BUILDING DIGEST
CENTRAL BUILDING RESEARCH INSTITUTE, INDIA

ENERGY CONSERVATION IN BUILDINGS

Efforts are being made all over the world to conserve energy as far as possible. Various measures are on way in India as well to conserve energy. This digest outlines the measures for conservation of electrical energy used for heating/cooling, lighting and ventilation in buildings.

1.0 Energy for Heating/Cooling

Energy consumption for thermal comfort is of the order of 60 per cent of total energy consumption in buildings. Conservation of a part of this energy, inside a building is possible by judicious selection of building components (roof, walls), correct orientation of building, adequate provision of windows, modification of limits of comfortable conditions, type and capacity of the system employed for comfort conditions. These factors are discussed below :

1.1 Selection of Roofs and Walls

Table 1 gives the maximum prescribed values of TPI* which should not be exceeded for thermal comfort. Values for different roof and wall sections are given in Tables 2, 3 and 4. One should select suitable roof and wall sections so that the TPI values do not exceed the prescribed values as far as possible. Larger the TPI value greater shall be the thermal discomfort in the building.

1.2 Orientation

Best orientation for thermal comfort is one in which the building receives maximum solar radiations in winters and minimum in summers. Therefore, the longer walls of a building should face North and South and the shorter walls should face East and West, as far as possible.

1.3 Windows

Windows are provided for daylight, vision and ventilation. Their percentage area varies from 15 to 40 per cent of the floor area and glass is the most commonly used material for windows, because of its various advantages. For thermal comfort, a compromise has to be made between the percentage of maximum glass area and the amount of shading so that the

Table-1

TPI--Maximum Prescribed Values

Sl. No.	Building component	TPI	
		Unconditioned Buildings	Conditioned Buildings
1	Wall	125	100
2	Roof	100	75

*TPI : Thermal Performance Index represents the relative performance of a building section. Its rating '100' corresponds to 8°C excess of inside surface temperature for unconditioned buildings (above 30°C) and to 40K. Cal/m² hr. peak heat gain for conditioned buildings maintained at 25°C.

Table—2

TPI—Flat Roofs

Sl. No.	Roof sections	Insulation	Water proofing	Unconditioned Buildings		Conditioned Buildings	
				TPI	Class*	TPI	Class*
1.	10.0 cm RCC Slab	—	Tarfelt	225	C	274	C
2.	,,	—	9 cm Lime Concrete	134	C	143	C
3.	,,	5 cm Mud Phuska	5 cm Bricktile	122	B	125	C
4.	,,	5 cm Vermuculite Concrete	Tarfelt	90	B	70	B
5.	,,	5 cm Foam Concrete	,,	81	B	55	B
6.	,,	10 cm Vermuculite Concrete	,,	72	A	39	A
7.	,,	10 cm Foam Concrete	,,	66	A	30	A
8.	11.5 cm R.B.C.	—	,,	203	C	235	C
9.	,,	—	9 cm Lime Concrete	126	C	128	C
10.	,,	5 cm Mud Phuska	5 cm Bricktile	116	B	114	C
11.	,,	5 cm Vermuculite Concrete	Tarfelt	89	B	65	B
12.	,,	7.5 cm Mud Phuska	5 cm Bricktile	105	B	97	B
13.	,,	5 cm Foam Concrete	Tarfelt	81	B	53	B
14.	5 cm Sand-stone	—	Tarfelt	306	C	384	C
15.	,,	—	9 cm Lime Concrete	182	C	205	C
16.	,,	7.5 cm Mud Phuska	5 Bricktile	143	C	147	C
17.	,,	5 cm Foam Concrete	Tarfelt	108	B	83	B
18.	13.0 cm Cored Unit	—	,,	184	C	210	C
19.	,,	—	9 cm Lime Concrete	119	B	117	C
20.	,,	7.5 cm Mud Phuska	5 cm Bricktile	99	B	90	B
21.	,,	5 0 cm Vermuculite Concrete	Tarfelt	85	B	61	A
22.	,,	5.0 cm Foam Concrete	,,	78	B	49	B
23.	7.5 cm Cellular Unit	—	,,	216	C	250	C
24.	,,	—	9 cm Lime Concrete	140	C	140	C
25.	,,	5 cm Mud Phuska	5 cm Bricktile	129	C	124	C
26.	,,	10 cm Foam Concrete	Tarfelt	79	B	42	A
27.	,,	10 cm Varmuculite Concrete	,,	72	A	32	A
28.	15.0 cm Siporex Slab	—	,,	92	B	42	A

