**BUREAU OF INDIAN STANDARDS**

**DRAFT FOR COMMENTS ONLY**



# *Draft* NATIONAL LIGHTING CODE OF INDIA

# PART 8 DAYLIGHTING FOR BUILDINGS

**[First Revision of SP 72 (Part 8)]**

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| **Illumination Engineering and Luminaries Sectional Committee, ETD 49** | **Last Date for Comments: ______________** |

## FOREWORD

Daylight has been intimately connected with architecture from the days of the early human civilization as man's visual activities could be performed only under daylight even inside buildings, before the invention of the early artificial light source like the plain oil lamp or the candle. All artificial lighting, including electric lighting, was in fact meant for use during night time to enhance the period of human visual activities. Due to a sense of euphoria on the availability of electricity and due to the undesirable thermal gain and losses associated with windows used for daylight inside buildings, the use of artificial lighting became popular inside buildings even during daytime hours, particularly in air-conditioned interiors. However, surveys conducted on occupants' responses showed preference for the dynamic and variable quantity and quality of daylight with windows providing a desirable view of and contact with the outside world.

The present energy scenario of limited fossil fuels and of degradation of the environment in the generation of energy from fossil fuels, has given daylight a new and very important dimension related to energy conservation and clean environment. Daylight is a renewable source of light whose utilization for lighting of building interiors during the period it is available, could lead to energy conservation and promotion of a friendly environment.

Since daylight is external to a building and varies with the time of the day and seasons of the year, planning for daylighting inside a building has to be made right at the time of the planning of the building. The sun is the main source of daylight, whereas skylight is the effect of scattering of sunlight by the atmosphere. In a tropical country like India, direct sunlight causes excessive glare in the visual field and is thus unsuitable for daylighting of building interiors. Skylight on the other hand, can be a major source of interior lighting. However, as skylight varies with time of the day and seasons of the year, the orientation and the design of windows should be the factors taken into consideration.

## 1 SCOPE

**1.1** This Part of the National Lighting Code (NLC) covers the general principles and methods of daylighting of dwellings, offices and hospitals. It recommends the minimum illumination values to be achieved by daylighting principles and gives general guidance for realizing the values in practice.

## 2 REFERENCES

| *IS Number/Other Standards/References* | *Title* |
|---|---|
| IS 2440:1975 | Guide For Daylighting of Buildings (Second Revision) |
| IS 3646(PART 1):1992 | Code of Practice for Interior Illumination: Part1 General Requirements and Recommendations for Working Interiors. |
| IS 6060:1971 | Code of Practice for Daylighting of Factory Buildings |
| 7942:1976 | Code of Practice for Daylighting of Educational Buildings |
| ISO 15469:2004/CIE S 011:2003 | Spatial Distribution of Daylight – CIE Standard General Sky |

Darula, Stanislav & Kittler, Richard. (2002): CIE general sky standard defining luminance distributions

Darula, Stanislav & Kittler, Richard: A set of standard skies characterizing daylight conditions for computer and energy conscious design(January 1998)

Tregenza, P. 1993.Daylighting algorithms.

## 3 TERMINOLOGY

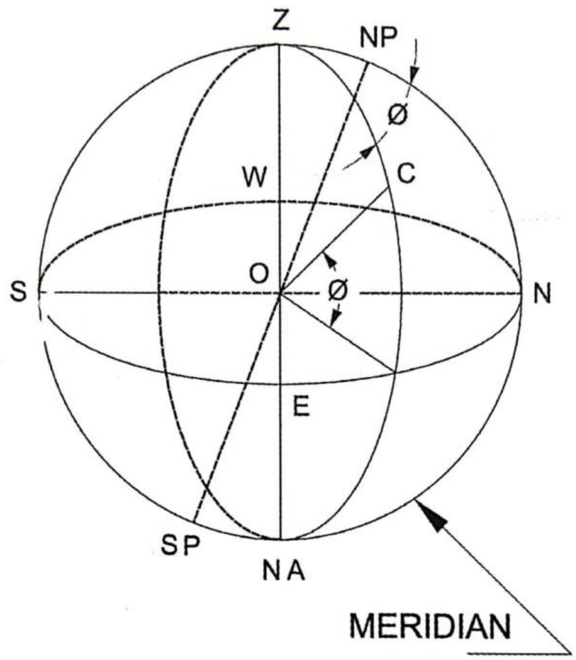
For the purpose of this Part of NLC, the following definitions shall apply in addition to those given under Part 1 of this code.

### 3.1 Altitude ( $\gamma$ )

The angular distance of any point of celestial sphere, measured from the horizon, on the great circle passing through the body and the zenith.

### 3.2 Azimuth ($\alpha$)

The angle measured between the meridians passing through the north point and the point in question.(Point C in Fig. 1)




| | |
|---|---|
| *O*- Observer's station | *S*-Geographical south |
| *C*-Celestial body | *E*-Geographical east |
| *Z*-Zenith | *W*-Geographical west |
| *NA*-Nadir | *NP*- Celestial north pole |
| *N*- Geographical north | *SP*- Celestial south pole |

**Fig. 1 Azimuth of a Celestial Body**

### 3.3 Clear Design Sky

The distribution of luminance of such a sky is non uniform; the horizon is brighter than the zenith, and when $L_M$ is observed minimum sky luminance, the luminance at an altitude ( $\gamma$) in the region away from the sun, is given by the expression:

$$L_{\gamma} = L_M \text{ Cosec } \gamma$$

where, $\gamma$ lies between 15° to 90°, and $L_{\gamma}$ is constant when $\gamma$ lies between 0° and 15°.

### 3.4 CIE Standard Clear Sky

Cloudless sky for which the relative luminance distribution is as described in ISO 15469:2004/CIE S 011:2003: Spatial distribution of daylight – CIE standard general sky.

### 3.5 CIE Standard Overcast Sky

Completely overcast sky for which the ratio of its luminance, $L_{\gamma}$, in the direction at an angle, $\gamma$, above the horizon to its luminance, $L_z$, at the zenith, is given by the relation:

$$\frac{L_\gamma}{L_Z} = \frac{1+2\sin\gamma}{3}$$

### 3.6 Daylight Factor (DF)

It is a measure of the total daylight illuminance at a point on a given plane expressed as the ratio (or percentage) which the illuminance at the point on the given plane bears to the simultaneous illuminance on a horizontal plane due to clear design sky at an exterior point open to the whole sky vault, direct sunlight excluded.
The daylight factor method is the most commonly used daylight prediction tool to estimate a quantitative measure of daylight in buildings. This gives a first order approximation to annual daylighting provision from which supplementary lighting requirements can be estimated.

NOTES –

1 The daylight factor approach is founded on the CIE standard overcast sky.

2 Sky luminance distributions of Clear design sky and CIE standard sky are independent of azimuth angle of sky element.

### 3.7 Daylight Coefficient (DC)

It is the ratio of total illuminance at a particular point to the product of luminance of that sky element and the solid angle subtended by that sky element. The daylight coefficient method is modern daylight prediction tool applicable to any sky type. DC relates the daylight illuminance of a room to the luminance patterns of the sky in the direction of view of the window at any given time.

### 3.8 Daylight Area

The superficial area on the working plane illuminated to not less than a specified daylight factor.

### 3.9 Daylight Penetration

The maximum distance up to which a given Daylight Factor contour penetrates into a room.

### 3.10 External Reflecting Component (ERC)

The ratio (or percentage) of that part of the daylight illumination at a point on a given plane which is received by direct reflection from external surfaces as compared to the simultaneous exterior illumination on a horizontal plane from the entire hemisphere of a unobstructed clear design sky.

### 3.11 Internal Reflected Component (IRC)

The ratio (or percentage) of that part of the daylight illumination at a point on a given plane which is received by direct reflection or inter-reflection from the internal surfaces as referred to the simultaneous exterior illumination on a horizontal plane due to the entire hemisphere of an unobstructed clear design sky.

**3.12 North and South Points**

The points in the respective directions where the meridian cuts the horizon.

**3.13 Reveal**

The side of an opening for a window.

**3.14 Sky Component (SC)**

The ratio (or percentage) of that part of the daylight illumination at a point on a given plane which is received directly from the sky as compared to the simultaneous exterior illumination on a horizontal plane from the entire hemisphere of an unobstructed clear design sky.

**3.15 Direct Solar Illuminance ($E_{vs}$)**

The illuminance at a point due to the sun with the light from the sky excluded.
Unit: $lx = lm \cdot m^{-2}$

**3.16 Diffuse Horizontal Illuminance (from the Sky) ($E_{vd}$)**

Illuminance produced by skylight on a horizontal surface on the Earth.
Unit: $lx = lm \cdot m^{-2}$

**3.17 Global Horizontal Illuminance ($E_{vg}$)**

Illuminance produced by daylight on a horizontal surface on the Earth.
Unit: $lx = lm \cdot m^{-2}$

**3.18 Gradation Function ($\phi$ (Z))**

Function which describes the changes of the luminance along the sky meridian from horizon to zenith from horizon to zenith, where Z is the zenith angle of the sky element.

**3.19 Indicatrix Function (f($\chi$ ))**

Function which expresses the diffusion of sunbeams within the atmosphere dependent on the angular direction.

**3.20 Horizontal Extraterrestrial Illuminance ( $E_{voh}$ )**

Illuminance on a horizontal plane at the outside border of the atmosphere considering the local reduction due to the real solar altitude, $\gamma_s$, i.e. $E_{voh} = E_{vo} \sin \gamma_s$, where $E_{vo}$ is the luminous solar constant.

### 3.21 Luminous Extinction Coefficient (of the Atmosphere) ($a_v$)

Measure that expresses the attenuation of the direct illuminance when the sun rays cross vertically the pure and dry atmosphere (Rayleigh atmosphere)
Unit: 1

### 3.22 Luminous Solar Constant ($E_{vo}$)

Illuminance produced by the extraterrestrial solar radiation on a surface at the outer border of the atmosphere perpendicular to the Sun's rays at mean Sun-Earth distance.
Unit: $lx = lm \cdot m^{-2}$

### 3.23 Luminous Turbidity Factor ($T_v$)

Ratio of the vertical optical thickness of a real turbid atmosphere to the vertical optical thickness of the pure and dry atmosphere (Rayleigh atmosphere), related to the visible part of the solar spectrum
Unit: 1

### 3.24 Overcast Sky

Sky completely covered with diffuse and dense cloud layers without direct sunlight

### 3.25 Daylight

Part of global solar radiation capable of causing a visual sensation.

