Indian Standard

GUIDE FOR DAYLIGHTING OF BUILDINGS

(Second Revision)

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0. FOREWORD

0.1 This Indian Standard (Second Revision) was adopted by the Indian Standards Institution on 31 December 1975, after the draft finalized by the Functional Requirements in Buildings Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 This standard was first published in 1963 and subsequently revised in 1968. The present revision is being taken up with a view to incorporate a number of modifications as decided by the Sectional Committee. The main modifications made in the second revision relate to the inclusion of some correction factors for external reflected components with respect to the mean angle of elevation of observation and calculation of the mean angle of obstruction in some examples given in Appendix B.

0.3 In view of lack of data in respect of optimum daylight illumination levels required for different visual tasks, illumination levels generally accepted in other countries were taken as the basis for design in the code at the time of its first publication. The code has been based on the data provided by Central Building Research Institute (CBRI) from the measurements over a period of years from 1962-67. It has been found that the basis of design should be the prevalent exterior daylight levels obtainable over the principal regions of India during the winter months. It is hoped that the Meteorological Department of India would undertake measurement of sky luminance and illumination over the principal cities in India and when further data become available this code will again be suitably modified.

0.4 A series of codes have been prepared by ISI to cover the functional aspects of buildings, such as, structural safety, heat and sound insulation, acoustics and ventilation. This code is intended to serve as a convenient guide to the engineers, architects and builders in understanding the general principles and methods of daylighting of dwellings, offices and hospitals. It recommends the minimum illumination values to be achieved by adopting daylighting principles and gives general guidance for realising the values in practice.

0.4.1 Daylighting requirements inside factory buildings have been covered in IS : 6060-1971* and IS : 7942-1976† deals in the daylighting of educational buildings.

*Code of practice for daylighting of factory buildings.

†Code of practice for daylighting of educational buildings.

0.5 The Sectional Committee responsible for the preparation of this standard has noted that influence of dusty conditions was an additional factor to be taken into account in daylighting in tropical regions, but in the absence of definite data, this aspect has not been, provisionally, taken into account in laying down the recommendations made in the code.

0.6 In the preparation of this code, the Sectional Committee has particularly felt the need for hourly and daily record for daylight illumination and investigation regarding optimum levels of illumination for different visual tasks. The National Physical Laboratory, New Delhi is currently engaged in investigations relating to daylight illumination and the optimum illumination levels for different visual tasks and it is the intention of the Committee to review the provisions contained in this code when sufficient experimental and observational data becomes available.

0.7 Typical sky component curves given in this standard (*see* Fig. 2 to 4) are based on the equation developed by the Central Building Research Institute for the proposed typical design sky based on their work on several places in India, rather than providing the values of sky component at a point due to some standard windows, the committee thought that the curves shown will give a clue to the extent by which sky component values change as one recedes from the window. The sky component table enables one to predetermine the sky component from the clear sky at the design time.

0.8 Some general notes on daylighting of buildings are given in Appendix C with a view to providing some additional and useful information relevant to the recommendations made in this code.

0.9 The recommendations made in this code may not, however, meet all the situations that may arise in individual cases, and it may become necessary to deviate from the provisions of this code or suitably adapt them to meet such situations.

0.10 Taking into consideration the views of engineers, architects and the building inhabitants, the Sectional Committee has related it to the design procedure followed in this country in this field. The committee felt that for Indian conditions where in the plains the weather is clear except during the monsoon seasons when it gets cloudy for a while and since the number of days in a year, when the sky is overcast is only about 70, the adoption of the C.I.E. overcast sky was not relevant. The Committee felt that the work done by the Central Building Research Institute on the luminance pattern of clear skies in India were reasonably representative of the situations normally met with in practice and generally agreed to switchover to the clear design sky conditions as formulated by the CBRI. The Committee felt that further work on the skies in India necessitating modifications in this code may be taken up by interested institutions. Assistance has also been derived from the 'Principles of modern building, Vol I' prepared by the

Department of Scientific and Industrial Research (Building Research Station) published by Her Majesty's Stationery Office, London (1961).

0.11 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard 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.

NOTE — For daylighting of factory buildings reference may be made to IS : 6060-1971† and for educational buildings to IS: 7942-1976‡.

2. TERMINOLOGY

2.0 For the purpose of this standard, the following definitions shall apply.

2.1 Altitude (θ) — The angular distance of any point of celestial sphere, measured from the horizon, on the great circle passing through the body and the zenith.

2.2 Azimuth (ϕ) — The angle measured between the meridians passing through the north point and the point in question (point *C* in Fig. 1).

2.3 Brightness (Photometric Brightness or Luminance) — The luminous intensity of the surface per unit of projected area in a given direction as viewed from that direction.

NOTE — The unit of measurement of brightness is candle per square centimetre.

2.4 Brightness Ratio or Contrast — The variations or contrast in brightness of the details of a visual task such as white print on blackboard.

2.5 Candela (Cd) — The SI unit of luminous intensity. Candela = 1 lumen per steradian.

2.6 Clear Design Sky — The distribution of luminance of such a sky is non-uniform; the horizon is brighter than the zenith and the brightness at an altitude (θ) in the region away from the sun, is given by the expression :

$$B_\theta = B_Z \text{ Cosec } \theta$$

*Rules for rounding off numerical values (*revised*).

†Code of practice for daylighting of factory buildings.

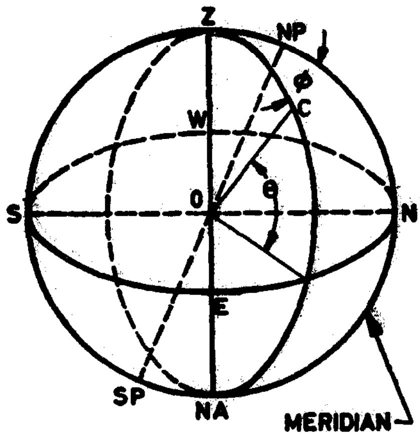
‡Code of practice for daylighting of educational buildings.

where

θ lies between 15° and 90°,

B_θ = constant when θ lies between 0° and 15°, and

B_Z = brightness at zenith.



REFERENCES

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

2.7 Daylight Factor — It is a measure of the total daylight illumination at a point on a given plane expressed as the ratio (or percentage) which the illumination at the point on the given plane bears to the simultaneous illumination on a horizontal plane due to a clear design sky at an exterior point open to the whole sky vault, direct sunlight excluded.

2.8 Daylight Area — The superficial area on the working plane illuminated to not less than a specified daylight factor, that is, the area within the relevant contour.

2.9 Daylight Penetration — The maximum distance which a given daylight factor contour penetrates into a room.

2.10 External Reflected 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 an unobstructed clear design sky.

2.11 Illumination — At a point of surface the ratio of the luminous flux incident on an infinitesimal element of surface containing the point under consideration to the area of this element.

NOTE — The unit of measurement of illumination is lux (one lumen per square metre).

2.12 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.

2.13 Lumen (lm) — SI unit of luminous flux. The luminous flux emitted within unit solid angle (one steradian) by a point source having a uniform intensity of one candela.

2.14 Luminous Flux — That quantity characteristic of radiant flux which expresses its capacity to produce visual sensation evaluated according to the values of relative luminous efficiency for the light adapted eye.

2.15 North and South Points — The points in the respective directions where the meridian cuts the horizon.

2.16 Reveal — The side of an opening for a window.

2.17 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.

2.18 Direct Solar Illumination — The illumination from the sun with the light from the sky excluded.

2.19 Working Plane — A horizontal plane at a level at which work will normally be done. For the purpose of this code the working plane, unless specified otherwise, shall be assumed as the horizontal plane 75 cm from the floor (normal table top level) in houses, flats, offices, and hospital wards and 90 cm (normal work bench level) from hospital operation theatre.

2.20 Visual Field — The visual field in a binocular which includes an area approximately 120 degrees vertically and 160 degrees horizontally centering on the point to which the eyes are directed. The line joining the point of fixation and the centre of the pupil of each eye is called its primary line of sight.

2.21 Central Field — The area of circle round the point of fixation and its diameter subtends an angle of about 2 degrees at the eye. Objects within this area are most critically seen both in their details and colour.

2.22 Peripheral Field — It is the rest of the visual field which enables the observer to be aware of the special framework surrounding the object seen.

