BUILDING DIGEST
CENTRAL BUILDING RESEARCH INSTITUTE, INDIA

SUPPLEMENTAL ARTIFICIAL LIGHTING IN BUILDINGS

Scope

Design for daylighting is based on external daylight availability between the design time hours. For Indian conditions the relevant I. S. I. Code of Practice defines the design hours as those between the morning and afternoon times when the sun is at an altitude of 15°. As the design is based on clear sky conditions, situations are likely to arise when supplemental lighting may be needed when (a) the sky conditions change (b) work is expected to be performed beyond design hours either during mornings or evenings and (c) architectural limitations cannot provide the required quantum of daylight through daylighting apertures. The purpose of this digest is to provide ready solutions to problems of general supplementary lighting that are likely to be met with in practice and the visual tasks are those involving reading and writing in any type of building. Special situations normally require localised artificial lighting as for instance in workshops or factories.

Design time, design illumination, design sky and basis for side lighting through windows

It follows that the interval between the solar altitudes of 15° in the morning and evening is the design hours during which the availability of daylight is within the limits expectable on the I. S. I. Code. The design illumination is 8000 Lux on the horizontal out, doors for sky component design and 16000 Lux on the horizontal outdoors for the reflected component design. It can be shown that the total illumination on the vertical facade opposite the sun is of the order of 8000 Lux at the design time under conditions usually met with in practice. These hold good when the sky is clear. C.B.R.I. Building Digest[1] and a Special Publication[2] enumerate how daylighting designs could be simplified by the use of ready made charts and tables, when interior dimensions and finish are known.

Need for Supplemental Lighting

The need for supplemental lighting can be met by providing artificial lighting upto a value governed by the following criteria :

(a) The illumination of the task does not drop below a critical value, and

(b) The overall surround luminance also correspondingly does not go below a value commensurate with the subjective feeling of pleasantness.

Norms for Supplemental Illumination

Investigations undertaken by this Institute on supplemental lighting indicate that the necessity for supplement is felt when the level of illuminance on the work plane drops below 100 Lux and the surround luminance also drops below 60 apostilbs. User preferences were judged by experimentation in different sized rooms. The range of working plane illumination between 100 to 150 Lux was considered as acceptable when external daylighting levels tend to drop below design figures. During the hot summer months, in the tropics, the practice of keeping windows closed and partly shielded and switching on the artifical lights shows that there is a need to avoid the heat through the windows and supplementing the reduction of daylight artificially. Here a fluorescent tube is preferable to an incendescent lamp.

Since the design of artificial lighting is based on the adaptation state of the eye for night time and that for daylighting is based on the bright adapted eye, the latter has also to be taken into consideration in the provision of supplemental lighting. This is taken care of in the experimentally established results enumerated earlier. Since the fluorescent lamp is more economical than the incandescent and the light quality of the former more nearly matches with that of the daylight it is recommended for supplemental lighting.

How to work out the requirements

Two possibilities arise. The first is where the execution of a critical task in a small area needs supplemental lighting. Here the solution is to employ a small table lamp to supplement the daylight at the required spot.

The other is the lighting of the entire area of a large room. The significant parameters are room

1. Fenestrations for Daylighting of Sidelit Rooms : A Simplified approach, Building Digest No. 82.
2. Design for Daylighting, A CBRI Special Publication.

size, ceiling height (assumed to be constant at 3.0m), window area expressed as a parcentage fraction of the floor area and room surface reflectance factors. The room is supposed to be proportioned in the length (window side) to width ratio of 0.3–1.5. Windows are supposed to be on one wall (long or short), glazed and unobstructed but provided with a suitable shading device, (horizontal louvre at the top edge about 60.0 cm deep).

