BUILDING DIGEST

CENTRAL BUILDING RESEARCH INSTITUTE, INDIA

DETERMINATION OF SUNLIGHT PENETRATION INDOORS

Introduction

It is a good practice to be able to predetermine the thermal performance of a proposed building with special reference to the availability of sunshine inside rooms or verandahs during winter and its exclusion during summer. An experienced designer may possibly know in a general way as to what extent sunlight may enter a fenestration but an exact delineation of the sunlight pattern indoors would require mathematical calculations. This digest provides a quick and easy graphical method for assessment of sunlight through openings.

How Shadows Are Formed ?

The procedure consists of determining the shadow positions corresponding to the four sides of a rectangular opening, on the floor or the inner vertical surfaces. The principle employed is the projection of shadows of the two vertical sides of a rectangular opening on to the floor and vertical inner surfaces and to graphically determine their direction and magnitude.

The pattern of sunlight penetration indoors through openings can be easily obtained by understanding the following properties and principles of shadow formation :

1. The shadow of the vertical edges of a rectangular opening can be in any direction on the floor, depending on the position of the Sun, but if it extends to a vertical inner surface, it rises up only vertically.

2. The length of the shadow of the vertical edges of an opening on the floor varies with the altitude of the Sun but that on a vertical surface is always equal to the corresponding length of the vertical edge

3. The length of the shadow of a horizontal object on a horizontal surface will be equal to the length of the object and in the same orientation as the object.

4. The shadow edges corresponding to any two parallel edges of the opening will also be parallel to each other on the same surface.

5. The shadow of the horizontal edges (top and bottom) of the opening on the floor or on the rear wall of the interior space will be parallel to the rear edge of the floor. On the rear wall therefore, it will be horizontal. But on the side-wall indoors, (sunlight can fall only on one side-wall at a time it will be slanting upwards in the outward direction, commencing from the point where it first reaches the side wall upto the point where the horizontal edge of the opening meets (or would meet when extended) the side wall

Shadow Chart

A shadow chart for 29°N latitude (Delhi and neighbourhood) is shown in Fig. 1. On the chart one finds (a) Curved lines showing dates, (b) Straight lines showing hours and (c) Concentric circular scale bearing numbers.

The curved lines (a) show the traverse of the shadow tip in sunlight of a vertical object of unit height placed at P on a horizontal plane, on the days of the year marked thereon. Since the Sun traverses the same path in the sky on two days in a year (except on solstices), each curved line (except the outermost two for solstices) represents the shadow traverse for the two days, indicated thereon. The straight lines (b) represent the hours (solar time) of the day. The concentric circles (c) with centre at P, represent a scale to read the magnitude of the shadow as multiple of the height of the vertical object. The geographic north and other points of compass are also shown on the chart to orient the building plan suitably.

A straight line joining P (Fig. 2) to the point of intersection A of the curved (day) and straight (hour) lines, represents the direction of the shadow of a vertical object at P at 11 a.m. on Dec. 22. The point A, reading 1.4 on the circular scale will give the length of the shadow as 1.4 times the height of the vertical object, and this length can be marked off from P on the shadow line PA.

