relative importance of particular design strategies for any given building depends to a large extent on its location. For instance, buildings in northern, heating-season-dominated climates are designed differently than those in southern, cooling-season-dominated climates.

Several factors influence the actual energy performance of the building envelope. Some of these are recognized in energy codes and sustainability programs because they are relatively easy to quantify. Others are more complex and are left to the discretion of the designer.

Much of the information and design criteria that follow are taken from or derived from the *ASHRAE Handbook of Fundamentals*[4], and the *ANSI/ASHRAE/IESNA Standard 90.1*. It is important to note that all design criteria are not given and the criteria used may change from time to time as the ASHRAE Handbook and Standard are revised. It is therefore essential to consult the applicable codes and revised references for the specific values and procedures that govern in a particular area when designing the energy conservation systems of a particular structure.

Building Orientation

Building orientation plays an important role in building energy consumption. If possible, the long axis of the building should be oriented in the east-west direction to help control the effect of the sun on heating and cooling loads. Solar gain through glazing on the east side of the building in the morning and on the west side in the afternoon when the sun is low increases the heat gain in the building. This increases the air-conditioning load on a building and makes it more difficult to control the building temperature in different portions of a building. However, east glazing will help warm an office building in early morning hours after night-temperature setbacks.

To maximize solar heating, glazing should be located on the south wall since winter sunshine in cold climates is predominantly from the south. South-facing glass should be shaded to minimize solar exposure in the summer while allowing maximum solar exposure in the winter.

In the southern regions of the U.S., the primary emphasis is on cooling. Glass should be more predominant on the north side of buildings in these regions to minimize heat gains from the sun.

Building Shape

Building shape influences energy performance in two ways. First, it determines the surface area of the building skin. The larger the skin area, the greater the heat gain (summer) or loss (winter). Second, shape influences how much of the floor area can be illuminated using natural light from the sun, called daylighting. The old "E" and "H" shaped buildings were designed to provide maximum exposure of occupants to operable windows, but had the added benefit of providing optimal daylighting.

Glazing

Glazing (the clear portion of windows) in buildings requires special consideration during the design stage. The type, amount and orientation of glazing will profoundly affect heating, cooling, and daylighting requirements, HVAC system selection, human comfort, and environmental satisfaction. Today's high-performance glazing comes in many forms: those with low emissivity (low-E), those filled with inert gas to further lower U-factors, and those that are spectrally selective. Heat gain through a sunlit glass area is many times greater than through an equal area of precast concrete and its effect is usually felt almost immediately. Direct solar gains also cause glare in the work space. Properly designed shading devices can modify the thermal effects of windows to a very great extent. Glazing with low solar heat gain and high visible light transmittance provide the most benefits in most climates. More information on glazing is available through the National Fenestration Rating Council (NFRC) (*www.nfrc.org*) and the chapter on fenestration in the ASHRAE Handbook of Fundamentals.

Daylighting

Daylighting saves energy by using natural light from the sun rather than artificial lighting for illumination. Controlling the type and amount of glazing influences the benefits of daylighting. The potential energy savings from daylighting is particularly significant in commercial buildings because of the large lighting requirements in these buildings. Lighting can account for approximately one-third of the building energy costs. Daylighting controls can be used to dim or turn off lights along the building perimeter when daylighting is prevalent. Daylighting is not as effective as direct sunshine; rather it is controlled low-glare sunshine moderated by shading. Daylighting should be maximized through location and size of windows and through use of glazing systems and shading devices appropriate to building orientation and space use.