*Class :—

A=Preferable where better standards are aimed at.

B=Accaptable though not adequate.

C=Unsatisfactory, requires treatment.

Table-3

TPI-Sloped Roofs

Sl. No.	Roof Sections	Unconditioned Buildings	
		TPI	Class
1.	0.625 cm A.C. Sheet	186	C
2.	0.625 cm A.C. Sheet+2.5 cm Air Space+Insulating Board	111	B
3.	0.625 cm A.C. Sheet+Air Space+5 cm Fibre Glass+0.625 Hard Board	80	B
4.	0.3 cm G.I. Sheet	198	C
5.	2.5 cm Thatch Roof+2.5 cm Bamboo Reinforcement	116	B
6.	5 cm Thatch Roof+2.5 cm Bamboo Reinforcement	102	B
7.	Mangalore Tiles on Wooden Rafters	140	C

heat gain factor[1] through glazed windows does not exceed 40 K. Cal/hr. m^2. Window sizes for daylight recommended in para 2.1 satisfy this requirement. Corresponding to this value of heat gain factor the shade factor[2] for unconditioned buildings should not exceed 0.5 and for conditioned buildings it should not exceed 0.3. This prescribed value of shade factor can be obtained for several combinations of internal and external shading devices as given in Table 5.

In situations where louvers are to be provided for outside shading, the percentage shading can be taken from Table 5. Corresponding to this percentage of shading and orientation of the window, size[3] of horizontal and vertical projections[4] can be worked out with the help of Fig. 1 for any size of window. These graphs in the figure are for eight orientations. For other orientations the size of projections can be interpolated with a fair degree of accuracy.

1. 4 Limits of Comfortable Conditions

For conservation of electrical energy the lower limit for cooling may be raised from 25°C to 27.5°C ±1°C and the upper limit for heating may be lowered from 20°C to 18°C±1°C Modification of these limits will not cause any appendix discomfort in the building.