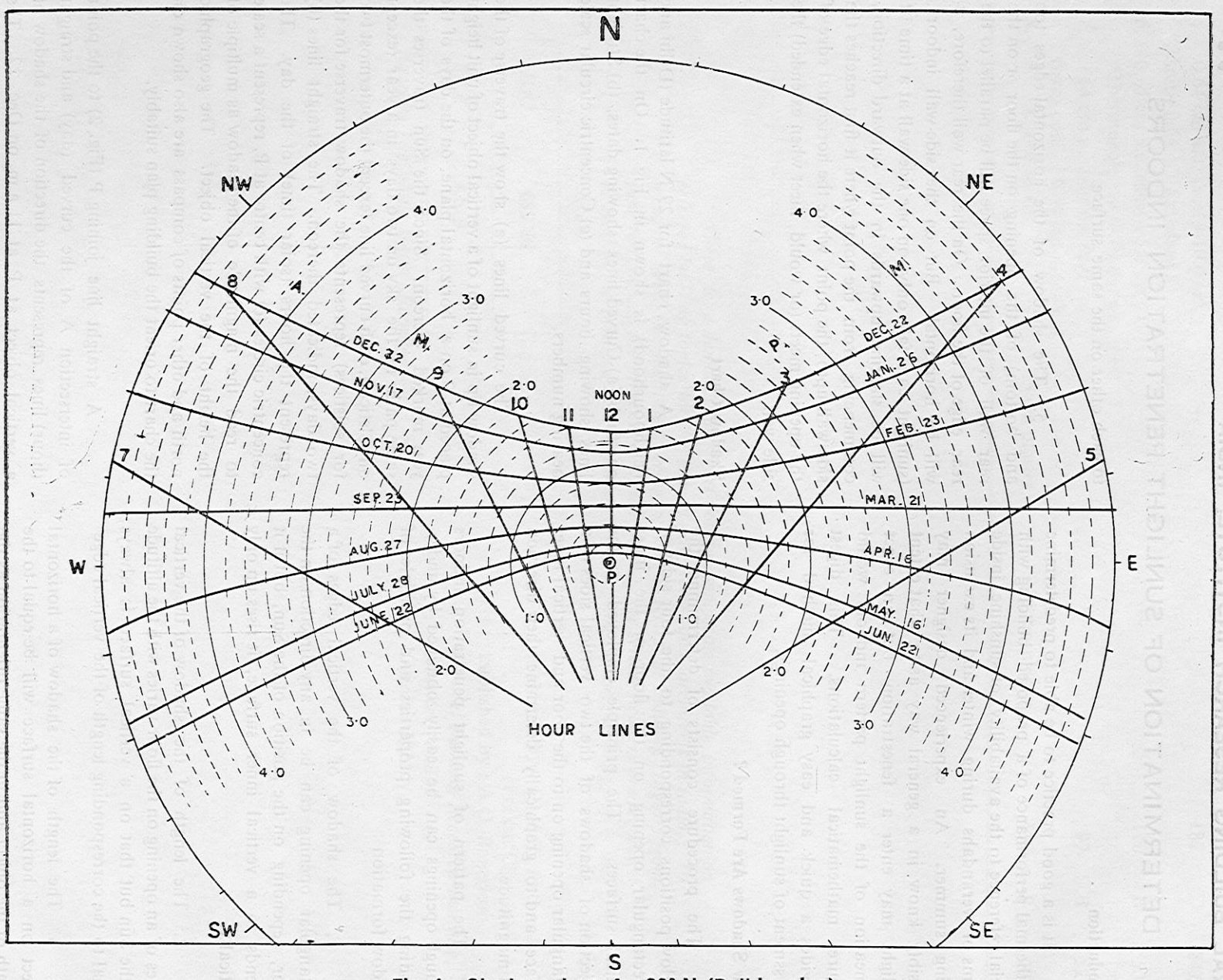


Fig. 1 Shadow chart for 29° N (Delhi region)

