BUILDING DIGEST 142
CENTRAL BUILDING RESEARCH INSTITUTE, INDIA

NORTHLIGHT SAWTOOTH ROOFS, IN THE TROPICS

Introduction

Utilisation of daylight for performing any visual task is healthy and economical. The amount of light required for satisfactory and strainfree performance of the task depends upon the nature of task itself and on other factors like contrast detail, fineness of work and acuteness of vision. Small variations of illumination are taken care of by the adjustment of the pupil of the eye but large variations result in undesirable eye strain. These considerations apart, changes in daylight intensity from sunrise to sunset provide a harmoneous variation of the visual environment inside a building normally welcomed in the performance of visual task.

In India, except during the monsoon season, the sky is clear and the sunlight plentiful. The proper utilisation of daylight to get the appropriate illumination levels on the working plane in factories will result not only in considerable economy of electric power but also add to the well being of workers inside the factory.

This Digest deals primarily with daylighting inside factories in the tropics and explains the various factors that contribute to the illumination on the working plane and methods of working out fenestration sizes for the required task illumination in accordance with Indian Standards* for clear design sky.

Results of calculations and model measurements at the Central Building Research Institute have conclusively proved that in latitudes north of the Tropic of Cancer (23 deg. N) northlight openings can provide adequate shadow-free illumination on the working plane in factories. The duration of sunshine on vertical northlight openings for several latitudes north of the Tropic of Cancer is given in Table 1. However, these values will change if the northlights are inclined.

The penetration of direct sunlight through the northlight openings is either during the early morning hours or the late evening hours of the day; hence for most part of the year this will not cause any serious inconvenience. It is to be borne in mind, however, that incidence of direct sunlight on machinery or moving parts in a factory is to be avoided.

TABLE 1-Sunshine Hours on North Facing Wall (Solar Time)

Location	Sept. 23 and March 21	April 16 and August 27	May 16 and July 28	June 21
23°N	Nil	Upto 0730 h After 1630 h	Upto 0930 h After 1430 h	Throughout the day
25°N	Nil	Upto 0725 h After 1635 h	Upto 0910 h After 1450 h	Upto 1030 h After 1330 h
27°N	Nil	Upto 0720 h After 1640 h	Upto 0850 h After 1510 h	Upto 1000 h After 1400 h
29°N	Nil	Upto 0710 h After 1650 h	Upto 0830 h After 1530 h	Upto 0920 h After 1430 h
31°N	Nil	Upto 0705 h After 1655 h	Upto 0820 h After 1540 h	Upto 0900 h After 1500 h
33°N	Nil	Upto 0700 h After 1700 h	Upto 0810 h After 1550 h	Upto 0850 h After 1510 h
35°N	Nil	Upto 0650 h After 1710 h	Upto 0800 h After 1600 h	Upto 0830 h After 1530 h

*1 IS 2440 (1975) Guide for Daylighting of Buildings
2 IS 6060 (1971) Daylighting of Factory Buildings

The Sky and Reflected Components of Daylight Factor

The daylight reaching the working plane inside a factory through the sawtooth openings consists of two parts, viz., that from the sky patch visible from the point of observation and that part of the daylight reaching the same point after reflection from the roof, ceiling, walls and other internal surfaces. The former when expressed as a percentage fraction of outdoor design illumination (D=8000 lux) is called the sky component (S.C.) and the latter the internal reflected component (I.R.C.) The sum of sky component and reflected compenent is called the daylight factor (D.F.). Daylight factor when multiplied by 80 gives the indoor illumination in units of lux for clear sky in India.

It has been found both from theory and model measurements that :

(i) Only three ceilings on either side of the point contribute significantly to the reflected part of light reaching that point,

(ii) Only three northlight openings north of a point contribute to the sky component at that point, and

(iii) The level of the daylight becomes quite steady after the third bay and beyond starting from the north.

For most purposes a working plane at a height of 85 cm above the floor is taken as a reference plane in design work. In this Digest, the height of the lower edge of the northlinght openings above floor has been considered as the sill height.