1. 5 Selection of System for Cooling/Heating

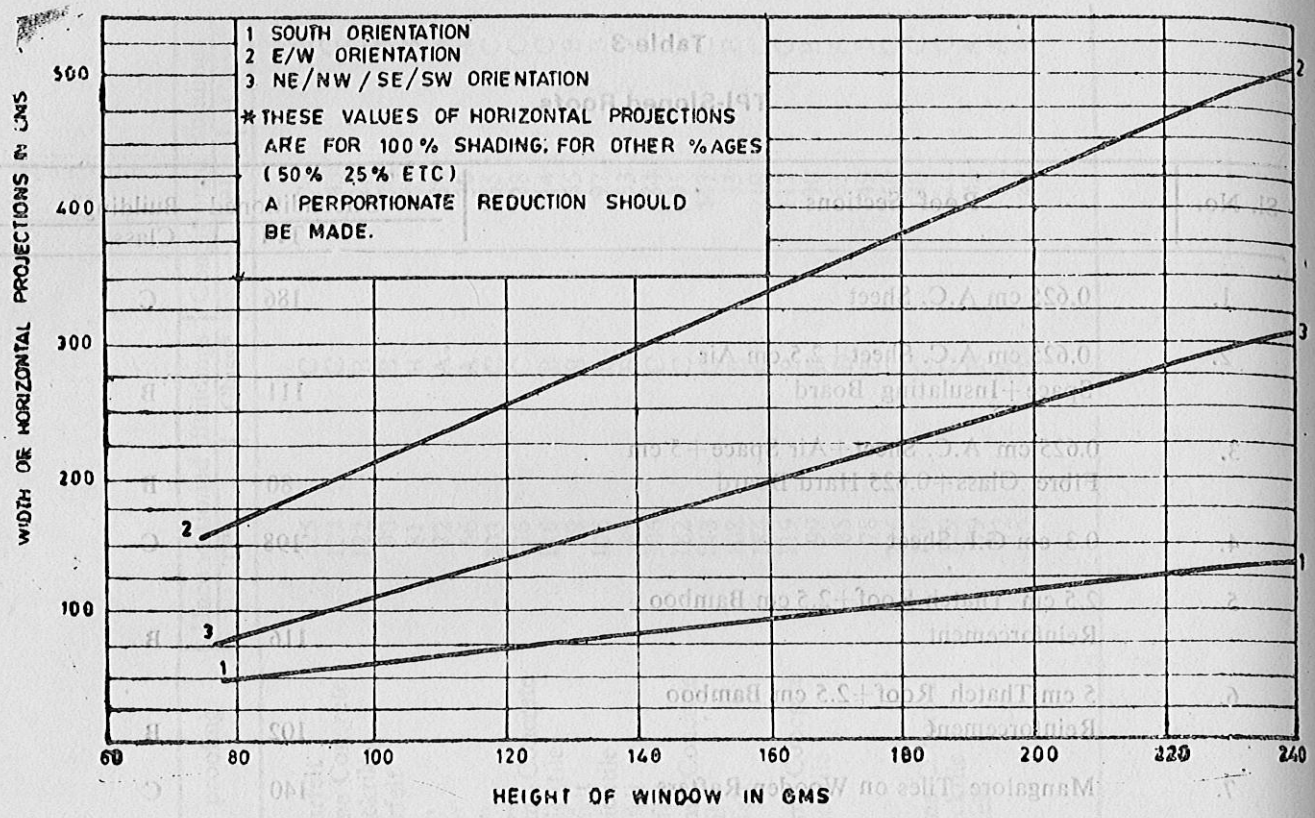
Different systems which are used for cooling and heating are unit air conditioners, package air conditioners, evaporative coolers, radiant heaters and heat convectors. For conservation of electrical energy one should select evaporative coolers instead of airconditioners and heat convectors instead of radiant heaters as far as possible. If airconditioners are to be employed their thermostats should be adjusted according to the modified temperature limits of comfort.

[1] Heat Gain Factor : It is the amonnt of heat in K. Cal that passes through a unit area of a surface in unit time.