### 3.26 Sunlight

Part of direct solar radiation capable of causing a visual sensation.

### 3.27 Zenith Luminance ($L_z$)

Luminance of the zenith sky element.

### 3.28 Relative Optical Air Mass (m)

Ratio of the optical thickness of the atmosphere at angle $\varepsilon$ to the vertical, $\delta(\varepsilon)$, to the vertical optical thickness, $\delta(0°)$, of the atmosphere

### 3.29 Sky Luminance ($L_{\gamma\alpha}$)

Luminance of a sky element at altitude $\gamma$ and azimuth $\alpha$.

## 3.30 Sky Luminance Distribution

Pattern of luminance on the sky vault.

## 3.31 Working Plane

The horizontal plane at a level at which work shall normally be done. For the purpose of this code, the working plane, unless specified otherwise, shall be assumed as the horizontal plane 80 cm from the floor (normal table top level) in houses, flats, offices, and hospital wards and 90 cm (normal or bench level) from hospital operation theatre.

## 3.32 Roof Light

Opening of one horizontal or nearly horizontal top boundary surface of a building.

## 3.33 Shading Device

Device to reduce or obstruct the solar or sky radiation or prevent excessive heat gain and glare.

## 3.34 Skylight (Diffuse)

Illuminance at a point due to the sky on a horizontal plane from the whole hemisphere.

NOTE: Skylight is also commonly known as sky illuminance.

## 3.35 Window

Opening on a vertical or nearly vertical surface of a room for admission of daylight.

# 4 CIE STANDARD SKY MODELS

In daylighting application sky dome is considered as the primary source of daylight and sky luminance distribution data is the most important one amongst the measured daylight parameters. Usually, this luminance distribution data is available in the form of monthly averaged series of measured data at regular interval of time throughout a year at a particular location either in tabular form or in graphical form (iso-luminance distribution). In India measured sky luminance distribution data is available in graphical form only for Roorkee. However, CIE(International Commission on Illumination) provides one mathematical model –Standard Sky Luminance Distribution (SSLD) model.

## 4.1 Basis of CIE Sky Standard

The set of fifteen SSLDs defined by the ISO/CIE Standard covers the whole range of normally and frequently-occurring typical sky patterns under quasi-homogeneous atmospheric conditions.
An SSLD is analytically defined at any point on the sky dome (a "sky element") in relative rather than absolute terms (i.e. normalized to zenith luminance), assuming that:

a) The resulting sky patterns are symmetrical about the solar meridian (i.e. the vertical plane of the momentary sun position);
b) The solar altitude and azimuth on any day and in true solar or local time per hour is known;
c) Except for homogeneous turbidity or cloudiness, the uneven cloud types and distributions can be neglected;
d) Sunshine with overcast sky types is completely absent; sunshine is present with clear skies, but real sunshine duration can be respected under dynamic, cloudy or partly cloudy skies which might occur either with or without sunshine;
e) SSLDs are not expressed in absolute units of the SI system (i.e. neither in $kcd \cdot m^{-2}$ nor in $cd \cdot m^{-2}$);
f) The ISO/CIE Standard does not state any parameter (such as $L_{vz}/E_{vd}$, direct normal and diffuse horizontal irradiance and/or illuminance) for the classification of sky scans or measured distributions related to the fifteen SSLDs.

The SSLD models are intended to represent a wide range of sky conditions based on two gradation parameters (*a* and *b*) and three indicatrix parameters (*c*, *d* and *e*). In its basic form, the model provides estimates for the relative luminance, normalized to a zenith luminance, at any point on the sky dome for a given sun position.

### 4.2 CIE Standard Sky Luminance Distribution (SSLD) Model [CIE 2003]

In 2003, CIE published standard on Standard Sky Luminance Distribution (SSLD). It provides relative spatial luminance distribution for fifteen CIE Standard General Skies. The luminance of any sky element specified by γ and α is modelled based on the theory of sunlight scattering within the atmosphere and expressed by the product of two different exponential functions viz, gradation function φ and indicatrix function given by

i) $\phi(\frac{\pi}{2} - \gamma)$ and
ii) $f(\chi)$ .

Thus, the expression of luminance of sky element is given by the following Equation:

$$L_{\gamma\alpha} = f(\chi) * \Phi(\frac{\pi}{2} - \gamma)$$

The zenith luminance $L_z$ can be obtained from the above Equation by putting the value of $\gamma = \pi/2$. Then $\chi = (\frac{\pi}{2} - \gamma_s)$ and thus

$$L_z = f\left(\frac{\pi}{2} - \gamma_s\right) * \Phi(0)$$

The CIE SSLD is the sky luminance distribution relative to the zenith luminance and is represented by the following Equation:

$$\frac{L_{\gamma\alpha}}{L_z} = \frac{f(\chi)*\phi(\frac{\pi}{2}-\gamma)}{f(\frac{\pi}{2}-\gamma_s)*\phi(0)}$$

$L_{\gamma\alpha}$ = luminance (cd/m$^2$) of any sky element
$L_z$ = zenith Luminance (cd/m$^2$)
$\chi$ = scattering angle between the sun and sky element
$\gamma_s$ and $\alpha_s$ = altitude and azimuthal angles of the sun.

Here angles are in radian and shown in Fig 2.

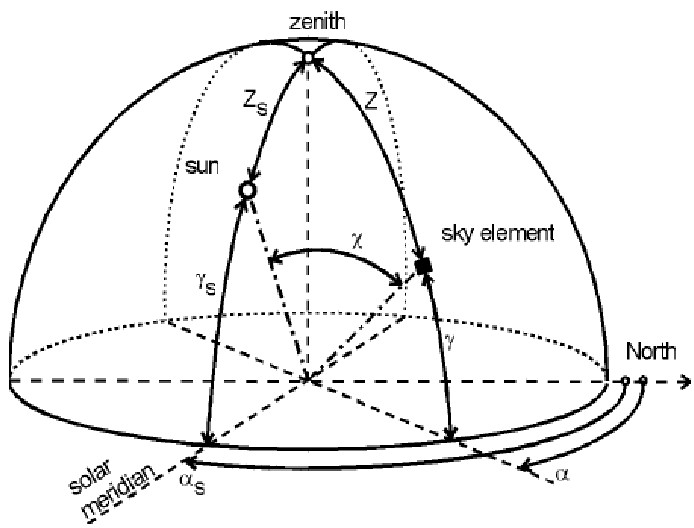



**Fig. 2 Angles Defining the Position of the Sun and a Sky Element**

The direction of altitude angle is measured from horizon ($0^0$) upward up to zenith ($90^0$) and the direction of azimuth angle is taken due north ($0^0$) and clockwise.

Now the gradation function is given by,

$$\phi(\frac{\pi}{2}-\gamma)=1+a*\exp(\frac{b}{Cos(\frac{\pi}{2}-\gamma)})$$

For zenith $\gamma = \pi/2$, and gradation function becomes

$$\phi(0)=1+a*\exp(b)$$

The indicatrix function is given by,

$$f(\chi) = 1+c*[\exp(d*\chi)-\exp(d*\frac{\pi}{2})]+e*Cos^2\chi$$

The scattering angle (χ) can be calculated from the following formula

$$\chi = \text{Cos}^{-1}[\text{Sin}\gamma * \text{Sin}\gamma_s + \text{Cos}\gamma * \text{Cos}\gamma_s * \text{Cos}(\alpha - \alpha_s)]$$

where $\alpha_s$ = solar azimuth angle (radian).

The indicatrix function for zenith is given by:

$$f\left(\frac{\pi}{2} - \gamma_s\right) = 1 + c * [\exp(d * (\frac{\pi}{2} - \gamma_s)) - \exp(d * \frac{\pi}{2})] + e * \text{Cos}^2\left(\frac{\pi}{2} - \gamma_s\right)$$

Where a, b, c, d, e are standard sky parameters used to represent CIE 15 Standard General skies. The values of these sky parameters are tabulated in Table 1.

**Table 1 Values of Standard Parameters for 15 CIE Standard Sky Types [*CIE, 2003*]**
*(Clause 4.2)*

| **Sl. No.** | **Type** | **Gradation** | **Indicatrix** | **a** | **b** | **c** | **d** | **e** | **Description of luminance distribution** |
|---|---|---|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| i) | 1 | I | 1 | 4.0 | -0.7 | 0 | -1 | 0 | CIE Standard Overcast Sky, alternative formsteep luminance gradation towards zenith, azimuthal uniformity |
| ii) | 2 | I | 2 | 4.0 | -0.7 | 2 | -1.5 | 0.15 | Overcast, with steep luminance gradation and slight brightening towards the sun |
| iii) | 3 | II | 1 | 1.1 | -0.8 | 0 | -1.0 | 0 | Overcast, moderately graded with azimuthal uniformity |
| iv) | 4 | II | 2 | 1.1 | -0.8 | 2 | -1.5 | 0.15 | Overcast, moderately graded and slight brightening towards the sun |
| v) | 5 | III | 1 | 0.0 | -1.0 | 0 | -1.0 | 0 | Sky of uniform luminance |
| vi) | 6 | III | 2 | 0.0 | -1.0 | 2 | -1.5 | 0.15 | Partly cloudy sky, no gradation towards zenith, slight brightening towards the sun |
| vii) | 7 | III | 3 | 0.0 | -1.0 | 5 | -2.5 | 0.30 | Partly cloudy sky, no gradation towards zenith, brighter circumsolar region |
| viii) | 8 | III | 4 | 0.0 | -1.0 | 10 | -3.0 | 0.45 | Partly cloudy sky, no gradation towards zenith, distinct solar corona |
| ix) | 9 | IV | 2 | - | - | 2 | - | 0.1 | Partly cloudy, with the obscured sun |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | 1.0 | 0.55 | | 1.5 | 5 | |
| x) | 10 | IV | 3 | -1.0 | -0.55 | 5 | -2.5 | 0.30 | Partly cloudy, with brighter circumsolar region |
| xi) | 11 | IV | 4 | -1.0 | -0.55 | 10 | -3.0 | 0.45 | White-blue sky with distinct solar corona |
| xii) | 12 | V | 4 | -1.0 | -0.32 | 10 | -3.0 | 0.45 | CIE Standard Clear Sky, low illuminance turbidity |
| xiii) | 13 | V | 5 | -1.0 | -0.32 | 16 | -3.0 | 0.30 | CIE Standard Clear Sky, polluted atmosphere |
| xiv) | 14 | VI | 5 | -1.0 | -0.15 | 16 | -3.0 | 0.30 | Cloudless turbid sky with broad solar corona |
| xv) | 15 | VI | 6 | -1.0 | -0.15 | 24 | -2.8 | 0.15 | White-blue turbid sky with broad solar corona |

