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Principles of Solar Shading

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Please note

The solar energy that enters a building through glass areas in the outside walls can be one of the major sources of heat in many contemporary buildings. This heat is unwanted in summer and has to be expelled by the cooling system. Heat gain is not the only problem associated with sunlight streaming through a window; glare is equally important. This Digest is intended to supplement an earlier one, Solar Heat Gain Through Glass Walls (**CBD 39**), by discussing both heat and glare control with various types of shading devices.

Direct sunlight falling on a bright surface can cause glare with attendant visual discomfort unless the level of illumination in the other parts of the room is not too different from that of the sunlit areas. Thus, paradoxically, a high level of direct solar illumination requires a concomitant high level of general illumination which may have to be provided artificially. It costs money to achieve this and much more to remove the resulting heat. A good shading system, on the other hand, will permit lower levels of illumination to be specified, because the eye can accommodate itself without strain to function within a wide range of illumination provided there is not too great a difference in the brightness of the objects that it sees.

With this background to the problem, it is possible to set out a list of objectives that the building designer must strive to meet when he designs windows and their shades. These are:

1. to minimize heat gain during summer;
2. to prevent the direct rays of the sun from falling on any light coloured surface that is visible to the normal occupants of the room;
3. to allow natural light to enter in such a way that it can be diffused as evenly as possible over the whole room;
4. to interfere as little as possible with the view from the window.

The last two requirements are the real nub of the problem; they represent the reasons for using a transparent rather than an opaque wall section in the first place. Obviously any shading system must involve a compromise between the requirement of unobstructed view and the exclusion of solar energy.

The Position of Shadows

A building may be shaded by a neighbouring structure or trees and consequently not require any special shading system at all. It is important, therefore, to determine which parts of a building facade will be in direct sunlight and which will be shaded at any particular time. This is the obvious first step in designing a shading system. It is also a necessary preliminary to the design of an air-conditioning system, because the cooling equipment and controls must allow for the continuously changing pattern of sunlight and shade on wall and window areas.

The boundaries of the shadows on a wall, whether from a shading device or an adjacent object, can be found by projecting the outline of the shading object on the wall - the lines of projection being parallel to the sun's rays. The direction of the sun's rays relative to the surface of a wall can be specified by two angles: the horizontal and vertical shadow angles (sometimes called the wall solar azimuth and profile angle, respectively).

The horizontal shadow angle (H.S.A.) is the angle on a plan drawing between a line perpendicular to the wall and the projection of the sun's rays on the horizontal plane. Similarly, the vertical shadow angle (V.S.A.) is the angle, on a vertical section drawing of the wall, between a line perpendicular to the wall and the projection of the sun's rays on the plane of the drawing. When these angles are known it is a simple matter to establish the boundaries between the sunlit and shaded areas on the facade, and inside the building too if part of the sunlit facade is transparent. Shadow angles are for a specific time, date, latitude and wall orientation, but are completely independent of the shape or position of the shading surface.

How to Find the Shadow Angles

The most precise way; of finding shadow angles is by calculation, using tables of solar altitude and azimuth as data. The H.S.A. is the difference between the solar azimuth angle and the azimuth of the normal to the wall. The V.S.A. is related to the H.S.A. and the solar altitude angle by the relationship

$$\text{Tan V.S.A.} = \frac{\text{Tan Altitude Angle}}{\text{Cos H.S.A.}}$$

The solar altitude and azimuth angles for any time date and latitude can be obtained from navigation tables such as the "Tables of Computed Altitude and Azimuth" published by the U.S. Navy Hydrographic Office and available from the Superintendent of Documents in Washington. The navigation tables are so voluminous that they are not very convenient for architectural purposes. Fortunately, the Swedish National Council for Building Research published, in 1962, a set of solar position tables specifically intended for building designers. These give the solar azimuth and altitude angles and the tangent of the altitude for every hour of the first and fifteenth day of every month for many latitudes.

The shadow angles can also be determined by using any one of the many charts or sun calculators that have been prepared by different organizations. One of the most convenient and widely used of the sets of solar diagrams is the Sun Angle Calculator, which is available from the Libby-Owens-Ford Glass Company in the United States. This is a slide rule type of device that will indicate directly the value of H.S.A. and V.S.A. for any time and date during the year at all the latitudes evenly divisible by four between 24 and 52 degrees.

The calculator can also be used to estimate the solar irradiation that any sunlit surface can receive on a clear day at any season. This is of particular significance to the air-conditioning designer, but should also be considered by the architect who designs the shading.

