Building and Environment, Vol. 28, No. 1, pp. 69–72, 1993.
Printed in Great Britain.

6687

0360–1323/93 $5.00+0.00

A Practical Tool for Sizing Optimal Shading Devices

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A nomogram is presented for use in regions with a-Mediterranean climate. Architects can use this tool as an easy way to optimize the design of shading devices. The nomogram allows the performance of a proposed external fixed shading device to be evaluated. The input variables required are (i) the location of the building, (ii) the orientation of the facade and (iii) two adimensional characteristics corresponding to the opening-shading device system. The accuracy reaches its minimum value during intermediate seasons but the margin of error is less than 10%.

INTRODUCTION

SOME modern buildings are characterized by the widespread use of glass on building facades. In addition to this, the use of lightweight structures has caused overheating problems even in cold or temperate countries. In the Mediterranean climate with warm summers it becomes important to shield the internal environment from any supplementary gains other than the internal ones so as to prevent excessive energy penalties due to additional cooling loads in summer, and all year round in cases like commercial buildings.

In order to minimize heat gain during summer while allowing winter sun to come in, and to interfere as little as possible with the window views, the building designer must consider the use of all shading devices and study their performances in all seasons.

There are many types of shading device [1]. It has been shown that external arrangement of shading devices is much more effective than internal arrangement, and their efficiency also depends on their orientation [2]:

- Adequate shading for east and west orientations can be provided by an egg-crate shading device, especially if the vertical components are at angle of 45° towards the south.
- For south, south-east and south-west orientations, while a frame shaped shading is most effective, horizontal shading is also found to be quite effective.

SHADING ANALYSIS

The existing tools for shading analysis may be divided into three categories [3]: graphic tools, manual calculation methods and scale models.

The conventional method based on stereographic projections does not provide accurate analytical information to assess the performance of a shading device from the point of view of quantitative energy, but it is a quick method for daylight obstruction analysis.

The advantage of using an analytical model is that it can provide knowledge of the exact amount of shading which will be supplied under different conditions (location, orientation, time, etc.) and it can integrate its efficiency over a period. Nevertheless, the solar shading models provide information of a strong regional character.

The existing computer models are not user-friendly for architects. Thus, the adoption of such simple tools as the nomogram presented here, with a suitable level of accuracy, may be suitable for inclusion in cooling studies.

Shading coefficient

The efficiency of a shading device is defined as the fraction of the total incident radiation transmitted through the opening. Therefore, the efficiency of a shading device is characterized by an adimensional parameter f defined as

$$f = I_p/I_i \times 100 \quad (<1)$$

where I_p, I_i, are the radiation incident over the opening with and without the shading device. This parameter is known as the solar factor of the opening or its shading coefficient (see values in Table 1).

The time dependent f-value is a geometric variable which depends on the shading device-opening system geometry, sun position, wall orientation, etc. The value of f integrated, for example throughout one day, is a geometric and solar radiation dependent variable.

To evaluate the influence of a shading device, energy behaviour such as daylight supply has to be considered.

Figures 1(a) and 1(b) show the hourly variation of f in absence of control for cold and warm seasons; we can observe an important variation in summer–winter behaviour of f in the near south orientations, which diminishes progressively to the east. In summer f takes

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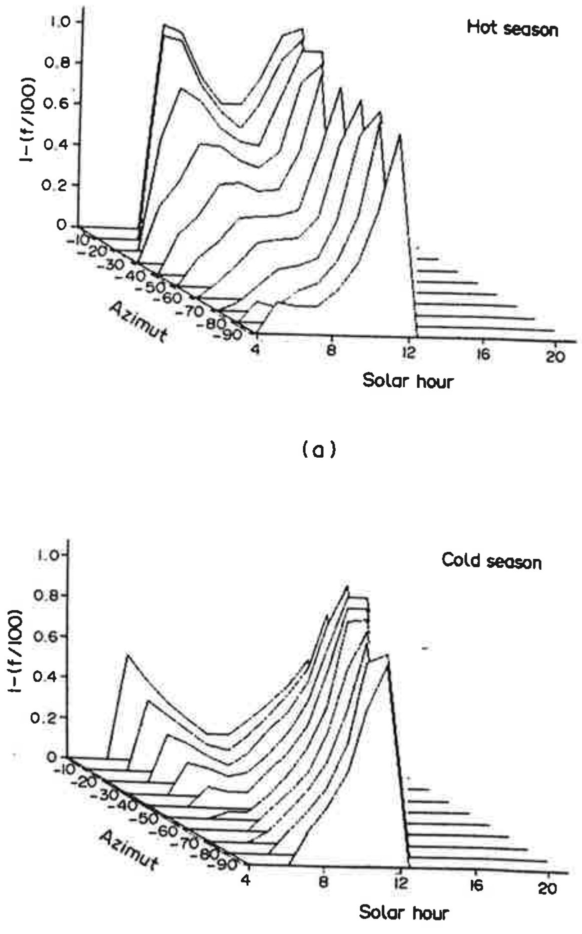
Table 1. Shade protection devices and their shading coefficient (i.e. their transmitted radiation impact)

