CENTRAL BUILDING RESEARCH INSTITUTE, ROORKEE-247667 (INDIA)

BUILDING RESEARCH NOTE

B.R N. 35

DESIGN FOR DAYLIGHTING

Introduction

Daylighting design of buildings for satisfactory illumination of work spaces depends upon visual task, outdoor daylight availability, room size, interior finish, size and location of windows, light transmittance of window panes and obstructions such as window frame, louvres, opposite buildings and trees etc. Lux grid method included in this Building Research Note is based on computation of daylight availability for clear design sky as incorporated in Indian Standard Code of Practice IS: 2440-1975 and IS: 7942-1976 and can be used to :

(a) assess the illumination level on the working plane or other horizontal surfaces as provided by a given arrangement of windows.

(b) calculate window sizes to give desired illumination on the working plane.

Illumination requirements for a few typical locations are given in Table **1.**

Table **1** : Illumination Requirement for Interiors
(Indian Standard Code of Practice IS : 2440-1975)

	Location	Illumination (Lux)
1.	Dwellings :	
	Kitchen	200
	Study	150
2.	Schools :	
	Class room	150
	Lecture theatre	150 to 200
	Study hall	150 to 200
	Laboratory	150 to 300
3.	Offices :	
	General	150
	Drawing	300
	Enquiry	70 to 150
4.	Hospitals :	
	General wards	100
	Pathological laboratory	200 to 300
5.	Libraries :	
	Stack room	70 to 150
	Reading room	150 to 300
	Counter area	200 to 300
	Catalogue room	150 to 200

Lux grid

It is a perspective of window wall comprising a grid of square elements in which their contribution to the workplane illumination is marked as dots, crosses and stars. A dot, a cross and a star represent 0.5 Lux, 1 Lux, and 2 Lux respecetively. The base line of the grid represents the level of the workplane and the centre of the base line is the projection of the given point at which the illumination is required. The dimension of square element is one tenth the distance of the given point from the window wall. A window or a set of windows can be outlined to the scale on the grid with respect to the distance of the reference point from the window wall. The summation of contribution of each element within window outlines gives the expectable daylight on a horizontal working plane. Figs, 1 and 2 illustrate the principle of the Lux grid method.

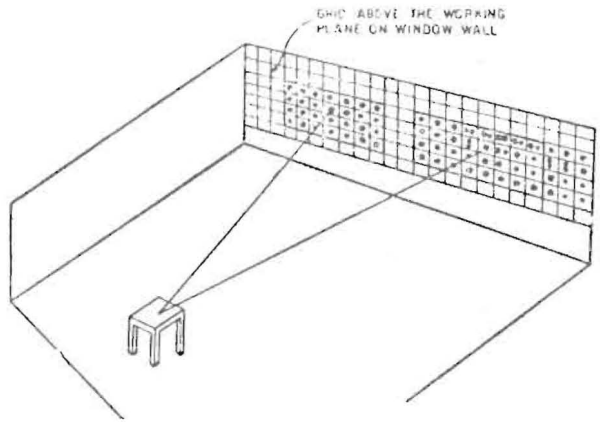


FIG. 1

Reduction of daylight due to glass transmittance, maintenance, louvers and metallic window sashes have been taken into account. Lux grid I, II are for daylighting design of windows with and without external obstruction respectively.

Sill Height of Windows

Illumination on the working plane comes mostly from that part of the window that is above its surface. Sill of the window should, therefore, be arranged either at or above the working plane height. Where, for some special reason, the sill of the window is below the surface of the working plane, the dots, stars or crosses in grid below the working plane should not be counted as illustrated in Fig. 3. Thus for point P_1 (Fig. 4) the illumination at a point 600 cm from the window wall comprises :

48 dots = 24 lux
32 stars = 64 lux
Total = 88 lux

Similarly, for point P_2 in Fig 4, where the point is 300 cm from the wall in the same room, the illumination is (refer to Fig 5).

176 dots = 88 lux
128 stars = 256 lux
Total = 344 lux

Interior Finish of the Room

Illumination on an interior surface is affected not only by the size of windows but also by inter-reflections of light within the