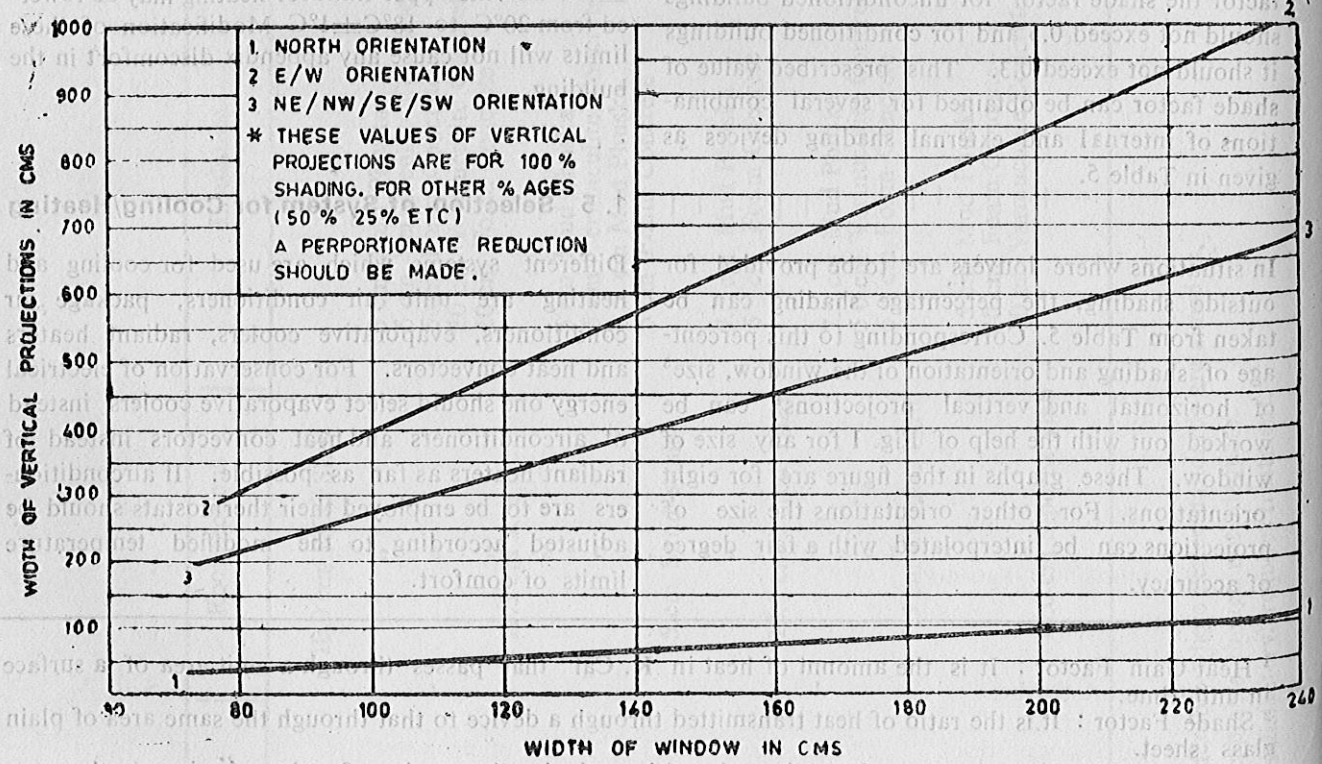
[2] Shade Factor : It is the ratio of heat transmitted through a device to that through the same area of plain glass sheet.

[3] If the size of projection is large it can be reduced by reducing the spacing of such projections in the same ratio.

[4] Horizontal projections in South, vertical projections in North and a combination of both in other orientations.



DESIGN OF HORIZONTAL LOUVERS



DESIGN OF VERTICAL LOUVERS

Fig. 1.

Table-4

TPI—Walls

Sl. No.	Basic Element	Treatment		Unconditioned Buildings		Conditioned Buildings	
		Exterior	Interior	TPI	Class	TPI	Class
1.	11.5 cm solid brick	1.25 cm plaster	1,25 cm plaster	164	C	212	C
2.	23.0 cm solid brick		1.25 cm plaster	96	B	107	C
3.	23.0 cm solid brick	1.25 cm plaster	1.25 cm plaster	93	B	102	C
4.	34.5 cm solid brick	1.25 cm plaster	1.25 cm plaster	64	A	61	B
5.	20.0 cm brick cavity wall	1.25 cm plaster	1.25 cm plaster	109	B	112	C
6.	11.5 cm brick+5.0 cm air space+2.5 cm W.W. board	—do—	—do—	108	B	92	B
7.	11.5 cm brick+5.0 cm foamed concrete	—do—	—do—	90	B	58	B
8.	23.0 cm solid brick	7.5 cm sand stone	—do—	76	B	82	B
9.	14.0 cm hollow clay unit			151	C	173	C
10.	10.0 cm precast concrete panel			223	C	321	C
11.	15.0 cm precast concrete panel			173	C	239	C
12.	20.0 cm sintered fly ash concrete panel			116	B	128	C
13.	12.5 cm foamed concrete (Siporex)			95	B	61	B
14.	20.0 cm lt. wt. hollow concrete blocks (2 holes)		1.25 cm plaster	102	B	85	B
15.	7.5 cm cellular unit			211	C	287	C
16.	10.0 cm cellular unit			214	C	284	C
17.	30.5 cm rubble masonry			89	C	104	C
18.	G.I. Sheet			357	C	554	C
19.	0.64 cm A.C Sheet			324	C	490	C
20.	23.0 cm Sundried brick	2.5 cm mud plaster	2.5 cm mud plaster	78	B	—	

