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BUILDING RESEARCH NOTE

62

CENTRAL BUILDING RESEARCH INSTITUTE, INDIA

WINDOW DESIGN FOR NATURAL VENTILATION IN TROPICS

Introduction

For town planning and design of buildings in tropics Architects and Engineers often require technical information regarding the design of fenestration and building orientation for optimum ventilation. The design consideration for ventilation involves the knowledge of the requirement of ventilation which depends upon the type of occupancy and the climate of the region in which the building is to be located. The climate of a particular region suggests the type of construction suitable for the purpose. For example in cold regions minimum ventilation is of prime importance and provision of large openings is undesirable, because any ventilation in excess of the minimum desirable for health will unnecessarily reduce the indoor temperature. In hot and arid regions a different set of considerations apply and good ventilation and elimination of heat is important. The design in such cases can be worked out from a knowledge of the number of air changes required for each specific case. The design of a building for comfort in hot and humid climate, depends not only on the number of air changes but also on the distribution or the pattern of air flow inside the building. The purpose of the Research Note is to provide the basic information on the influence of window size, location and orientation on indoor air motion Thus it may be utilized for designing the windows for any desired air motion or comparing the probable indoor wind pattern for a number of designs.

The wind velocity distribution patterns and other relevant data given in the Research Note, have been obtained by wind tunnel tests on models in CBRI as also elsewhere. These are applicable to normal rectangular rooms (with height about 3 m) in which one of the windows is assumed to be in the wall facing the natural outdoor wind. The results obtained for different window combination are summarized in this Research Note.

Rooms with single window

(i) The average internal wind velocity in a room with single window on windward side does not vary significantly with either increasing the size of the window or changing the orientation with respect to the incident wind.

(ii) The wind velocity at the points near the window are higher than the average wind velocity.

(iii) Provision of single window does not improve indoor ventilation.

(iv) In rooms with only exposed wall, natural ventilation can be augmented by providing two windows with a vertical projection in between them i.e. at the inner edges of the windows.

Rooms with windows in opposite walls

A. Effect of window size

(i) The average indoor velocity does not change significantly if the width of inlet opening is increased while the outlet is kept constant. However, if the inlet opening is kept fixed and width of the outlet increased, the indoor wind velocity

shows a definite upward trend. Thus it is preferable to keep the outlet as large as possible.

(ii) If the inlet and outlet openings are of identical dimensions the average indoor velocity increases significantly by increasing the width of the openings. The results of a typical case are shown in Fig. 1. It is noted that any increase in the window width beyond a value 2/3 of the room width, affords only a small possibility of improving the inside ventilation.

(iii) The average indoor velocity increases by increasing the heights of identical inlet and outlet opening. The available velocity at various levels above the floor, for various values of window height are given in table 1. It is observed that any increase in window height beyond a value 1.1 m has a very small effect on the air movement in the normally occupied zone.

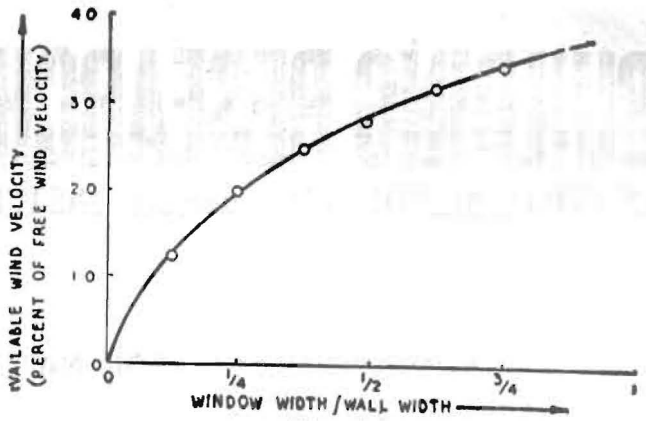
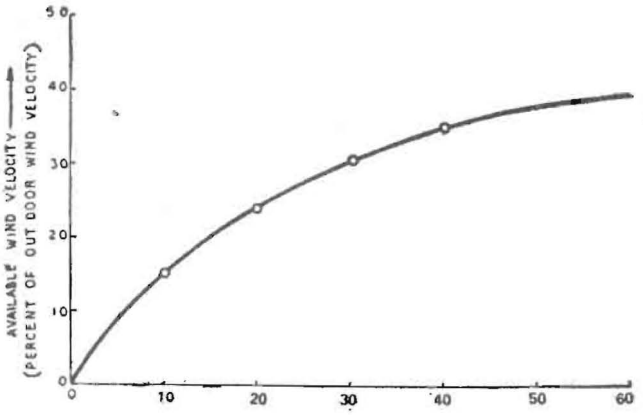