Another very useful set of charts is the *Diagrammes Solaires* prepared by the Centre Scientifique et Technique du Bâtiment in France. These charts and an accompanying brochure on how to use them (in French) are available through the Division of Building Research of the National Research Council of Canada or directly from C.S.T.B. in Paris. They can be used to construct the H.S.A. and V.S.A. for any combination of time, date, latitude and wall orientation, and are highly recommended to the designer who wishes to make an extensive analysis of solar effects.

The position of shadows on the various facades of a building can be determined very easily if an architectural model has been constructed. The model is mounted on a heliodon and illuminated by a beam of light from a reasonably bright source such as a slide projector. A heliodon is a special turntable that causes the model to move with respect to the lamp as the real building will move with respect to the sun. It is adjustable for latitude and date, and the platform carrying the model can be rotated to simulate the daily rotation of the earth. The orientation of the building is taken into account when the model is mounted on the rotatable base. Plans are available from the Division of Building Research for a very simple heliodon, which can be constructed of wood. The use of a heliodon is probably the most convenient and economical means of determining shadow positions whenever a suitable model is available.

Shading Devices

One fact is basic to any consideration of shading; a window facing south or with any bearing up to about 90 degrees from south is subjected to almost the same annual maximum of solar irradiation. It occurs when the sun is directly in front of the wall and between 30 and 35 degrees above the horizon. The time and date when these conditions obtain depends on the wall orientation - east and west facades experience their maximum during July, where as a south-facing surface receives its annual maximum in the late fall or winter.

A simple projection from a wall is a relatively ineffective shade when the vertical shadow angle is as low as 30 degrees, hence, a blind type of shade is required to control the peak solar irradiation. The best position for this shade depends on the orientation of the window. It should be on the outside of east and west windows to keep the summer heat gain low, but can be on the inside of a south window if a canopy shade is also provided to control the heat gain during summer.

Outside Shades

Table I gives the length of horizontal projection necessary to cast a shadow 1 foot high on a wall facing different directions at 44 degrees north latitude. The values for orientations east of south also apply for the same angle west of south if the times are reflected about noon.

Table I. Length of Projection in Feet Required to Cast A Shadow 1 Foot High on a Building at 44° North Latitude

Time (Sundial Time)	Wall Orientation							
	South		30° East of South		60° East of South		East	
	21 May 21 July	21 March 21 Sept.	21 May 21 July	21 March 21 Sept.	21 May 21 July	21 March 21 Sept.	21 May 21 July	21 March 21 Sept.

8	0.14	0.97	0.83	2.04	1.29	2.56	1.41	2.40
9	0.30	0.97	0.73	1.53	0.95	1.68	0.93	1.39
10	0.39	0.97	0.62	1.24	0.69	1.18	0.57	0.80
11	0.43	0.97	0.51	1.02	0.45	0.81	0.27	0.37
12	0.45	0.97	0.39	0.84	0.22	0.48	-	-
13	0.43	0.97	0.24	0.65	-	0.16	-	-
14	0.39	0.97	0.05	0.44	-	-	-	-
15	0.30	0.97	-	0.14	-	-	-	-
16	0.14	0.97	-	-	-	-	-	-

The numbers in the table show that windows facing south can be completely shaded from 21 March to 21 September by a projection just a little shorter than the height of the window, whereas a window facing only 30 degrees from south needs a projection of more than twice the height of the window to achieve essentially the same shading. Projections of more than 5 or 6 feet are usually impractical structurally and undesirable aesthetically. Tall windows can be shaded, however, by using several shorter shades spaced at regular intervals between the sill and head. As the number of shades increases and the size of the individual shade (and the gap between them) is reduced such a system evolves into a venetian blind. Most of the comments in the following section on slat type blinds apply to external slat type shading as well.

There is one other technique that can be classed as an outside shade and should be considered particularly for east or west facades where the canopy type is of very limited value. This is to use a sheet of heat-absorbing glass as a semi-transparent shade. When there is a free circulation of outside air over both sides of the heat-absorbing glass, most of the absorbed energy is dissipated to the air and the room heat gain is correspondingly reduced. Heat-absorbing glass absorbs both the visible and near infra-red radiation in the solar spectrum, but the absorption factor for the infra-red is usually larger than for the visible. In situations where the view is of primary importance, a semi-transparent glass shade may be the best type of solar control device.