Table-5

Values of Shade Factors

Sl. No.	Type of Shading devices	Shade Factor	Per cent increase in cost over plain glass window*
1.	Plain glass sheet (0 31 cm)	1.0	0
2.	Wire mesh outside with P.G. sheet	0.65	11.0
3.	Painted glass (0.32 cm)		
	(i) White Paint	0.35	3.1
	(ii) Yellow Paint	0.37	3.2
	(iii) Green Paint	0.40	3.2
4.	Heat absorbing glass (0.31 cm)	0.45	16.0
5.	Plain glass sheet with venetian blinds outside		
	(i) White colour	0.25	62
	(ii) Light green colour	0.30	62
6.	Plain glass sheet with venetian blinds inside		
	(i) White colour	0.35	62
	(ii) Light green colour	0.40	62
7.	Plain glass sheet with curtain inside		
	(i) Light colour	0.35	12
	(ii) Dark colour	0.40	12
8.	Plain glass sheet with curtain outsIde		
	(i) Light colour	0.30	12
	(ii) Dark colour	0.35	12
9.	Plain glass sheet with louvers outside		
	(i) 100% shaded	0.14	83
	(ii) 75% shaded	0.34	67
	(iii) 50% shaded	0.56	48

* Cost of plain glass window is taken as Rs. 33.50 per sq. cm.

1. 6. Capacity of System

The heating/cooling equipment should have adequate capacity to maintain optimum comfort conditions inside the room and its capacity should be estimated at a value which accounts both for reasonable comfort and minimum energy consumption. Tables 6 to 8 provide the capacity of the systems for different sizes of rooms. In deciding the capacity of systems for heating/cooling there are many variables like area of windows, percentage of shading, occupancy, top floor/intermediate floor, orientation etc. but the systems are available in limited number of standard capacities. Therefore these tables are for average conditions in practical use in India.

2. 0. Energy for Lighting

Energy consumption for lighting is of the order of 15 per cent of the total energy consumption in a building. A substantial portion of this energy can be conserved by provision of windows for optimum daylight, rational design of supplementary artificial lighting, selection of efficient lights and luminaires, suitable finishes inside and adequate schedule for cleaning. These factors are discussed below :

Table-6

Capacity of Systems for Cooling

Sl. No.	Room Area (m^2)	Air-conditioner		Evaporative Coolers	
		Capacity (Tons)	Nos.	Diameter of Exhaust Fan Cooler	Numbers
1	10	1	1	400 mm	1
2	15	1	1	400 mm	1
3	30	2	2 of 1 ton each	450 mm	1
4	45	3	2 of 1.5 ton each	600 mm	1
5	50	3	2 of 1.5 ton each	450 mm	2

Table-7

Capacity of Systems for Heating (Radiators)

Sl. No.	Design Conditions		Number and capacity	
	Occupancy	Floor area (m^2)	Number	Capacity
1	3	15	1	750 watt
2	6	30	2	750 watt
3	9	45	3	750 watt

Table-8

Capacity of Systems for Heating (Convectors)

Sl. No.	Design conditions		Number	Capacity
	Occupancy	Floor Area		
1	4	30	1	2000 watt
2	8	60	2	2000 watt
3	12	90	3	2000 watt