## 5 PREDICTION OF DAYLIGHT AVAILABILITY

Direct and diffuse daylight illuminance on horizontal and vertical planes can be predicted by the mathematical models derived by CBRI, Roorkee from Indian measured daylight data. The direct or solar illuminance on horizontal surface ($E_{DH}$) and vertical surface ($E_{DV}$) are predicted by the following Equations:

$$E_{DH} = E_{voh}\ .\exp\left(-a_v\ m\ T_v\right)$$

$$E_{DV} = E_{vov}\ .\exp\left(-a_v\ m\ T_v\right)$$

Where $E_{voh}$ and $E_{vov}$ are extraterrestrial horizontal and vertical component of solar illuminance respectively.

$a_v$ : luminous extinction coefficient

m: relative optical air mass

$T_v$ : luminous turbidity factor

Now, $E_{voh}$ and $E_{vov}$ can be predicted from $E_{vo}$ – the luminous solar constant (133.8 kLux). $E_s$ varies with Julian day number (J) as given by the following equation

$$E_{vo} = 133.8\ [1 + 0.034\ cos2\pi \left(\frac{J-2}{365}\right)]$$

The horizontal and vertical components of $E_{vo}$ are given by the following equations:

$$E_{voh} = E_{vo}.\sin\gamma_s$$

and

$$E_{vov} = E_{vo}.\cos\gamma_s \cos\beta$$

The values of $a_v$, m and $T_v$ depend on sky condition i.e., nature and spatial distribution of cloud. Establish modes are available for their prediction from measured daylight data as presented below:

$$m = \frac{1}{\sin\gamma_s + 0.50572\,(\gamma_s + 6.07995^0)^{-1.6364}}$$

$$a_v = \frac{1}{9.9 + 0.043\ m}$$

$$T_v = -\frac{\ln\left(\frac{E_{DH}}{E_{voh}}\right)}{a_v\, m}$$

### 5.1 Diffuse Solar Horizontal Illuminance ($E_{dH}$)

The diffuse solar horizontal illuminance ($E_{dH}$) for low, medium and high luminous turbidity can be predicted by the following equations, developed by CBRI from measured daylight data in India. Values of the constants are presented in Table 2.

For low ($T_v = 3$) luminous turbidity:

$$E_{dH} = \left(\frac{1}{K_1}\right)\left[(K_1 - 1) + \frac{C}{\sin^2\gamma_S + C}\right]\left[6.276 + \frac{165\sin^2\gamma_S}{\sin^2\gamma_S + 0.3135}\right]$$

For medium ($T_v = 6$)luminous turbidity:

$$E_{dH} = \left(\frac{1}{K_2}\right)\left[(K_2 - 1) + \frac{C}{\sin^2\gamma_S + C}\right]\left[5.668 + \frac{160\sin^2\gamma_S}{\sin^2\gamma_S + 0.3135}\right]$$

For high ($T_v = 9$)luminous turbidity:

$$E_{dH} = \left(\frac{1}{K_3}\right)\left[(K_3 - 1) + \frac{C}{\sin^2\gamma_S + C}\right]\left[4.886 + \frac{154\sin^2\gamma_S}{\sin^2\gamma_S + 0.3135}\right]$$

**Table 2 Values of $K_1$, $K_2$, $K_3$ and C**

*(Clause 5.1)*

| **Sl. No.** | **Solar Altitude in degree** | $K_1$ | $K_2$ | $K_3$ | **C** |
|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) |
| i) | 10 | 1.0102 | 1.0405 | 1.2010 | 0.0160 |
| ii) | 15 | 1.0805 | 1.1105 | 1.2900 | 0.0191 |
| iii) | 20 | 1.0904 | 1.2405 | 1.5172 | 0.0206 |
| iv) | 25 and above | 1.0944 | 1.2764 | 1.6403 | 0.0222 |

Hourly values of horizontal sky illuminance have been computed from the above equations for latitudes from $9^0$ N to $35^0$N for winter solstice, summer solstice and equinox for luminous turbidity ranging from 3 to 9.

### 5.2 Vertical Window Plane Illuminance ($E_{dV}$)

It consists of global illuminance and ground reflected illuminance as incident on the window plane and can be computed from the values of vertical global illuminance, $E_{gV}$ and horizontal global illuminance, $E_{gH}$ and ground reflectance ρ, using the following equations:

$E_O = E_{gV} + (\rho/2).E_{gH}$

$EO = (E_{DV} + E_{dV}) + (\rho/2).(E_{DH} + E_{dH})$

The vertical diffuse illuminance $E_{dV}$ can be computed from the sky luminance distribution for half of the sky vault illuminating the window façade.

$$E_{dV} = \int_{\alpha=0}^{\pi} \int_{\gamma=\gamma_b}^{\pi/2} L_{\gamma\alpha} \cos^2 \gamma.\cos(\alpha - \nu).d\gamma.d\alpha \; + \; (\rho_b.E_{gVb}/\pi) \int_{\alpha=0}^{\pi} \int_{\gamma=0}^{\gamma_b} \cos^2 \gamma.\cos(\alpha - \nu).d\gamma.d\alpha$$

where
$L_{\gamma\alpha}$= luminance of a sky element,
$E_{gVb}$ = vertical illuminance of obstructions e.g. buildings in front of the window facade, $\rho_b$ = reflectance of the obstructing building surface,
$\gamma_b$ = altitude of the obstruction,
ν = angle between normal to vertical surface and azimuth of sky element

## 6 DAYLIGHTING

### 6.1 Sources of Daylighting

**6.1.1** The primary source of light for daylighting is the sun. The light received by the earth from the sun consists of two parts, namely, direct solar illumination and skylight. For the purpose of the daylighting design, direct solar illumination shall not be considered and only skylight shall be taken as a contributing factor to illuminance of the building interiors during the day.

**6.1.2** The amount of skylight depends on the position of the sun defined by its altitude which is turn varies with the latitude of the location, the day of the year and the time of the day.

**6.1.3** The external available horizontal skylight (diffuse) values which are exceeded for about 90 percent of the daytime working hours may be taken as outdoor design illuminance values for ensuring adequacy of daylighting design. The outdoor design sky illuminance varies for different climatic regions of the country. The recommended design sky illuminance values are 6800 lux for cold climate, 8000 lux for composite climate, 9000 lux for warm humid climate, 9 500 lux for temperate climate and 10500 lux for hot-dry climate. For integration with the artificial lighting during daytime working hours an increase of 500 lux in the recommended sky design illuminance for day lighting is suggested. The external available horizontal illumination which may be assumed for design purpose in the country broadly covering India from north to south under clear sky condition may be taken 8000 lux. Since the design is based on the solar position of 15° altitude the corresponding illumination from the design sky has been found to be nearly constant all over the country. However, the prevalent atmospheric haze which varies from place to place may necessitate a 25 percent increase in the value of 8000 lux design illumination suggested in this code, where haze conditions prevail at design time.

**6.1.4** The Daylight Factor is dependent on the sky luminance distribution, which varies with atmospheric conditions. A clear design sky with its non-uniform distribution of luminance is adopted for the purposes of design (*see* **3.3**).

**6.2 Components of Daylight Factor**

**6.2.1** Daylight Factor is the sum of all the daylight, directly and indirectly, reaching on an indoor reference point from the following sources:

a) The direct sky patch visible from the point,
b) External surfaces reflecting light directly (*see* Note 1) to the point, and
c) Internal surfaces reflecting and inter-reflecting light to the point.

**NOTES**

a) External surface reflection may be computed approximately only for points at the centre of the room. For detailed analysis, procedures are complicated and these may be ignored for actual calculations.

b) Each of the three components, when expressed as a ratio or percent of the simultaneous external illuminance on the horizontal plane, defines respectively the Sky Component (SC), the External Reflected Component (ERC) and the Internal Reflected Component (IRC) of the Daylight Factor.

**6.2.2** The daylight factors on the horizontal plane only are usually taken, as the working plane in a room is generally horizontal. However, the factors in vertical planes should also be considered when specifying daylighting values for special cases, such as daylighting on class-rooms, blackboards, pictures and paintings hung on walls.

**6.3 Sky Component (SC)**

**6.3.1** Sky component for a window of any size is computed by the use of the appropriate table of Annex A.

The recommended sky component level should be ensured generally on the working plane at the following positions:

a) At a distance of 3 to 3.75 m from the window along the central line perpendicular to the window,
b) At the centre of the room if more appropriate, and
c) At fixed locations, such as school desks, black-boards and office tables.

The daylight area of the prescribed sky component should not normally be less than half the total area of the room.

**6.3.2** The values obtainable from the tables are for rectangular, open unglazed windows, with no external obstructions. The values shall be corrected for the presence of window bars, glazing and external obstructions, if any. This assumes the maintenance of a regular cleaning schedule.

### 6.4 Corrections for Window Bars

The corrections for window bars shall be made by multiplying the values read from tables in Annex A by a factor equal to the ratio of the clear opening to the overall opening.

**6.4.1** *Daylight Coefficient Method*

The Daylight Coefficient [$D_{\gamma\alpha}$] is defined by the ratio of total illuminance at a particular point to the product of luminance of that sky element and the solid angle subtended by sky element at that point and mathematically expressed as

$$D_{\gamma\alpha} = \frac{\Delta E_{\gamma\alpha}}{L_{\gamma\alpha} * \Delta S_{\gamma\alpha}}$$

where,

$\Delta E_{\gamma\alpha}$= illuminance at any station point for the sky element specified by angles γ, α

$L_{\gamma\alpha}$= luminance of that sky element

$\Delta S_{\gamma\alpha}$ = solid angle subtended by above sky element at the station point.