Fig. 1

Table 1

HEIGHT OF WORK PLANE (m) \ WINDOW HEIGHT →	0.3	0.6	0.9	1.05	1.2	1.35	1.5	1.8
0.6	16.0	22.3	23.8	21.8	22.4	24.4	22.2	21.44
0.9	13.5	19.5	23.5	26.4	27.1	28.6	26.2	26.0
1.2	7.7	16.8	24.7	26.3	26.1	30.8	26.7	28.0
1.5	7.4	12.48	25.2	25.6	26.0	29.9	27.9	29.8
1.8	7.7	11.8	15.7	18.5	23.2	27.6	27.9	29.4
2.1	8.6	12.6	14.6	14.2	17.6	19.6	23.5	30.8

(iv) In case of forms with identical windows on opposite walls, the variation of average indoor wind velocity with total area of fenestration is as shown in Fig. 2. For a total fenestration area of 20 to 30 per cent of floor area, the average indoor wind velocity is around 27 per cent of outdoor



Total fenestration (Inlet & outlet) area (percent of floor area)

Fig. 2

velocity. Further increase in window size increases the available velocity but not in the same proportion. In fact even under ideal conditions the maximum average indoor velocity does not exceed 40 per cent of the outdoor velocity.

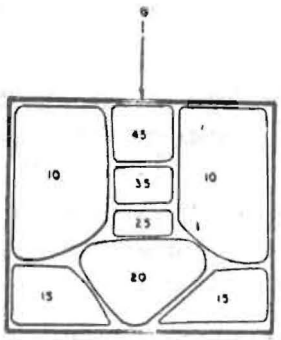
(v) The wind velocity distribution pattern for window area equal to 5, 10 and 15 percent of floor area, are shown in Fig. 3. The plan has been divided into different zones of nearly equal velocities. Each closed curve represents such a zone and the figure there shows the percentage of outdoor wind velocity available in that region. It is observed that wind velocities at the points close to the inlet and outlet are higher as compared to those near the side walls.

B. Effect of window location and orientation

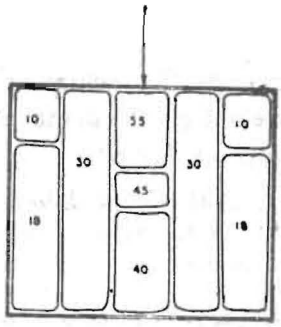
Effect of window location along the height (i.e. the sill-height) and along the length of the wall are given below :

Effect of sill-height

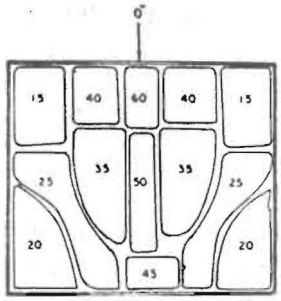
The distribution of wind velocities at the planes 0.6, 0.9 and 1.2 m above the floor for sill-heights 0.6



Window Area = 5% of Floor Area



Window Area = 10% or Floor Area



Window Area = 15% of Floor Area

Fig. 3 Effect of Window Area on Indoor wind Pattern

0.9 and 1.2 m are given in Table 2. For deriving maximum advantage in the normally occupied zone the sill-height must be kept 0.9 m above the floor. The other important conclusions arrived at by the

Table 2

HEIGHT OF WORK PLANE (m) \ SILL HEIGHT (m)	0·6	0·9	1·2	1·5
1·2	21·3	23·2	24·5	17·3
0·9	22·2	25·5	21·2	14·1
0·6	26·8	23·7	17·8	12·7

study of sill-height effect may be summarised as follows :

(i) Sill-height must be kept at about 85% height of the plane at which maximum air movement is desired.

(ii) The indoor wind pattern is mainly governed by the location of inlet and is not affected significantly by changing the position of outlet.

Effect of window location along the length of the wall

Table 3 depicts the available wind velocities for the followihg window locations :

(a) Inlet and outlet in the centre of the corresponding walls;
(b) Inlet in the centre and outlet in the corner;
(c) Inlet in the corner and outlet in the centre;
(d) Inlet and outlet in the corners just opposite to each other;
(e) Inlet and outlet in the corners diagonally opposite to each other.