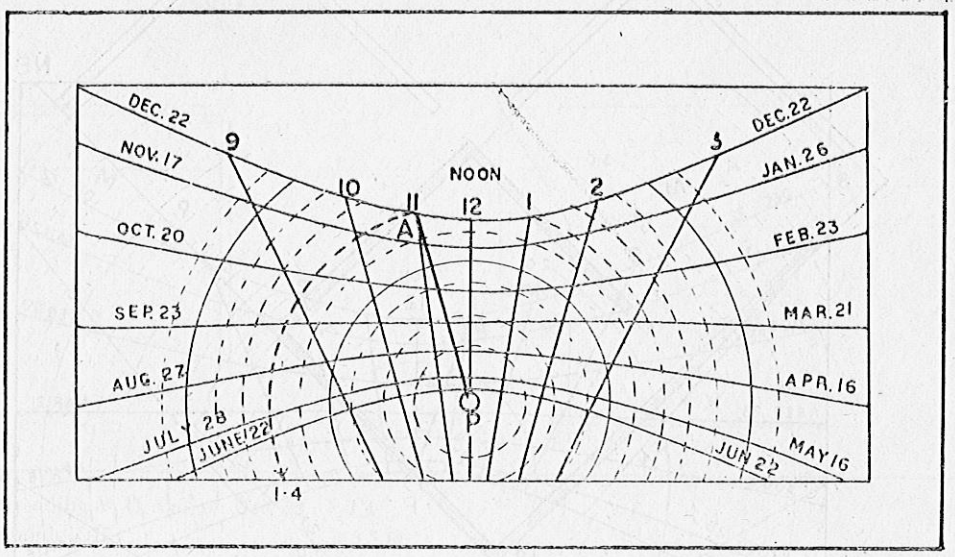


Fig. 2 Direction of shadow at 11 a.m. on December 22

Use of the Chart

The chart is used to determine the direction and magnitude of the shadow due to the vertical sides of a rectangular opening in a wall (window or verandah) on to the floor at any hour and day. To use the chart, a plan of the proposed building is drawn on a tracing paper to a suitable scale showing window and verandah openings. It is then placed over the shadow chart, in the appropriate orientation with one end of the discontinuity representing a window or verandah opening, placed at P (Fig. 3). A straight line MM passing through P on the chart (Fig. 3) represents a vertical wall in plan, oriented in the SE direction. The direction of shadow of the vertical edge over this end of the window or verandah opening can then be drawn for any day and hour as described earlier (See Page 1, para 4 right column). The length of the shadow is obtained by multiplying the height of the opening above the floor with the multiplying factor (i.e. 1.4 for 11 a.m. on Dec. 22) obtained by reading the position of the point A, i.e. the desired hour and day, on the concentric circular scale. This magnitude of the shadow can then be marked off along the shadow line drawn on the building plan, to the same scale as that of the plan.

The chart in Fig. 1 can be made direct reading if the scale of the building plan is chosen such that the distance from P to the concentric circular scale marked 1.0 represents the height of the verandah or window opening. In such a case, distances from P on the chart would represent actual shadow lengths. But if the height of the verandah opening is different from the window height, the scales of the building plan for the cases of verandah and window will have to be different.

It may be noted that sunlight can not penetrate into a building from every position of the Sun on the sky. In Fig. 3, if the line joining P to a point on the chart does not enter the room, sunlight does not enter it either. The line MM in Fig. 3 divides the chart into two parts indicating the hours of various days on either side when sunlight can enter indoors, whichever side of it the room may be situated.

How to Draw Sunshine Patterns Indoors ?

Case I : When the sunlight falls on the floor only

The direction of shadow of the vertical edges of a rectangular window for the desired hour and day is first drawn on the tracing of the building plan, as explained earlier (See Page 3, para 1 left column) through the edges of the window opening. The shadow positions of the top corners A and B of the window are shown marked in Fig. 4 on these shadow lines as A′ and B′ for a SE facing window at 11 a.m. on Dec. 22. This is done, as already explained, by multiplying the height of the window above the floor with the multiplying factor (i.e. 1.4 in this case) obtained from the position of the desired hour and date on the concentric circular scale. A′B′ is thus the shadow of the upper edge AB of the opening on the plan.

Similarly, the shadow positions C′ and D′ of the bottom corners C and D of the window are also marked off on the respective shadow lines corresponding to the sill height. Thus C′D′ is the shadow of the lower horizontal edge CD. The sunshine pattern due to the opening ABCD is thus A′B′C′D′ (Fig. 4) on the floor.

The pattern of sunlight penetration through a SE facing verandah opening KHCD is shown in Fig. 5