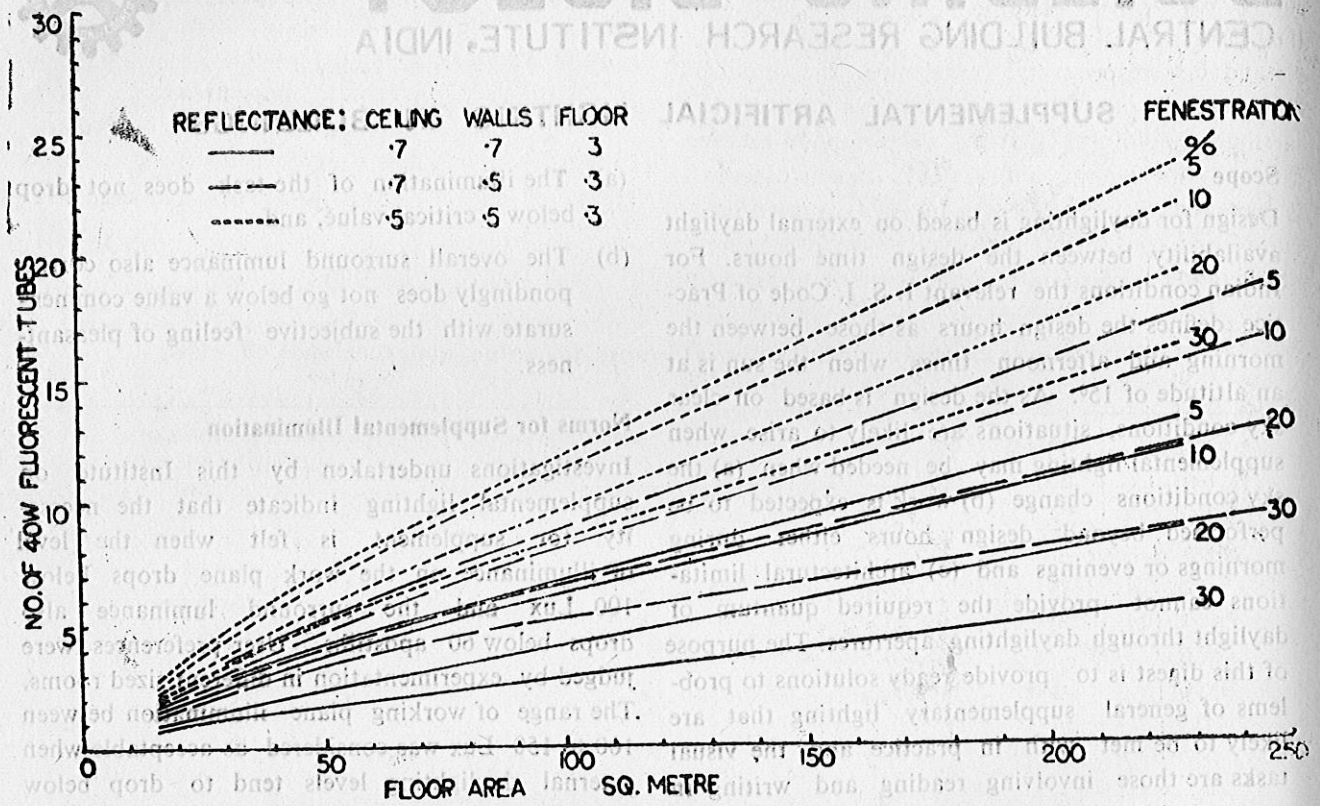

FIG.1

Requirement of daytime supplementary artificial lighting for different room sizes (ceiling height 3.0 m), window sizes (% of floor area) and interior finish (reflectances : white 0.7, off white 0.5, medium grey 0.3).

The set of curves shown in Fig. 1 are helpful in arriving at the optimum number of tube lights required to make up the deficiencies in daylight during daytime. The fluorescent lamps (tube lights) are the 120 cm long 40 W type operating at a CCT of 6800°K and are provided with a simple reflector such that about 50 to 60 per cent of the lamp lumens are made available for providing the illumination required. Any modification in the luminaire system will increase the number of lamps required for supplementing in simple proportion.

Where to supplement

The quantum of supplement is provided in those work areas where the level of daylight tends to get sharply decreased when external conditions worsen These are the rear areas of the room removed farthest from the side windows. It is best provided directly over the work spots adjacent to the rear wall. The distribution of the required number of tube lights should be such as to reinforce the light in the rear areas. If daylighting is provided for by windows in opposite walls the central region of the room between the windows should correspond to the location of the supplementing luminaires.