The wind velocity distribution pattern for some specific cases are shown in Fig. 4.1, 4.2 and 4.3. The

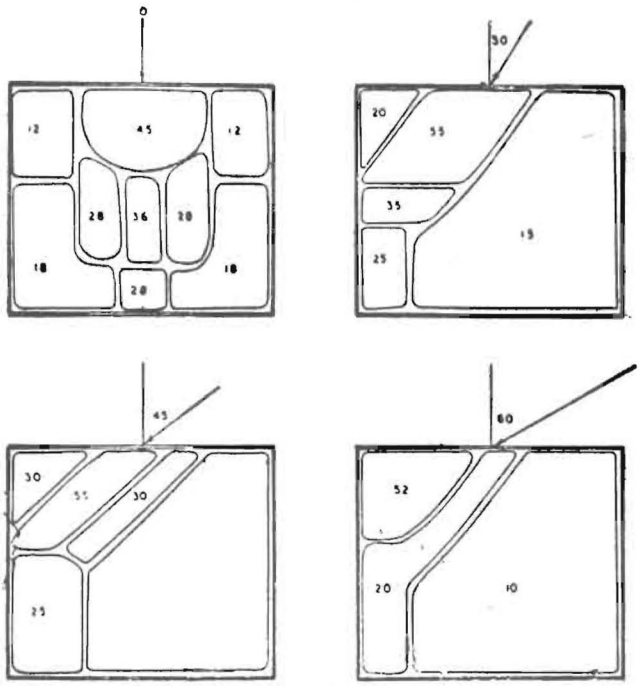


Fig. 4.1 Wind pattern inside the rooms with windows in the centre of the opposite walls for different wind directions.

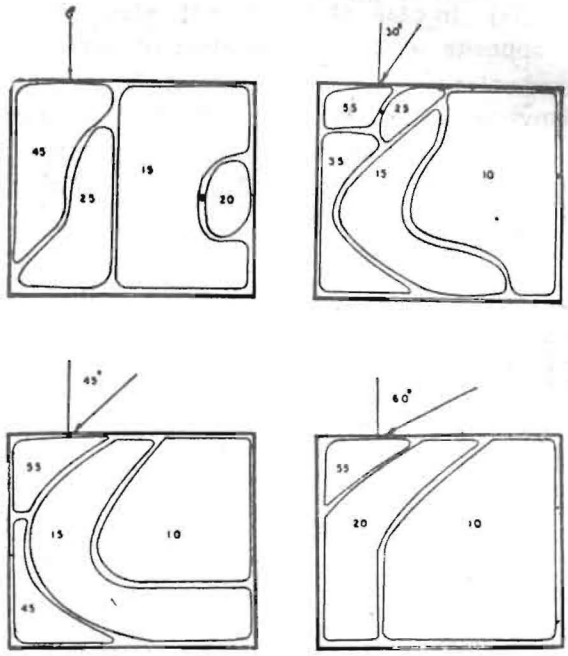


Fig. 4.2 Wind pattern inside the rooms with inlet in the corner and outlet in the centre of the wall for different wind direction

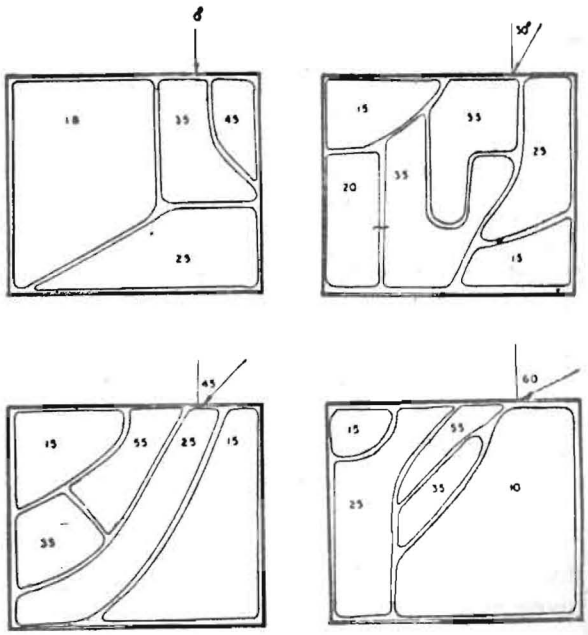


Fig. 4.3 Wind pattern inside the rooms with windows in the corners diagonally opposite to each other of the walls, for different wind directions

areas enclosed in different curves represent the zones of nearly equal velocities and the average wind velocity therein, has been expressed as percentage of free wind velocity. The important conclusions are as follows :

(1) The variation in the location of opening does not produce any significant change in the average indoor velocity, in case of normally incident wind.