Slat Type Blinds

A horizontal slat type of blind with the slats slightly wider than the gaps between them can be adjusted to intercept all of the direct sunlight coming through any window at any time of the year. The light that enters the room in this case has been reflected at least once from the surfaces of the slats. The amount of light that gets through a venetian blind depends on the colour of the slats, the angle at which they are set, and the vertical shadow angle that obtains for the window at the particular time in question. Figure 1 shows the transmission factors for a typical light-coloured venetian blind with slats set horizontally and tilted at 22 1/2 degrees and 45 degrees. Each of the curves starts at the V.S.A. where no direct sunshine can shine through the blind. The curves in this figure show that a horizontal slat type of blind can transmit about 15 per cent of the direct solar radiation even though there is no direct sunshine going between the slats.

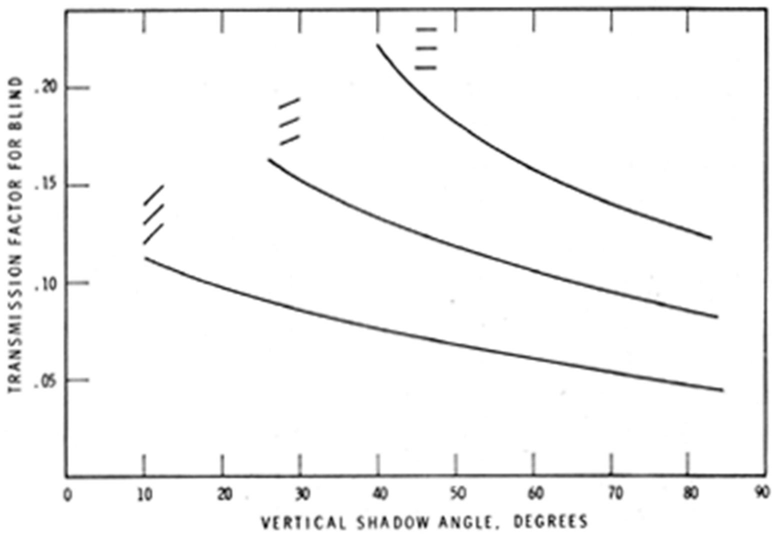

Figure 1. Transmission factors for light coloured venetian blinds.

A little over half of the light that is transmitted through the blind enters the room in an upward sloping direction, as if it were from a source on the ground in front of the window. This light falls on the ceiling where it is again partially reflected and so adds to the general illumination of the room. The remainder of the transmitted light enters the room as though the blind itself were a source of diffuse light. The brightness of the blind can be reduced by painting the under surface of the slats a darker colour. This causes only a slight reduction in the amount of light that falls on the ceiling, because this comes mainly from the upper surface of the slats.

A light coloured blind with slats at about 20 degrees absorbs about half of the direct solar radiation falling on it and reflects about 35 per cent toward the outside. If the blind is inside the room, most of the absorbed energy is transferred to the room air and contributes to the room heat gain - the only reduction is the radiation reflected back through the window. If the blind is on the outside of the window, however, the absorbed energy is transferred to the outside air and the heat gain is much less.

With double-glazed windows there is a possibility of placing a shade between the panes of glass. In this case, some of the absorbed energy is transferred to the room and the rest to the outside air. Thus, the use of an inter-pane blind is intermediate in its effectiveness for reducing solar heat gain, although it has almost the same light transmission characteristics as an inside or outside blind.

A slat type blind can be made with the slats vertical instead of horizontal. This kind of blind has characteristics similar to those of the horizontal slat variety except that the transmission depends on the horizontal rather than the vertical shadow angle. Figure 1 applies therefore, for a vertical slat blind if the abscissa is taken as horizontal shadow angle. The most important difference is that the bright outer surface of the vertical slats may be in the field of view of some of the occupants of the room and consequently cause glare. Also, the transmitted light will not be distributed as uniformly as if the slats were horizontal.

Drapes

Drapery is not usually as reflective as white painted blinds and does not transmit light toward the ceiling more readily than towards the occupants of a room, as a venetian blind does. In these respects, drapery is inferior to venetian blinds for solar control. If drapery is required, however, as part of the decoration of a room, it can also be used to control glare. As with inside blinds, drapes can be easily adjusted to allow an uninterrupted view when they are not needed to intercept sunlight.

Summary

Large areas of glass in any facade that receives direct sunshine require shading if people must work near the windows. The best arrangement, from the point of view of solar control, is to design the building with the glass facing north; the second best arrangement is to have it facing south and to provide both a canopy shade and a venetian blind when windows must face east or west, the summer heat gain can be minimized by placing a slat type shade on the outside, or if this is impractical, by using double glazing with a blind between the panes.