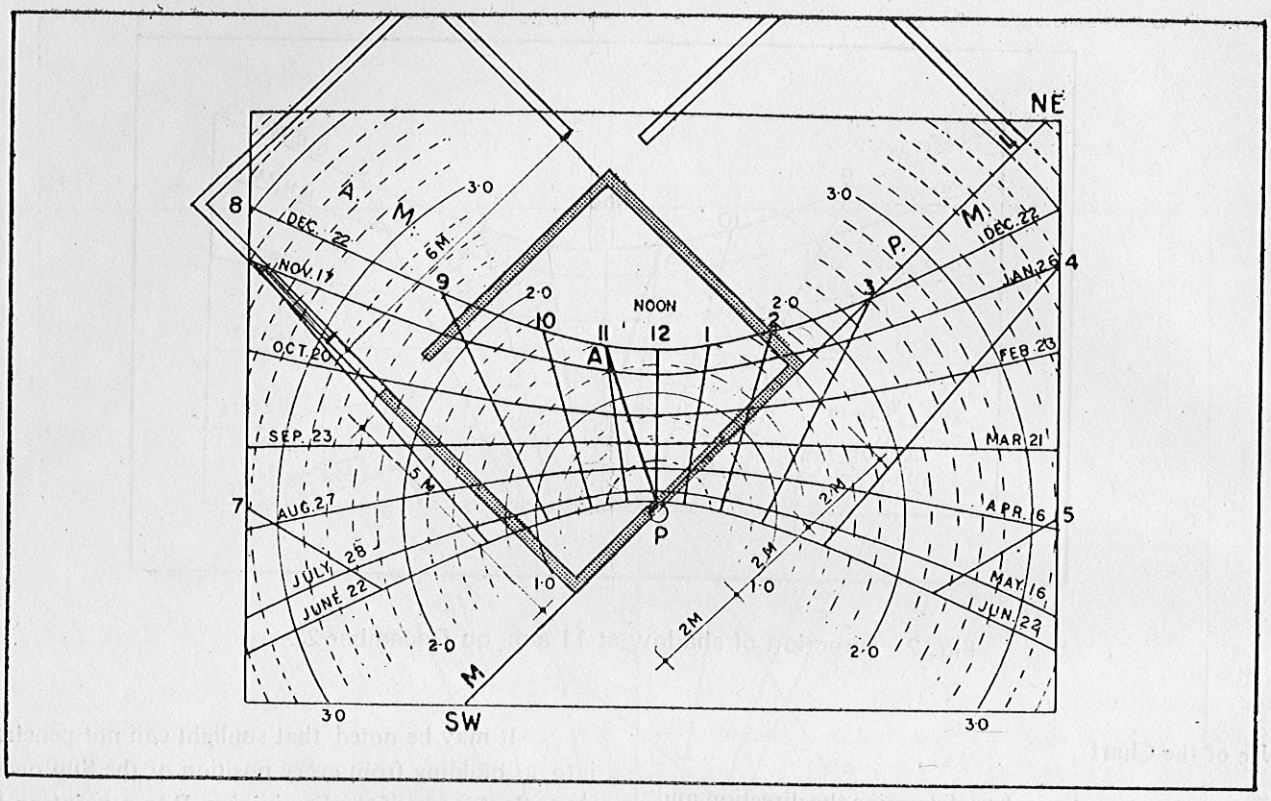


Fig. 3 Plotting shadow line (PA) on the building plan.