For point-specific horizontal illuminance,

$$D_{\gamma\alpha} = sin\gamma$$

and for point-specific vertical illuminance

$$D_{\gamma\alpha} = cos\gamma * \cos(\alpha - \nu)$$

where $\nu$ is the angle between normal to vertical surface and azimuth of sky element.

**6.4.2** *Discretization of Sky Vault for Sky Luminance Measurement*

The sky luminance data were measured at 145 discrete points on the sky and were completed in 3 minutes. The spatial distribution of 145 sky elements is presented in Fig. 3 and the distributions of 145 sky elements are shown in Table 3 [Daylight Algorithms, 1993][Tregenza, P. 1993. "Daylighting algorithms." United Kingdom.].

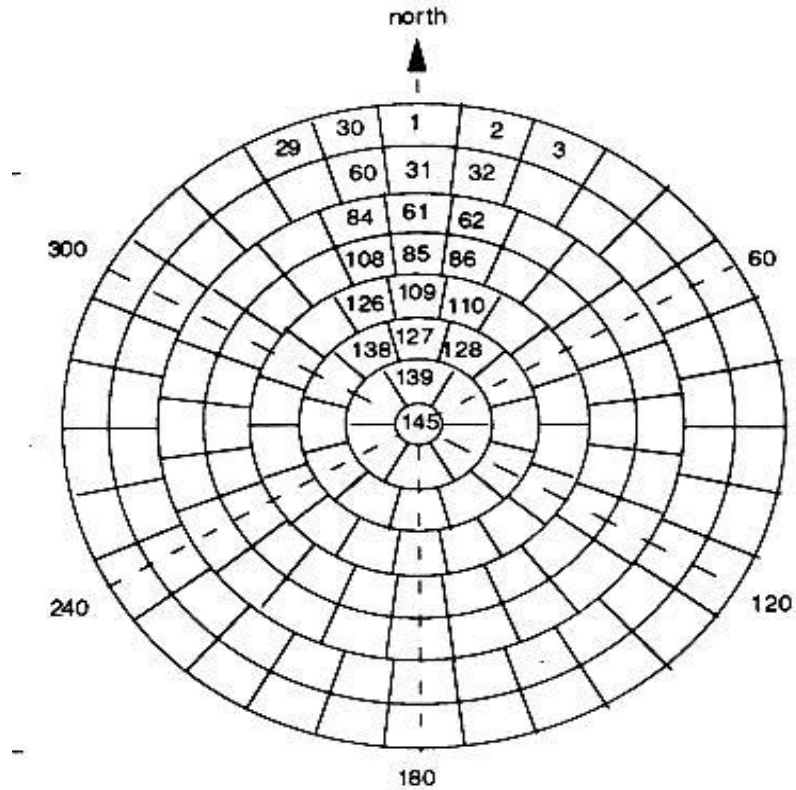



**Fig. 3 Sub Division of Sky Vault**

**Table 3 Altitude and Azimuthal Angles of 145 Sky Elements**
*(Clause 6.4.2)*

| Sl. No. | Altitude of band centre (degrees) | Number of zones in band | Azimuth increment (degrees) | Solid angle subtended by zone (steradians) |
|---|---|---|---|---|
| **(1)** | **(2)** | **(3)** | **(4)** | **(5)** |
| i) | 6 | 30 | 6 | 0.0435 |
| ii) | 18 | 30 | 18 | 0.0416 |
| iii) | 30 | 24 | 30 | 0.0474 |
| iv) | 42 | 24 | 42 | 0.0407 |
| v) | 54 | 18 | 54 | 0.0429 |
| vi) | 66 | 12 | 66 | 0.0445 |
| vii) | 78 | 6 | 78 | 0.0455 |
| viii) | 90 | 1 | 354 | 0.0344 |

## 7 WINDOW DESIGN

**7.1** Clauses **7.1.1** to **7.2.5.4** give a simplified method of arriving at the window dimensions to provide a given daylight factor on the working plane in rooms whose floor area is less than 60 sq m and the proportions of the rectangular rooms with side length is in the ratio of 2:3.

**7.1.1** The location of the window (s) on the shorter or longer wall has to be taken into consideration, as it influences the availability of daylight at the centre of the room or nearby area.

**7.1.2** The relation between Daylight Factor at the centre of a room (or the rear of it, that is near the rear wall) and window are expressed as a percentage of floor area that will provide the Daylight Factor as shown in Fig. 4 and Fig. 5 for four possible situations, namely : (a) the aperture is just an opening in the wall, (b) the opening is glazed with 3 mm thick glass, (c) the glazed opening is a wooden window, and (d) the glazed opening is a metal window (it is to be noted that a wooden window frame cuts off more daylight as compared to metallic window frame). The abscissa is marked accordingly.

**7.1.3** The effect of unobstructed windows on long or short wall on the daylight availability at the centre of a room or its rear can be ascertained from Fig. 4 and Fig. 5. The following assumptions were made:

a) Interior of the room possesses the following reflection factors:

  i) walls : 45-50 percent

  ii) ceiling : 70-75 percent, and

  iii) floor: 24-30 percent.

b) Ceiling height is taken to be 2.75 m;

c) Windows are provided with louvres to cut the incursion of sunlight;

d) Combined thickness of wall and width of louvre is taken to be 60 cm;.

e) Ground reflection factor is taken as 0.25; and

f) No external obstruction.

**7.1.4** The fenestration percentage of floor area arrived at by using Fig 4, Fig. 5 and Table 4 is expected to provide the required amount of daylight at the point in question. However, the presence of dirt on glass reduces the quantity of light entering the room and the glazing have to be cleaned periodically. The area of the window arrived at may be split into two or three and located on the window wall that will provide uniform distribution of day lighting on the working planes. The sill height should be between 80 and 105 cm to get the maximum advantage of vertical and horizontal plane illumination. The need to provide suitable louvre or overhangs to avoid direct sunshine should be considered.

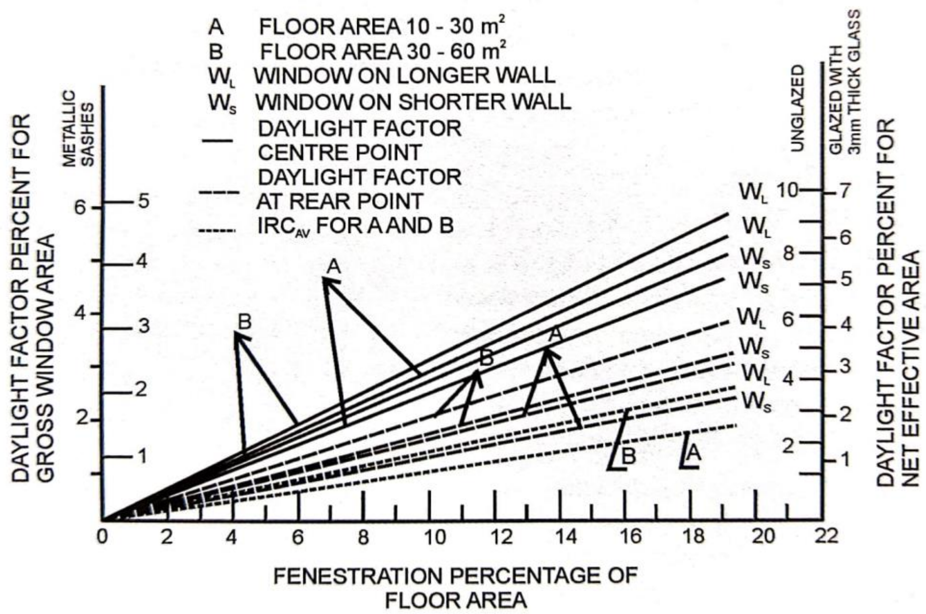



**Fig. 4 Daylight Factor on the Working Plane for a Corner Located Window**

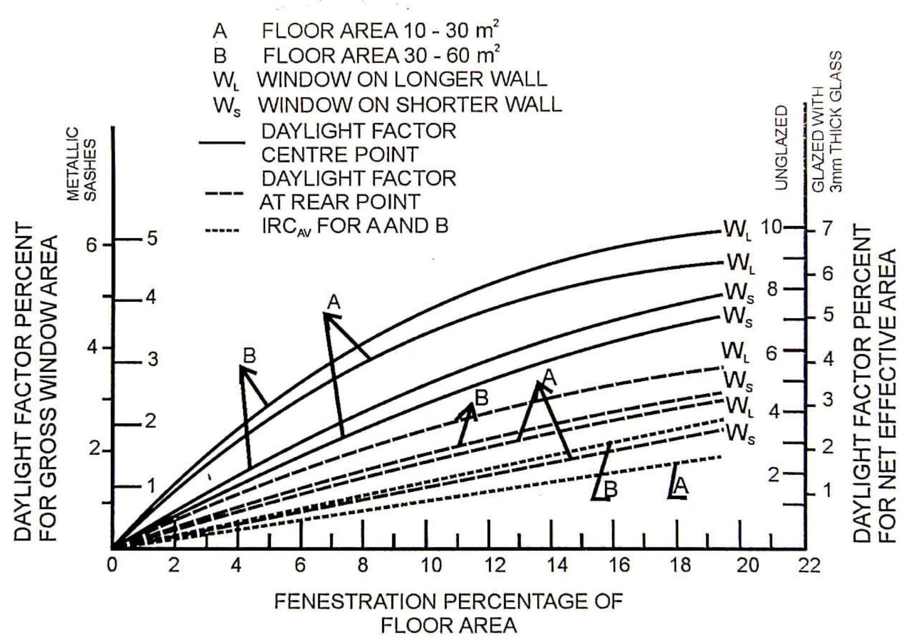



**Fig. 5 Daylight Factor on the Working Plane for a Centrally Located Window**

### 7.2 Lux Grid Method

The lux- grid method may be used within 10 percent accuracy to:

a) assess the illumination level on the working plane or other horizontal surfaces as provided by a given arrangement of window, and

b) calculate window sizes to give desired illumination levels on the working planes.