Type of shading device	Shading coefficient
Venetian blind	0.75
Roller shade	0.62–0.81
Tinted glass	0.52–0.66
Non-dense tree	0.50–0.60
Insulating curtain	0.36–0.60
Outside shade screen	0.23–0.28
Outside metal blind	0.28–0.43
Coating on glass surface	0.20–0.50
Dense tree	0.20–0.25
Outside awning	0.25
Outside fixed shading device	0.23–0.31
Outside moveable shading device	0.10–0.15

lower values because the solar altitude Ó is greater, and this bears with a greater shaded surface.

DESIGN OF A SHADING NOMOGRAM FOR A HORIZONTAL OVERHANG

The hourly solar intensity supplies a weighting factor of the efficiency of a shading device according to the quantity of solar radiation entering versus total hourly available radiation. A monthly shading coefficient gives an accurate indication of the seasonal effectiveness of the device.



(a)

(b)

Fig. 1. Seasonal efficiency of an opening with solar control, (a) summer and (b) winter.

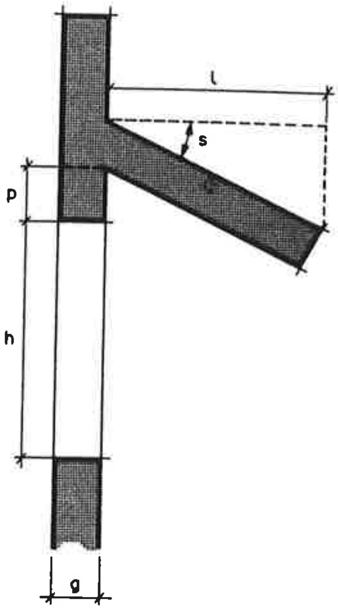


Fig. 2. Geometry of an overhang.

Model hypothesis

The shading device studied corresponds to the overhang type (Fig. 2), where the shading device-opening system is defined according to the following parameters:

l, horizontal length of the sun control;
L, frontal length of the overhang;
s, the control slope with respect to the horizontal plane;
h, height and width of the window;
w, width of the window;
g, thickness of the wall; and
p, the level of overhang above the top edge of the window.

Some structural constraints such as wall thickness reduce the possible range of variation of the geometrical parameters which define an overhang-opening system.

The constrained dimensions which have been fixed to a usual set of values are: w/h $(=1.0)$, g/h $(=0.2)$ and the overhang slope s $(=0°)$, and the relation l/h vs p/h has been studied.

The location of the building is characterized by its latitude in order to take into account the variation in solar radiation. The azimuth angle of the facade completes the description of the system location.

Solar radiation on a horizontal plane has been considered to be composed of a direct solar component, an isotropic diffuse component and an average reflected component, also of an isotropic nature.

Although the use of anisotropic models is recommended, these have not been considered because from a strict energy point of view the f-value shows no relevant change. However, daylight studies have to be carried out using anisotropic models [4].