Allowances for Factors affecting Daylighting Design

Daylight on the working plane is related to the size of fenestration, bay width of northlight roofs and sill height of northlight openings. Fig. 1 provides design curves for sawtooth northlight factory for four-bay, six-bay and eight-bay giving fenestration per cent per unit daylight factor at the centre of the workplane for assumed reflectances of ceiling, walls, floor, roof and outside ground as 0.5, 0.5, 0.3, 0.25 and 0.25 respectively, where 0.5 represents an off white finish and 0.3-0.25 a dull finish. Allowances have been made for 3 mm thick clear glass transmittance* (0.85), reduction due to dust collection under medium maintenance** condition (0.7), glass area to gross window area ratio (0.9), obstruction due to beams and trusses (0.7) and the presence of louvres on windows (0.8). Value of I R.C. for different sets of interior finish are given in Table 2. Any variation in finish from

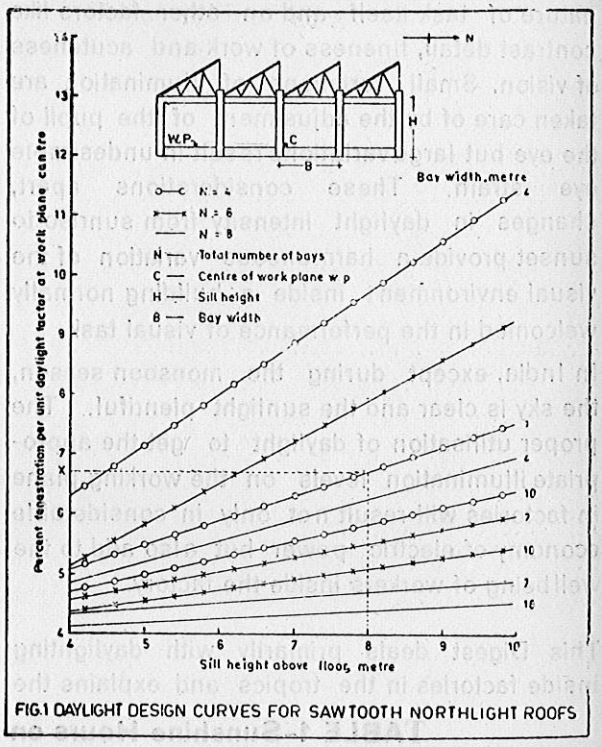

FIG.1 DAYLIGHT DESIGN CURVES FOR SAWTOOTH NORTHLIGHT ROOFS

that assumed in Fig. 1 may be accounted for with the help of this table. For cylindrical shell roof which is a variant of sawtooth northlight roof, there is reduction in the reflected component for baywidths exceeding 5 m; for 13 meters baywidth it provides nearly one-half of the reflected component as given by the equivalent sawtooth having same baywidth and fenestration per cent. The Z-folded plate which is another variant of sawtooth roof is, however, as efficient as the equivalent sawtooth for all the bay widths.

*6 mm thick wired cast glass transmittance =0.67.
**(a) Good maintenance = 0.9
(b) Poor maintenance = 0.6

TABLE 2-Average Internal Reflected Components (IRC) for Sets of Surface reflectances Representing Good, Medium and Dull Finish.

Fenestration per cent	Surface reflectances for different finihses					
	A Good Finish		B Medium* finish		C Dull finish	
	Ceiling	0.8	Ceiling	0.5	Ceiling	0.3
	Walls	0.8	Wall	0.5	Wall	0.3
	Floor	0.3	Floor	0.3	Floor	0.3
10	2.2		1.0		0.5	
15	2.8		1.3		0.7	
20	3.4		1.6		0.9	
25	3.95		1.9		1.05	
30	4 35		2.15		1.2	

*in design curves of Fig. 1

The span has been assumed to be 60 m beyond which there is no change in the expectable illumination. A reduction in the span from 60 m to 20 m reduces the workplane illumination by a factor of 0.9. The values given here refer to the design time corresponding to a solar altitude of 15° in the sky. An increase in daylighting occurs when the sun goes up in the sky. As a general rule on clear days this increase at noon time will be between 1.2 and 1.5 times the value given in Fig. 1.