(2) If the inlet is located in the centre of the wall, the average indoor wind velocity is more or less independent of the location of outlet.

(3) Average indoor velocity is greater for most of the building orientations when inlet and outlet are located diagonally opposite to each other.

Rooms with windows in adjacent walls

The average indoor wind velocity resulting from the various combinations, locations and orientations of windows are given in table 4. The indoor wind velocity distribution pattern for some typical cases are shown in Fig. 5.1 and 5.2 in a manner similar to Fig. 4. Following are the important conclusions :

(i) If the wind is incident normally, the average indoor and velocity is more or less independent of the location of openings.

(ii) Indoor wind velocity is minimum when wind is incident at 45° to the openings. Hence it is not advisable to provide the windows in adjacent walls when the building is oriented at 45° to the prevailing wind direction.

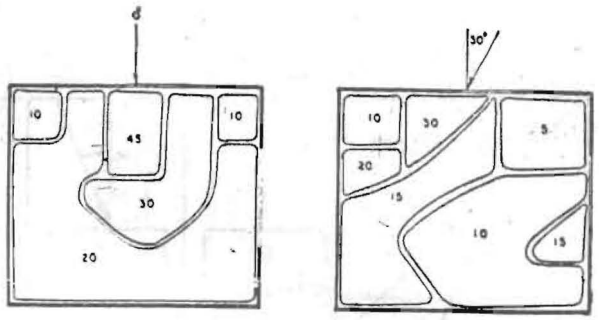


Fig. 5.1 Wind pattern inside rooms with windows in the centre of the adjacent walls, for different wind directions.

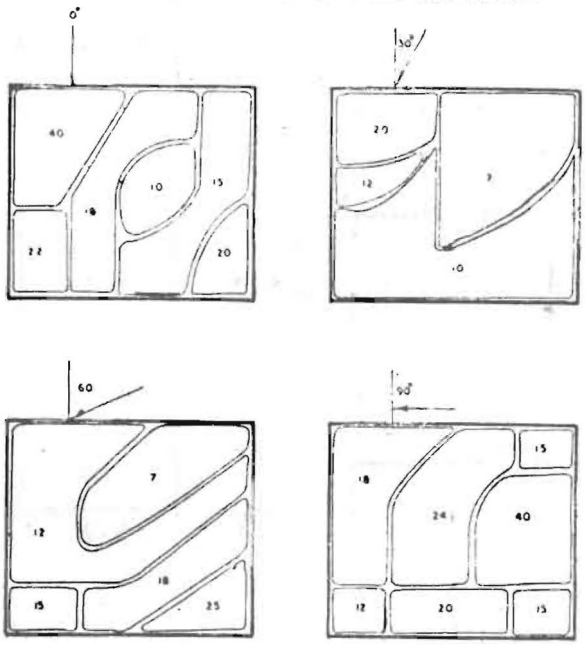


Fig. 5.2 Wind pattern inside the rooms with inlet in the corner and outlet in the centre of adjacent walls, for different wind directions

How to proceed for window design

The design of windows for good natural ventilation involves the following steps :

The first step is to have a knowledge about the climatic design data like dry bulb temperature, relative humidity, wind speed and wind direction of the particular region in which the building is to be designed. The desired wind speed is then determined with the help of Table 5 which is based on the results of studies carried out in this Institute on acceptable thermal environment for sedentary office workers. Thus knowing free wind velocity, and desired wind velocity, the size of the openings can be determined from Fig. 2.

The distribution of wind velocities for a particular size of centrally located openings can be observed from Fig. 3. The probable indoor wind pattern for various window locations and orientations may be determined from Fig. 4 and 5 Out of these patterns the desired one is selected and window location and orientation are fixed correspondingly.