**7.2.1** The grid (Fig. 6 and Fig. 7) represents the window wall of a room above the working plane. The window wall is divided into small squares and each square contains a few dots and a few crosses. The system is symmetrical about the vertical line PY passing through the point P. The horizontal PW through P corresponds to the plane of reference, usually the working plane. By drawing the elevation of the window on the grid and counting the number of dots and crosses within the window outline, the illumination can be found. If the desired illumination is known, the size of the windows can also be determined.

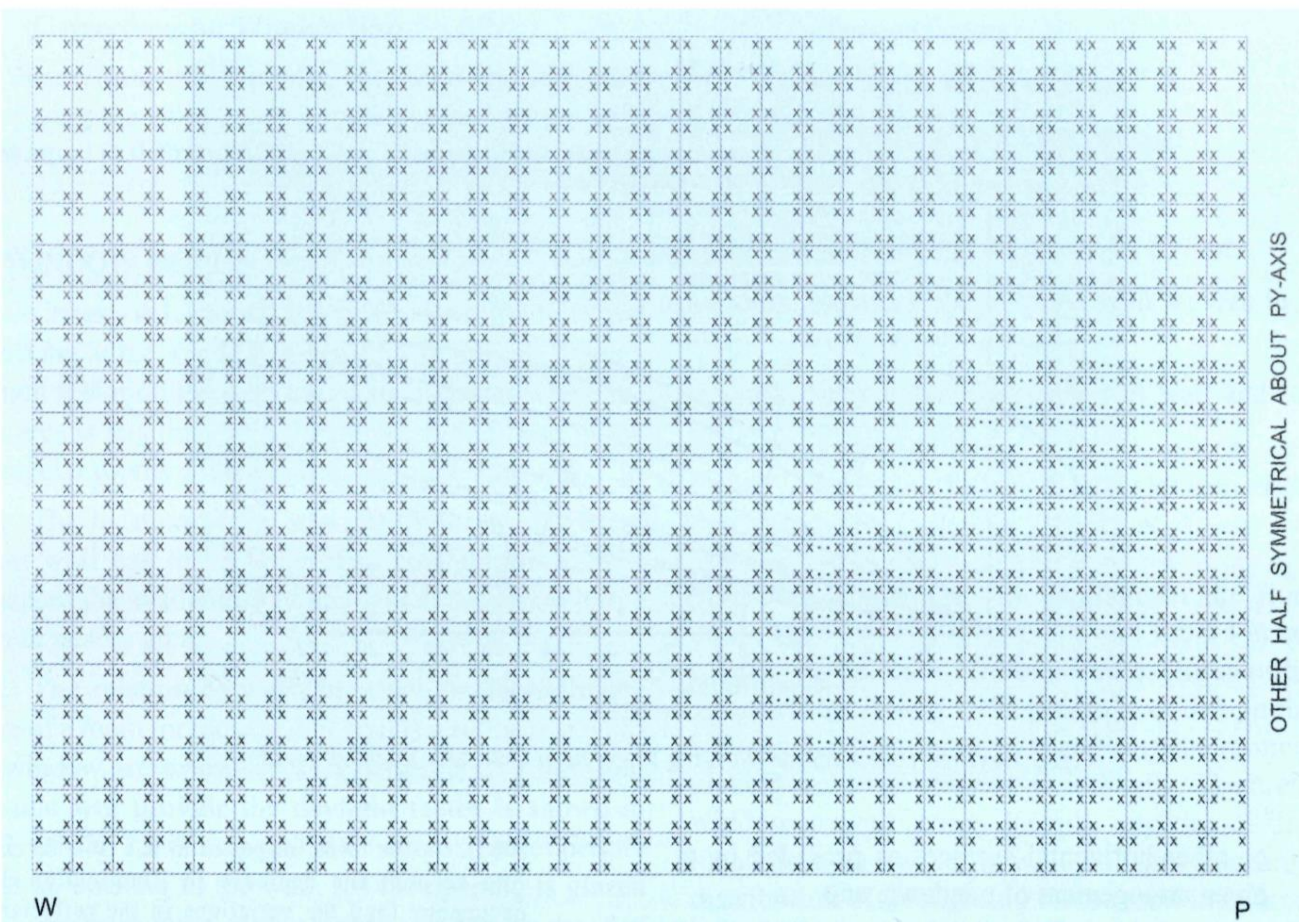



**Fig. 6 Lux-Grid I for Daylighting of a Side-lit Window in Absence of External Obstruction**

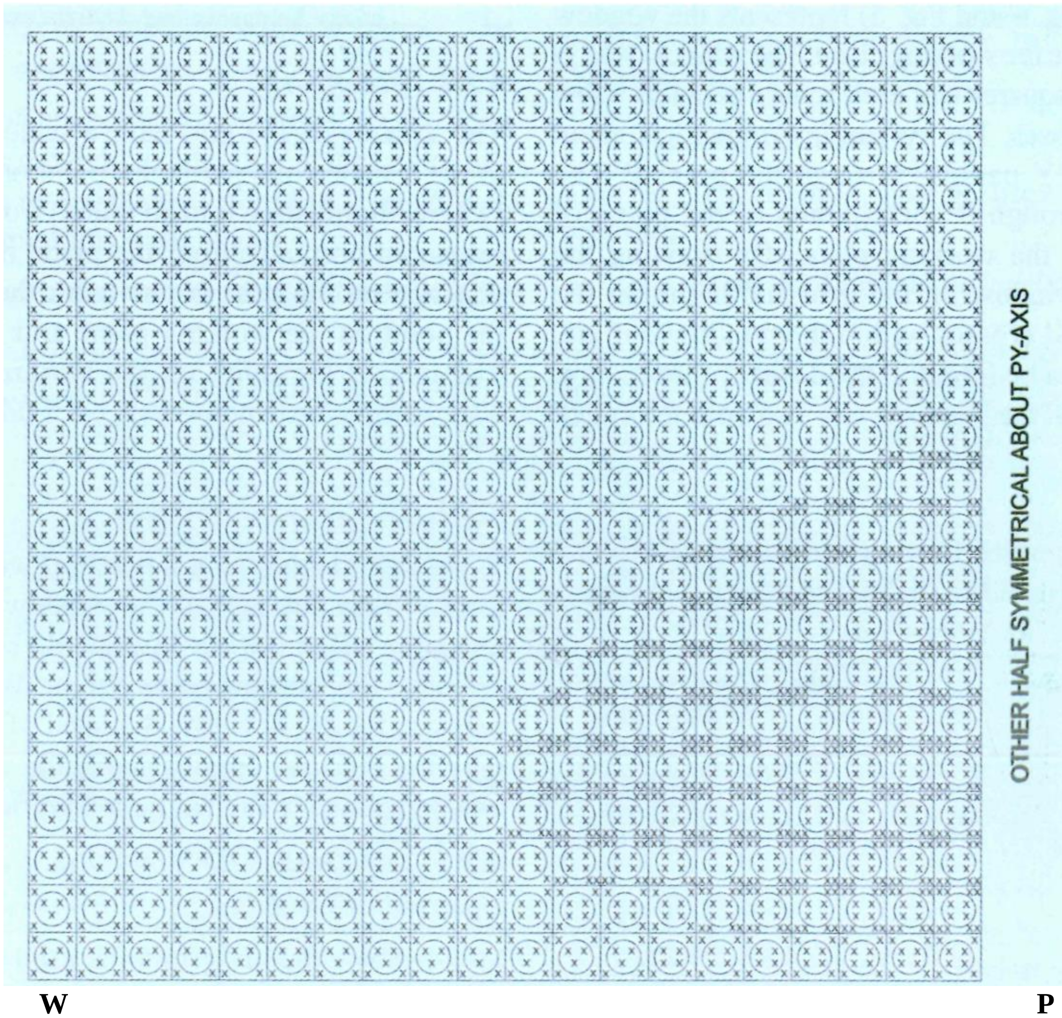



**Fig. 7 Lux-Grid II for Daylighting of a Side-lit Window in Presence of External Obstruction**

**Table 4 Recommended Illuminance Levels on Work Areas for Educational Buildings**
(*Clause* 7.1.4)

| Sl No. | Work Area/Visual Task | Illuminance (lux) | Corresponding Daylight Factor (%) |
|---|---|---|---|
| (1) | (2) | (3) | (4) |
| i | Class-room desk, writing boards | 150-300 | 1.9-3.8 |
| ii | Laboratories | 200-300 | 2.5-3.8 |
| iii | Library (reading tables ) | 150-300 | 1.9-3.8 |
| iv | Drawing, typing, sewing | 300 | 3.8 |
| v | Toilets | 150 | 1.9 |

NOTE — The levels suggested in this table do not take into account the decrease in illumination due to occupancy (and the variations in the reflectance of school uniforms) and should be used as a guide only.

However, in the first instance this reduction can be treated as negligible. The grid is based on measurements of sky luminance and daylight availability all over India.

**7.2.2** *Size of Grid*

The squares on the grid have a scale dimension relative to the distance of a particular point on the working plane (where illumination is to be found) from the window wall measured normally from the plane of the glazing. Unit distance on the grid is one-tenth the distance between the point on the working plane and window plane. For example, if the point on the working plane is located 375 cm from the window wall, each side of the small grid is 37.5 cm.

**7.2.3** *Sill-Height of Window*

Since illumination or a horizontal working plane comes mostly from that part of the window which is above its level, the sill of the window should be arranged either at or above the working plane height. Where due to special purpose, the sill is below the level of working plane, only the dots and crosses above the working plane level will contribute to the daylight significantly.

**7.2.4** *Lux-Grid I for Use with Negligible External Obstructions*

Fig. 6 shows lux-grid to be used for determining the illumination when obstruction outsides the windows are at a distance more than three times their own height from the window.

**7.2.4.1** *Dots and crosses*

In Fig. 6 one dot has a value of 0.5 lux and one cross has a value of 2.0 lux.

**7.2.4.2** Correction factor for interior finish Illumination level calculated using lux-grid I, shall be corrected for interior finishes of the room (and of different reflectance) using figures in Table 5A and Table 5B depending on reflectance variations, room geometry, mounting height and maintenance factor.