NOTE — A central part of the peripheral field, subtending an angle of about 30 degrees on either side of the point of fixation, is chiefly involved in the perception of glare.

3. FACTORS AFFECTING VISION

3.1 Seeing — It is fundamentally governed by differences in brightness and colour in the objects seen. Good contrasts of colour and brightness are desirable, especially in the central 2-degree field. Better contrasts or brightness ratios outside tend to detract attention. The criterion of successful lighting, for optimum seeing comfort and efficiency, is to maintain the whole field bright and the central 2-degree field (containing the objects of attention) a little brighter and more contrasting.

3.2 Glare

3.2.1 Excessive contrast or abrupt and large changes in brightness produce the effect of glare. When glare is present the efficiency of vision is reduced and small details or subtle changes in tone cannot be perceived.

3.2.2 Glare may be:

a) direct glare due to light sources within field of vision,

b) reflected glare due to reflections from light sources or surfaces of excessive brightness, and

c) veiling glare where the peripheral field is comparatively very bright.

3.2.3 An example of glare source in daylighting is the view of the bright sky through a window especially when the surrounding wall is comparatively dark or weakly illuminated. Glare can be minimized in this case either by shielding the open sky from direct sight by louvers, external hoods or deep reveals, or by cross lighting the surrounding wall to a comparable level. A gradual transition of brightness from one portion to the other within the field of vision always avoids or minimizes the glare discomfort.

4. SOURCES OF DAYLIGHTING

4.1 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 sky radiation. For the purposes of the daylighting design, direct solar illumination shall not be considered and only sky radiation shall be taken as contributing to illumination of the building interiors during the day.

4.2 The relative amount of sky radiation depends on the position of the sun defined by its altitude which in turn varies with the latitude of the locality, the day of the year and the time of the day, as indicated in Table 1.

4.3 The external available horizontal illumination which may be assumed for design purposes in this country, broadly covering Indian from north to south, may be taken 8 000 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 8 000 lux design illumination suggested in this code, where haze conditions prevail at design time.

5. DAYLIGHT FACTORS

5.1 General

5.1.1 The daylight intensity at any point inside a room is subject to severe and frequent fluctuations, but it is, however, found to bear a more or less constant ratio to the simultaneous external intensity when the sky is clear or overcast throughout. It has, therefore, become customary to express the intensity of daylight illumination inside a room at any point in any plane as a ratio or percentage of the simultaneous intensity in a horizontal plane at an outside point open to the entire sky vault. Direct sunlight, if any, is always excluded from both interior and exterior values of illumination.

5.1.2 The factor, as defined above, is independent of the absolute brightness of the sky but is dependent on its surface distribution.

5.1.3 The surface distribution for the brightness of the sky varies with the conditions of the sky. Large variation of sky luminance distribution in so far as clear skies are concerned do not exist since there is a general rise of daylight availability as the sun goes up in the sky. However, it has been found that the regions of the sky opposite the sun has generally less luminance and may, therefore, provide the basis for design. The design may be based on the clear sky with sun at 15° altitude. The region of the sky directly opposite the sun will be design sky for side-lit windows and the corresponding 'sky' illumination will be known as the 'design exterior illumination' for computing the sky components indoor.

5.2 Components of Daylight Factor

5.2.1 Daylight factor (DF) is a measure of all the daylight reaching on an indoor reference point from the following sources :

a) The direct sky visible from the point,

b) External surfaces reflecting light directly to the point, and

c) Internal surfaces reflecting and inter-reflecting light to the point.

5.2.1.1 Each of the three components, when expressed as a ratio or percent of the simultaneous external illumination on the horizontal plane

TABLE 1 SOLAR ALTITUDES (TO THE NEAREST DEGREE) FOR INDIAN LATITUDES

(*Clause* 4.2)

Hours of Day / Latitude	June 22						March 21 and September 23						December 22					
	0700	0800	0900	1000	1100	1200	0700	0800	0900	1000	1100	1200	0700	0800	0900	1000	1100	1200
	1700	1600	1500	1400	1300		1700	1600	1500	1400	1300		1700	1600	1500	1400	1300	
10°N	18	31	45	58	70	77	15	30	44	59	72	80	9	23	35	46	53	57
13°N	19	32	46	60	72	80	15	29	44	58	70	77	8	21	33	43	51	54
16°N	20	33	47	61	74	83	14	29	43	56	68	74	7	19	31	41	48	51
19°N	21	34	48	62	75	86	14	28	42	55	66	71	5	18	29	48	45	48
22°N	22	35	49	62	76	89	14	28	41	53	64	68	4	16	27	36	42	45
25°N	23	36	49	63	76	88	13	27	40	52	61	65	3	14	25	34	39	42
28°N	23	36	49	63	76	88	13	26	39	50	59	62	1	13	23	31	37	39
31°N	24	37	50	62	75	82	13	25	37	48	56	56	—	11	21	28	34	36
34°N	25	37	49	62	73	79	12	25	36	46	53	56	—	9	18	26	31	33

NOTE — Hours are by local solar time.

defines respectively the Sky Component (SC), the External Reflected Component (ERC) and the Internal Reflected Component (IRC).

5.2.2 The daylight factors on the horizontal plane only 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 classroom blackboards, pictures and paintings hung on walls.

5.2.3 Daylight factor is the sum of the individual components, namely, SC, ERC and IRC, separately determined (*see* **6.3.1**).

5.3 Sky Components (SC)

5.3.1 Sky component for any size of window is computed by the use of the appropriate table of Appendix A on the lines indicated in the worked examples in Appendix B.

5.3.2 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, for glazing and external obstructions, if any.

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

5.3.4 *Correction for Glazing* — Where windows are glazed, the sky components obtained from Appendix A shall be reduced by about 10 to 20 percent provided the panes are of clear glass tolerably clean. Where glass is of the frosted (ground) type, the sky components read from Appendix A may be reduced by about 15 to 30 percent. Higher indicated correction corresponds to larger windows and/or near reference points.

5.3.5 *Correction for External Obstructions* — There is no separate correction except that the values from tables in Appendix A shall be read only for the unobstructed portions of the window, by method indicated in Appendix B.

5.4 External Reflected Component (ERC) — The values of the sky component corresponding to the portion of the window obstructed by the external obstructions can be found by the use of methods described in Appendix B. These values when multiplied by the correction factors, corresponding to the mean elevation of obstruction from the point in question as given in Table 2, can be taken as the external reflected components for that points.

5.5 Internal Reflected Component (IRC) — The component of daylight factor contributed by reflection from the inside surfaces varies directly as the window area and inversely as the total area of internal surfaces, and depends on the reflection factors of the floor, wall and roof surfaces inside and of the ground outside. For rooms white washed on walls and ceiling and windows of normal sizes, the IRC will have a sizeable value even at

TABLE 2 CORRECTION FACTORS FOR ERC

(*Clause* 5.4)

Mean Angle of Elevation	Correction Factor
5°	0·086
15°	0·086
25°	0·142
35°	0·192
45°	0·226
55°	0·274
65°	0·304
75°	0·324
85°	0·334

points far away from the window. External obstructions, when present, will proportionally reduce the IRC. Where accurate values of IRC are desired, a precise method of evaluation of the same is given in **B-4**.

6. DAYLIGHTING REQUIREMENTS

6.1 Design External Illumination — The daylight factor to be maintained in any internal environment shall be specified in relation to external illumination.

6.2 Illumination Levels Necessary for Different Visual Tasks — Illumination levels necessary for different visual tasks shall be assumed to be those given in IS : 3646 (Part II)-1966*. If the required amount of illumination is not achieved by daylighting only, it may have to be supplemented by artificial lighting.

6.3 Recommended Daylight Factor to be Maintained in Different Interiors

6.3.1 If design for daylighting based only on sky component values are recommended, as sky components are easily determinable, this will tend to make the daylighting more liberal; however, where more precise values are desired, account may be taken of ERC and IRC values given in **5.4** and **5.5**.

6.3.2 Based on an assumed external design illumination level of 8 000 lux (*see* **4.3**) and the acceptable levels of minimum illumination necessary for different visual tasks (*see* **6.2**), the daylight factors recommended for different locations are given in Table 3.