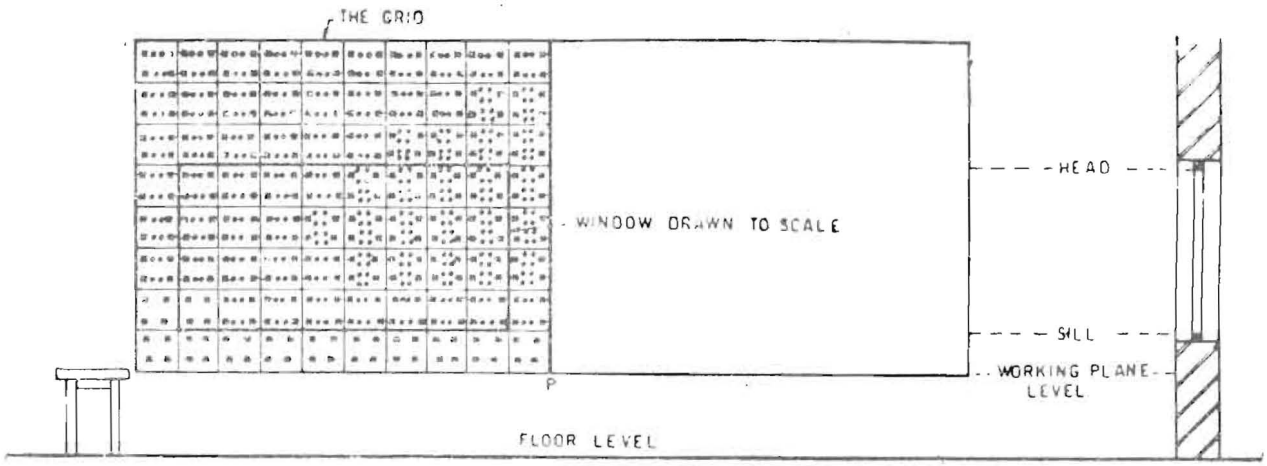


FIG. 2

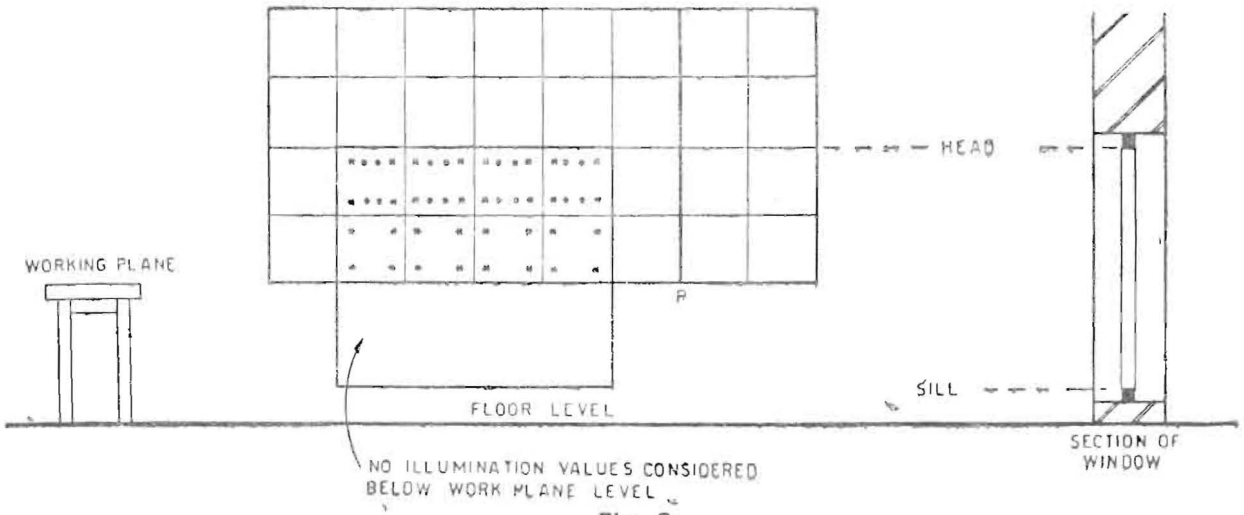
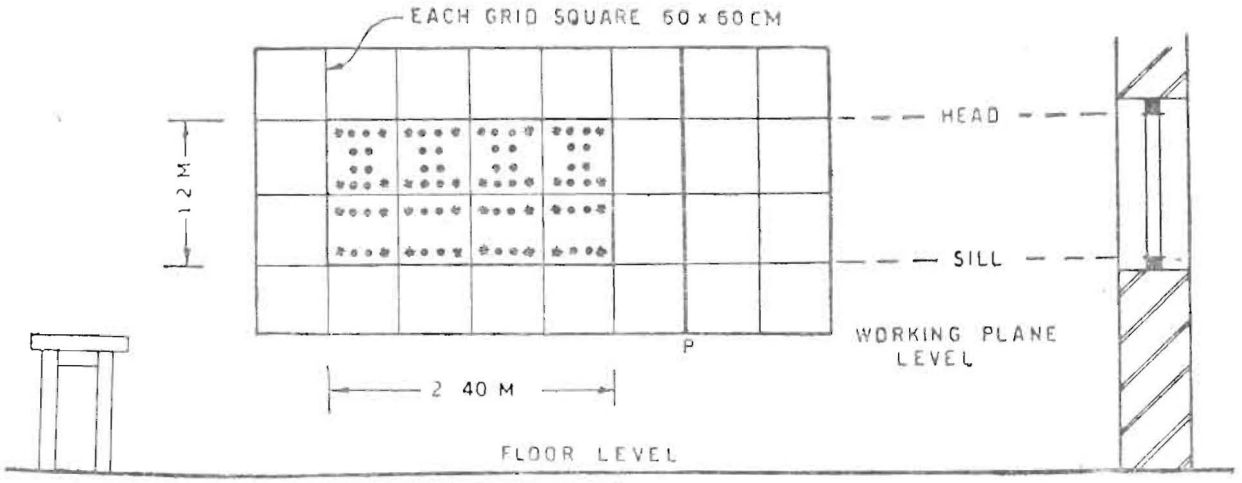
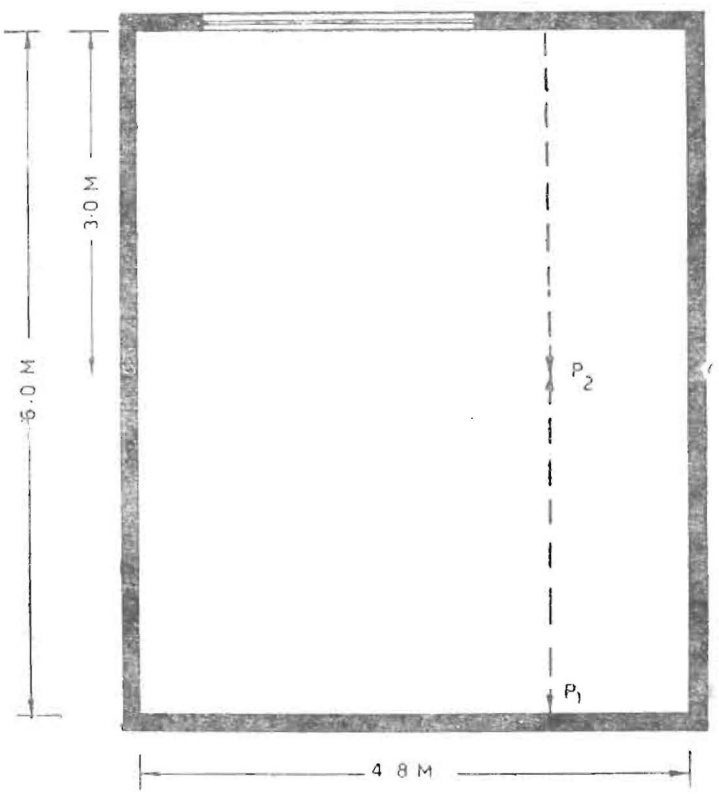


Fig. 3





PLAN Fig. 4

room. If the internal finishes are dull and dark, the inter-reflections will be less and the illumination on a surface somewhat lower than if the room is finished with lighter colours. Illumination levels have to be corrected for different interior finishes as shown in Table 2.