**7.2.4.3** *Limitations of the method*

a) It is assumed that the ground outside the window has a reflection factor of 0.25 that is, grass with some brick or concrete paving;

b) The ceiling is 2.75 m above the floor level, at the supports pitched or flat; and

c) It is assumed that the window has a 60 cm box type louvre around it or a 60 cm horizontal louvre. It is supposed to be glazed.

When a verandah or overhang obstructs the window, the portion of the window obscured from the point of observation as seen projected on the window plane should be treated as not contributing to the daylighting of the point in question.

**7.2.4.4** *Illustrative example*

A worked example has been given in Annex A to explain the use of the method.

> NOTE - The example given in Annex A deals with determination of total illumination due to two windows with external obstructions, where in both Lux-grid I and II have been involved.

For irregular obstructions like a row of trees parallel to the plane of the window, equivalent straight boundaries horizontal and vertical may be drawn, and the methods indicated in Annex A.

For bay windows, dormer windows or corner windows the effective dimensions of window opening computed should be taken when using the figures to find the total illuminance.

**7.2.5** *Lux-Grid II for Use in Presence of External Obstructions*

Fig. 7 shows lux-grid to be used for determining the illumination when obstruction (having reflection factor lying between 0.4 and 0.6) outside the windows are at a distance three times or less their own height from the window.

**7.2.5.1** *Circle, dots and crosses*

In Fig. 7 (Lux-grid II) in addition to dots and crosses inside each grid, a circle enclosing a few dots and crosses is present. The dots and crosses within the circle correspond to the daylight contributed by obstruction, while those outside the circle represent the contribution due to the unobstructed window including all external reflections. One dot has a value of 0.5 lux, one cross outside the circle has a value of 2.0 lux and one cross inside the circle has a value of 1.0 lux.

**7.2.5.2** *Correction factor for interior finish*

Illumination levels calculated using lux-grid II, shall be corrected for interior finishes of the room (and of different reflectance) using figures in Table 5A and Table 5B depending on reflectance variations, room geometry, mounting height and maintenance factor.

**7.2.5.3** 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.

**Table 5 A Correction Factor Per Square (α x α) Lux**
(*Clause* 7.2.4.2 and 7.2.5.2)

| Sl. No. | Distance of point from the window D (cm) | Size of one square in the grid A (cm) | Floor area within ($10-25\ mm^2$) | | | Floor area within ($25-50\ mm^2$) | | | Floor area within ($50-100\ mm^2$) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | A[1] | B[2] | C[3] | A[1] | B[2] | C[3] | A[1] | B[2] | C[3] |

| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| i) | 900 | 90 | +26.6 | +18.0 | +9.5 | +9.5 | +5.2 | +1.0 | +1.0 | -1.2 | -3.3 |
| ii) | 840 | 84 | +22.2 | +14.7 | +7.3 | +7.3 | +3.6 | 0 | 0 | -2.0 | -3.9 |
| iii) | 780 | 78 | +18.0 | +11.7 | +5.2 | +5.2 | +2.0 | -1.2 | -1.2 | -2.8 | -4.4 |
| iv) | 720 | 72 | +14.3 | +8.8 | +3.3 | +3.3 | 0 | -2.1 | -2.1 | -3.5 | -4.9 |
| v) | 660 | 66 | +10.8 | +6.2 | +1.6 | +1.6 | -0.7 | -3.0 | 3.0 | -4.2 | -5.3 |
| vi) | 600 | 60 | +7.6 | +3.8 | 0 | 0 | -1.9 | -3.8 | -3.8 | -4.8 | -5.7 |
| vii) | 540 | 54 | +4.7 | +1.6 | -1.4 | -1.4 | -3.0 | -4.5 | -4.5 | -5.3 | --6.1 |
| viii) | 480 | 48 | +2.1 | 0 | -2.7 | -2.7 | -4.0 | -5.2 | -5.2 | -5.8 | -6.4 |
| ix) | 420 | 42 | 0 | -2.0 | -3.9 | -3.9 | -4.8 | -5.7 | -5.7 | -6.2 | -6.7 |
| x) | 360 | 36 | -2.1 | -3.5 | -4.9 | -4.9 | -5.5 | -6.2 | -6.2 | -6.6 | -6.9 |
| xi) | 300 | 30 | -3,8 | -4.8 | -5.7 | -5.7 | -6.2 | -6.7 | -6.7 | -6.9 | -7.1 |
| xii) | 240 | 24 | -5.2 | -5.8 | -6.4 | -6.4 | -6.7 | -7.0 | -7.0 | -7.1 | -7.3 |
| xiii) | 180 | 18 | -6.2 | -6.6 | -6.9 | -6.9 | -7.1 | -7.3 | -7.3 | -7.3 | -7.4 |
| xiv) | 120 | 12 | -7.0 | -7.1 | -7.3 | -7.3 | -7.4 | -7.4 | -7.4 | -7.5 | -7.5 |

NOTES –

**1** Finish A **-** ceiling walls (reflection factor 0.7 to 0.8), walls off-white (reflection factor 0.45 to 0.55) and floor gray (reflection factor 0.3)

**2** Finish B **-** ceiling off -white, walls off-white and floor grey.

**3** Finish C **-** ceiling off-white, walls dark (reflectance factor 0.25 to 0.3) and floor grey.

## Table 5 B Correction Factor per Square (α x α) Lux
(*Clause* 7.2.4.2 and 7.2.5.2)

| **Sl. No.** | **Distance of point from the window D(cm)** | **Size of one square in the grid A(cm)** | **Floor area within (10-25 mm$^2$ )** | | | **Floor area within (25-50 mm$^2$ )** | | | **Floor area within (50-100 mm$^2$ )** | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **A$^1$** | **B$^2$** | **C$^3$** | **A$^1$** | **B$^2$** | **C$^3$** | **A$^1$** | **B$^2$** | **C$^3$** |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
| i. | 900 | 90 | +10.6 | + 7.2 | + 3.8 | + 3.8 | + 2.1 | + 0.4 | + 0.4 | - 0.5 | - 1.3 |
| ii. | 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 |
| iii. | 720 | 72 | +5.7 | + 3.5 | + 1.3 | + 1.3 | 0 | - 0.9 | - 0.9 | - 1.4 | - 1.9 |
| iv. | 660 | 66 | + 4.3 | + 2.5 | + 0.6 | + 0.6 | - 0.3 | - 1.2 | - 1.2 | - 1.7 | - 2.1 |
| v. | 600 | 60 | +3.0 | + 1.5 | 0 | 0 | - 0.8 | - 1.5 | - 1.5 | - 1.9 | - 2.3 |
| vi. | 540 | 54 | +1.9 | + 0.7 | - 0.6 | - 0.6 | - 1.2 | - 1.8 | - 1.8 | - 2.1 | - 2.4 |
| vii. | 480 | 48 | +0.9 | 0 | - 1.1 | - 1.1 | - 1.6 | - 2.1 | - 2.1 | - 2.3 | - 2.6 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| viii. | 420 | 42 | 0 | - 0.8 | - 1.6 | - 1.6 | - 1.9 | - 2.3 | - 2.3 | - 2.5 | - 2.7 |
| ix. | 360 | 36 | -0.9 | - 1.4 | - 1.9 | - 1.9 | - 2.2 | - 2.5 | - 2.5 | - 2.6 | - 2.8 |
| x. | 300 | 30 | -1.5 | - 1.9 | -2.3 | -2.3 | - 2.5 | - 2.7 | - 2.7 | - 2.8 | - 2.9 |
| xi. | 240 | 24 | -2.1 | - 2.3 | -2.5 | -2.5 | - 2.7 | - 2.8 | - 2.8 | - 2.9 | - 2.9 |
| xii. | 180 | 18 | -2.5 | - 2.6 | - 2.8 | - 2.8 | - 2.8 | - 2.9 | - 2.9 | - 2.9 | - 3.0 |
| xiii. | 120 | 12 | -2.8 | - 2.9 | - 2.9 | - 2.9 | - 2.9 | - 3.0 | - 3.0 | - 3.0 | - 3.0 |

NOTES –

**1** Finish A **-** ceiling walls (reflection factor 0.7 to 0.8), walls off **-**white (reflection factor 0.45 to 0.55) and floor gray (reflection factor 0.3)

**2** Finish B **-** ceiling off **-**white, walls off**-**white and floor grey.

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

**7.2.5.4** Depending on the height H and distance D of the obstruction from the point and window wall respectively, four cases arise:

a) D>3H: This case can be dealt as unobstructed as far as day lighting is concerned and lux-grid I shall be used.

b) 1.5H<D<H:

First Step: The contribution due to unobstructed portion of the window using lux-grid I and lux-grid II shall be found out and the mean value taken.

Second Step: The contribution due to the obstructed portion by counting the dots and crosses enclosed circle (in the obstructed part) should be found out using lux-grid II and the value so obtained be multiplied by a factor 1.8.

Third Step: The values obtained in the above two steps should be added.

c) 0.5H < D < 0.5H:

The contribution of the unobstructed and obstructed portions of the window should be found out using lux-grid II separately and the values be added; and

d) D < 0.5 H:

First Step: The daylight due to unobstructed part should be found out using lux-grid II.

Second Step: The daylight due to obstructed part should be found out using lux-grid II and the value so obtained be reduced by 50 percent.

Third Step: The values obtained in the above two steps should be added.

## 8 DAYLIGHTING REQUIREMENTS

### 8.1 Design External Illumination

The Daylight Factor to be maintained in any internal environment shall be specified in relation to external illumination.

### 8.2 Illumination Levels Necessary for Different Visual Tasks.

Illumination levels necessary for different visual tasks shall be {*see* IS 3646 (Part 1)}. If the required amount of illumination is not achieved by daylighting only, it may have to be supplemented by artificial lighting.

### 8.3 Recommended Daylight Factor to be maintained in Different Interiors.

**8.3.1** If design for daylighting based only on sky component values are recommended, as sky components are easily determinable, this will tend to make the day lighting more easy however, where more precise values are desired, account may be taken of ERC and IRC values.