*Code of practice for interior illumination: Part II Schedule for values of illumination and glare index.

TABLE 3 RECOMMENDED DAYLIGHT FACTORS FOR INTERIORS

(*Clauses* 6.3.2 *and* 7.1.1)

LOCATION	DAYLIGHT FACTOR PERCENT
Dwellings:	
Kitchen	2·5
Living room	0·625
Study	1·9
Circulation	0·313
Schools:	
Class-room	1·9
Lecture theatre	2·0 to 2·5
Study hall	2·0 to 2·5
Laboratory	1·9 to 3·8
Offices:	
General	1·9
Drawing	3·75
Enquiry	0·625 to 1·9
Hospitals:	
General ward	1·25
Pathological laboratory	2·5 to 3·75
Libraries:	
Stack 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 8 000 lux design exterior illumination.

6.3.2.1 Daylight factor values for other external intensities (*see* **4.3**) may be obtained by evaluation.

Example:

For external design illumination levels of 1 000 lux the illumination of 100 lux will be $\frac{100 \times 100}{10\,000} = 1$ percent daylight factor.

6.3.3 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.

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

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

6.3.5 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.

6.3.6 A few typical examples of cross-sectional vertical distribution of light for two sizes of windows at certain assumed sill levels are given in Fig. 2, 3 and 4.

7. WINDOW

7.1 Window Sizes

7.1.1 The width and height of the appropriate window shall be decided upon by referring to the tables in Appendix A corresponding to the daylight factor (*see* Table 3) and the chosen depth of penetration from among the three alternatives given in **6.3.3**.

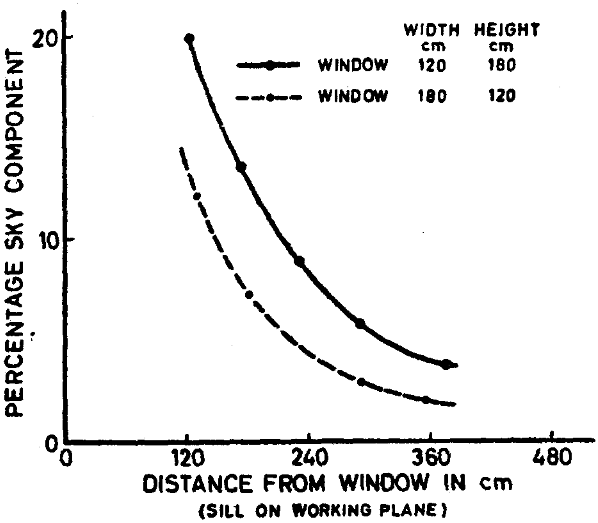


FIG. 2 TYPICAL SKY COMPONENT CURVES ON VERTICAL CROSS SECTION ALONG THE CENTRAL LINE

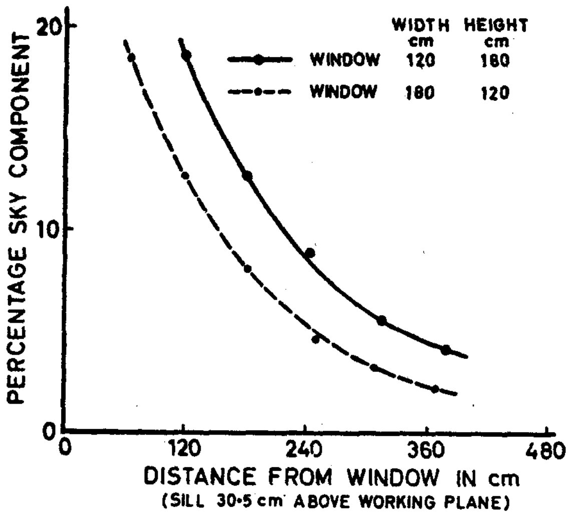


FIG. 3 TYPICAL SKY COMPONENT CURVES ON VERTICAL CROSS SECTION ALONG THE CENTRAL LINE

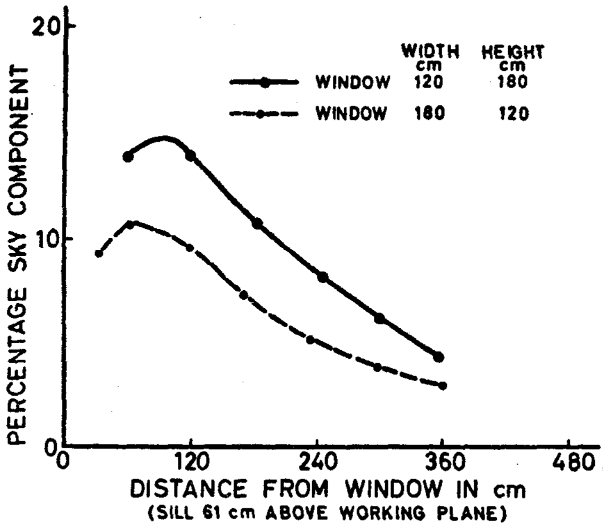


FIG. 4 TYPICAL SKY COMPONENT CURVES ON VERTICAL CROSS SECTION ALONG THE CENTRAL LINE

7.1.2 The tables, in general give a number of window sizes contributing to the recommended illumination. Economic and architectural consideration should decide the final choice.

7.1.3 Before referring to the tables in Appendix A for deciding upon a suitable window size, the daylight factor 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 (*see* **5.3.4**).

7.2 General Principles of Window Design to Afford Good Daylighting

7.2.1 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 to 25 degrees should light up the working plane.

7.2.2 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, etc.

7.2.3 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.

7.2.4 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.

7.2.5 Windows on two opposite sides will give greater uniformity of internal daylight 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 clerestory windows on the opposite side may be provided where the situation so requires.

7.2.6 Crosslighting with windows on adjacent walls tends to increase the diffused lighting within a room.

7.2.7 Windows in deep reveals tend to minimize glare effects.

7.2.8 Windows shall be provided with *CHAJJAHS*, louvers, baffles or other shading devices to exclude, as far as possible, direct sunlight entering the room. *CHAJJAHS*, louvers, 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 very considerably. Glare will result if it falls on walls at low angles, more so than when it falls on floors especially when the floors are dark coloured or less reflective.

7.2.9 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 views. The chief purpose of such fixtures 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.

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

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

8. SITING OF BUILDINGS

8.1 Proper planning and layout of buildings can add appreciably to the daylight illumination inside.

8.2 Certain dispositions of building masses offer much less mutual obstruction to daylight than others and hence have a significant relevance especially when intensive site planning is undertaken. The relative availability of daylight in multistorey blocks of different relative orientations are given in Table 4.

8.3 Where a number of similar building blocks is to be raised fairly close to each other, it will be more advantageous to have alternate blocks perpendicular to each other than all in a parallel formation.

8.4 Building heights and spacings are interdependent and can in general be adjusted to provide optimum daylighting advantage, for any density of building development, that is, for any ratio of floor area to the overall site area.

TABLE 4 RELATIVE AVAILABILITY OF DAYLIGHT ON THE WINDOW PLANE AT GROUND LEVEL IN A FOUR-STOREYED BUILDING BLOCKS (CLEAR DESIGN-SKY AS BASIS, DAYLIGHT AVAILABILITY TAKEN AS UNITY ON AN UNOBSTRUCTED FACADE, VALUES ARE FOR THE CENTRE OF THE BLOCKS)

(*Clause* 8.2)

Distance of Separation Between Blocks	Infinitely Long Parallel Blocks	Parallel Blocks Facing Each Other (Length = 2 × Height)	Parallel Blocks Facing Gaps Between Opposite Blocks (Length = 2 × Height)
0·5 Ht	0·15	0·15	0·25
1·0 Ht	0·30	0·32	0·38
1·5 Ht	0·40	0·50	0·55
2·0 Ht	0·50	0·60	0·68

APPENDIX A

(*Clauses* 5.3.1, 5.3.3, 5.3.4, 5.3.5, 7.1.1 *and* 7.1.3)

SKY COMPONENT TABLES

A-1. DESCRIPTION OF TABLES

A-1.1 There are three tables included in this Appendix:

Table 5 Percentage sky components on the horizontal plane due to a vertical window for the tropical design sky.

Table 6 Percentage sky components on the vertical plane/perpendicular to a vertical window for the tropical design sky.