2.1. Design of Windows for Optimum Daylight

Recommended task illumination level for different buildings is given in Table-9. This amount of daylight should be made available upto work areas in the rear region of a room. For this level of illumination, sizes of windows as percentage of floor area of the room can be directly taken from graph in Fig. 2. These window areas are for windows with metalic sashes and usual dirt collection on glass. In case of wooden sashes, these areas should be increased by 10 per cent. External reflected light from other objects and ground has also been accounted for. These values of window areas hold good for room depths up to 10 metres.The windows should be located so as to have uniform spread of light in the room. Sill level should be 1.0 to 1.2 m and the height of the window should be another 1. 2 m or more because higher a window, greater is the penetration of light in the room.

Table-9

Task Illumination

Sl. No.	Task	Daylight factor*	Lux
1.	DWELLING		
	Kitchen	2.5	200
	Living room	0.625	50
	Bed room	0.313	25
	Study room	1.9	150
	Circulation	0.313	25
2	SCHOOLS		
	Classroom	1.9	150
	Lectutre theatre	1.9–2.5	150–200
	Laboratories	1.9–3.8	150–300
3.	OFFICES		
	General	1.9	150
	Drawing	3.8	300
	Enquiry	0.625–1.9	50–150
4.	HOSPITALS		
	General Wards	1.25	100
	Pathological Lab.	2.5–3.8	200–300
5.	LIBRARY		
	Stack room	0.9-1.9	70–150
	Reading room	1.9-3.8	150-300
	Counter area	2.5-3.8	200-300
	Catalogue room	1.9-2.5	150-200

* Daylight Factor : It is the ratio of illumination at reference point indoors to the design illumination outdoors due to the entire sky on a horizontal plane.