Night time lighting and supplemental lighting

The question may arise regarding the compromise between night time lighting and supplemental lighting during day time. It has been observed that in most buildings the existing night time lighting is switched on to provide daytime supplemental lighting. This practice is usually more energy consuming. The method of arriving at the supplemental lighting during daytime involves the use of less numbers of fixtures and hence provides long term economy. If the night lighting system could be modified to take the supplementing system an ideal compromise is achieved. A switch board with seperate switching arrangements for the two systems will be desirable to attain maximum savings in energy consumption. If a building is not going to be used for sustained work at night, additional night lights need not be provided. These factors are described in detail in the illustrative examples.

Worked Examples

Example 1

A room of size 5m×3m×3m is provided with a window 1.5 m×1.0 m located centrally on the shorter wall at a sill height of 1.25m above floor and the reflectance of ceiling, walls and floor are 0.7, 0.5 and 0.3 respectively. Determine the number of 40 watt fluorescent tubes required for supplemeting daylight and that for catering 150 Lux on a work plane 0.75 m above floor level at night. It is proposed to use diffusing plastics-enclosed two lamp luminaries of the semi-direct type at a mounting height of 1.5 m above the working plane, and it is required to provide an integrated design for both the supplementary lighting and night lighting. (See Fig. 2).

Solution

Step I-Night Lighting requirement by Lumen Method :

(a) Room ratio $= \frac{\text{floor area}}{\text{Mounting height} \times \frac{1}{2} \text{ Perimeter}}$

$$= \frac{5 \times 3}{1.5 \times (5+3)} = \frac{10}{8} = 1.25$$

(b) Coefficient of utilization :

Table 1-Typical values of coefficients of utilization for ceiling white and walls off white

Room Ratio	Bare lamp unit	Two lamp luminaire : Aluminium troffer with baffles.	Two lamp luminaire : Diffusing plastic enclosed
0·6	0·29	0·27	0·17
0·8	0·38	0·32	0·22
1.0	0.46	0.36	0.26
1.25	0.52	0.39	0.30
1.5	0.56	0.42	0.33
2.0	0.63	0.44	0.37
2.5	0.67	0.46	0.39
3.0	0.71	0.47	0.40
4.0	0.75	0.49	0.43
5.0	0.78	0.50	0.45

Refering to Tables of the coefficient of utilization in any book on illumination (See Table 1 for typical values), this value, for the above room ratio and for the type of Luminaire and surface reflectances specified in the problem, is found to be 0.3.

(c) Number of Lamps $= \frac{\text{(Required Illumination} \times \text{Floor Area)}}{\text{Lumen output per lamp} \times \text{Maintenance factor} \times \text{Coefficient of utilization.}}$

Taking maintenance factor into account, an out put of 2000 lumens can be assumed from a 40 watt fluerescent tube.

Number of Lamps required $= \frac{150 \times 15}{2000 \times 0.3} = \frac{15}{4} \simeq 4$

Number of two lamp luminaires $= 2$

Step II—Supplementary lighting requirement :

Floor area $= 5 \times 3 = 15$ Sq. m.

Per cent Fenestration of floor area

$$= \frac{1.5 \times 1.0}{5 \times 3} \times 100 = 10\%.$$

Refering to the curve for ceiling, wall and floor reflectances as 0.7, 0 5, 0:3 respectively in Fig. 1 and reading on the ordinate for 15 Sq. m. floor area and 10% fenestration, the number of 40 watt fluerescent tubes $\simeq 2$.

Therefore number of two lamp luminaires required = 1.

Step III-Daylight availability at the centre and rear of the room :

Distance of the room centre from the window wall d = 2.5 m.

Distance of the room rear from the window wall d = 5.0 m.