Table 7 Percentage sky components on the vertical plane parallel to a vertical window for the tropical design sky.

A-1.2 All the tables are for an unglazed opening illuminated by the clear design sky.

A-1.3 The values tabulated are the components at a point P, distant d from the opening on a line perpendicular to the plane of the opening through one of its lower corners. l and h are the width and height respectively of the rectangular opening (*see* Fig. 5).

TABLE 5 PERCENTAGE SKY COMPONENTS ON THE HORIZONTAL PLANE DUE TO A VERTICAL WINDOW FOR THE TROPICAL DESIGN SKY
(*Clause* A-1.1)

l/d → h/d ↓	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9	1·0	1·1	1·2	1·3	1·4	1·5	1·6	1·7	1·8	1·9	2·0	3·0	4·0	5·0	10·0	INF
0·1	0·036	0·071	0·104	0·133	0·158	0·179	0·198	0·213	0·225	0·235	0·243	0·250	0·256	0·261	0·264	0·268	0·270	0·272	0·274	0·276	0·284	0·286	0·287	0·288	0·288
0·2	0·141	0·277	0·403	0·516	0·614	0·699	0·770	0·829	0·878	0·918	0·950	0·977	0·999	1·018	1·033	1·046	1·056	1·065	1·072	1·079	1·110	1·118	1·122	1·125	1·125
0·3	0·300	0·589	0·859	1·102	1·315	1·499	1·653	1·782	1·888	1·976	2·048	2·108	2·157	2·197	2·231	2·259	2·282	2·302	2·318	2·333	2·401	2·421	2·429	2·436	2·437
0·4	0·460	0·905	1·322	1·702	2·041	2·337	2·590	2·804	2·984	3·134	3·258	3·361	3·446	3·516	3·574	3·623	3·664	3·699	3·728	3·753	3·873	3·909	3·922	3·935	3·937
0·5	0·604	1·189	1·741	2·247	2·700	3·099	3·444	3·740	3·992	4·204	4·383	4·533	4·659	4·765	4·853	4·928	4·990	5·043	5·088	5·126	5·312	5·366	5·387	5·408	5·410
0·6	0·732	1·443	2·114	2·732	3·289	3·781	4·211	4·582	4·900	5·171	5·401	5·596	5·761	5·901	6·020	6·121	6·208	6·281	6·344	6·397	6·661	6·739	6·769	6·798	6·802
0·7	0·844	1·665	2·441	3·159	3·808	4·385	4·891	5·330	5·709	6·034	6·311	6·548	6·751	6·924	7·071	7·198	7·307	7·400	7·481	7·551	7·902	8·006	8·047	8·087	8·092
0·8	0·942	1·858	2·727	3·532	4·262	4·914	5·488	5·989	6·423	6·798	7·119	7·395	7·632	7·836	8·011	8·162	8·292	8·405	8·502	8·587	9·029	9·164	9·217	9·268	9·276
0·9	1·026	2·025	2·974	3·855	4·657	5·375	6·011	6·567	7·051	7·470	7·832	8·144	8·413	8·645	8·846	9·019	9·170	9·301	9·415	9·515	10·045	10·214	10·280	10·345	10·355
1·0	1·099	2·169	3·188	4·135	5·000	5·776	6·465	7·071	7·600	8·060	8·458	8·803	9·102	9·361	9·585	9·780	9·950	10·093	10·228	10·343	10·957	11·162	11·243	11·323	11·335
1·1	1·161	2·294	3·372	4·377	5·296	6·124	6·861	7·510	8·079	8·576	9·008	9·383	9·709	9·992	10·239	10·454	10·642	10·806	10·951	11·078	11·776	12·017	12·114	12·209	12·224
1·2	1·215	2·401	3·531	4·586	5·553	6·425	7·204	7·893	8·498	9·027	9·489	9·892	10·243	10·549	10·816	11·050	11·254	11·434	11·593	11·732	12·509	12·786	12·900	13·013	13·030
1·3	1·262	2·493	3·668	4·767	5·775	6·687	7·503	8·226	8·863	9·422	9·912	10·339	10·713	11·040	11·326	11·577	11·797	11·992	12·163	12·314	13·167	13·478	13·609	13·742	13·762
1·4	1·302	2·573	3·787	4·924	5·968	6·915	7·764	8·517	9·183	9·769	10·283	10·733	11·127	11·473	11·777	12·044	12·279	12·487	12·670	12·833	13·758	14·102	14·251	14·404	14·427
1·5	1·337	2·643	3·891	5·060	6·136	7·114	7·991	8·772	9·464	10·073	10·609	11·080	11·493	11·857	12·176	12·458	12·707	12·927	13·122	13·295	14·289	14·666	14·832	15·006	15·033
1·6	1·367	2·703	3·981	5·179	6·283	7·287	8·190	8·996	9·710	10·341	10·897	11·386	11·817	12·196	12·531	12·826	13·088	13·319	13·525	13·708	14·768	15·176	15·359	15·555	15·585
1·7	1·394	2·756	4·060	5·283	6·412	7·440	8·366	9·192	9·927	10·577	11·151	11·657	12·104	12·498	12·846	13·154	13·427	13·669	13·885	14·078	15·199	15·638	15·838	16·056	16·091
1·8	1·417	2·803	4·129	5·375	6·526	7·574	8·520	9·366	10·119	10·786	11·376	11·898	12·359	12·766	13·127	13·446	13·730	13·983	14·208	14·409	15·590	16·058	16·274	16·516	16·554
1·9	1·438	2·884	4·190	5·456	6·626	7·693	8·656	9·520	10·289	10·972	11·577	12·112	12·586	13·006	13·378	13·708	14·002	14·264	14·498	14·707	15·944	16·441	16·673	16·937	16·980
2·0	1·456	2·880	4·244	5·527	6·714	7·798	8·778	9·656	10·440	11·137	11·755	12·303	12·789	13·220	13·603	13·943	14·246	14·516	14·758	14·975	16·265	16·790	17·037	17·325	17·372
2·0	1·559	3·087	4·553	5·937	7·223	8·403	9·478	10·448	11·321	12·103	12·804	13·431	13·993	14·496	14·947	15·353	15·718	16·048	16·346	16·676	18·301	19·051	19·432	19·943	20·046
2·0	1·600	3·168	4·676	6·100	7·426	8·646	9·759	10·768	11·678	12·498	13·235	13·897	14·493	15·030	15·514	15·951	16·347	16·706	17·033	17·330	19·241	20·142	20·623	21·322	21·495
2·0	1·620	3·208	4·735	6·179	7·525	8·765	9·897	10·925	11·854	12·693	13·448	14·128	14·742	15·296	15·798	16·252	16·664	17·040	17·382	17·695	19·740	20·740	21·293	22·148	22·393
2·0	1·648	3·263	4·818	6·289	7·662	8·930	10·089	11·144	12·100	12·965	13·747	14·454	15·094	15·674	16·201	16·681	17·118	17·518	17·885	18·222	20·491	21·681	22·390	23·676	24·238
INF	1·657	3·282	4·846	6·327	7·710	8·986	10·155	11·220	12·186	13·060	13·851	14·567	15·217	15·806	16·342	16·831	17·278	17·688	18·064	18·410	20·770	22·046	22·838	24·463	26·111