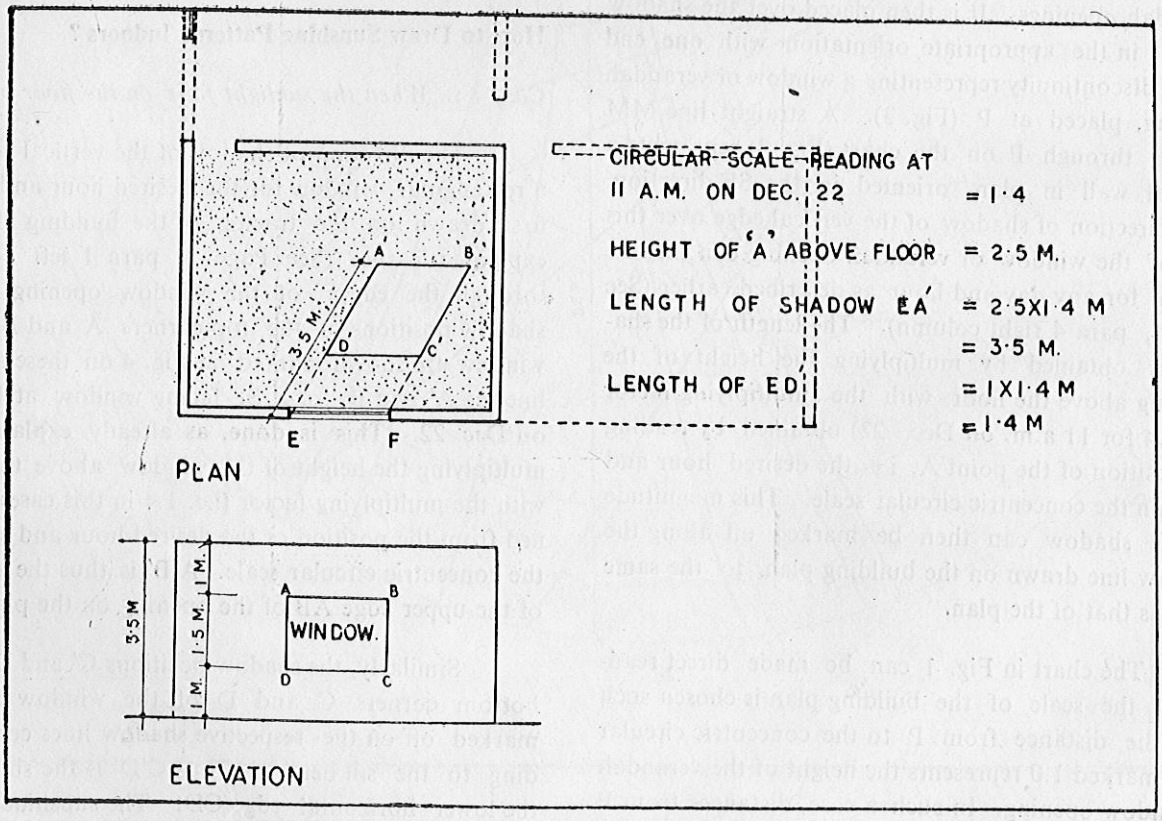
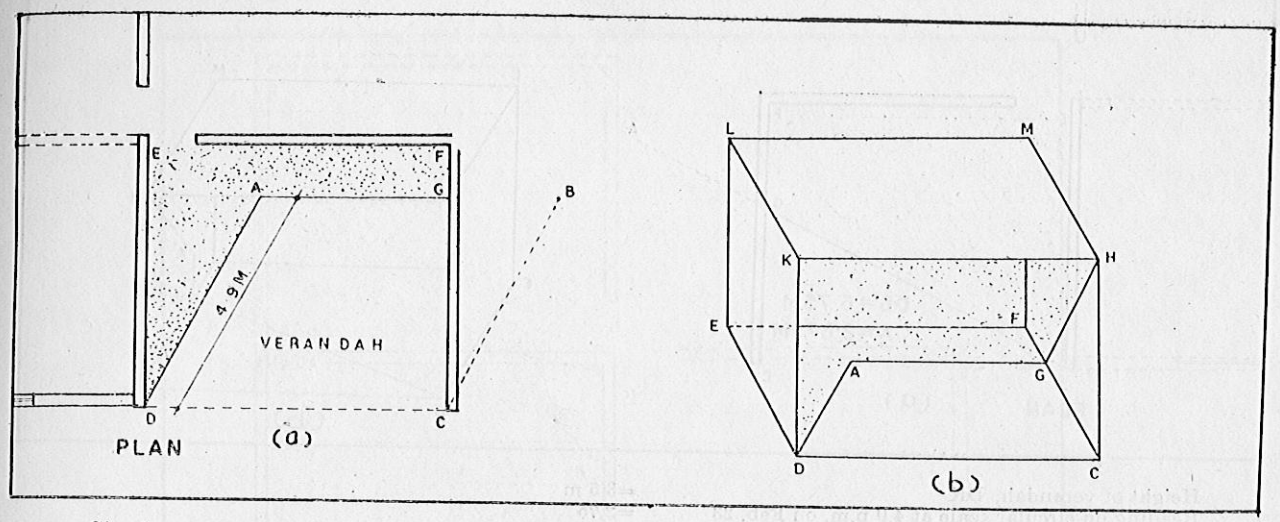


Fig. 4 Sunlight pattern through a SE window at 11 a.m. on December 22



Circular scale reading at 11 a.m. on Dec. 22 =1.4
Height of Verandah, DK =3.5 m
Length of shadow, DA due to one vert. edge =3.5 x 1.4 =4.9 m