The Design of the Sawtooth Roof

Depending upon the task to be performed inside the factory, a level of illumination is chosen from Table 3. The size of the machinery employed decides the height at which the northlight openings are to be located. Once the illumination level and the height of the sill above the working plane has been decided upon, fenestration per cent can be determined from set of design curves as follows:

(1) Determine task illumination in terms of daylight factor from Tabe 3.

Table 3. Recommended Lighting Levels for Factory Interiors (Indian Standard Code of Practice IS: 6060-1971)

Type of work	Recommended illumination	
	Lux	Daylinght Factor (D. F.)
Assembly shops:		
(a) Rough work, for example, frame assembly and assembly of heavy machinery	150	1.9
(b) Medium work e. g. machined parts, engine assembly and vehicle body assembly	300	3.8
(c) Fine work, e g, radio and telephone equipment, typewriter and office machinery assembly	700	8.8
(d) Very fine work, e. g. assembly of very small precision mechanisms and instruments	1500	18.8
Bookbinding	200-300	2.5–3.8
Boot and Shoe factory	700-1000	8.8–12.5
Carpet factory-Winding, weaving	200,450	2.5,5.6
Chemical works-Plants, Control rooms	150,200-300	1.9,2 5–3.8
Clothing factory-Cutting Sewing. Light, Medium, Dark	300,450,700	3.8,5 6,8.8
Electricity generating stations-Turbine halls, Control desks	200,300	2.5,3 8
Forges	150	1.9
Foundries-Rough moulding, fine moulding	150,300	1.9,3.8
Iron and steel works-Melting shops, Inspection	100,200-300	1.3,2.5-3-8
Machine and fitting shops:		
(a) Rough bench and machine works	150	1 9
(b) Medium bench and machine work, ordinary machines, rough grinding, medium buffing and polishing	300	3.8
Paint works-Rough spraying, Processes, Finishing	150,200,450	1.9,2.5,5.6
Paint works-Retouching and colour matching	700	8.8
Paper works-Machine houses, Inspection	200,300	2.5,3.8
Printing works-Block making, Composing room	200,450	2.5,5.6
Soap Factory-General areas, Control panels	150,200-300	1.9,2.5-3.8
Textiles-Spinning, cloth inspection	150,700	1.9-8.8
Warehouse and storing-Loading bays, Packing	100,150	1,3,1.9

(2) Locate curve for given baywidth and number of bays in Fig. 1. For given sill height on the abscissa, read along the ordinate of Fig. 1 the value (X) of per cent fenestration per unit daylight factor.

(3) Multiply X with the required daylight factor to obtain the required per cent fenestration.

(4) If the glass transmittance or maintenance factors are different from the assumed values, the required per cent fenestration will be modified proportionately.

Example

Determine the fenestration per cent required for an assembly shop for medium work,e.g., engine assembly for (a) medium, (b) poor maintenance conditions in a four-bay sawtooth northlight factory building of 7 m bay width and 8 m sill height.

Solution

(a) Medium maintenance condition

(1) From Table 3. illumination requirement for assembly shop for medium work = 300 Lux, i.e., 3.8 D. F.

(2) Locate curve for 7 m bay width and 4 bays. For 8 m sill height on the abscissa, read the value (X) of fenestration per cent per unit daylight factor along the ordinate. as 6.7.

(3) Fenestration per cent = $6.7 \times 3.8 = 25.5\%$ of the floor area. Since Fig. 1 assumes medium maintenance this is the required fenestration.

(b) Poor maintenance condition

For poor maintenance condition, the maintenance factor should be 0.6

Required fenestration per cent will be $\frac{25.5 \times 0.7}{0.6}$ = 29.8% of the floor area.

Recommendations

(a) Glass area should be provided in accordance with the required task illumination.

(2) Vertical glazing should be preferred over sloping type glazing.

(3) Wherever possible a good light reflecting finish should be provided on the roof, ceiling and other inside surfaces.

(4) The poor maintenance of glazings is one of the major factors responsible for poor level of lighting. Therefore, a periodic schedule for cleaning need be followed to achieve better work plane illumination.

(5) The production lines and machines, such as, shapers, milling machines, planers and lathes should preferably be located with axis at right angles to the roof lights and the critical tasks should face the roof lights.

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