Illustrative Examples

A : Unobstructed windows (lux grid I)

Ex. 1 : Determine the illumination at Point P_1 (Fig. 4) located at 600 cm from the window. Assume that the room in which the point is located has Finish B and floor area approximately 30 sq m.

Number of grid squares enclosed by the outline of the window is 8. Correction factor for Finish B (from Table 2) = — 1.9

Total correction = 8 (−1.9) = — 15.2 lux.

Now add this algebraically to the lux value obtained by counting the dots and stars.

∵ Illumination at point P_1

from dots and stars	=	88.0 lux
Correction	=	— 15.2 lux
Total Illumination	=	72.8 lux

Ex. 2 : Consider a point P_2 300 cm from the window wall. in the same room as in Ex. 1.

The number of grid squares enclosed by the window is 32 (Fig. 5). The correction factor from Table 2 is —6 2.

Total correction = 32 × (—6.2) = — 198 4 lux

Illumination at P_2		
from dots and stars	=	344.0 lux
Correction	=	— 198.4 lux
Total Illumination	=	145 6 lux

Ex. 3 : Illumination from more than one window.

Fig. 6 shows a room of floor area approximately 42 square metres, with 'A' type interior finish. It is desired to check the illumination levels at two points, P_1 and P_2 distant 600 cm and 150 cm from the window respectively.

(i) Consider Point P_1

Point P_1 being 600 cm from the wall, the size of a square on the grid is 60 cm. Take a piece of tracing paper and lay it over the grid. Draw the elevation of all the windows on it with the point P_1 on the plan coinciding with the heavy line at P on the grid. Make sure that the working plane height, which is the base of the grid, is correctly related to the sill height. Fig. 7 shows what should appear on the tracing paper.