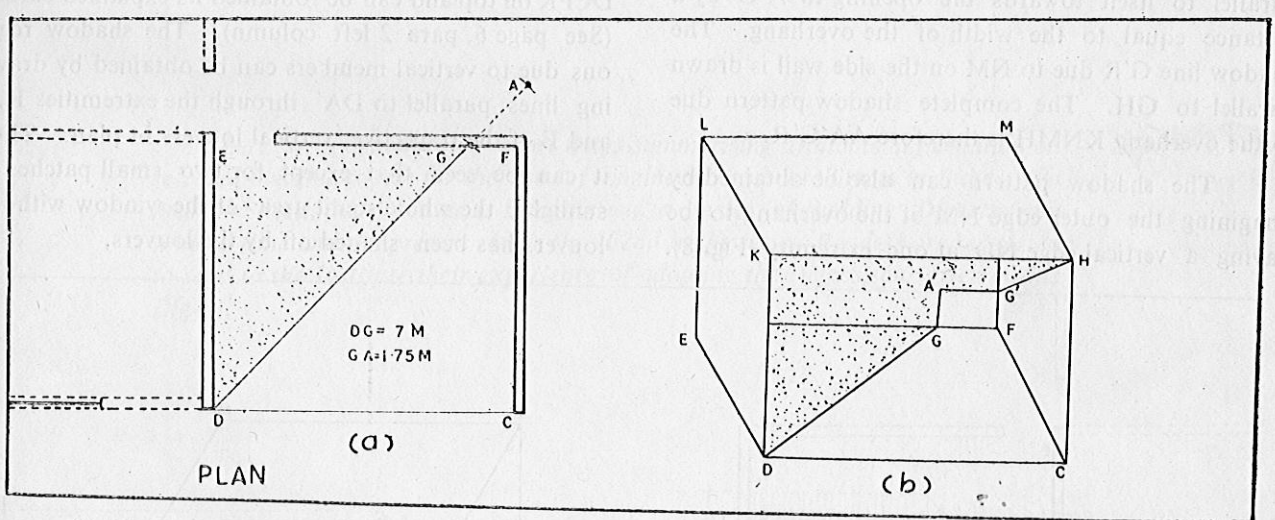
Fig. 5. Sunlight pattern through a SE facing verandah opening at 11 a.m. on December 22

for 11 a.m. on Dec. 22 on the floor EFCD of the verandah. DA, the shadow of the vertical edge DK is obtained as explained earlier. (See Page 3 para 1 left column). AG, drawn parallel to the rear edge EF of the floor, is the shadow of a part of the upper horizontal edge KH on the floor. GH, the shadow of the remaining part of KH on the side wall MHCF is obtained as explained earlier (See Page 1, para 1 right column). Thus the complete shadow pattern on the interior surfaces is DAGH.

Case II : *When the sunlight extends beyond the floor*

If the shadow length DA (Figs. 6 & 7) of the vertical edge DK of the verandah opening drawn in accordance with earlier direction (See Page 3 para 1 left column) extends beyond the floor plan, the distance AG, outside the floor plan is measured and divided by the multiplying factor corresponding to the point A. This gives the length of the upper portion of the vertical edge DK which casts the shadow GA. Actually, the shadow due to this upper portion of DK will be on the inner walls: (a) on the rear wall in the case of Fig. 6 and (b) on the side wall in the case of Fig. 7. The shadow of the upper portion of the vertical edge DK on the walls will be a vertical line GA′ of equal length, as earlier explained (See Page 1, para 5 left column).

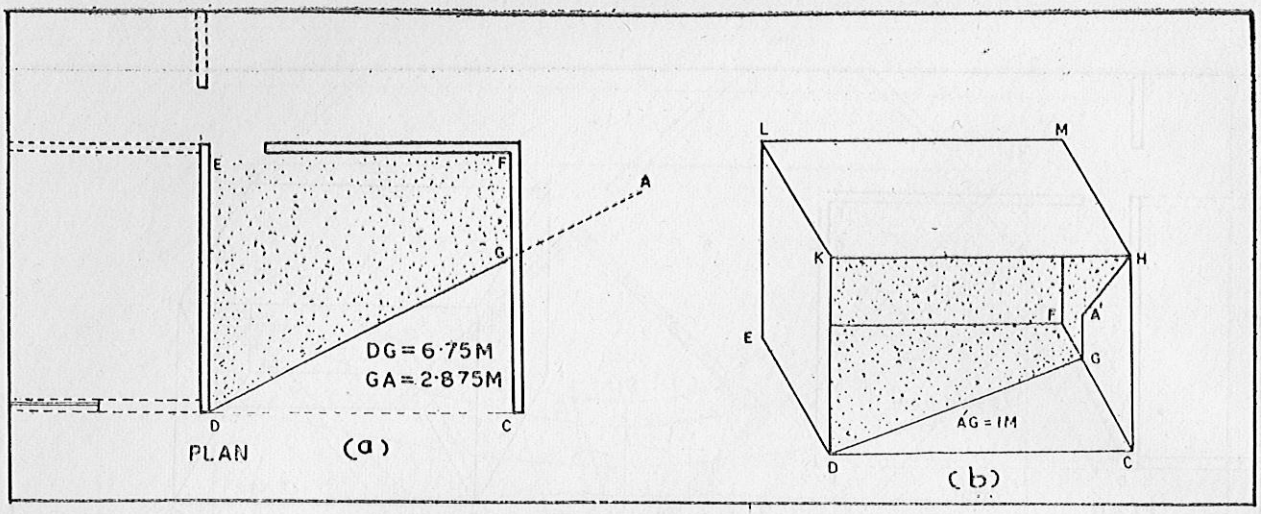
The shadow of the vertical edge is therefore DGA′ (Figs. 6 & 7). The shadow of the upper