TABLE 6 PERCENTAGE SKY COMPONENTS ON THE VERTICAL PLANE PERPENDICULAR TO A VERTICAL WINDOW FOR THE TROPICAL DESIGN SKY

(*Clause* A-1.1)

h/d ↓ \ l/d →	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9	1·0	1·1	1·2	1·3	1·4	1·5	1·6	1·7	1·8	1·9	2·0	3·0	4·0	5·0	10·0	INF
0·1	0·036	0·141	0·303	0·506	0·734	0·971	1·207	1·432	1·643	1·836	2·011	2·168	2·308	2·433	2·544	2·642	2·730	2·808	2·878	2·940	3·309	3·461	3·536	3·641	3·678
0·2	0·071	0·277	0·594	0·993	1·442	1·910	2·374	2·820	3·236	3·618	3·964	4·276	4·554	4·802	5·022	5·219	5·393	5·549	5·688	5·812	6·547	6·850	7·000	7·211	7·284
0·3	0·103	0·401	0·863	1·445	2·100	2·793	3·475	4·130	4·743	5·306	5·818	6·278	6·690	7·058	7·385	7·677	7·936	8·168	8·375	8·560	9·657	10·110	10·335	10·651	10·760
0·4	0·126	0·491	1·059	1·779	2·597	3·460	4·326	5·166	5·958	6·691	7·359	7·967	8·507	8·990	9·420	9·804	10·146	10·451	10·724	10·968	12·421	13·024	13·323	13·743	13·889
0·5	0·142	0·554	1·197	2·015	2·947	3·937	4·938	5·914	6·842	7·707	8·503	9·228	9·883	10·472	10·999	11·476	11·897	12·273	12·610	12·912	14·712	15·462	15·835	16·360	16·542
0·6	0·154	0·600	1·298	2·187	3·204	4·288	5·389	6·468	7·498	8·464	9·358	10·177	10·922	11·596	12·204	12·752	13·244	13·686	14·084	14·441	16·583	17·478	17·924	18·552	18·771
0·7	0·162	0·634	1·372	2·316	3·397	4·552	5·729	6·887	7·997	9·042	10·013	10·907	11·723	12·465	13·138	13·746	14·296	14·793	15·241	15·646	18·111	19·148	19·665	20·397	20·653
0·8	0·169	0·660	1·429	2·413	3·543	4·754	5·990	7·209	8·382	9·490	10·523	11·476	12·350	13·147	13·873	14·531	15·129	15·670	16·161	16·606	19·361	20·538	21·127	21·961	22·253
0·9	0·174	0·680	1·472	2·487	3·655	4·909	6·192	7·460	8·683	9·841	10·924	11·926	12·847	13·690	14·459	15·159	15·796	16·375	16·902	17·381	20·386	21·701	22·360	23·297	23·625
1·0	0·178	0·695	1·505	2·545	3·743	5·030	6·350	7·657	8·921	10·120	11·243	12·284	13·245	14·126	14·931	15·666	16·337	16·948	17·504	18·012	21·237	22·680	23·408	24·446	24·810
1·1	0·181	0·707	1·532	2·591	3·812	5·126	6·475	7·814	9·110	10·342	11·498	12·573	13·566	14·478	15·314	16·079	16·778	17·416	17·999	18·531	21·946	23·508	24·303	25·441	25·841
1·2	0·183	0·716	1·552	2·626	3·866	5·202	6·575	7·939	9·261	10·521	11·705	12·807	13·827	14·776	15·628	16·418	17·141	17·802	18·407	18·961	22·543	24·208	25·072	26·309	26·745
1·3	0·185	0·723	1·568	2·655	3·910	5·263	6·655	8·040	9·384	10·666	11·873	12·998	14·041	15·003	15·887	16·698	17·442	18·123	18·747	19·320	23·049	24·809	25·735	27·070	27·542
1·4	0·186	0·729	1·582	2·678	3·945	5·312	6·720	8·122	9·484	10·785	12·011	13·155	14·217	15·198	16·101	16·931	17·692	18·391	19·032	19·621	23·480	25·326	26·308	27·741	28·249
1·5	0·188	0·734	1·592	2·697	3·973	5·352	6·773	8·189	9·566	10·883	12·124	13·285	14·364	15·361	16·280	17·125	17·902	18·616	19·272	19·875	23·850	25·772	26·808	28·336	28·880
1·6	0·189	0·738	1·601	2·712	3·996	5·385	6·816	8·244	9·634	10·963	12·219	13·394	14·486	15·497	16·430	17·289	18·079	18·806	19·475	20·090	24·169	26·161	27·245	28·866	29·445
1·7	0·189	0·741	1·608	2·724	4·016	5·412	6·852	8·290	9·690	11·031	12·298	13·484	14·589	15·611	16·556	17·427	18·229	18·968	19·648	20·274	24·444	26·501	27·629	29·340	29·955
1·8	0·190	0·744	1·614	2·735	4·032	5·434	6·882	8·328	9·737	11·087	12·364	13·561	14·675	15·708	16·663	17·545	18·357	19·105	19·795	20·431	24·684	26·799	27·969	29·765	30·416
1·9	0·191	0·746	1·619	2·743	4·045	5·453	6·908	8·360	9·777	11·135	12·420	13·625	14·749	15·791	16·755	17·645	18·466	19·224	19·922	20·567	24·893	27·062	28·270	30·149	30·835
2·0	0·191	0·748	1·623	2·751	4·056	5·469	6·929	8·387	9·811	11·175	12·468	13·680	14·811	15·861	16·833	17·731	18·560	19·325	20·031	20·684	25·077	27·294	28·537	30·496	31·217
3·0	0·193	0·756	1·642	2·785	4·109	5·544	7·030	8·517	9·972	11·371	12·699	13·950	15·120	16·211	17·224	18·164	19·036	19·844	20·594	21·289	26·082	28·619	30·108	32·676	33·742
4·0	0·194	0·759	1·648	2·794	4·124	5·566	7·058	8·554	10·018	11·427	12·767	14·029	15·212	16·316	17·343	18·298	19·185	20·008	20·772	21·483	26·439	29·128	30·745	33·687	35·064
5·0	0·194	0·760	1·650	2·798	4·129	5·574	7·069	8·568	10·036	11·449	12·793	14·060	15·248	16·357	17·390	18·351	19·243	20·073	20·844	21·562	26·592	29·359	31·049	34·232	35·872
10·0	0·194	0·761	1·652	2·801	4·135	5·581	7·080	8·582	10·053	11·470	12·818	14·090	15·283	16·398	17·436	18·403	19·302	20·138	20·917	21·641	26·758	29·624	31·419	35·049	37·513
INF	0·194	0·761	1·652	2·802	4·136	5·582	7·081	8·584	10·056	11·473	12·822	14·095	15·288	16·404	17·443	18·411	19·311	20·143	20·928	21·654	26·785	29·672	31·490	35·274	39·172

TABLE 7 PERCENTAGE SKY COMPONENTS ON THE VERTICAL PLANE PARALLEL TO A VERTICAL WINDOW FOR THE TROPICAL DESIGN SKY

(*Clause* A-1.1)