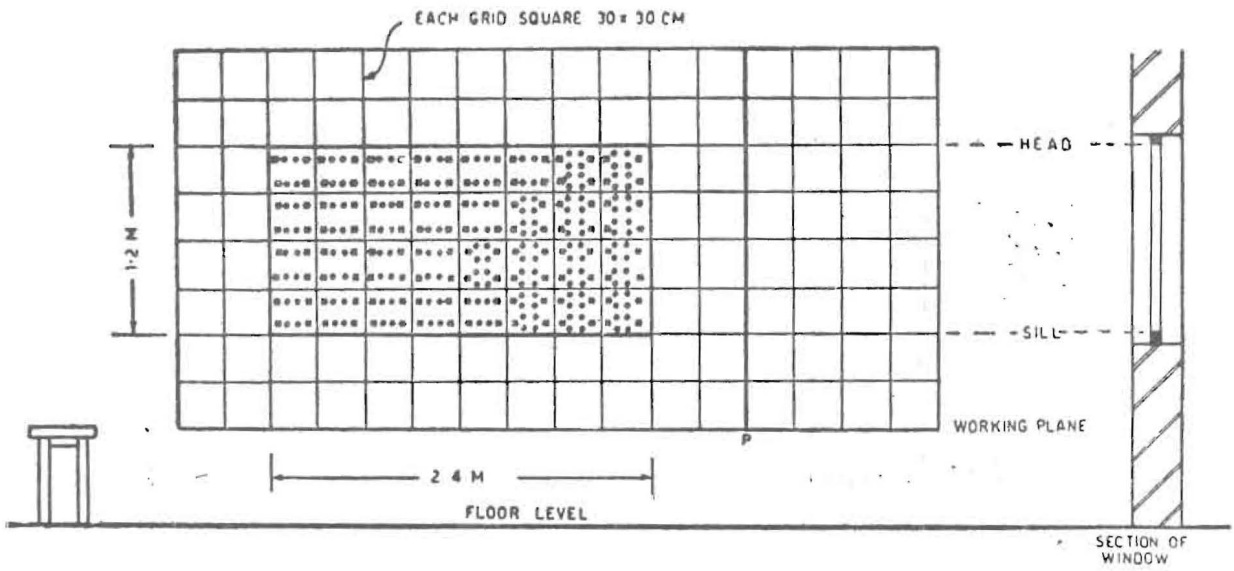


FIG. 5

CORRECTION FACTORS PER SQUARE (axa)-LUX

a = side of one square in the grid

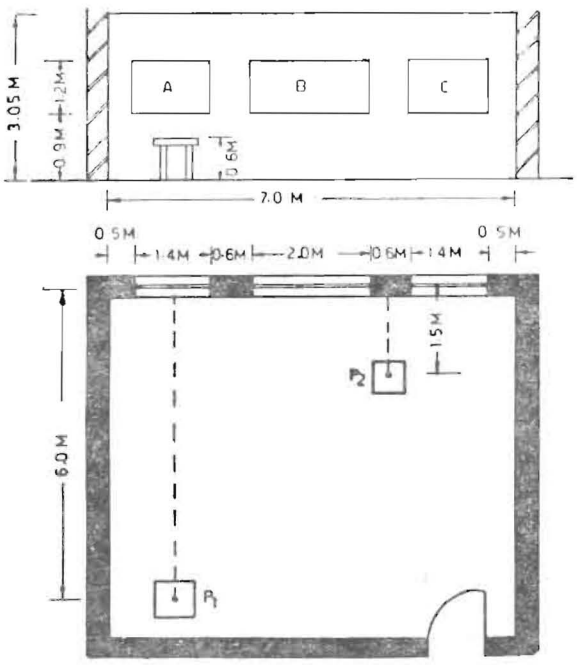
d = distance of point from the window

d	a	Floor Area Within 10-25 M²			Floor Area Within 25-50 M²			Floor Area Within 50-100 M²		
cm	cm	A	B	C	A	B	C	A	B	C
900	90	+26.6	+18.0	+9.5	+9 5	+5 2	+1 0	+1.0	—1 2	—3.3
840	84	+22.2	+14.7	+7.3	+7.3	+3.6	0	0	—2.0	—3.9
780	78	+18.0	+11.7	+5.2	+5.2	+2.0	—1.2	—1.2	—2.8	—4.4
720	72	+14.3	+8.8	+3.3	+3.3	0	—2.1	—2.1	—3 5	—4 9
660	66	+10.8	+6.2	+1.6	+1.6	—0.7	—3.0	—3.0	—4 2	—5.3
600	60	+7.6	+3.8	0	0	—1.9	—3.8	—3.8	—4.8	—5.7
540	54	+4 7	+1.6	—1.4	—1.4	—3.0	—4.5	—4.5	—5.3	—6.1
480	48	+2.1	0	—2.7	—2.7	—4.0	—5 2	—5.2	—5.8	—6.4
420	42	0	—2 0	—3.9	—3.9	—4.8	—5.7	—5.7	—6 2	—6.7
360	36	—2.1	—3.5	—4.9	—4.9	—5.5	—6.2	—6.2	—6.6	—6.9
300	30	—3.8	—4.8	—5.7	—5.7	—6.2	—6.7	—6.7	—6.9	—7.1
240	24	—5.2	—5.8	—6.4	—6.4	—6.7	—7.0	—7.0	—7.1	—7.3
180	18	—6.2	—6.6	—6.9	—6.9	—7.1	—7.3	—7.3	—7.3	—7.4
120	12	—7.0	—7.1	—7.3	—7 3	—7.4	—7.4	—7,4	—7.5	—7.5

FINISH A. Ceiling white (reflection factor = 0.7 to 0.8), walls offwhite (reflection factor = 0.45 to 0.55) and floor grey (reflection factor = 0.3).

FINISH B. Ceiling off white, walls off white and floor grey.

FINISH C. Ceiling off white, walls dark (reflection factor = 0 25 to 0.3) and floor grey.



PLAN

FIG. 6

Next, count the dots and stars enclosed by the outline of all the windows and add them together :

	Dots	Stars
Window A	16	16
Window B	27	28
Window C	11	20
	Total 54	64

Illumination = 27 + 128 = 155 lux

Correction for finish : The correction factor for finish A from Table 2 is 0. The illumination at point P_1 is thus 155 lux.

(ii) Consider point P_2

The point being 150 cm from the window wall, the size of a square on the grid is 15 cm, Take a piece of tracing paper and lay it over the grid. Draw the elevation of all the windows on it with the point P_2 on the plan coinciding with the heavy line at P on the grid. Check that the base of the grid is at the level of the

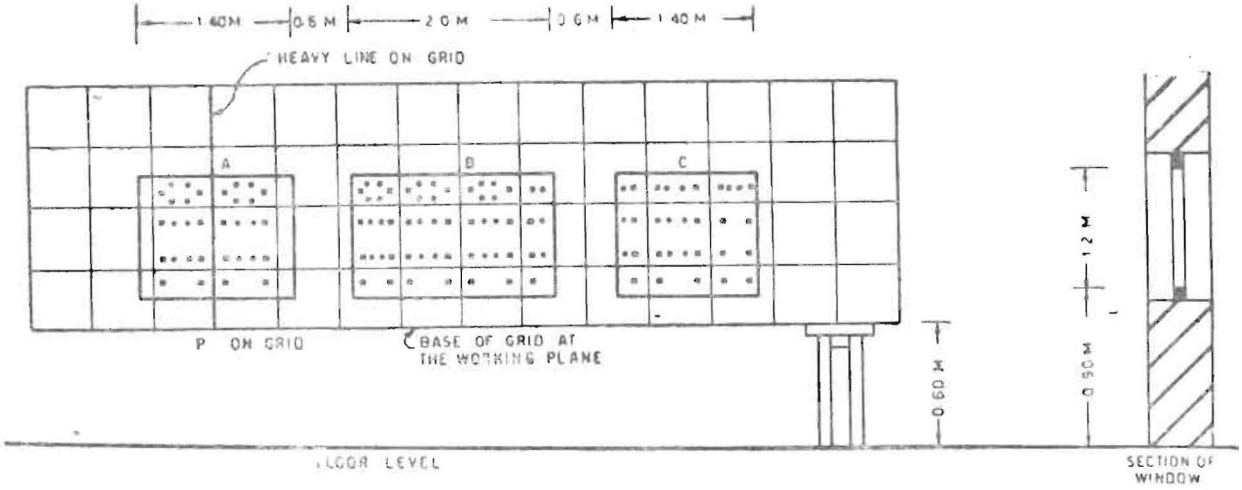


FIG. 7

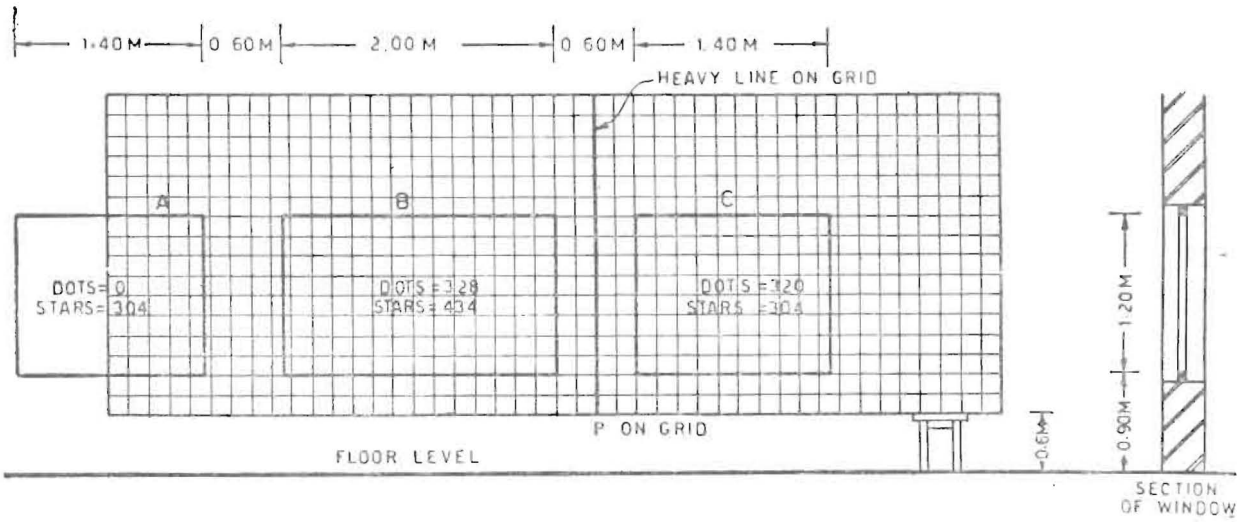


FIG 8

working plane and correctly located in relation to the height. Fig. 8 shows what should appear on the tracing paper.