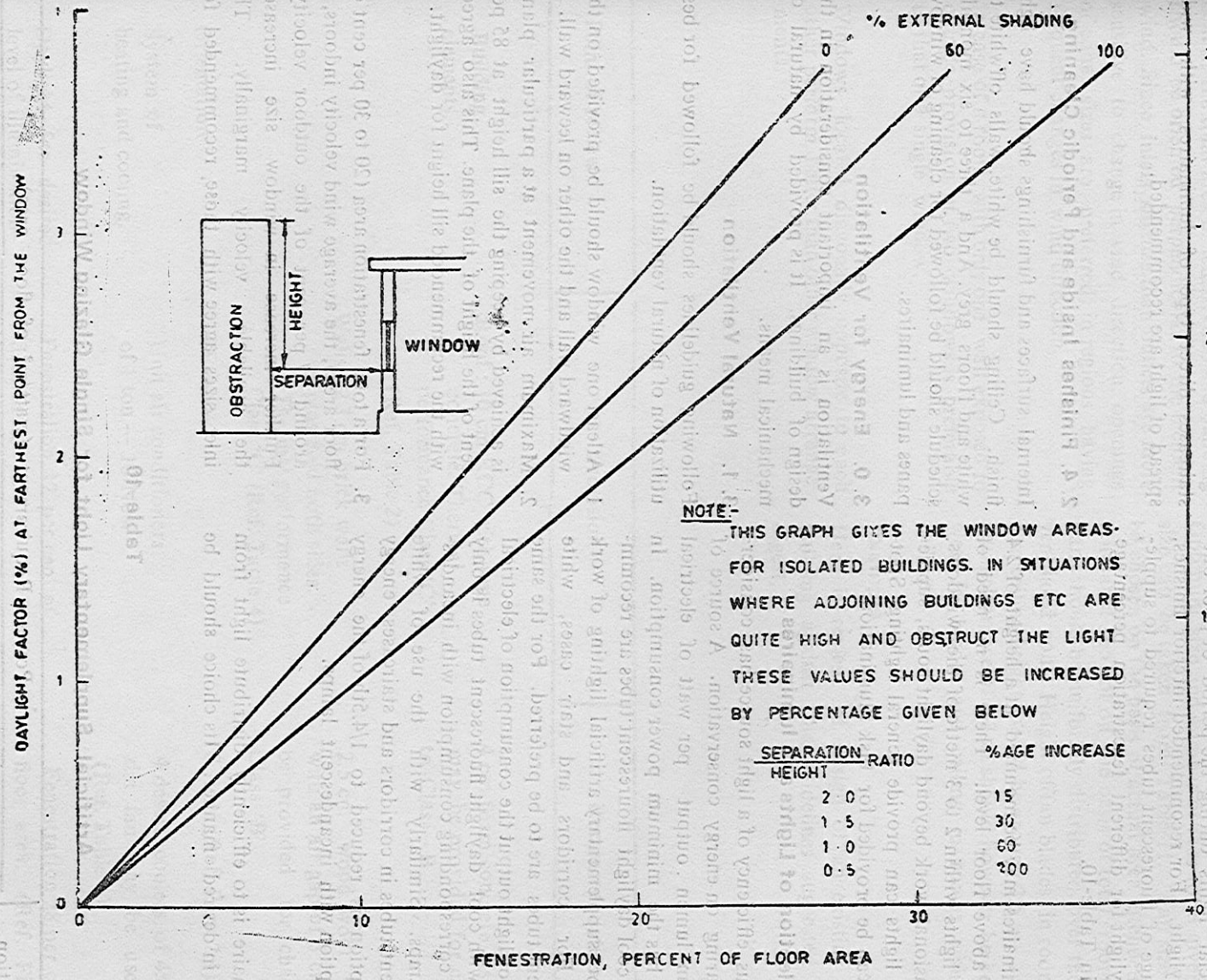


Fig. 2. Daylight Availability for Different Window Sizes

2. 2. Artificial Lighting

Present practice of artificial lighting design takes no account of daylight availability indoors. Generally adequate light for a good part of the day is available indoors. It needs to be supplemented by artificial lights during the period of poor outdoor daylight. For recommended interior finishes, the wattage of fluorescent tubes required to supplement daylight for different fenestration percentage is given in Table-10.

The luminaires may be mounted at a height of 2.4 to 2.7 m above floor level. There is no need of artificial lights within 2 to 3 metre of the windows. For occasional work beyond daylight hours, supplementary lights can provide general lighting. Spot-lighting can be provided for task illumination.

2. 3. Selection of Lights and luminaires

Luminous efficiency of a light source has considerable bearing on energy conservation. A source of maximum lumen output per watt of electrical energy has the minimum power consumption. In general, cool daylight flourescent tubes are recommended for supplementary artificial lighting of work areas. For corridors and stair cases, white fluorescent tubes are to be preferred. For the same amount of light output the consumption of electrical energy with cool daylight fluorescent tubes is only 1/4th of corresponding consumption with incandescent lamps. Similarly with the use of white fluorescent tubes in corridors and staircases, energy consumption is reduced to 1/4.5th of the energy consumption with incandescent lamps.

A luminaire is to efficiently distribute light from a lamp in desired manner. Its choice should be such that it is efficient not only initially but throughout its life. If cleaned periodically it can retain its initial efficiency. In general semidirect type of Luminaires are recommended so that both the workplane illumination and surround illumination can be effectively enhanced. For corridors and staircases direct type of luminaires with wide spread of light are recommended.

2. 4. Finishes Inside and Periodic Cleaning

Internal surfaces and furnishings should have light finish. Ceiling should be white, walls offwhite to white and floors grey. And a three to six monthly schedule should be followed for cleaning of window panes and luminaires.

3. 0. Energy for Ventilation

Ventilation is an important consideration in the design of buildings. It is provided by natural or mechanical means.

3. 1. Natural Ventilation

Following guidelines should be followed for best utilization of natural ventilation.