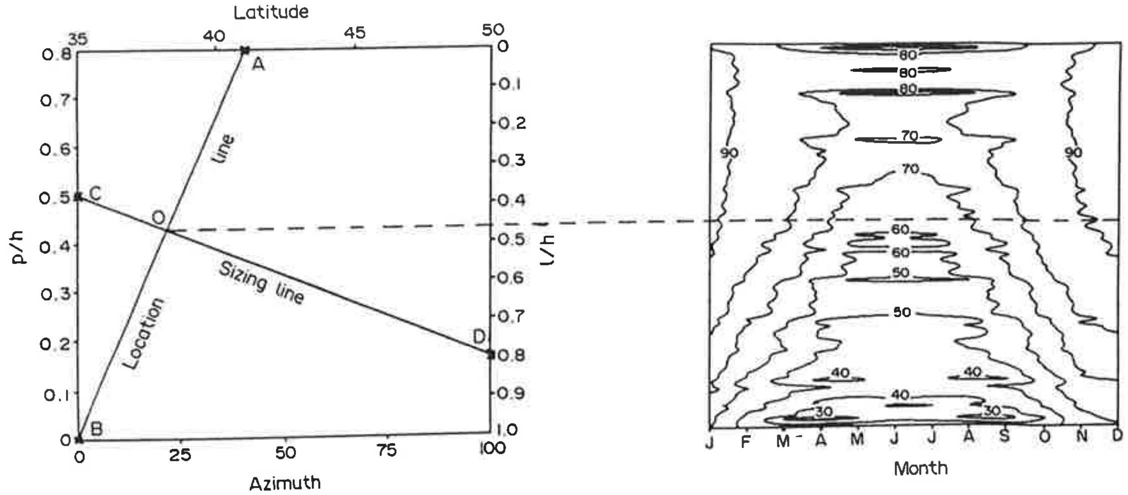


Fig. 3. Efficiency of a proposed solar control.

Graphic results

The resulting nomogram under the conditions mentioned in the previous section consists of two squares. The left one is used to draw the location line that goes from the latitude value of the location to the opening orientation, and the sizing line that joins the combination of *l*/*h* and *p*/*h* values of solar control-opening system. The right square shows the shading coefficient isolines in all months of the year.

We can observe that *p*/*h* and *l*/*h* scales are inverted against each other. We have adopted this criterion in order to take the relative dimensions which produce a similar amount of shading at the same horizontal level, that it is a lower shading efficiency for values that were at the top of the left square (greater *f* value), as we can see in the values of isolines, and vice versa.

Examples

To exemplify the practical use of the nomogram, we present the resolution of two examples we have worked on, where we use this simple practical tool to design solar controls.

In the first one we calculate the average shading coefficient of an existing overhang in a fixed location for all the months of a year. In the second one we can establish the range of available overhang dimensions according to some specific seasonal radiation thresholds.

(a) Efficiency of an existing solar control:

In order to calculate the energy influence of a horizontal overhang, Fig. 3 shows the way to determine its monthly efficiency straight away, with an error of less than 10%. Guidelines:

(i) draw the location line from the location of the building (point A, latitude = 41°) to the orientation of the opening (point B, azimuth = 0°, corresponding to the south).

(ii) draw the sizing line joining the points which represents the relative dimensions of solar control-opening system (points C, $p/h = 0.5$ and D, $l/h = 0.8$).

The horizontal line (dashed line in the figure) that starts at the intersection point O crosses the lines of equal efficiency (or shading coefficient isolines) and shows the control performance for every month of the year in the right picture.

With a normal error of less than 10% we obtain from the nomogram the following *f* values according to the system dimensions considered:

Month	J	F	M	A	M	J	J	A	S	O	N	D
f (%)	92	86	81	72	64	63	64	69	77	83	88	93

(b) Sizing of an overhang with some energy and seasonal requirements:

In designing a fixed horizontal overhang in regions with a Mediterranean climate, a solar radiation threshold for summer and for winter must be established as design constraints in order to avoid overheating problems in summer and allow a minimum of heat gains in winter.

The use of the nomogram in this case is as follows:

(i) take a value of the *f*-threshold for December (>70%) and another one for June (<50%) which define a zone in the right picture of the nomogram;

(ii) select a horizontal line inside this region (named line of constraints);

(iii) draw the location line (latitude = 41°, azimuthal opening angle = 0°, 90°, south and east, respectively, Figs 4(a) and 4(b).

The location line crosses the line of constraints at a point O. The set of possible combinations of values of *p*/*h* and *l*/*h* is obtained by considering the *p*/*h* interval that according to the normal use of the nomogram carries the major interval of *l*/*h*. The reason for working in this way is that *l*/*h* is the most important relative dimension of an overhang in architectural projects.

It is possible that there is no solution if the *f*-threshold is not available.

CONCLUSIONS

In order to evaluate the energy efficiency of a fixed external overhang, or to design its adequate dimensions,