l/d → / h/d ↓	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9	1·0	1·1	1·2	1·3	1·4	1·5	1·6	1·7	1·8	1·9	2·0	3·0	4·0	5·0	10·0	INF
0·1	0·728	1·429	2·078	2·600	3·167	3·600	3·964	4·265	4·513	4·717	4·883	5·020	5·132	5·225	5·301	5·365	5·418	5·463	5·501	5·533	5·687	5·733	5·749	5·765	5·766
0·2	1·429	2·803	4·077	5·221	6·220	7·073	7·790	8·385	8·876	9·278	9·609	9·830	10·103	10·286	10·439	10·565	10·671	10·760	10·835	10·899	11·207	11·296	11·330	11·362	11·365
0·3	2·068	4·061	5·913	7·530	9·040	10·285	11·337	12·212	12·934	13·528	14·016	14·417	14·747	15·020	15·246	15·434	15·591	15·724	15·836	15·931	16·390	16·523	16·574	16·623	16·627
0·4	2·529	4·970	7·249	9·312	11·133	12·707	14·042	15·164	16·097	16·870	17·507	18·025	18·458	18·816	19·113	19·360	19·568	19·742	19·890	20·015	20·624	20·801	20·868	20·933	20·939
0·5	2·852	5·608	8·186	10·529	12·606	14·410	15·952	17·256	18·350	19·262	20·021	20·652	21·177	21·613	21·978	22·275	22·530	22·746	22·923	23·082	23·836	24·056	24·140	24·222	24·229
0·6	3·086	6·070	8·867	11·415	13·681	15·656	17·353	18·793	20·008	21·027	21·879	22·592	23·189	23·689	24·109	24·462	24·761	25·014	25·229	25·412	26·299	26·561	26·662	26·759	26·768
0·7	3·259	6·413	9·373	12·074	14·482	16·588	18·402	19·949	21·257	22·359	23·285	24·063	24·716	25·267	25·731	26·124	26·458	26·742	26·984	27·192	28·214	28·517	28·634	28·748	28·758
0·8	3·389	6·672	9·755	12·573	15·090	17·296	19·201	20·830	22·212	23·380	24·365	25·195	25·895	26·486	26·987	27·412	27·775	28·084	28·350	28·578	29·720	30·065	30·198	30·327	30·339
0·9	3·489	6·869	10·046	12·955	15·556	17·840	19·817	21·511	22·952	24·173	25·206	26·078	26·816	27·441	27·972	28·424	28·810	29·141	29·426	29·672	30·927	31·303	31·451	31·596	31·610
1·0	3·565	7·021	10·272	13·250	15·917	18·263	20·297	22·043	23·531	24·795	25·866	26·773	27·542	28·196	28·752	29·226	29·633	29·982	30·283	30·544	31·889	32·302	32·467	32·627	32·643
1·1	3·625	7·139	10·447	13·481	16·200	18·594	20·674	22·462	23·989	25·288	26·391	27·326	28·121	28·798	29·375	29·869	30·293	30·658	30·973	31·246	32·670	33·117	33·297	33·473	33·491
1·2	3·672	7·233	10·586	13·663	16·423	18·857	20·973	22·795	24·353	25·681	26·810	27·770	28·587	29·283	29·878	30·388	30·826	31·201	31·532	31·816	33·309	33·796	33·981	34·173	34·193
1·3	3·709	7·307	10·696	13·807	16·602	19·067	21·213	23·062	24·646	25·998	27·148	28·128	28·963	29·676	30·286	30·810	31·261	31·651	31·989	32·283	33·836	34·350	34·550	34·756	34·779
1·4	3·739	7·366	10·784	13·924	16·745	19·236	21·406	23·278	24·884	26·255	27·424	28·420	29·271	29·998	30·621	31·157	31·618	32·018	32·365	32·667	34·274	34·813	35·035	35·247	35·271
1·5	3·763	7·414	10·856	14·018	16·861	19·373	21·563	23·454	25·077	26·465	27·649	28·660	29·523	30·262	30·897	31·443	31·914	32·322	32·677	32·986	34·641	35·202	35·436	35·663	35·689
1·6	3·783	7·453	10·914	14·095	16·956	19·485	21·692	23·599	25·236	26·638	27·835	28·857	29·732	30·482	31·126	31·680	32·160	32·575	32·937	33·253	34·950	35·532	35·776	36·017	36·046
1·7	3·799	7·485	10·962	14·158	17·034	19·578	21·798	23·718	25·368	26·781	27·989	29·022	29·906	30·665	31·317	31·879	32·366	32·788	33·156	33·477	35·211	35·812	36·067	36·321	36·352
1·8	3·812	7·512	11·002	14·211	17·099	19·655	21·886	23·817	25·478	26·900	28·118	29·160	30·052	30·818	31·477	32·046	32·539	32·967	33·340	33·666	35·435	36·052	36·316	36·584	36·617
1·9	3·824	7·534	11·035	14·254	17·153	19·719	21·960	23·900	25·570	27·001	28·226	29·276	30·175	30·948	31·613	32·188	32·686	33·119	33·497	33·828	35·626	36·259	36·532	36·812	36·847
2·0	3·833	7·553	11·062	14·291	17·199	19·773	22·022	23·970	25·647	27·086	28·318	29·374	30·279	31·058	31·728	32·308	32·811	33·249	33·631	33·965	35·791	36·438	36·719	37·011	37·048
3·0	3·876	7·639	11·192	14·463	17·412	20·027	22·316	24·302	26·016	27·491	28·757	29·846	30·783	31·592	32·291	32·898	33·427	33·889	34·294	34·651	36·640	37·380	37·715	38·107	38·157
4·0	3·888	7·663	11·228	14·511	17·471	20·098	22·398	24·396	26·121	27·606	28·884	29·983	30·930	31·748	32·457	33·074	33·611	34·082	34·496	34·860	36·915	37·699	38·063	38·510	38·579
5·0	3·893	7·672	11·241	14·529	17·494	20·125	22·430	24·432	26·161	27·650	28·932	30·035	30·986	31·808	32·521	33·142	33·683	34·157	34·574	34·945	37·028	37·834	38·214	38·696	38·781
10·0	3·897	7·681	11·254	14·546	17·515	20·150	22·459	24·466	26·199	27·693	28·978	30·085	31·041	31·867	32·584	33·208	33·753	34·231	34·652	35·024	37·144	37·978	38·332	38·927	39·057
INF	3·898	7·682	11·256	14·548	17·518	20·154	22·464	24·471	26·205	27·699	28·985	30·093	31·049	31·876	32·593	33·218	33·764	34·243	34·664	35·037	37·162	38·003	38·411	38·978	39·172

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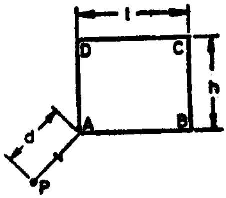


FIG. 5

A-1.4 Sky components for different h/d and l/d values are tabulated, that is, for different sizes of windows and for different distances of the point P from the window.

A-1.5 By suitable combination of the values obtained from the three tables, for a given point for a given window, the sky component in any plane passing through the point can be obtained.

APPENDIX B

(*Clauses* 5.3.1, 5.3.5, 5.4 and 5.5)

CALCULATION OF SKY COMPONENT

B-1. METHODS OF USING THE TABLES IN APPENDIX A

B-1.1 Methods of using the tables in Appendix A to get the sky components at different points are explained with reference to specific examples. Since the working plane is usually horizontal, Table 5 alone will be generally used. Only in Example 12, both Tables 6 and 7 are utilized.

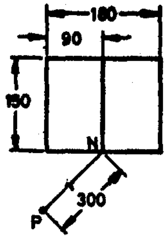
B-2. EXAMPLES

Example 1:

Point P is 300 cm from the window on a perpendicular line passing through the centre of the sill. The width of the window is 180 cm and height 150 cm. Considering one half of the window (*see* Fig. 6):

$$l/d = 90/300 = 0{\cdot}3$$
$$h/d = 150/300 = 0{\cdot}5$$

The component as read from Table 5 is 1·74 percent. The component for the total window is 2 × 1·74 = 3·48 percent.

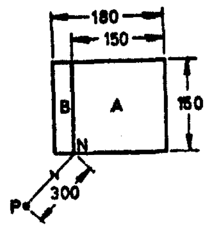


All dimensions in centimetres.

FIG. 6

Example 2:

Point P is 300 cm from the same window, the foot of the perpendicular N being on the sill 30 cm from one corner and 150 cm from the other (*see* Fig. 7).



All dimensions in centimetres.

FIG. 7

Part A,

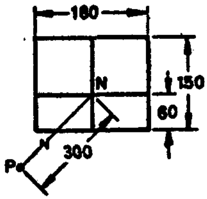
$$l/d = 150/300 = 0{\cdot}5$$
$$h/d = 150/300 = 0{\cdot}5$$
$$F_a = 2{\cdot}70 \text{ percent (from Table 5)}$$

Part B,

$$l/d = 30/300 = 0{\cdot}1$$
$$h/d = 150/300 = 0{\cdot}5$$
$$F_b = 0{\cdot}604 \text{ percent (from Table 5)}$$
$$F = F_a + F_b = 2{\cdot}70 + 0{\cdot}604 = 3{\cdot}304$$

Example 3:

Point P is 300 cm from the same window. Foot of the perpendicular N is 60 cm above the sill at the centre (*see* Fig. 8).



All dimensions in centimetres.

FIG. 8

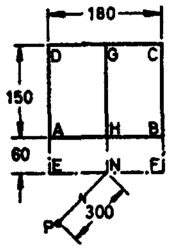
The portion of the window below the horizontal line passing through N will be ineffective as no sky can be seen through that part.

For each half: effective $l/d = 90/300 = 0{\cdot}3$

$$\text{effective } h/d = (150-60)/300 = 0{\cdot}3$$
$$F_1 = 0{\cdot}859 \text{ percent (from Table 5)}$$
$$F = 2 \times F_1 = 2 \times 0{\cdot}859 = 1{\cdot}718 \text{ percent}$$

Example 4:

Point P is 300 cm from the same window. Foot of the perpendicular N is 60 cm below the sill at the centre (*see* Fig. 9).



All dimensions in centimetres.