**8.3.2** Based on an assumed external design illumination level of 8000 lux and the acceptable levels of minimum illumination necessary for different visual tasks the daylight factors recommended for different locations are given in Table 6.

**Table 6 Recommended Daylight Factors for Interiors**
(*Clause* 8.3.2)

| Sl. No. (1) | Location (2) | Daylight Factor (%) (3) |
|---|---|---|
| i) | *Dwellings* | |
| | Kitchen | 2.5 |
| | Living room | 0.625 |
| | Study | 1.9 |
| | Circulation | 0.313 |
| ii) | *Schools* | |
| | Class room | 1.9 |
| | Lecture room | 2.0 to 2.5 |
| | Study hall | 2.0 to 2.5 |
| | Laboratory | 1.9 to 3.8 |
| iii) | *Offices* | |
| | General | 1.9 |
| | Enquiry | 0.625 1.9 |

| | | |
|---|---|---|
| iv) | *Hospitals* | |
| | General ward | 1.25 |
| | Pathological laboratory | 2.5 to 3.75 |
| v) | *Libraries* | |
| | Stock room | 0.9 to 1.9 |
| | Reading room | 1.9 to 3.75 |
| | Counter area | 2.5 to 3.75 |
| | Catalogue room | 1.9 to 2.5 |

NOTE – 100 lux is equal to a sky component of value 1.25 percent based on a 8000 lux.

**8.3.2.1** Daylight Factor values for other external intensities may be obtained by evaluation.

*Example*:

For external design illumination levels of 10000 lux the illumination of 100 lux will be 100 × 100/10,000 = 1 percent daylight factor.

**8.3.3** The recommended daylight levels should be ensured generally on the working plane at the following positions:

a) At a distance of 3 to 3.75 m from the window along the central line perpendicular to the window.
b) At the centre of the room if more appropriate; and
c) At fixed locations, such as school desks, blackboards, and office tables.

**8.3.3.1** In selecting any one position for design purposes, due consideration should be given to the needs of the situation.

**8.3.4** The daylight area of the prescribed daylight factor should not normally be less than half the total area of the room.

**8.3.5** Supplementary artificial illumination may have to be provided:

a) against the possibility of the level of illumination falling below the specified values at such times when the outside illumination falls below the design value; and
b) where the fineness of visual task may demand a higher level of illumination at special locations, occasionally.

**8.3.6** The figures in general give a number of window sizes contributing to the recommended illumination. Economic and architectural consideration should decide the final choice.

**8.3.7** The Daylight Factor values corresponding to the particular location shall be increased by appropriate factors if the window is to be glazed and/or is externally obstructed and/or is to be provided with window bars.

## 9 GENERAL PRINCIPLES OF WINDOW DESIGN TO AFFORD GOOD DAYLIGHTING

**9.1** Generally, while taller windows give greater penetrations, broader windows give better distribution of light. It is preferable that some area of the sky at an altitude of 20 degrees should light up the working plane.

**9.2** But, broader windows may also be equally or more efficient provided their sills are raised by 30 cm to 60 cm above the working plane. Such raised sills will not cut the outside view appreciably and afford in most situations, valuable wall space within easy reach, especially in schools and hospitals where it may be utilized to carry electric wiring, gas and water connections.

**9.3** For a given penetration, a number of small windows properly positioned along the same, adjacent or opposite walls will give better distribution of illumination than a single large window. The sky component at any point, due to a number of windows, can be easily determined from the corresponding sky component contour charts appropriately superimposed. The sum of the individual sky component for each window at the point gives the overall component due to all the windows. The same charts may also facilitate easy drawing of sky component contours due to multiple windows.

**9.4** Unilateral lighting from side windows will in general be unsatisfactory if the effective depth of the room is more than two to two-and-a half times the distance from the floor to the top of the window.

**9.5** Windows on two opposite sides will give greater uniformity of internal daylighting illumination especially when the room is 7 m or more across. They also minimize glare by illuminating the wall surrounding each of the opposing windows. Side windows on one side and windows on the opposite side may be provided where the situation so requires.

**9.6** Cross lighting with windows on adjacent walls tends to increase the diffused lighting within a room.

**9.7** Windows shall be provided with suitable louvres, baffles or other shading devices, to exclude, as far as possible, direct sunlight entering the room. Louvres etc. reduce the effective height of the windows for which due allowance shall be made. Broad and low windows are, in general much easier to shade against sunlight entry. Direct sunlight when it enters increases the inside illumination considerably. Glare will result, if it falls on walls at low angles, more so when it falls on floors, especially when the floors are dark coloured or less reflective.

**9.8** Light control media, such as translucent glass panes (opal or matt) surfaced by grinding, etching or sand blasting configurated or corrugated glass, certain types of prismatic glass and glass blocks are often used. They should be provided either fixed or movable, outside or inside, especially in the upper portions of the window. The lower portions are usually left clear to afford desirable view. The chief purpose of such fixture is to reflect part of the light on to the ceiling and thereby increase the diffuse lighting within, light up the farther areas in the room and thereby produce a more uniform illumination throughout. They will also prevent the window causing serious glare discomfort to the occupants but will provide some glare when illuminated by direct sunlight.

**9.9** Design should be such in addition to direct illumination, provision should be made for diffuse lighting by internal reflections and inter-reflections. The design should be such that luminance ratio of the task to its immediate surrounding and distant areas in the room should be as 10: 3: 1 and not exceeded.

**9.10** To ensure a good level of diffused lighting, all internal surfaces should be light coloured and have good reflectance.

**9.11** The illumination level in a given room for a finite window, will be higher when the walls are light coloured than when these are dark coloured. It is necessary, therefore at an early stage to consider the colour of the rooms of the building and not to leave this until later. Lighting is not merely a matter of window openings and quite half the eventual level of lighting may be dependent on the decorations in the room whatever may be the colour the occupants want to use. It is most desirable to maintain proper values of reflectance factors for ceiling, wall and floors so that the level of daylight illumination is maintained.

## 10 GENERAL NOTES ON DAYLIGHTING OF BUILDINGS

### 10.1 Aim of Daylighting

The main aim of daylighting design for buildings is to provide a visual field inside buildings for efficient performance of different visual tasks by the occupants of the buildings, without resulting in uncomfortable glare or thermal discomfort for the occupants.

Because of the highly variable nature of daylight from hour to hour and from season to season, no simple formula for daylighting can be given which is valid for the entire day and for the entire year.

### 10.2 Sunlight

Direct sunlight admitted into a building could lead to glare and thermal discomfort particularly in summer. However, in latitudes above 23° N in India, admitting sunlight in winter may mean thermal comfort and daylighting design may have to take into account the shading devices for admitting sunlight and avoiding glare depending on the local climate and the nature of the activity in the interior space.

### 10.3 Visual Task and Time Factor

When designing for an interior where specific visual tasks have to be performed, the time and duration of the task has to be taken into account while designing for daylight and a suitable provision made for supplementing with electric lighting as may be required.

## 10.4 Window

For daylighting of building interiors two types of windows may be used, namely those situated in a side wall and those placed in the roof. In the case of a side wall window, larger height and smaller width would result in more light in the distant interior of the room than in the case of larger width and smaller height. However, the view and the contrast with the outside would be better in the case of larger width and similar height of the window. A balance has to be reached depending on the nature of the visual tasks in distant interior of the room and the expected occupant's desire.

Though roof lights are more efficient in admitting daylight into buildings, they are useful only in single story buildings or in the top floor of multistory buildings. Water condensation, dripping and rain water penetration may be a source of trouble with roof lights.

## 10.5 Shading Devices

Some shading devices like projections from the walls above window are part of the architectural design. They have to be planned in relation to the climate, sun path diagram at the place and the possible orientation of the windows.

Manually operated shading devices are those which can be rolled up and down as desired. Venetian blinds are also manually operated and can be rolled up and down as well as openings controlled.

Automatic shades which work on motors can be controlled through sensors and automatically operated depending upon entry of direct sunlight.

## 10.6 Daylight Luminous Efficacy

Luminous efficacy is lumens per watt of input power. In the case of daylight, it is lumens per watt of radiant power. This differs for the different components of daylight. The average of sunlight is about 95 lm/W, and, for diffuse skylight it is about 120 lm/W. The thermal balance of any interior depends upon this parameter, so far as this is an indication of the level of irradiance associated with a given level of illuminance. While outdoor luminous efficacy values are different for different components of daylight like, sunlight, diffuse skylight and global illuminance, the luminous efficacy values of interior daylight, in cases where externally reflected component from buildings and trees is strong, would be lower than the outdoor values. Proper evaluation of this aspect has to be made before determining the irradiance levels associated with different illuminance levels inside buildings.

## 10.7 Directional Property of Daylight

Daylight which enters building from a side wall window is incident on a horizontal working plane at an angle other than the vertical, though the light internally reflected from the walls and ceiling comes from all directions. This condition could produce glare for tasks viewed at low angles in the direction of window. This has to be taken into account when fixing work positions and task desks in relation to window position.

## 10.8 Window Glazing

Common window glazing materials suitable for admission of daylight are glass, plastics, and fiberglass. Plastic materials degrade under UV radiation which accompanies daylight and change their transmission characteristics while glass is not subject to such degradation. Tinted glass and glass with sun film are used for their antiglare and heat filtering properties. Glass with different transmission properties are also used taking into account the climatic factors and orientation of the window.

### 10.9 Noise

Windows can be cause for excessive noise inside buildings. Noise control is an important requirement which should go with window design for daylighting of building. Factors like site selection, orientation of windows with respect to noise source like continuous and heavy traffic, wind direction, etc., need to be taken into account.

Another problem of windows is that the window panes go into resonance at low frequency of noise. A solution for this problem is possible if one can foresee the direction of low frequency noise and avoid window in that direction.

## 11 AVAILABILITY OF DAYLIGHT IN MULTISTORIED BUILDING

**11.1** Proper planning and layout of building can add appreciably to daylighting illumination inside. Certain dispositions of building masses offer much less mutual obstruction to daylight than others and have a significant relevance, especially when intensive site planning is undertaken. The relative availability of daylight in multistory blocks of different relative orientations is given in Table 7.