Next, count the dots and stars enclosed by the outlines of all the windows and add them together.

	Dots	Stars
Window A	0	304*
Window B	328	434
Window C	320	304
Total	648	1042

Illumination = 324 + 2084
= 2408 lux.

Correction for finish : The correction factor for Finish A from Table 2 is

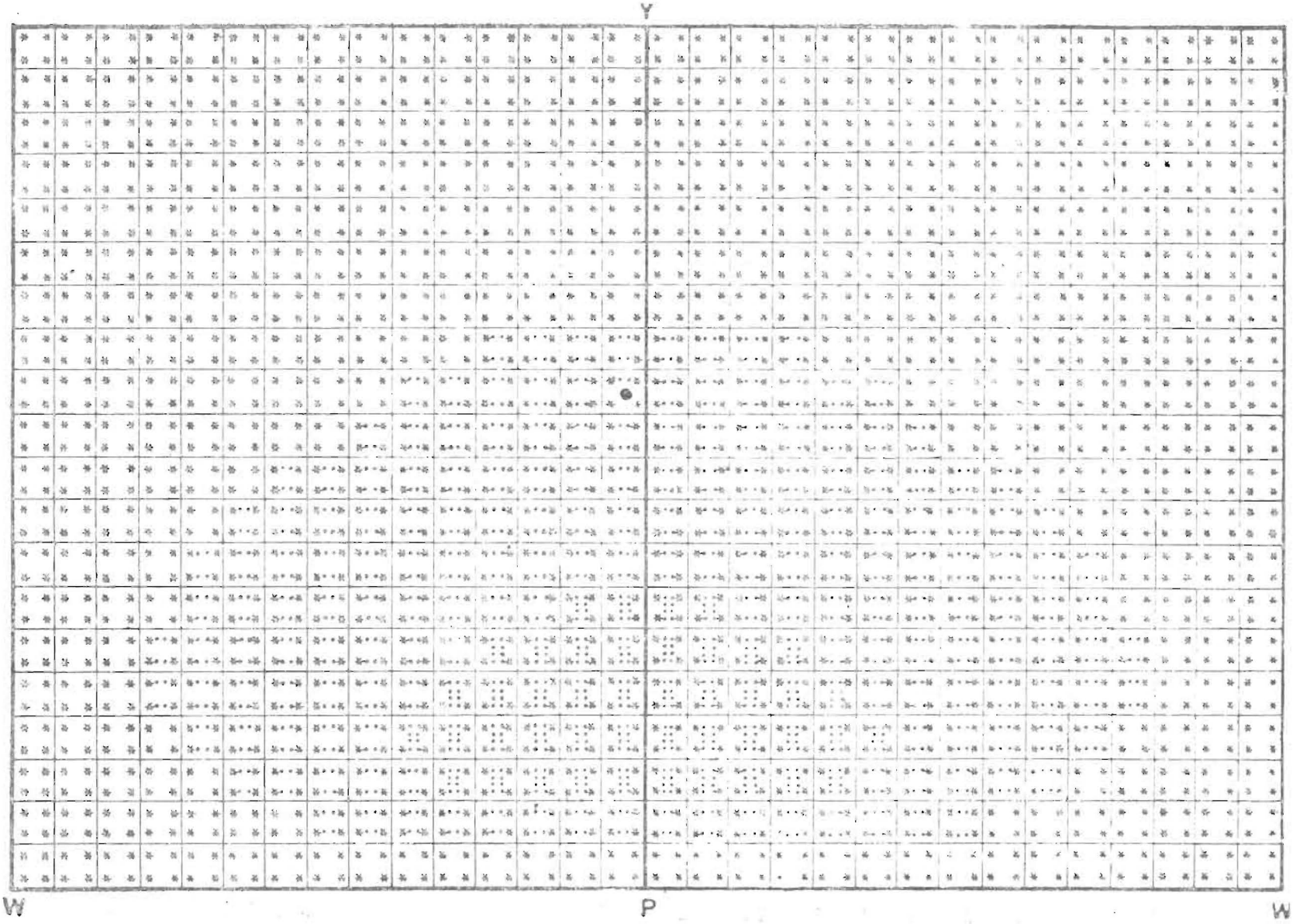
$$\frac{-(7.3+6.9)}{2} = -7.1$$

The number of grid squares enclosed by all the three windows is :