Sill height above work plans = 1.25—0.75 =0.5 m. Refering to CBRI Special Publication[2] the side 'a' of squares on the Lux grid will be 0.25 m and 0.5 m for the centre point and rear point respectively. On this scaling, sketch the given window 1.5 m

× 1.0 m at sill of 0.5 m above base line and count the number of dots and stars enclosed within the window outline. The Lux values are obtained by multiplying the number of stars by 2 and the number of dots by 0.5. The correction factors are given in Table 2 of this special publication. The correction factor is multiplied by number of squares enclosed within the window outline and is added to the above Lux value, in order to obtain the expectable daylight.

For centre point

No. of dots = 192	=	96 Lux
No. of stars = 96	=	192 Lux
Total	=	288 Lux

No. of Squares = 24

Correction factor = −5.0 × 24 = −120

Expectable Daylight = 168 Lux

For rear point :

No. of dots	= 36	= 18 Lux
No. of stars	= 24	= 48 Lux
Total		= 66 Lux

No. of Squares = 6

Correction factor = +3 × 6 = +18

Expectable daylight : = 84 Lux

Step IV–Distribution of Luminaires :

Step III shows that the daylighting of the room is good (>2% Daylight Factor at the centre) and therefore supplementary lighting should be for the rear region and that too when design conditions fail.