**11.2** Where a number of similar building blocks are to be raised fairly close to each other, it will be more advantageous to have alternative blocks perpendicular to each other than all in a parallel formation. Building heights and spacing are interdependent and can in general be adjusted to provide optimum day lighting advantage, for any density of building development, that is, for any ratio of floor area to the overall site area.

**Table 7 Relative Availability of Daylight on the Window Plane at Ground Level in Four-Storeyed Building Blocks (Clear Design-Sky as Basis, Daylight Availability Taken as Unity on an Unobstructed Façade, Values are for the Centre of the Blocks)**

(*Clause* 11.1)

| Sl. No. (1) | Distance of Separation Between Blocks (2) | Infinitely Long Parallel Blocks (3) | Parallel Blocks Facing Each Other (Length =2 x Height) (4) | Parallel Blocks Facing Gaps Between Opposite Blocks (Length= 2 x Height) (5) |
|---|---|---|---|---|
| i) | 0.5 | 0.15 | 0.15 | 0.25 |
| ii) | 1.0 | 0.30 | 0.32 | 0.38 |
| iii) | 1.5 | 0.40 | 0.50 | 0.55 |
| iv) | 2.0 | 0.50 | 0.60 | 0.68 |

## ANNEX A

(*Clause* 6.3.1, 6.4, 7.2, 7.2.4.4)

## ILLUSTRATIVE EXAMPLE OF DESIGN OF WINDOWS WITH EXTERNAL OBSTRUCTION

### A.1 EXAMPLE

**A.1.1** Consider (Fig. 8) .A point $P_1$ at 6 m away the window wall. Assume that the room in which the point is located has finish B, and floor area is approximately 43 $m^2$. The room has two windows each of size 2.4 x 1.5 $m^2$ at a height of 30 cm above the working plane symmetrically located with respect to point $P_1$. The windows face an infinitely long parallel distance (reflectance 0.5) located at a distance of 18 m (D) from the windows and of height (H) 6.0 m above the working plane.

This corresponds to case (b) of **7.2.5.4** where 1.5H<D<3H

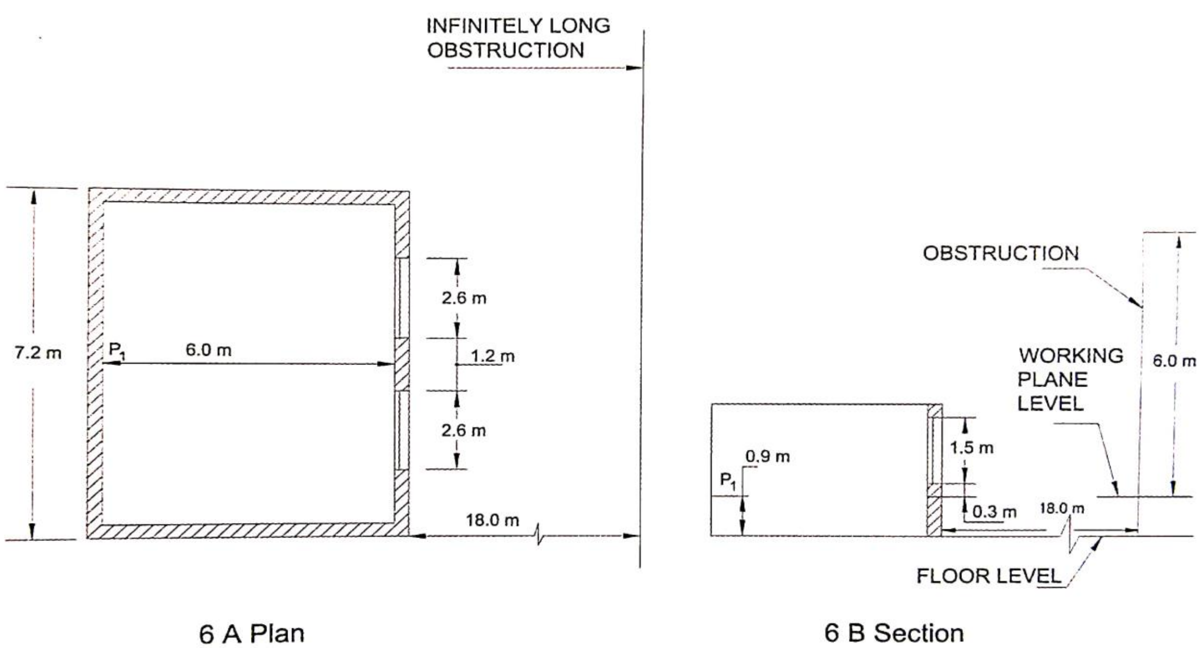



**Fig. 8 Typical Example for Windows with External Obstruction**

*First Step:*

The projection of the obstruction on the lux-grid I and II are shown in Fig. 9A and 9B. The contribution due to unobstructed portion of the windows using lux-grid I (Fig. 9A) and lux-grid II (Fig. 9B) are determined as follows:

i) (Use grid I *see* Fig. 9A)

The number of grid squares for unobstructed part of window = 4.

Correction factor for interior finish B (Table 5) = –1.9 lux.

Total correction for 4 squares=4x (–1.9) = –7.6 lux.

Illumination at P1 from Fig. 9A:

Crosses 16 = 32.0 lux

Dots 32 = 16.0 lux

Total = 48.0 lux

Correction = 7.6 lux

Net illumination = 40.4 lux

ii) Use grid II (see Fig. 9B)

The number of grid squares for unobstructed part of windows is again 4 but these include now 28 crosses and 4 dots giving total illumination at P1=28x1.0 + 4x0.5 = 30.0 lux.

Correction factor per square, using Table 5 = - 0.8 lux

Hence total correction 4 x (-0.8) =-3.2 lux

Net illumination as given by lux-grid II=30.0 -3.2 = 26.8 lux.

The mean values obtained from grid I and II 1/2(40.4+26.8) =33.6 lux which is net illumination from the unobstructed part of the windows.

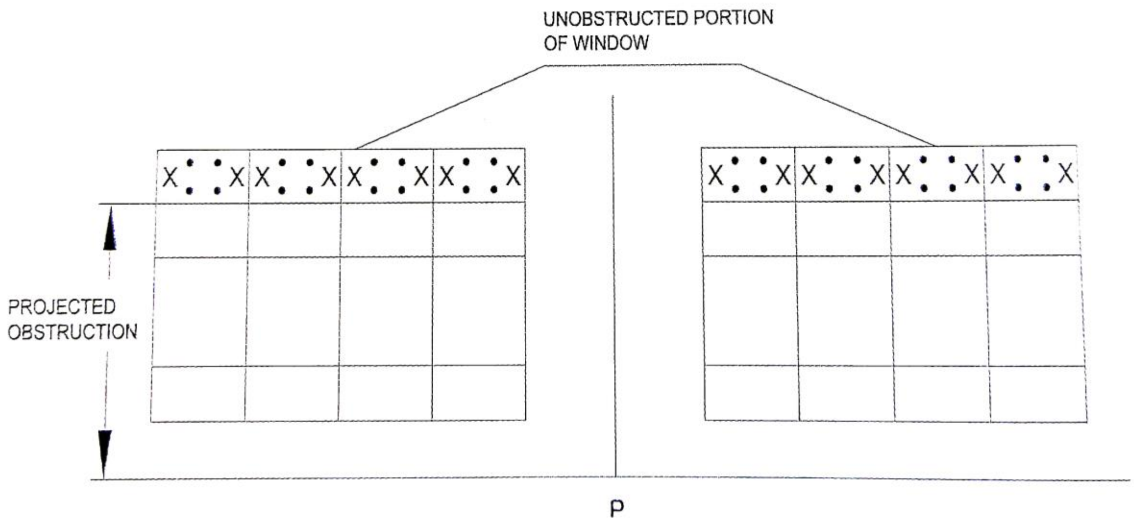



**Fig. 9A Typical Projection of Obstruction on the Lux-Grid I**

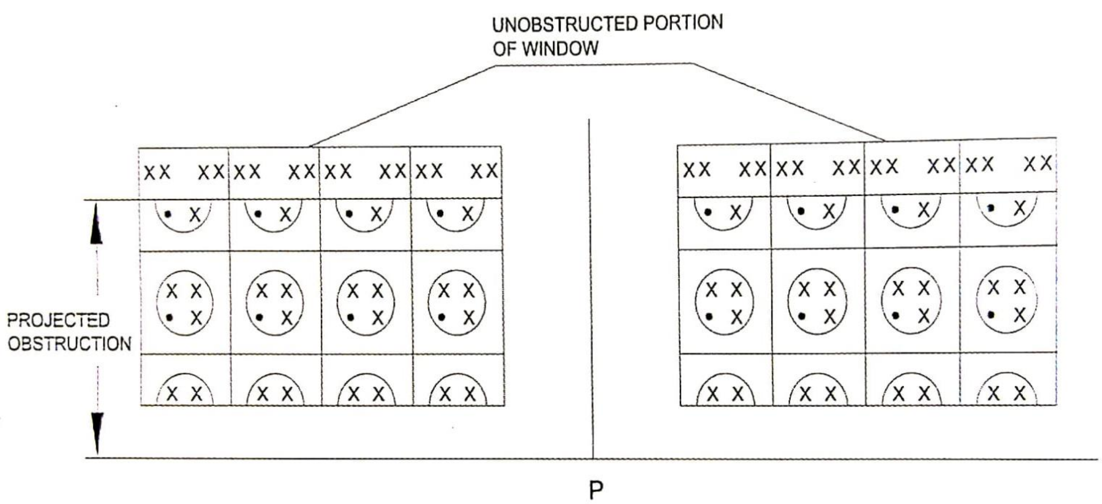



**Fig. 9B Typical Projection of Obstruction on the Lux-Grid II**

*Second Step:*

The number of squares enclosed by the obstructed part of the windows (Fig. 9B) = 16

Correction factor from Table 3= –0.8 lux

Net correction = 16(–0.8) = –12.8 lux

Total illumination at P1 from Fig. 9B

Crosses 48 = 48.0 lux

Dots 16 = 8.0 lux

| | | |
|---|---|---|
| Total | = | 56.0 lux |
| Correction | = | –12.8 lux |
| Net illumination | = | 56.0–12.8=43.2 lux |

Which is the net illumination due to obstructed portion of the windows