Height of verandah, DK =3.5 m
Circular scale reading at 3 p.m. on Dec. 22 =2.5 m
Length of shadow on horizontal plan, DA =3.5 x 2.5 m=8.75

1.75 m length of shadow corresponds to a height= $\frac{1.75}{2.5}$ =0.7 m=A′G

Fig. 6. Sunlight through a South facing verandah opening at 3 p.m. on December 22



Height of verandah, DK $=3.5$ m
Reading on circular scale at 4.0 p.m. on Feb. 23 $=2.75$
Length of shadow, DA $=3.5 \times 2.75$ m $=9.625$ m

2.875 m length of shadow, GA on the floor $= \frac{2.875}{2.75} \approx 1$ m $=$ GA′on the wall

Fig. 7. Sunlight pattern through a South facing verandah at. 4.00 p.m. on February 23/Octobbr 20

horizontal edge KH in Fig. 6 is A′G′H and in Fig. 7, it is A′H as explained earlier (see page 1, para 1 right column). The complete shadow patterns in Figs. 6 & 7 are therefore DGA′G′H and DGA′H respectively.

Case III : When the opening has a horizontal overhang on top

KHMN (Fig. 8-b) is the overhang on the verandah opening KHCD. The shadow of the SE facing verandah opening without the overhang at 11 a.m. on Dec. 22 would be DAGH as given earlier (See Page 3 para 4 righ column) and shown in Fig. 5. The shadow line A′G′ due to the outer edge NM of the overhang is obtained by shifting the shadow line AG parallel to itself towards the opening to A′G′ by a distance equal to the width of the overhang. The shadow line G′R due to NM on the side wall is drawn parallel to GH. The complete shadow pattern due to the overhang KNMH is therefore AA′G′R.

The shadow pattern can also be obtained by imagining the outer edge NM of the overhang to be having a vertical edge ND′ at one extremity (Fig. 8). D′A′ can then be drawn as the imaginaryshadow of ND′ and A′G′R can be drawn as usual. This in effect means shifting the opening outward to the overhang. The actual shadow due to DKNMH is therefore DAA′G′R as shown in Fig 8 (b).

Case IV : When the window is provided with both horizontal and vertical louvers

The shadow pattern has been drawn for such a window in Fig. 9. The orientation of the window and the direction of sunlight is the same as used in Fig. 4. It can be seen from Fig. 9 that the sunlight pattern without the louvers would be A′B′C′D′. But the region A′B′P′R′ is shaded due to the horizontal louver DCPR on top and can be obtained as explained earlier (See page 6, para 2 left column). The shadow regions due to vertical members can be obtained by drawing lines parallel to DA′ through the extremities R,F and E of the respective vertical louvers in plan. Thus it can be seen that except for two small patches of sunlight, the whole sunlit area of the window without louvers has been shaded off by the louvers.