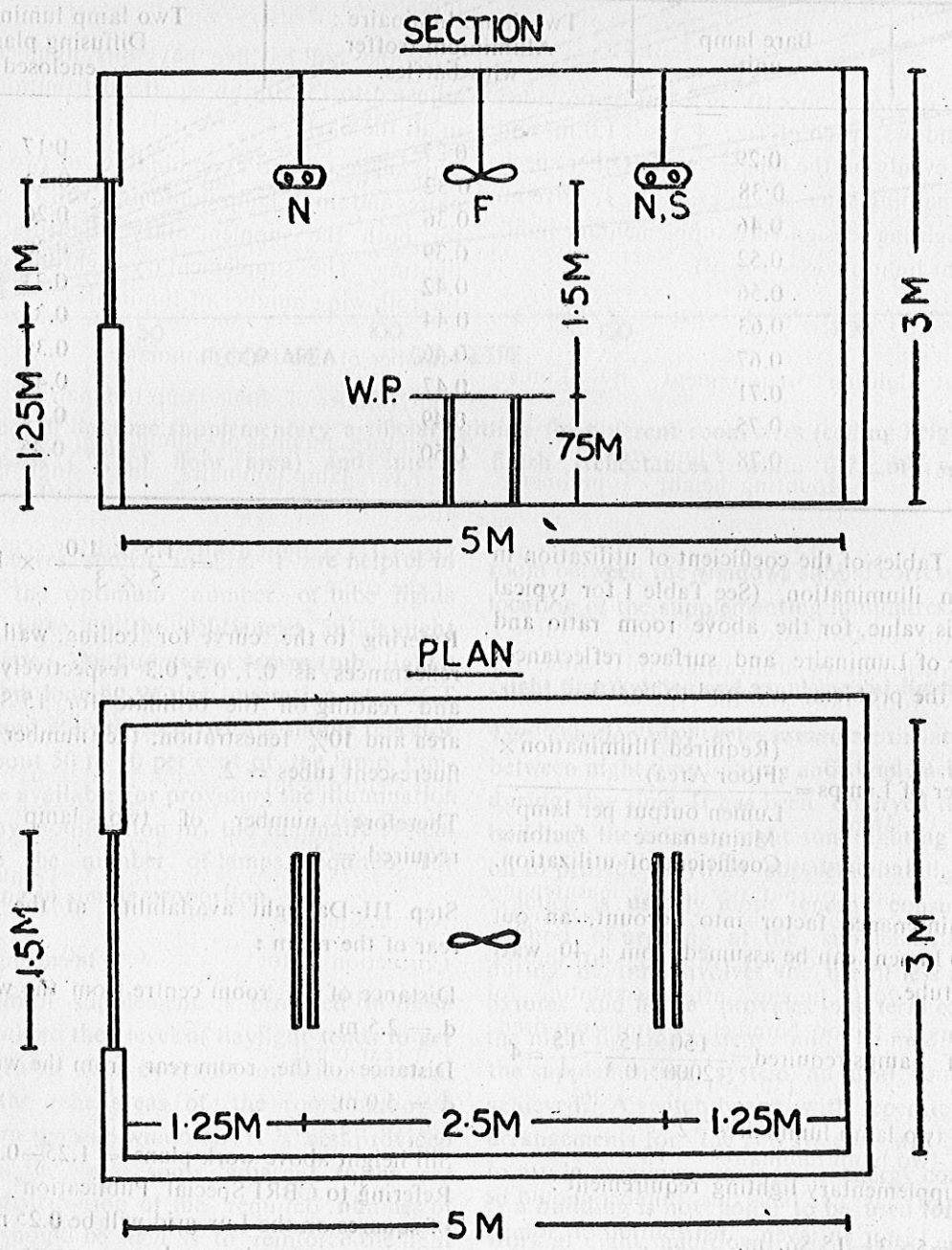

Fig. 2. Plan and section in example 1. (W.P. — Working plane, S—Daytime supplementary lights, N— Night time lights, F—Fan).

According to Lumen method the maximum spacing between luminaires should be 1.5 times the mounting height i.e. $1.5 \times 1.5 = 2.25$ m. and the maximum distance between a luminaire and end wall should be 0.75 times the mounting height i.e. $0.75 \times 1.5 = 1.13$ m. Making slight adjustments, the two luminaires may be fixed parallel to window wall at a separation of 2.5 m from each other and 1.25 m from respective walls. The two lamp luminaire in the rear region will be required for supplementary lighting whereas both the luminaires (i.e. all the 4 lamps)will be used for night lighting. The location of the luminaire in the rear region as arrived at by the lumen method is also quite appropriate in general for the supplementary lighting. However if some particular work area is specified in this region, the location of this luminaire can be suitably adjusted to be nearer this area.

Example 2.

A large hall of size 15 m × 10 m × 3 m is provided with five windows, each of size 1.5 m × 1.0 m and distributed evenly on the longer wall. Other specifications remaining same as in example 1, give an integrated lighting design for supplementary lighting and night lighting. (See Fig. 3).

Solution

Step I–Night lighting requirement by Lumen method.

(a) Room ratio $= \dfrac{\text{Floor area}}{\text{Mounting height} \times \frac{1}{2} \text{ perimeter}}$

$$= \frac{15 \times 10}{1.5 \times (15+10)} = \frac{100}{25} = 4.0$$

(b) Coefficient of utilization : Refering to table 1 of the coefficient of utilization, this value for the above room ratio and the type of luminaire and surface reflectances specified in the problem is found to be 0.43.

(c) Number of lamps

$$= \frac{\text{Required illumination} \times \text{Floor area}}{\text{Lumen output per lamp} \times \text{maintenance factor} \times \text{Coefficient of utilization.}}$$

Assuming the Lumen output of a 40 watt fluorescent lamp as 2000 lumens, after accounting for the maintenance factor, Number of lamps required

$$= \frac{150 \times 150}{2000 \times 0.43} \simeq 26$$

Number of two lamp luminaires = 13

Since the hall has five bays this number should be adjusted to 15 for an even distribution of luminaires in all the bays. Therefore, number of luminaires required per bay = 3. Alternatively, a single lamp luminaire of similar specifications can be chosen and a combination of 10 two lamp luminaires and 5 single lamp luminaires can be taken as an approximate solution, the number of lamps being only one less than the calculated requirement. The number of luminaires required per bay will remain the same i.e. 3.

Step II–Supplementary lighting requirement :

Floor area $= 15 \times 10 = 150$ Sq. m.

per cent Fenestration of floor area

$$= \frac{5 \times 1.5 \times 1.0}{15 \times 10} \times 100 = 5\%.$$

Refering to curve for ceiling, walls and floor reflectances as 0.7,0.5,0.3 respectively in Fig.1 and reading on the ordinate for 150 Sq. m. floor area and 5% fenestration, the number of 40 watt fluerescent tubes $\simeq$ 13.

Since the hall has five bays this number should be adjusted to 15 for an equal distribution of lamps in all the bays.