FIG. 9

Consider the window extended up to EF

For portion $NFBH$

$$l/d = 90/300 = 0{\cdot}3$$
$$h/d = 60/300 = 0{\cdot}2$$
$$F_1 = 0{\cdot}403 \text{ percent (from Table 5)}$$

For portion $NFCG$

$$l/d = 90/300 = 0{\cdot}3$$
$$h/d = (150 + 60)/300 = 0{\cdot}7$$
$$F_2 = 2{\cdot}441 \text{ percent (from Table 5)}$$

For the portion *HBCG*

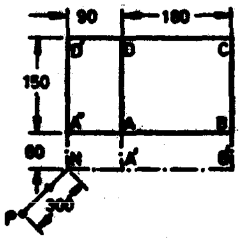
$$F' = F_2 - F_1 = 2{\cdot}441 - 0{\cdot}403 = 2{\cdot}038$$

For the total window *ABCD*

$$F = 2\,F' = 2 \times 2{\cdot}038 = 4{\cdot}076 \text{ percent}$$

Example 5:

Point *P* is 300 cm from the same window. Foot of the perpendicular *N* is 60 cm below the sill and 90 cm to the left of *AD* (*see* Fig. 10).



All dimensions in centimetres.

FIG. 10

Consider *ABCD* extended to *NB′CD′*

1) For *NB′CD′*

$$l/d = (180 + 90)/300 = 0{\cdot}9$$
$$h/d = (150 + 60)/300 = 0{\cdot}7$$
$$F_1 = 5{\cdot}709 \text{ percent (from Table 5)}$$

2) For *NA′DD′*

$$l/d = 90/300 = 0{\cdot}3$$
$$h/d = (150 + 60)/300 = 0{\cdot}7$$
$$F_2 = 2{\cdot}441 \text{ percent (from Table 5)}$$

3) For *NB′BA′*

$$l/d = (180 + 90)/300 = 0{\cdot}9$$
$$h/d = 60/300 = 0{\cdot}2$$
$$F_3 = 0{\cdot}878 \text{ percent (from Table 5)}$$

4) For *NA′AA″*

$$l/d = 90/300 = 0{\cdot}3$$
$$h/d = 60/300 = 0{\cdot}2$$
$$F_4 = 0{\cdot}403 \text{ percent (from Table 5)}$$

Since

$$ABCD = NB'CD' - NA'DD' - NB'BA'' + NA'AA''$$

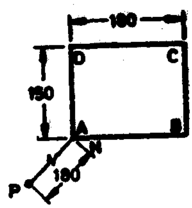
$$F = F_1 - F_2 - F_3 + F_4$$
$$= 5{\cdot}709 - 2{\cdot}441 - 0{\cdot}878 + 0{\cdot}403$$
$$= 2{\cdot}793 \text{ percent}$$

Example 6:

Point P is 300 cm from the same window, N falls above the lintel level. No sky can be seen from P and, therefore, $F = 0$.

Example 7:

Point P is 180 cm from the same window. N coincides with A (*see* Fig. 11).



All dimensions in centimetres.

Fig. 11

$$l/d = 180/180 = 1{\cdot}0$$
$$h/d = 150/180 = 0{\cdot}833$$

Interpolation is necessary to get F from the table

For $l/d = 1{\cdot}0$ and $h/d = 0{\cdot}9$

$$F_1 = 7{\cdot}470 \text{ percent}$$

For $l/d = 1{\cdot}0$ and $h/d = 0{\cdot}8$

$$F_2 = 6{\cdot}8 \text{ percent}$$

For $l/d = 1{\cdot}0$ and $h/d = 0{\cdot}833$

$$F = 6{\cdot}8 + \tfrac{1}{3}(7{\cdot}47 - 6{\cdot}8)$$
$$= 6{\cdot}8 + 0{\cdot}223$$
$$= 7{\cdot}023 \text{ percent}$$

Example 8:

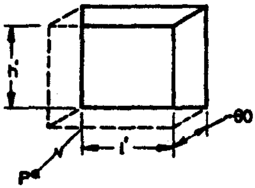
Point P is 210 cm from the same window. N coincides with A.

$l/d = 180/210 = 0{\cdot}86$
$h/d = 150/210 = 0{\cdot}71$
For $l/d = 0{\cdot}8$ and $h/d = 0{\cdot}7$, $F_1 = 5{\cdot}33$ percent (from Table 5)
For $l/d = 0{\cdot}8$ and $h/d = 0{\cdot}8$, $F_2 = 5{\cdot}99$ percent (from Table 5)
For $l/d = 0{\cdot}8$ and $h/d = 0{\cdot}71$, $F' = F_1 + 0{\cdot}1\ (F_2 - F_1)$
$= 5{\cdot}33 + 0{\cdot}1 \times 0{\cdot}66$
$= 5{\cdot}4$ percent approximately
For $l/d = 0{\cdot}9$ and $h/d = 0{\cdot}7$, $F_3 = 5{\cdot}709$ percent (from Table 5)
For $l/d = 0{\cdot}9$ and $h/d = 0{\cdot}8$, $F_4 = 6{\cdot}423$ percent (from Table 5)
For $l/d = 0{\cdot}9$ and $h/d = 0{\cdot}71$, $F'' = F_3 + 0{\cdot}1\ (F_4 - F_3)$
$= 5{\cdot}709 + 0{\cdot}1 \times (6{\cdot}423 - 5{\cdot}709)$
$= 5{\cdot}709 + 0{\cdot}1 \times 0{\cdot}714$
$= 5{\cdot}7804$
$= 5{\cdot}78$ percent

For $l/d = 0{\cdot}86$ and $h/d = 0{\cdot}71$
$F = F' + 0{\cdot}6\ (F'' - F')$
$= 5{\cdot}40 + 0{\cdot}6 \times 0{\cdot}38$
$= 5{\cdot}628$ percent

Example 9:

Point P is in front of the window, below the sill and to the left. Depth of reveal 60 cm (*see* Fig. 12).



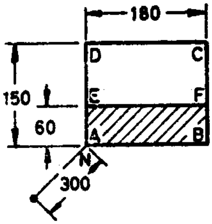
All dimensions in centimetres.

FIG. 12

l' and h', the apparent length and height of the opening, are first calculated geometrically and the table is used afterwards to get sky component by methods indicated earlier.

Example 10:

Point P is 300 cm from the same window. N coincides with A. Top or external obstruction is EF 60 cm apparently above AB as seen from P (*see* Fig. 13).



All dimensions in centimetres.

FIG. 13

For $ABCD$

$$l/d = 180/300 = 0{\cdot}6$$
$$h/d = 150/300 = 0{\cdot}5$$
$$F_1 = 3{\cdot}1 \text{ percent (from Table 5)}$$

For $ABFE$

$$l/d = 180/300 = 0{\cdot}6$$
$$h/d = 60/300 = 0{\cdot}2$$
$$F_2 = 0{\cdot}7 \text{ percent (from Table 5)}$$

For the unobstructed portion $EFCD$

$$F = F_1 - F_2 = 2{\cdot}4 \text{ percent}$$

Mean angle of obstruction $\tan^{-1} \dfrac{30}{300} = 5°$ approximately

From Table 2, corresponding correction factor $= 0{\cdot}086$

$ERC = F_2 \times 0{\cdot}086 = 0{\cdot}7 \times 0{\cdot}086 = 0{\cdot}0602 = 0{\cdot}06$ percent

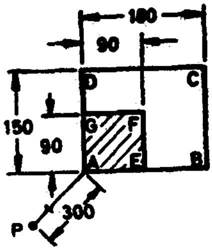
Obstruction 20 percent of $F_2 = 0{\cdot}7/5 = 0{\cdot}14$ percent

Example 11:

Point P is 300 cm from the same window. N coincides with A. External obstruction is 90 cm $\times$ 90 cm as seen from P. The apparent obstruction is shown in the figure (*see* Fig. 14).

For $ABCD$

$$l/d = 180/300 = 0{\cdot}6$$
$$h/d = 150/300 = 0{\cdot}5$$
$$F_1 = 3{\cdot}1 \text{ percent (from Table 5)}$$



All dimensions in centimetres.