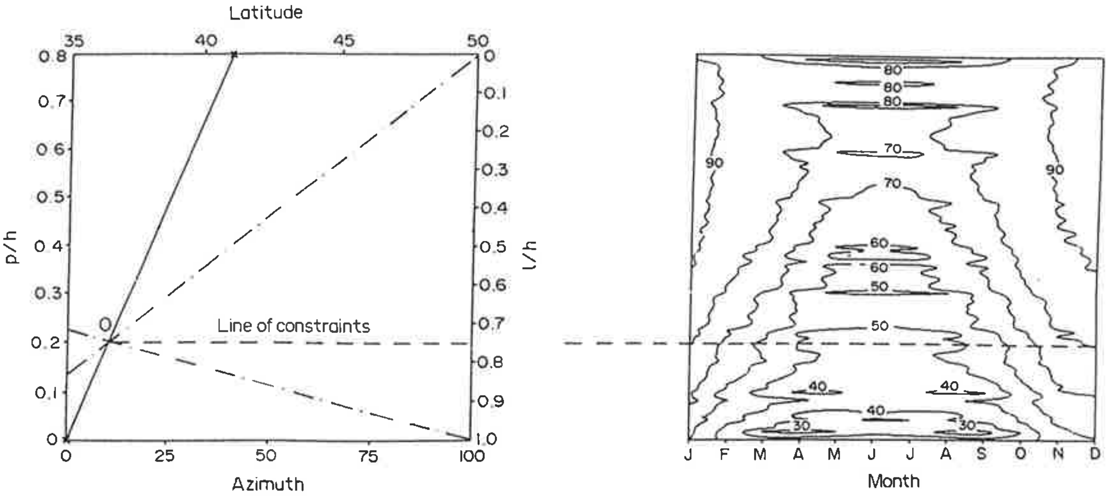


Fig. 4(a). Sizing a solar control with energy requirements: south orientation.

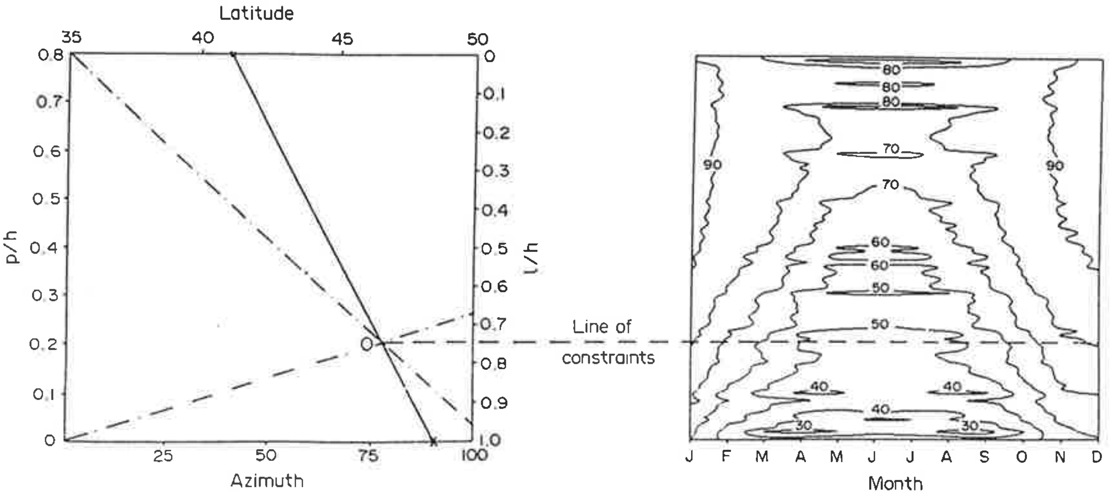


Fig. 4(b). Sizing a solar control with energy requirements: east orientation.

if the daylighting is not an important design requirement, a nomogram is proposed as a practical tool. Its study allows us to establish the following conclusions:

(a) To assess the performance of a shading device in the region from 35° to 50° latitude the proposed nomogram can be used with 10% as the maximum error.

(b) Its use allows us to determine the appropriate set of sizing combinations $(l/h, p/h)$ in order to achieve the energy requirements for designing a new overhang or qualifying an existing one in terms of energy.

(c) The overhang shading device is an appropriate typology of solar control for a south facade and not recommendable for east-west facades.

REFERENCES

1. E. González, E. Hinz, P. de Oteiza and C. Quirós, *Proyecto Clima y Arquitectura. Universidad de Zulia, Maracaibo*. Ed. G. Gili, México (1986).
2. M. S. Sodha, N. K. Bansal, P. K. Bansal, A. Kumar and M. A. S. Malik, *Solar Passive Building*. Pergamon Press, Oxford (1986).
3. P. Achard and R. Gicquel,(Eds.), *European Solar Passive Handbook*, preliminary edition, CEC (1986).
4. J. Jorge, J. Puigdomènech, J. A. Cusidó and J. Esteve, El modelo de Pérez de distribución de la radiación difusa: efectos sobre el dimensionado de controles solares y de iluminacíon natural. *Proceedings of the V Congreso Ibérico de Energias Renovables*, pp. 339–348. ISES, Madrid (1990).