This suggests that a combination of two lamp luminaires and single lamp luminaires will be appropriate for both the supplementary lighting and night lighting. The supplementary lighting will require the following number of luminaires :

Number of two lamp luminaires = 5

and Number of single lamp luminaires = 5

Therefore number of luminaires required per bay = 1 two lamp luminaire and 1 single lamp luminaire.

Step III–Daylight availability at the centre and rear of the room :

Using CBRI Special Publication[2] and making outlines of the windows as in example 1 with side 'a' of squares as 0.5 m and 1.0 m or the centre (d = 5.0 m) and rear (d = 10.0 m) respectivelly,

For Centre point

No. of dots	= 76	=	38 Lux
No. of stars	= 120	=	240 Lux
		Total =	278 Lux
No. of Squares	= 30		
Correction factor	$= -6.4 \times 30$	=	−192
Expectable Daylight		=	86 Lux

For rear point :

No. of dots	= 13	=	6.5 Lux
No. of stars	= 30	=	60.0 Lux
		Total	66. 5 Lux
No. of Squares	= 7.5		

Correction factor (on extrapolation)

$= -3 \times 7.5 = -22.5$

Expectable Daylight = 44 Lux

Step IV–Distribution of Luminaires :

It is seen from Step III that the daylight in the hall is poor in general, and the daylight at the room centre is below 100 Lux. Therefore, supplementary lighting is required not only in the rear region but also near the centre. However, the supplementary lighting in the rear region need be relatively higher than the room centre. Therefore, single lamp luminaire should be placed near the centre of each bay and the two lamp luminaire will be distributed in the rear and front half of each bay.