1. Atleast one window should be provided on the windward wall and the other on leeward wall.
2. Maximum air movement at a particular plane is achieved by keeping the sill height at 85 per cent of the height of the plane. This also agrees with the recommended sill height for daylight.
3. For a total fenestration area (20 to 30 per cent of floor area), the average wind velocity indoors, is around 27 per cent of the outdoor velocity. Further increase in window size increases the available velocity marginally. The inlet sizes agree with those recommended for

Table-10

Artificial Supplementary Light for Single Glazing Window

Fenestation percentage	Power Requirement (watt/m² of floor area)			
Separation / Height	0.5	1.0	1.5	3.0
10	6.5	5.0	4.5	4.0
20	4.5	3.5	3.0	2.5
30	3.5	2,5	2.0	2.0

daylight. However adequate opening arrangement in the glazing should be provided.

4. In regions having fairly constant wind direction, size of inlet should be kept within 30 to 50 per cent of the total area of fenestration and building should be oriented perpendicular to the incident wind. Since inlets smaller than outlets are more sensitive to change in wind direction, openings of equal sizes are preferred in regions having frequent changes in wind direction.

5. In case of a room with only one wall exposed to outside, provision of two windows is preferable to that of a single window.

6. Windows located diagonally opposite to each other perform better than other window arrangements.

3. 2. Mechanical Ventilation

For inducing air motion, ceiling fans are used. Exhaust fans are also used in a few places like stores, bath rooms etc., for the replacement of vitiated air.

Optimum size and number of fans for a given room size can be taken from Table-11. Fan size should be chosen on the basis of actual area intended to be ventilated and not on the basis of total room area. Fans should be uniformly distributed over the entire ventilated zone. Height of fan blades in rooms with 3 m ceiling height should be around 2.5 m. A minimum clearance of 0.3 m should however be kept between fan blades and ceiling in rooms with lower ceilings.

Example

Here is review of design of an existing library building against the guidelines suggested in this digest.

Point of review	Provision	Recommendation
Building elements.	Roof : 10 cm RCC with lime concrete. Thermal performance Class 'C' (Ref. Table 2)	4 cm foam concrete insulation may be provided for change to Class—B
	Walls : 2 3 cm brick walls plastered both sides. Thermal performance Class 'C' (Ref. Table 4)	2.5 cm wood wool board with an air gap of 5 cm may be provided for change to Class 'B'
Orientation	SE—NW	S — N (Ref. Para 2.1)
System of heating and cooling.	Unit air conditioners of 1 ton — 10 Nos.	4 desert coolers of 450 mm dia fan may be used (Ref. Table 6)
Daylight for desired level of illumination (Daylight factor—3) (Ref. Table 9)	Fenestration 12 per cent of floor area.	Fenestration 28 per cent of floor area. (Ref. Fig. 2)
Supplementary artificial lights (Tube lights)	5 watts/m^2	2.5 watts/m^2 (Ref Table 10)
Number of fans.	7	12 (Ref. Table 11)

The measures suggested in this Digest shall reduce the present consumption of electricity up to 20 per cent and this will not cause any discomfort to the occupants.

Table-11

Optimum/Size/Number of Fans for Rooms of Different Sizes

Length m / Width m	4	5	6	7	8	9	10	11	12
3	1200/1	1400/1	1500/1	1050/2	1200/2	1400/2	1400/2	1400/2	1200/3
4	1200/1	1400/1	1200/2	1200/2	1200/2	1400/2	1400/2	1500/2	1200/3
5	1400/1	1400/1	1400/2	1400/2	1400/2	1400/2	1400/2	1500/2	1400/3
6	1200/2	1400/2	900/4	1050/4	1200/4	1400/4	1400/4	1500/4	1200/6
7	1200/2	1400/2	1050/4	1050/4	1200/4	1400/4	1400/4	1500/4	1200/6
8	1200/2	1400/2	1200/4	1200/4	1200/4	1400/4	1400/4	1500/4	1200/6

Size of fan are in milimetres.

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 129th 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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