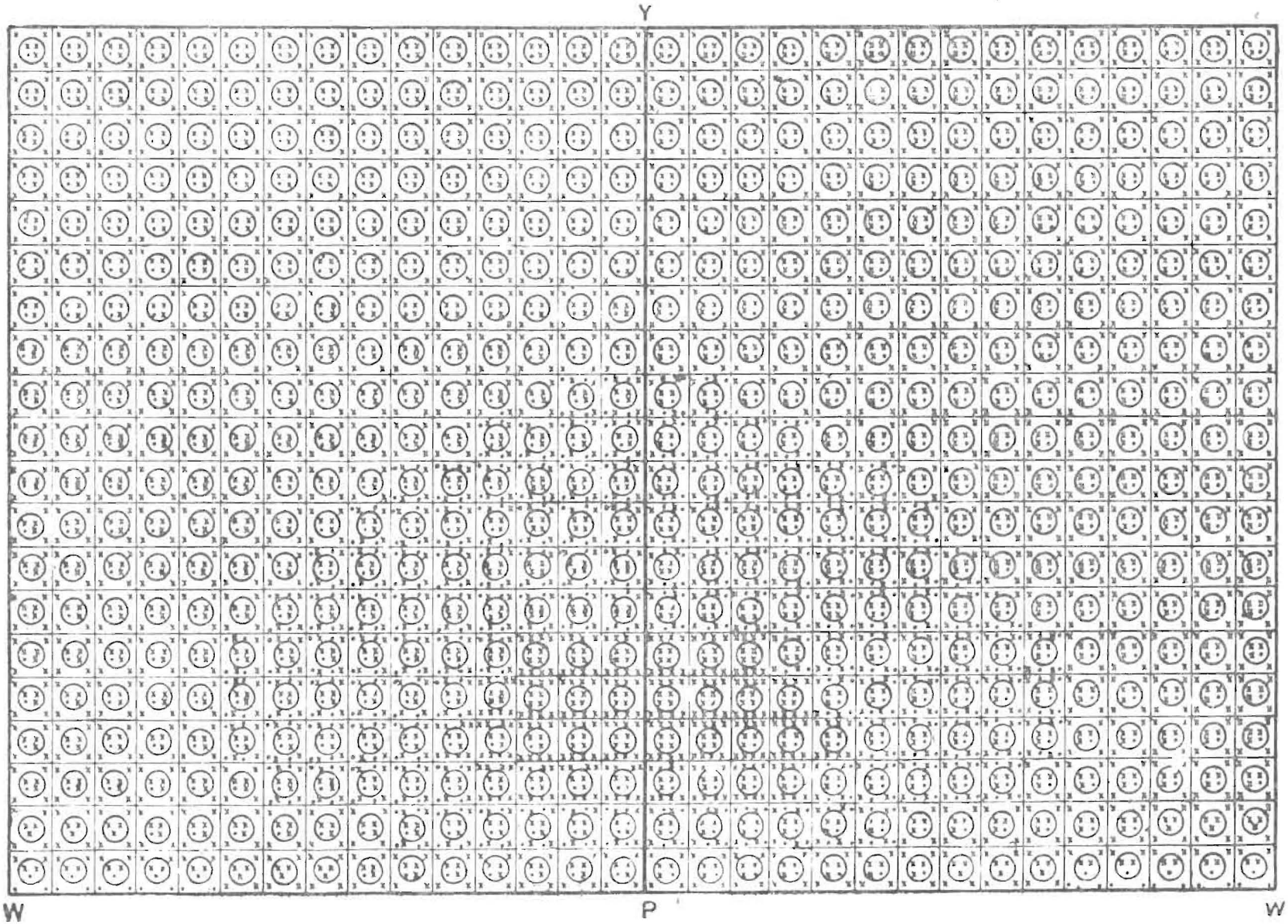
Window A = 76
Window B = 108
Window C = 76
Total = 260 grid squares

*What is to the left of A in Fig. 8 and outside the grid squares contributes negligibly to the illumination at P_1. The effective contribution per grid square may be treated as 4 stars per square.

LUX - GRID I FOR DAYLIGHTING DESIGN OF WINDOWS IN ABSENCE OF EXTERNAL OBSTRUCTIONS



LUX - GRID II FOR DAYLIGHTING DESIGN OF WINDOWS IN PRESENCE OF EXTERNAL OBSTRUCTIONS



Thus the total correction is

$= (-7.1 \times 260)$

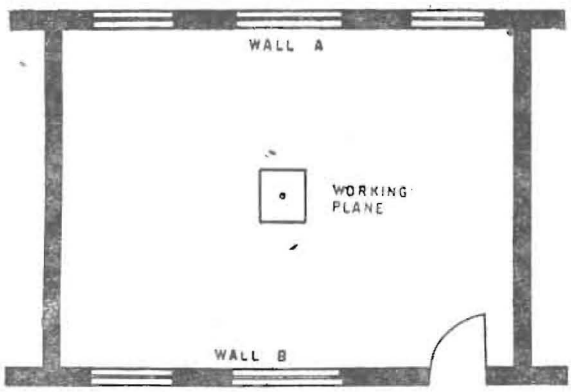
$= -1846.0$

Total illumination at P_2 is thus

2408—1846 = 562.0 lux.

Windows in Two Walls

Sometimes, in a room one may receive illumination from windows in opposite walls as shown in Fig. 9.



PLAN OF A ROOM

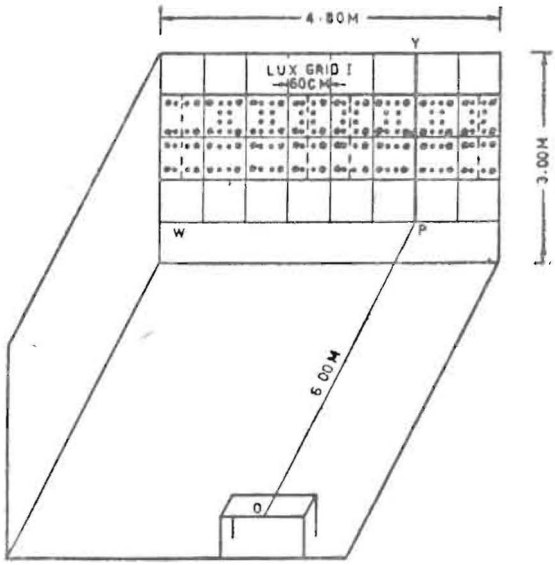
Fig. 9

In such cases, the illumination on the selected point is calculated by adding the illumination obtained from windows in wall A to that obtained from windows in wall B. Method of calculation is similar to that explained in the examples above.

Ex. 4: Determination of window size to achieve required level of daylight on the working plane.

Fig 10 shows the outline plan of a room 8.0 m × 4.8 m × 3.0m in which it is desired to provide an illumination level of 150 lux at the point P_1 on the working plane which is at a distance of 600 cm from the window wall.

Since the distance of the given point is 600 cm from the window wall, the side of squares on the grid is 60 cm. As there is no obstruction, lux grid 1 is to be used. Further as the sill level is 0.6 m. above the workplane. the window outline will be one square element above the base-line. Assuming a window of height 1,2m running over the entire wall of length 4.8 m, make outline of the window opening (Fig. 10) on the lux grid I.



Counting the number of dots and stars with in the window outline and converting to lux values we obtain.

92 dots = 46 lux
64 stars = 128 lux
Total = 174 lux

This exceeds the required value by 24 lux. So either the central part or the ends of the window can be filled by masonry. Assuming that 0.3 m on either side of the window is filled up with masonry, the dots and stars that would be covered are

10 dots = 5 lux
8 stars = 16 lux
Total = 21 lux

Therefore, this solution gives a window size of 4,2m × 1.2m and the daylight will be 174 −21 = 153 lux which is approximately the required illuminance.