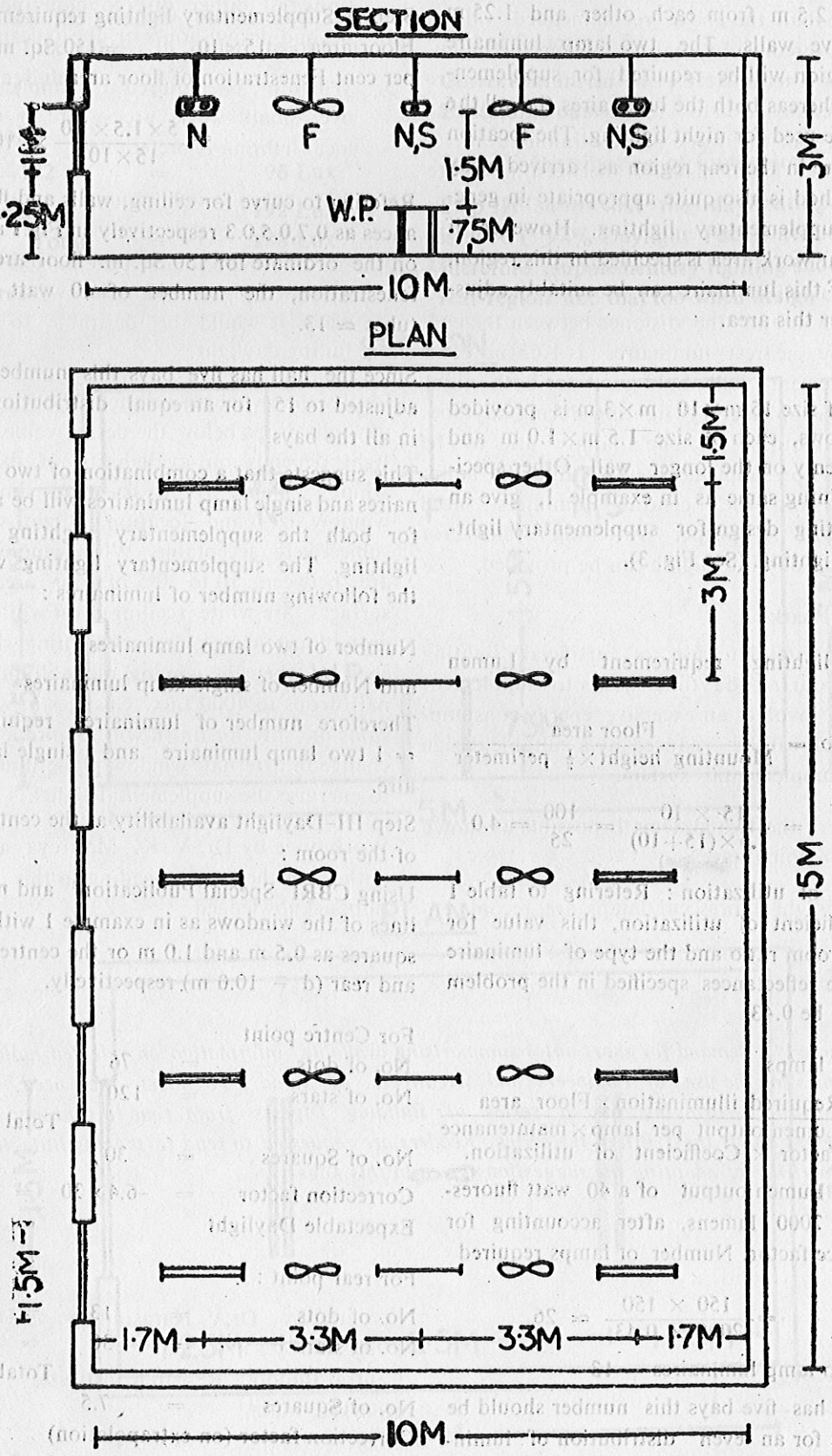

Fig. 3. Plan and Section in example 2. (W.P.—Working plane, S—Daytime supplementary lights, N—Night time lights, F—Fan).

According to Lumen method the maximum spacing between luminaires should be 2.25 m and the maximum distance between end wall and nearest luminaire should be 1.13 m Since the depth of the room is 10 m, centre to centre distance between luminaires can be 3.3 m and distance between end wall and nearest luminaire can be 1.65 m. These distances are more than the above recommended values. This can be overcome by slightly raising the mounting height. Alternatively, if the luminaires are placed perpendicular to the window wall the nonuniformity of the work plane illumination resulting from the larger distance between luminaire centres will be slightly offset. Therefore, the luminaires can be placed perpendicular to the window wall, along the central line of each bay such that the centre to centre distance between luminaires in a bay is 3.3 m and the distance between the end wall and the nearest luminaires is 1.65 m. The same arrangement will hold good for both night lighting and supplementry lighting during daytime. For night lighting all the lamps are to be used, whereas for supplementary lighting the lamps of the rear and the central luminires need be employed. A proper switching system for night time and daytime lights can be provided.

Concluding remarks

1. The indiscriminiate use of artificial lighting systems during daytime hours to supplement daylight involves an excessive energy consumption which can be reduced by a suitable design of the supplemental system.

2. A blend of the two systems is possible as shown in the foregoing pages.

3. Cool daylight fluorescent lamps are recommended for the supplemental system in view of their suitable characteristics and long term economy.

4. The system so designed caters to the needs of internal requirements of lighting during such hours of day time when external lighting conditions fail either due to cloudiness or working beyond design hours or due to design limitations.

5. Where it is required to supplement daylight over small work areas and/or critical tasks local lighting is preferable

6. Automatic switching units are available which will energise the supplemental artificial light system when the external daylight level on the window plane drops below a critical value when it would be desirable to augment the failing daylight.

Ideally the switching on should be when the interior daylight drops below the design value. Interior daylight depends on availability of daylight on the window plane, room size and finish as well as window sizes and location. Slight variations are subjectively acceptable. When window dimensions are between 10 to 20% of floor area, and room surfaces are white (ceiling), off white (walls) and grey (floor), supplementary lighting should be switched on when the window plane illumination (external) drops to 4000 Lux. Changes in window dimensions or interior finish will require a proportionate change in external window plane illumination level to energise the supplemental lights

Work done by Dr. V. K. Maitreya along with the authors in the project leading to this digest is gratefully acknowledged.

There is a demand for short notes summarising available information on selected building topics for the use of Engineers and Architects in India. To meet the need this Institute is bringing out a series of Building Digests from time to time and the present one is the 120th in the series. Readers are requested to send to the Institute their experience of adopting the suggestions given in this Digest.

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