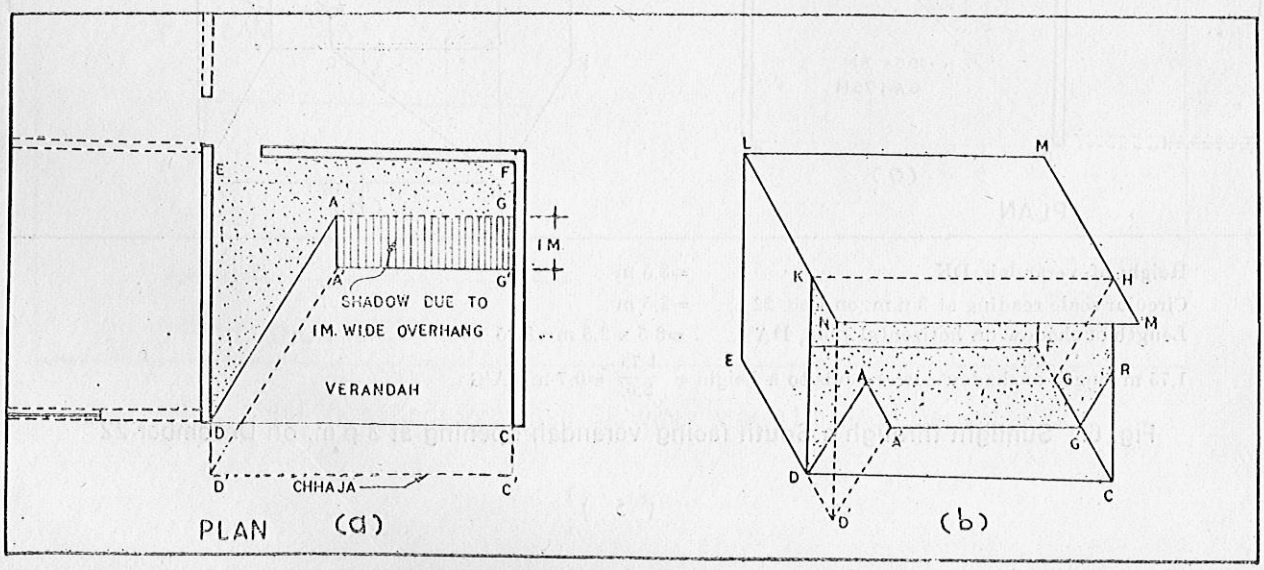


Fig. 8. Sunlight pattern due to an overhang on a SE facing verandah at 11 a.m. on December 22

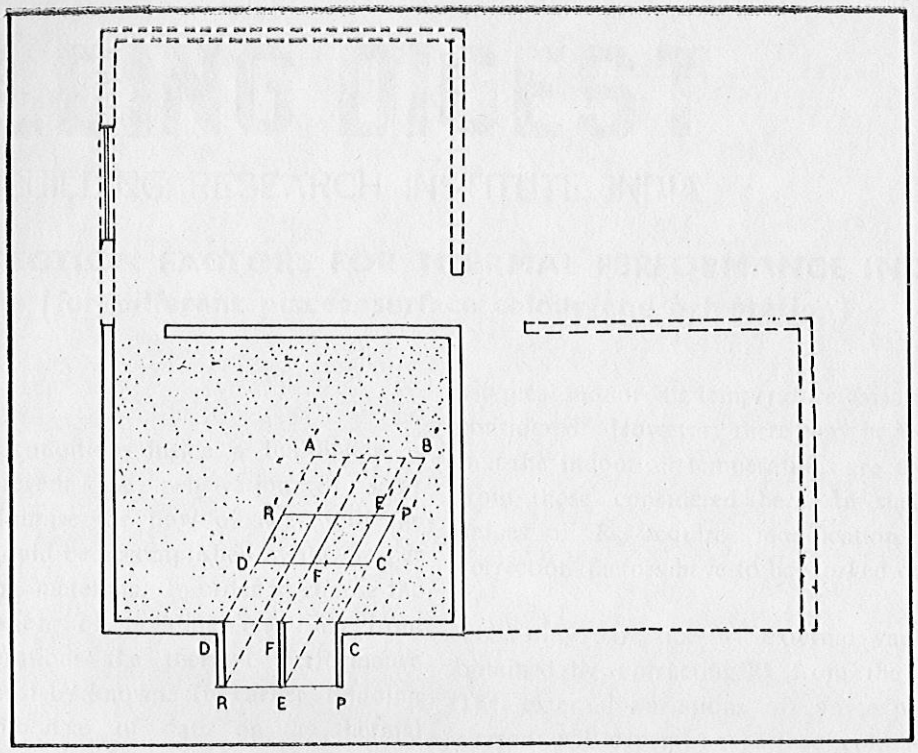


Fig. 9. Sunshine pattern due to horizontal and vertical louvers on a SE facing window at 11 a.m. on Dec. 22

There is a demand for short notes summarising available information on selected building topics for the use of engineers and architects in India. To meet the need, this Institute is bringing out a series of Building Digests from time to time and the present one is the 102nd in the series. Readers are requested to send to the Institute their experience of adopting the suggestions given in this Digest.

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