Material surface	Solar Reflectance
Black acrylic paint	0.05
New asphalt	0.05
Black rubber or bitumen roof material	0.06
Aged asphalt	0.1
"White" asphalt shingle	0.2
Aged concrete	0.2 to 0.3
New concrete (traditional)	0.4 to 0.5
New concrete with white portland cement	0.7 to 0.8
Aged average white membrane roof	0.77
White acrylic paint	0.8
Average white membrane roof	0.82

Table 1 – Solar reflectance (albedo) of select material surfaces[5,6,7,8]

Color

Color (albedo) of precast concrete panels can be used to improve the energy conserving features of the walls. Panels with high albedo (generally lighter in color) can help reduce the urban heat island effect. Albedo, which in this case is synonymous with solar reflectance, is the ratio of the amount of solar radiation reflected from a material surface to the amount that shines on the surface. Solar radiation includes the ultraviolet, as well as the visible spectrum. Albedo is measured on a scale of 0.0 to 1.0, from not reflective to 100% reflective. Generally, materials that appear to be light-colored in the visible spectrum have high albedo and those that appear dark-colored have low albedo. Because reflectance in the solar radiation spectrum determines albedo, color in the visible spectrum is not always a true indicator of albedo.

On exterior surfaces, high albedo surfaces (generally light colors) decrease solar heat gain; low albedo (dark colors) increase solar heat gain. For instance, a low-albedo north wall and high-albedo east and west walls and roof form the most energy-conserving arrangement in a northern hemisphere climate that uses both heating and cooling. For example, changing an uninsulated wall in Miami from a low albedo to a high albedo can reduce annual cooling energy flux (heat flow through the building envelope) by about 15%. High albedo surfaces are especially important where cooling dominates the energy requirements. It should be noted, however, that the color of the exterior walls has less effect on energy consumption when the walls have high R-values and thermal mass. The benefit of high-albedo surfaces in decreasing cooling loads is often greater than the benefit of low-albedo surfaces in decreasing heating loads even in cold climates. This occurs due to the decreased benefit of the sun in the winter due to its lower angle, shorter days, and often more cloudy conditions.

Light-colored exterior surfaces also help reduce urban heat islands. Urban areas are up to 7 °F warmer than the surrounding areas. This difference is attributed to more buildings and pavements that have taken the place of vegetation. Trees provide shade that reduces temperatures at the surface. Vegetation including trees provides transpiration and evaporation that cool their surfaces and the air surrounding them. Where buildings and paved surfaces are required, using materials with higher albedos will reduce the heat island effect, save energy by reducing the demand for air conditioning, and improve air quality. Smog greatly increases whenever air temperatures exceed 75 °F. Using trees and light-colored surfaces can help reduce the number of hours a city temperature is above 75 °F, and thereby reduce smog.

Planting deciduous trees that lose their leaves in the winter, such as oak and maple, helps keep a building and the surrounding area cool. During the winter months when no leaves are present, the building benefits from solar gains. Trees planted on the south and west sides of building are particularly effective in providing shading and reducing solar gains in buildings.

Wind

Wind can decrease the exterior still-air film that usually surrounds a building and contributes to the insulating R-values of wall elements, thus increasing heating and cooling loads. This effect is most predominant in uninsulated concrete walls and becomes less marked as the R-value and thermal mass increase. Wind also carries solar heat away from a building and evaporates moisture on wet surfaces, thus possibly cooling the skin to temperatures lower than the ambient air. High winds create pressure differences across walls which will increase air leakage through the walls. Cold air leakage to the inside must be heated and probably humidified. This also requires an expenditure of energy. Planting non-deciduous evergreen trees on the windward (generally north and west) side of buildings decreases energy losses in winter.

Texture

Texture of precast panels has a minor effect on energy conservation. Increasing the surface roughness of the wall exterior causes an increase in the amount of sunlight absorbed and reduces the effect of wind on heat loss and gain. Ribbed panels act as baffles to wind, thereby reducing conductive heat loss and infiltration. Although this has a somewhat smaller effect than proper color selection, it can help to reduce total energy consumption. However roughness and ribs can also decrease solar reflectivity and increase solar heating.

Air Infiltration

Air infiltration has significant effects on the amount of energy required to heat and cool a building. Air leaks into or out of the building envelope through gaps between building materials. The amount of leakage is dependent on the size of the gaps and pressure differences due to building height, indoor-outdoor temperature differences, and wind pressure. Air leakage increases as pressure differences increase. Additional information on air infiltration is provided later.