FIG. 14

For obstruction *AEFG*

$$l/d = 90/300 = 0{\cdot}3$$
$$h/d = 90/300 = 0{\cdot}3$$
$$F_2 = 0{\cdot}86 \text{ percent (from Table 5)}$$

For unobstructed portion *EBCDGF*

$$F = F_1 - F_2 = 2{\cdot}24 \text{ percent}$$

Mean angle of obstruction $= \tan^{-1} \frac{45}{1300} = 8°$ approximately

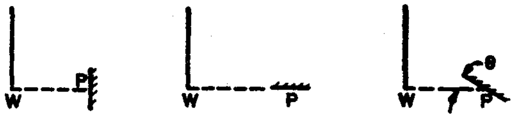
Correction factor $= 0{\cdot}086$

$ERC = 0{\cdot}86 \times 0{\cdot}086 = 0{\cdot}07396 = 0{\cdot}074$ percent

Obstruction 1/5 of $0{\cdot}86 = 0{\cdot}172$ percent

Example 12 :

Same window. Vertical blackboard 300 cm from window parallel to the window plane. Sky component at centre required (*see* Fig. 15).



PLAN

FIG. 15

Similar methods as described earlier should be used to find sky component F_1. But Table 6 should be used in this case.

If the plane of the blackboard is perpendicular to the window plane, Table 5 should be used to find the sky component F_2.

If the plane of the blackboard is inclined at an angle θ to the perpendicular direction :

$$F = F_1 \text{ Sin } \theta + F_2 \text{ Cos } \theta$$

NOTE — In certain positions only a part of the window will be lighting the blackboard but the above examples indicate the method to follow in such or other complicated situations.

B-3. GENERAL INSTRUCTIONS

B-3.1 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 Examples 10 and 11 can then be used.

B-3.2 For extremely irregular obstructions or obstructions not in a plane parallel to the window, diagrammatic methods, such as Waldrams diagrams will have to be employed.

B-3.3 For bay windows, dormer windows or corner windows the effective dimensions of window opening computed should be taken when using the tables to find the sky components.

B-4. CALCULATION OF *IRC*

B-4.1 The internal reflected component is a variable quantity which varies from point to point in a room depending upon the interior finish. *IRC* value is maximum at the centre of the room and decreases elsewhere in all directions. For processing calculations of *IRC* at any given point of the room, special techniques have to be made out. The internal reflected component may be calculated by using the following formula:

$$IRC = \frac{0{\cdot}85\ W}{A\,(1 - R)}\,(CR_{fw} + 10\ R_{cw})$$

where

W = window area;

C = a constant of value 78 when there is no external obstruction but it has different values as shown in Table 8 when there are obstructions;

R_{fw} = average reflection factor of the floor and those parts of the wall below the plane of the mid-height of the window (excluding the window wall);

R_{cw} = average reflection factor of the ceiling and those parts of the wall above the plane of the mid-height of the window (excluding the window wall);

A = area of all the surfaces in the room (ceiling walls, floor and windows); and

R = the average reflection factor of all surfaces in the room (ceiling, walls, floor and windows) expressed as a decimal part of unity.

TABLE 8 VALUES OF *C*

(*Clause* B-4.1)

Angle of Obstruction (1)	Sky+External Obstruction, C (2)	Angle of Obstruction (1)	Sky+External Obstruction, C (2)
Degree		Degree	
5	68·9	55	15·8
15	50·6	65	12·9
25	36·2	75	11·1
35	26·7	85	10·36
45	20·1		

B-4.1.1 *Example* :

Consider two rooms of dimensions :

Room X = 6 m (l) × 5 m(w) × 3 m (ht)

Room Y = 3·7 m × 3 m × 3 m

Let the window area be 15 percent of the floor area and be glazed

Window size in room X = 2·5 m × 1·8 m

Window size in room Y = 1·5 m × 1·1 m

The windows are on the 6 m × 3 m side in room X and 3·7 m × 3 m side in room Y, and the sill heights are 0·9 m from floor level.

Reflection coefficients of

walls and ceiling	=	70 percent
Floor	=	20 percent
Glazing	=	15 percent

Value of IRC in room X:

a) Total interior area = A = 2 (30+18+15) = 126 m²

b) Average reflection factor of interior :

$$R = \frac{61{\cdot}5\times0{\cdot}7+30\times0{\cdot}7+30\times0{\cdot}2+4{\cdot}5\times0{\cdot}15}{61{\cdot}5+30+30+4{\cdot}5} = 0{\cdot}56$$

c) $1 - R = 0{\cdot}44$

d) Mid-height of window is 1·83 m from floor, average reflection factor of room below 1·83 m level excluding the wall containing the window :

$$R_{fw} = \frac{29{\cdot}28\times0{\cdot}7+30\times0{\cdot}2}{29{\cdot}28+30} = 0{\cdot}45$$

e) Average reflection factor of room above 1·83 m level excluding the wall containing the window:

$$R_{cw} = \frac{18{\cdot}72 \times 0{\cdot}7 + 30 \times 0{\cdot}7}{18{\cdot}72 + 30} = 0{\cdot}7$$

f) $$IRC = \frac{0{\cdot}85 \times 4{\cdot}5}{126 \times 0{\cdot}44}(78 \times 0{\cdot}45 + 10 \times 0{\cdot}7) = 2{\cdot}904$$

Value of *IRC* in room *Y*:

a) Total interior area

$$A = 2(3{\cdot}7 \times 3 + 3{\cdot}7 \times 3 + 3 \times 3)$$
$$= 62{\cdot}4 \text{ m}^2$$

b) Average reflection factor

$$R = \frac{38 \times 55 \times 0{\cdot}7 \times 3 \times 0{\cdot}7 + 3{\cdot}7 \times 3 \times 0{\cdot}2 + 1{\cdot}5 \times 1{\cdot}1 \times 0{\cdot}15}{38{\cdot}55 + 11{\cdot}1 + 11{\cdot}1 + 1{\cdot}65} = 0{\cdot}596$$

c) Mid-height of window from floor $= 1{\cdot}46$ m

d) Average reflection factor below 1·46 m level

$$R_{fw} = \frac{3{\cdot}7 \times 3 \times 0{\cdot}7 + 1{\cdot}54 \times 9{\cdot}7 \times 0{\cdot}7}{11{\cdot}1 + 14{\cdot}94} = 0{\cdot}48$$

e) Average reflection factor above 1·46 m level

$$R_{cw} = \frac{3{\cdot}7 \times 3 \times 0{\cdot}7 + 1{\cdot}54 \times 9{\cdot}7 \times 0{\cdot}7}{11{\cdot}1 + 14{\cdot}94} = 0{\cdot}7$$

f) $$IRC = \frac{0{\cdot}85 \times 1{\cdot}65}{62{\cdot}4 \times 0{\cdot}404}(78 \times 0{\cdot}48 + 10 \times 0{\cdot}7) = 2{\cdot}472$$

APPENDIX C

(*Clause* 0.8)

GENERAL NOTE ON DAYLIGHTING OF BUILDING

C-1. The main aim of daylighting design is how to admit enough light for good visibility without setting up uncomfortable glare. No simple solution may be given as the sky varies so much in its brightness from hour to hour, and from season to season.

C-2. Different visual tasks need differing amounts of lights for the same visual efficiency. The correct amount of light for any task is determined by the following:

a) The characteristics of the task — size of significant detail, contrast of detail with background and how close it is to the eyes;

b) The sight of the worker—for example, old people need more light;

c) The speed and accuracy necessary in the performance of work. If no errors are permissible, much more light is needed; and

d) The ease and comfort of working—long and sustained tasks must be done easily whereas workers can make a special effort for tasks of very short duration.

These factors have been made the subject of careful analysis as a result of which tables of necessary levels of illumination have been drawn up.

C-3. Levels of lighting determined analytically must be translated into levels of daylight and then into size of window opening or *vice-versa* for checking the size of window assumed for required levels of daylight.

C-4. One of the many important factors involved in the translation is the lightness of the room surface. The illumination level in a given room with 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 colouring 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.

BUREAU OF INDIAN STANDARDS

Headquarters:

Manak Bhavan, 9 Bahadur Shah Zafar Marg, NEW DELHI 110002

Telephones : 331 01 31, 331 13 75 — Telegrams : Manaksanstha (Common to all offices)

Regional Offices :	*Telephone*
*Western : Manakalaya, E9 MIDC, Marol, Andheri (East), BOMBAY 400093	6 32 92 95
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