CHAPTER 7 SOLAR RADIATION

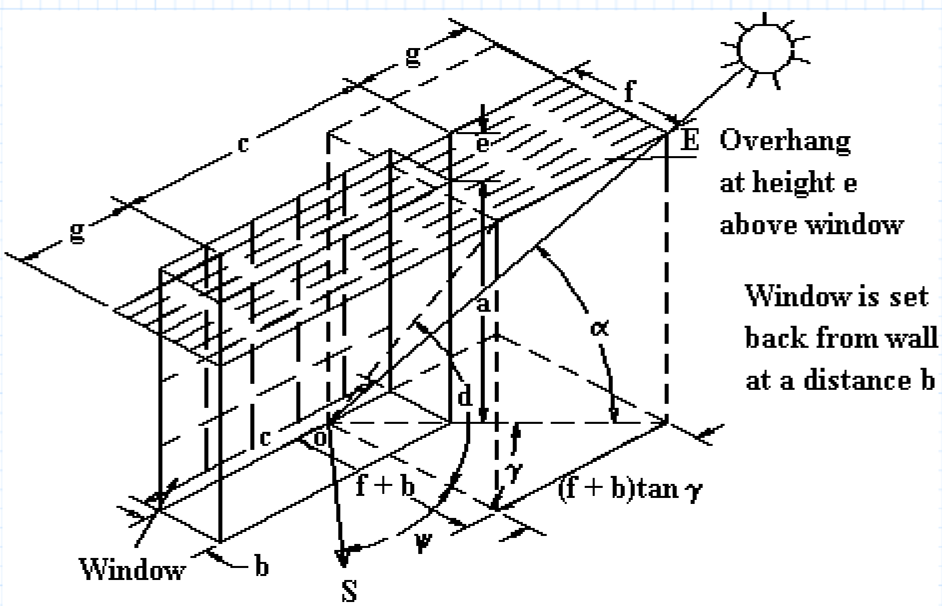
7.4 Solar Shading Calculations and Design of Overhangs

Architectural projections, known as overhangs when they are horizontal or side fins when vertical, are commonly used in the building envelope to prevent or control the irradiation of a surface (typically a window). The shading device is usually designed to exclude solar radiation in summer when it contributes to a reduction in cooling loads and to admit it in winter when it contributes to a pleasant indoor environment and a reduction of heating requirements.

Here we consider a window (width c and height a) set back from the front wall surface at a distance b as shown in the in the sketch below. Our objective is to design an overhang with length equal to c+2g, and width f. Note that the overhang is located at a distance e above the window.

The ray projection diagram shows the minimum dimensions for f and g for complete shading of the window given a solar altitude angle equal to α, surface solar azimuth angle γ and surface azimuth angle ψ.

Point E at the outer edge of the overhang is projected to point O on the window plane.



Example:

$L := 42 \cdot deg$ latitude

South-facing vertical window:

$\psi := 0 \cdot deg$ $\beta := 90 \cdot deg$

The date is April 15:

$n := 31 + 28 + 31 + 15$ $n = 105$

Solar time is 9:00 a.m. Therefore, hour angle

$h := (9 - 12) \cdot 15 \cdot deg$ $h = -45\ deg$

$\delta := 23.45 \cdot deg \cdot \sin\left(360 \cdot \frac{284 + n}{365} \cdot deg\right)$ solar declination

$\alpha := \operatorname{asin}(\cos(L) \cdot \cos(\delta) \cdot \cos(h) + \sin(L) \cdot \sin(\delta))$ solar altitude

$\delta = 9.415\ deg$ $\alpha = 38.893\ deg$

$\phi := \operatorname{acos}\left(\frac{\sin(\alpha) \cdot \sin(L) - \sin(\delta)}{\cos(\alpha) \cdot \cos(L)}\right) \cdot \frac{h}{|h|}$ solar azimuth

$\phi = -63.671\ deg$

$\gamma := \phi - \psi$ $\gamma = -63.671\ deg$ surface solar azimuth

The profile angle d is given by

$d := \operatorname{atan}\left(\frac{\tan(\alpha)}{\cos(\gamma)}\right)$ $d = 61.197\ deg$

Window geometry (meters):

$a := 1.5$ $c := 2.0$ $b := 0.2$ $e := 0.32$

Now determine the dimensions f and g for the overhang such that the window is completely shaded between 9 a.m. and 3 p.m. solar time from April 15 to August 29. Note that the period in question is symmetrical about June 21. Therefore, solar angles for the two days are the same for given solar times.

$f := \dfrac{a+e}{\tan(d)} - b$ $\qquad$ $g := f \cdot |\tan(\gamma)|$

$f = 0.801$ $\qquad$ $g = 1.618$

Overhang dimensions:

$c + 2 \cdot g = 5.236$ $\qquad$ length

$f = 0.801$ $\qquad$ width

The window is continuously shaded between 9 a.m. and 3 p.m. solar times on April 15 because the solar altitude is higher and the solar azimuth smaller than the values found above. The window is also shaded during these times between April 15 and August 15 because the solar altitude becomes higher during this period.

Now let's see how much of the window is sunlit at solar noon on December 22.

Solar noon: $\qquad$ $h := 0$

South-facing, vertical surface: $\qquad$ $\gamma := 0$

$n := 356$

$\delta := 23.45 \cdot deg \cdot \sin\left(360 \cdot \dfrac{284+n}{365} \cdot deg\right)$

$\alpha := \operatorname{asin}(\cos(L) \cdot \cos(\delta) \cdot \cos(h) + \sin(L) \cdot \sin(\delta))$

$\delta = -23.445\ deg$ $\qquad$ $\alpha = 24.555\ deg$

In this case

$d := \alpha$

The projection of the overhang edge on the window plane lies at a distance a' from the top of the window given by

$$a' := (f + b) \cdot \tan(d) - e \qquad a' = 0.137$$

Therefore, percent sunlit is:

$$\frac{a - a'}{a} = 90.853\ 1\%$$

For a window set back at a distance b from the wall surface, but without an overhang, we may show that the sunlit fraction of window is:

$$F_s := 1 - \frac{b}{a} \cdot \tan(d) - \frac{b}{c} \cdot \tan(\gamma) + \frac{b^2}{a \cdot c} \cdot \tan(d) \cdot \tan(\gamma)$$

$F_s = 0.939$ (Note that the last two terms are zero in this case)

Therefore, 93.9% of the window is sunlit.