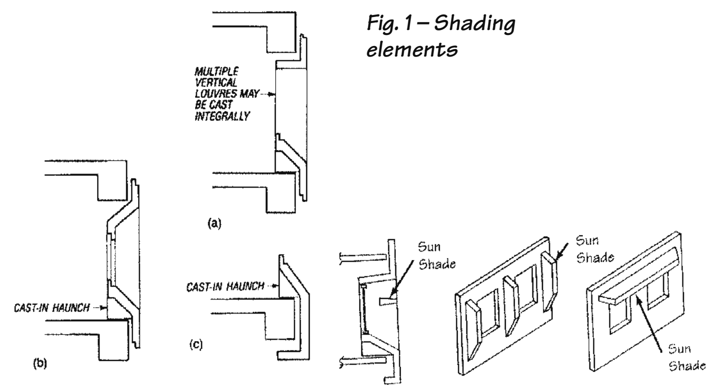


Fig. 1 – Shading elements

Shading

Shading is a fundamental design strategy for preventing solar heat gain and diffusing bright sunlight. Recessed window walls, vertical fins, and various other sculptured shapes facilitate the design of many types of shading devices for windows, including vertical and horizontal sunshades. In the cooler months, when the sun's angle of incidence is low, the shading devices may be angled to let the sunshine in and help reduce heating loads, as shown in Fig. 1. The shading approach selected can reinforce and enhance the design content and form of the building, in some cases becoming the prime form-giving element. Shading may have to be modified or compromised in order to meet other important requirements. Fig. 1 shows preferred cross sections (in elevation) for economical use of precast concrete as shading elements. Note that in each case, the spandrel and sunscreening elements are integral and may be lifted into place in one operation. The designer should be aware of the possibility of glass breakage from sharp shading lines if heat treated glass is not used where required.

Shading using horizontal or vertical plane(s) projecting out in front of or above a window can be designed to block the summer sun, allow most of the winter sun, and provide a view for occupants. If the plane projects far enough from the building, a single projection may be sufficient, as in the case of generous roof overhangs or windows recessed deeply between vertical fins. Alternatively, more

Fig. 2 – Horizontal sunscreen. Photo: © Brian Gassel/TVS & Assoc.

Fig. 3 – Horizontal sunscreen. Photo: © Steve Rosenthal

Fig. 4 – Detached screens. Photo: © Brian Gassel/TVS & Assoc.

Fig. 5 – Free-standing screen.

modest projections can be equally effective in shading but they must be more closely spaced. Closely spaced horizontal or vertical planes may begin to dominate the view out of a window and in any case change the scale of the window. The proportion of the space divided by the shading planes becomes as important as the overall window proportion in determining the aesthetic effect of the fenestration.

In summer, vertical fins will shade the early morning and late afternoon sun while horizontal fins keep out the high-altitude mid-day sun. In winter these shades will not interfere with the sun because of its low altitude and southerly azimuth at sunrise and sunset.

Horizontal shading is most effective on southern exposures, but if not extended far enough beyond the windows, it will permit solar impingement at certain times of the day. Designs may be flat or sloping; sloping versions may be of shorter length, but obstruct more of the sky view, Figs. 2 and 3. The detached screen panel parallel to the wall in Fig. 4 was used to block the rays of the sun, while still allowing light to enter the windows. Sun-shading may also be provided through the use of a free-standing perimeter structure set in front of the actual building enclosure, Fig. 5.

Fig. 6 – Variation of panel shape. Photo: © Balthazar Korab

Horizontal shading can have a significant impact on heat gain through windows. In Miami, overhangs with a projections factor of 0.5 can reduce annual energy flux (heat flow through the building envelope) by about 15%. The relative impact declines to about a 10% reduction in northern climates. A projection factor is defined as the horizontal length of the overhang divided by distance from the bottom of the glass to the underside of the projection. So a projection about half the height of the window, directly above the window, will have a projection factor of about 0.5. Permanent projections can be used to help meet the solar heat gain coefficient (SHGC) requirement when using *ANSI/ASHRAE/IESNA Standard 90.1-2001*.

In windy areas, the solar screens can be made to serve the double purpose of wind-breaks. Trees adjacent to the building can also serve the function of sun shading and windbreaks.