Alternatively, if two windows are provided with a central pillar of 0.6 m in between, the dots and stars that would be covered are

12 dots = 6 lux
8 stars = 16 lux
Total = 22 lux

Therefore, according to this solution two windows each of 2.1×1.2m are to be provided and the daylight at the given point will be 174 −22 = 152 lux. Similarly, for any other window height and sill height, a single window

or multiple windows can be arrived at to give the required illuminance at the given point.

Limitations of the Method

1. It is assumed that the ground outside the windows has a reflection factor of 0.20, that is, grass with some brick or concrete paving

2. The ceiling is from 2.75 to 3.05 metres above the floor level, pitched or flat.

3. Obstructions outside the windows can be ignored if they are at a distance of more than 3 times their own height from the window. For obstructious that are closer, the method given ahead should be used.

4. In designing the grid, it is assumed that the window has a 60 cm. sunshade around or a 60 cm. horizontal louvre is incorporated in the window, which is supposed to be glazed.

If there is a verandah or other large overhang outside the window, the size of the window for the purpose of counting the dots and stars should be reduced appropriately (Fig. 11).

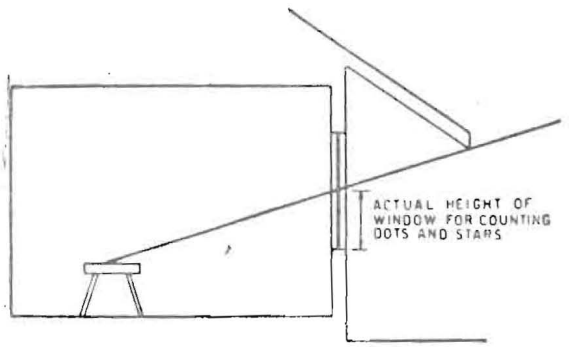


Fig. 11

B : Windows with External Obstruction (lux grid II).

When obstructions outside the window (having a reflection factor lying between 0.4 & 0.6) restrict the entry of dayliqht, lux grid II together with its correction Table No. 3 has to be used. Here one finds in addition to the dots and crosses inside each grid, a circle enclosing a few dots and crosses. The dots and crosses within the circle correspond to the daylight contributed by obstructions, while those out side the circle represent the contribution made by the unobstructed window including inter-reflections. One cross is equal to 1.0 lux.

To estimate the available daylight at a point, the outline of the window and the obstruction are projected on the lux grid using proper scales corresponding to the distances of window and obstruction from the point in question.

Depending on the height (H) and distance (D) of the obstruction from window-wall respectively, four cases arise:

(i) $D > 3\ H$: This case can be treated as unobstructed as far as daylighting is concerned and grid I should be used (described earlier).

(ii) $1.5\ H < D \leqslant 3\ H$

Step a. Find the contribution made by unobstructed portion of the window using lux grid I and II separately and take the mena value.

Step b. Find the contribution made by the obstructed portion by counting the dots and crosses within the enclosed circle (in the obstructed part) using lux grid II and multiply the value so obtained by a factor = 1.8.

Step c. Add the two values.

(iii) $0.5\ H < D \leqslant 1.5\ H$.

Find the contributions of the unobstructed and obstructed portions of the window separately using lux grid II and add the values.

(iv) $D \leqslant 0.5\ H$

Step a. Find the daylight due to unopstructed part using lux grid II.

Step. b. Find the daylight due to obstructed part using lux grid II but reduce the value obtained by 50 percent.

Step c. Add the values.

Ex. 5 : Consider Fig. 12, a point P_1 at 6 m from the window wall. Assume that the room in which the point is located has finish B, and floor area approximately 48 sq metres. The room has two windows each of size 2.4 × 1.5 m at a sill height of 30 cm above the working plane symmetrically located with respect to point P_1, The windows face an infinitely long parallel obstruction (reflectance

TABLE 3

CORRECTION PER SQUARE (axa)-LUX

a=side of square in the grid

d=distance of point from the window

d	a	Floor Area Within 10-25 M²			Floor Area Within 25-50 M²			Floor Area Within 50-100 M²		
cm	cm	A	B	C	A	B	C	A	B	C
900	90	+10 6	+7.2	+3.8	+3.8	+2.1	+0 4	+0.4	—0.5	—1.3
840	84	+8.9	+5.9	+2.9	+2.9	+1.4	0	0	—0.8	—1.6
780	78	+7.2	+4.7	+2.1	+2.1	+0.8	—0.5	—0.5	—1.1	—1.8
720	72	+5.7	+3.5	+1.3	+1.3	0	—0.9	—0.9	—1.4	—1.9
660	66	+4.3	+2.5	+0.6	+0 6	—0.3	—1.2	—1.2	—1.7	—2 1
600	60	+3 0	+1.5	0	0	—0.8	—1.5	—1.5	—1.9	—2.3
540	54	+1.9	+0.7	—0.6	—0.6	—1.2	—1 8	—1.8	—2.1	—2.4
480	48	+0 9	0	—1.1	—1.1	—1.6	—2.1	—2.1	—2.3	—2.6
420	42	0	—0.8	—1.6	—1.6	—1.9	—2.3	—2 3	—2.5	—2 7
360	36	—0.9	—1.4	—1.9	—1.9	—2.2	—2 5	—2.5	—2.6	—2.8
300	30	—1.5	—1.9	—2.3	—2.3	—2.5	—2.7	—2.7	—2.8	—2.9
240	24	—2 1	—2.3	—2.5	—2.5	—2.7	—2.8	—28	—2.9	—2.9
180	18	—2 5	—2 6	—2.8	—2.8	—2.8	—2.9	—2.9	—2.9	—3.0
120	12	—2.8	—2.9	—2.9	—2.9	—3.0	—3 0	—3.0	—3.0	—3.0

Finish A. ceiling white (reflection factor=0.7 to 0.8), walls off white (reflection factor=0.45 to 0.55) and floor grey (reflection factor=0.3).

Finish B. ceiling off white, walls off white and floor grey.

Finish C. ceiling off white, walls dark (reflection factor=0.25 to 0.3) and floor grey.