Table 4

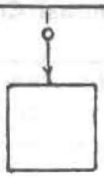
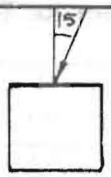
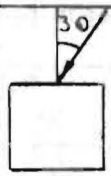
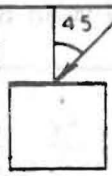
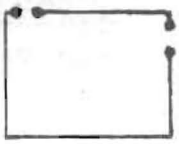
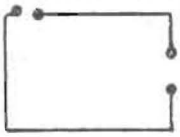
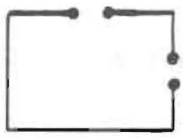
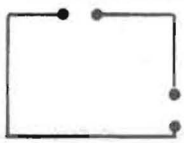
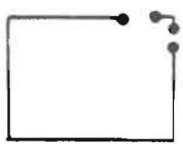
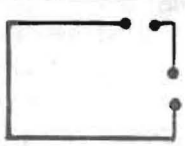
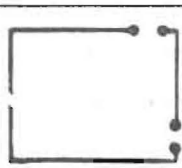
ORIENTATION / WINDOW LOCATION							
	22·08	16·12	9·88	10·76	16·88	22·60	22·08
	19·96	14·88	9·88	8·88	13·64	20·96	25·36
	21·36	14·68	9·56	8·28	10·76	17·24	22·52
	24·16	21·80	11·76	8·96	17·84	23·48	26·12
	23·80	20·24	10·08	8·28	13·68	21·60	27·04
	22·20	19·20	12·48	8·44	10·80	18·20	23·72
	22·80	21·96	17.24	10·04	17·68	23·80	23·72
	23·88	21·20	14·48	10·60	14·40	22·48	27·60
	22·20	20·80	17·44	10·04	13·36	19·64	24·16

Table 5 Desirable Wind Speeds (m/sec) for Thermal Comfort

Dry Bulb Temp. °C	Relative Humidity (percentage)						
	30	40	50	60	70	80	90
28	—	—	—	—	—	—	—
29	—	—	—	—	—	0.06	0.19
30	—	—	—	0.06	0.24	0.53	0.85
31	—	0.06	0.24	0.53	1.04	1.47	2.10
32	0.20	0.46	0.94	1.59	2.26	3.04	—
33	0.77	1.36	2.12	3.00	—	—	—
34	1.85	2.72	—	—	—	—	—
35	3.20	—	—	—	—	—	—

Example 1

The windows of a habitable room are to be designed on the basis of the following climatological design data

Dry Bulb temperature	=	32°C
Relative Humidity	=	50%
Prevailing outdoor wind speed	=	12 Km/hr
Prevailing wind direction	=	SW

Find out the size and location of windows for optimum ventilation :

Solution

The desired wind speed as determined from Table 5 = 0.94 m/sec. = 3.4 km/hr.

$$\therefore \quad \frac{\text{Desired wind speed}}{\text{Free wind speed}} \times 100 = \frac{3.4 \times 100}{12} = 28$$

Now from Fig. 2, corresponding to 28% available wind velocity. the window area = 14 percent of the floor area.

Thus windows each having area equal to about 14 per cent of floor area should be provided in walls facing SW and NE walls.

Example 2

If in the above case the building is oriented with its longer sides facing North and South, instead of SW & NE, what must be location of windows ?

Solution

An analysis of Fig. (4) and Table 3 suggests that in case the wind is incident at an angle 45° to the window as in the present situation, the windows must be placed diagonally opposite to each other as shown in Fig. 6.

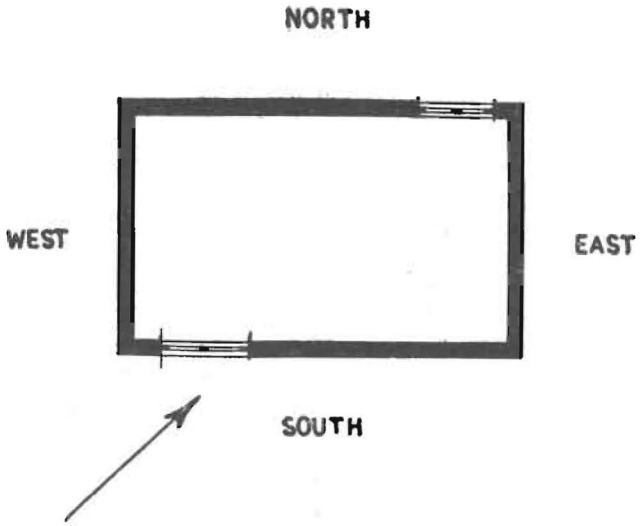


Fig. 6

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