Sunscreen panels, which have pockets to receive precast double tees, form the south, east and west faces of the midrise office building in Fig. 6 while the north face features flat panels with punched openings.

Solar control through the use of shading devices is most effective when designed specifically for each façade, since time and duration of solar radiation vary with the sun's altitude and azimuth. The designer can predict accurately the location and angles of the sun, designing overhangs or fins to shade exactly the area desired. This type of envelope response can be seasonal (shade during certain times of the year) or daily (shade during certain hours of the day).

Fig. 7 – Variation of window opening orientation.

Fig. 8 – Use of vertical projections.

Fig. 9 – Cantilevered floor used to shade windows.

The versatility of precast concrete was used to change the window opening configuration with respect to wall orientation in order to maximize solar gains in the winter and minimize them in the summer, Fig. 7. Since the windows are small relative to the wall surface, the window units were splayed back on two different planes (at the sill and jamb) so that the windows could be recessed and shaded.

East and west facing windows are more effectively shaded by vertical projecting planes, Fig. 8. Vertical projections from either side of the window narrow the peripheral view from the window. The further south a building is located, the more important shading east- and west-facing windows becomes, and the less important shading south-facing windows becomes. This is due to the high position of the summer sun in southern latitude with the resulting decrease in direct sunlight transmitted by the south-facing windows.

Fig. 10 – Deep recessed windows. Photo: © 1990 Glen Allison

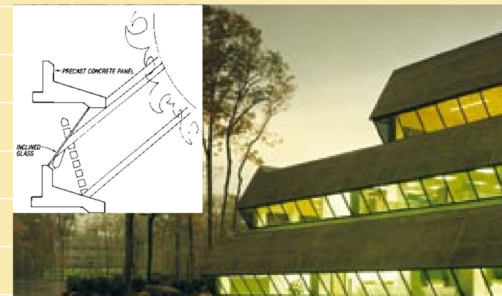


Fig. 12 – Inclined glass. Photo: © Steve Rosenthal

Fig. 13 – Hooded shading device.

Fig. 11 – Deep recessed windows and overhang (eggcrate device). Photo: © MBA

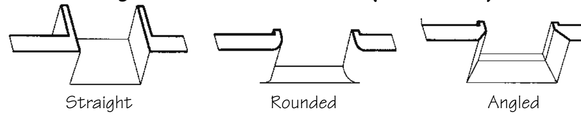
In Fig. 9 the top floor is cantilevered over the main floor to shade the windows. All second floor windows on the east and west sides are oriented directly south or north for sun control. The vertical wingwall shading devices completely shade the windows during the four summer months.

The use of three-dimensionally profiled precast concrete window wall units permits windows to be recessed within an enclosing concrete surround. The sides may be vertical or angled. Deeply recessed windows are particularly effective in minimizing solar heat gains without reducing natural light and view. Eggcrate shading works well on walls facing southeast, and is particularly effective for a southwest orientation. Because of its high shading efficiency, the eggcrate device (deeply recessed windows) is often used in hot climates. The deep, recessed window areas and massive overhangs in Fig 10 illustrate the total flexibility of design that precast concrete offers the architect.

Three foot deep "eyebrows," Fig. 11, was the shading device used to keep out the sun's rays in the summer and reduce cooling loads.

Precast concrete and inclined glass can work together for optimum use of daylighting. Direct sun strikes the glass at an angle and is reflected, reducing glare, while indirect sunlight reflects off the sill of the precast concrete panel and through the glass to provide soft natural light at the perimeter of the building, Fig. 12. By keeping the direct rays of the sun out of the building, cooling loads are considerably reduced and daylighting is maximized. "Eyelid" or hooded shading devices and inclined glass can be very effective in controlling the penetration of the sun into a building by reducing the area of glass exposed to the sun, Fig. 13. This shading device softens the brightness contrast between the interior and exterior. Rounded head, sills and jambs or deep window wells could also be used to soften brightness contrasts, Fig. 14.

Fig. 14 – Jambs, Head or Sill (Rotate 90°).



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References available online

To be continued. Thermal resistance (R-value, thermal mass and moisture content of exterior envelope materials) will be covered in the Summer 2005 issue