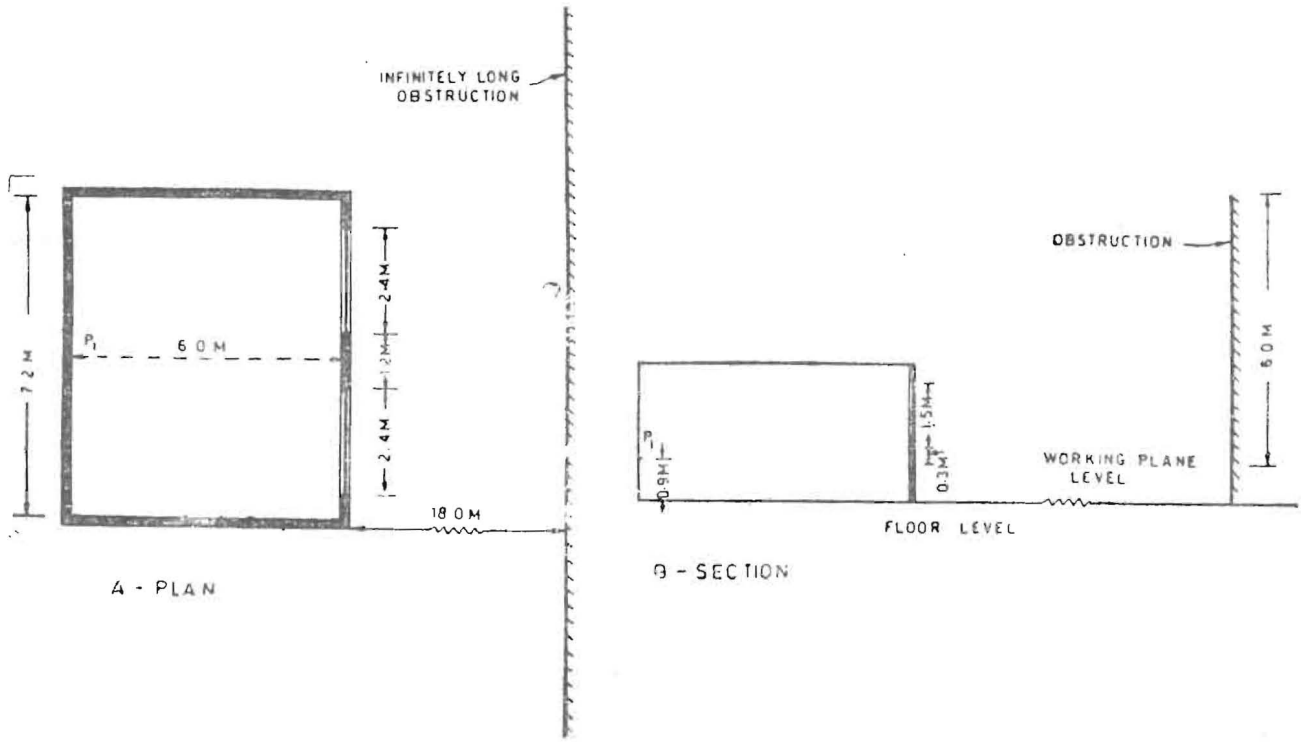


FIG 12

= 0.5) located at a distance of 18.0 m (D) from the windows and of height (H) 6.0 m above the working plane.

This corresponds to case (ii) where 1.5 H < D ⩽ 3.0 H.

Step a. The projection of the obstruction on the lux grids I and II are shown in Fig. 13 (a) and (b). The contribution due to unobstructed portion of the windows using lux grid I and lux grid II are determined as follows :

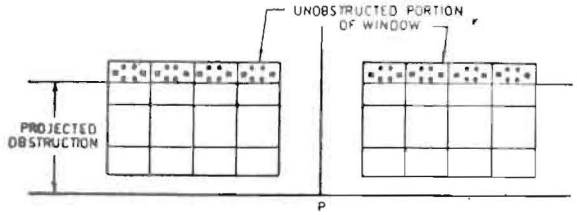
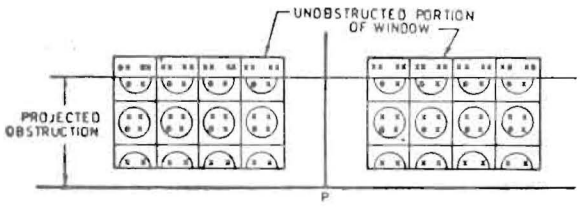


FIG 13 a



(i) Use grid I (see Fig. 13 a).

The number of grid squares for unobstruc- parts of windows = 4.

Correction factor for interior finish B (Table 2),

= — 1.9 lux.

Total correction for 4 squares.
= 4 × (—1.9) = —7.6 lux.
Illumination at P_1 from Fig. 13 a.
Stars 16 = 32.0 lux,
Dots 32 = 16.0 lux
Total : = 48.0 lux
Correction = —7.6 lux
Illumination = 40.4 lux.

(ii) Use grid II (see Fig. 13 b)

The number of grid squares for unobstructed part of windows is again 4, but these include now 28 crosses and 4 dots giving a total illumination at P_1 = (28 × 1.0) + (4 × 0.5) = 30.0 lux. This value has to be corrected using Table No. 3.

From Table 3, for interior finish B, this correction factor (per square) is—0 8 lux and the total correction = 4 × (— 0.8) = — 3.2 lux. Hence illumination as given by lux grid II = (30.0—3.2) = 26.8 lux.

The mean of the two values obtained from grid I & II = ½ (40.4 + 26.8) = 33.6 lux, which is the net illumination from the unobstructed part of the windows.

Step b. The number of squares enclosed by the obstructed part of the windows (Fig. 13) = 16. The correction factor from Table 3 is—0 8 lux.

Correction = 16 × (—0.8)
= — 12.8 lux.

Total illumination at P_1 from Fig. 13 (b), (counting the dots and crosses inside the circles).

Crosses 48 = 48.0 lux
dots 16 = 8.0 lux
Total : = 56.0 lux
correction = —12.8 lux
Net illumination = 43 2 lux.

To get the illumination due to obstructed portion of the windows, multiply the above value by 1.8.

Hence this value becomes
= 1.8 × 43.2
= 77.76 lux

Step c. Finally, the total illumination due to these windows is
= 33.6 + 77.76
= 111.36 lux
≅ 110. lux

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