BUILDING DIGEST

CENTRAL BUILDING RESEARCH INSTITUTE, INDIA

PREDICTION OF AIR MOVEMENT IN BUILDINGS

Introduction

The contribution of air movement to thermal comfort in hot humid conditions is well known. The design of buildings for best possible utilization of natural breeze requires a knowledge of probable indoor air movement that will take place under specified conditions. The aim of the present digest is to provide a simple approach which will help the designers in assessing the anticipated quantum of indoor air motion for a given design under the outdoor conditions.

Factors Influencing Air Movement in Buildings

The process of natural air movement in buildings is governed by two factors, viz, motive forces and the architectural features of the building. The two motive forces producing air movement in buildings are the thermal or temperature forces and aeromotive or wind forces. In warm humid climate the contribution of thermal forces is small and the indoor air movement is mainly governed by the forces caused by wind impingement on the building. The magnitude of the wind force is influenced by wind direction relative to the building, external obstructions interfering with the air flow around the building and the external form and dimensions of the building. The second factor, i.e. architectural features covers, interalia, sizes and locations of windows, their number on a wall, presence or absence of louvers and the type of interconnection between different rooms of the building.

The overall effect of the above mentioned factors is rather complex and difficult to evaluate mathematically. The analysis of the test results on models in low speed wind tunnel provides a simple approach for the evaluation of room air motion and is discussed in the present digest.

Room with Windows on One Wall Only

1. The available wind velocity in a room with single window on the windward side is about 10 percent of outdoor velocity at points upto a distance one-sixth of room width from the window. Beyond this, the velocity decreases rapidly and hardly any air movement is produced in the leeward half portion of the room. Variation in the height/width ratio of a window does not produce any significant change in the value of average indoor wind velocity.

2. The average indoor wind velocity is generally less than 10 percent of outdoor velocity. The value, however, is increased upto 15 percent when two windows are provided instead of one and wind impinges obliquely on them.

Room with Windows on Two Sides

1. When identical windows are provided on opposite walls and one of the windows faces normally incident wind, the average indoor velocity at a plane passing through the sill of the windows, 0.9 m above the floor, is determined from Fig. 1. For example, for windows with 20 percent of floor area, the average indoor wind velocity is about 25 percent of outdoor velocity.

2. For a different sill height, the available average velocity (V_s) at the sill level may be computed using the equation

$$V_s = V_{0 \cdot 9} + 7.2\,(1-S)$$

where $V_{0 \cdot 9}$ = Average indoor wind velocity as determined from (1)

S = Relative sill height with reference to normal sill height of 0.9 m

For example, for a sill height of 0.75 m

$$S = \frac{0.75}{0.9} = 0.83$$

and

$$V_s = V_{0 \cdot 9} + 7.2\,(1-.83)$$
$$= V_{0 \cdot 9} + 1.23$$

3. When the sizes of inlet and outlet are not equal, the area of inlet is first expressed as percent of the total area of fenestration and the corresponding value of performance efficiency (E) is determined from Fig. 2. The average indoor wind velocity V is

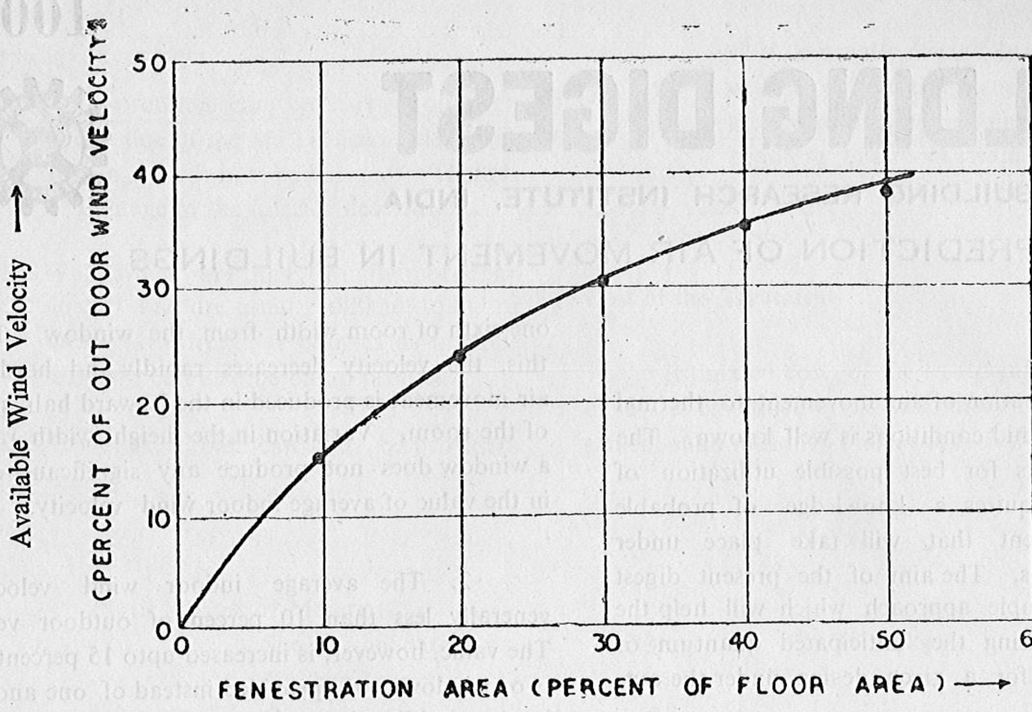


Fig. 1

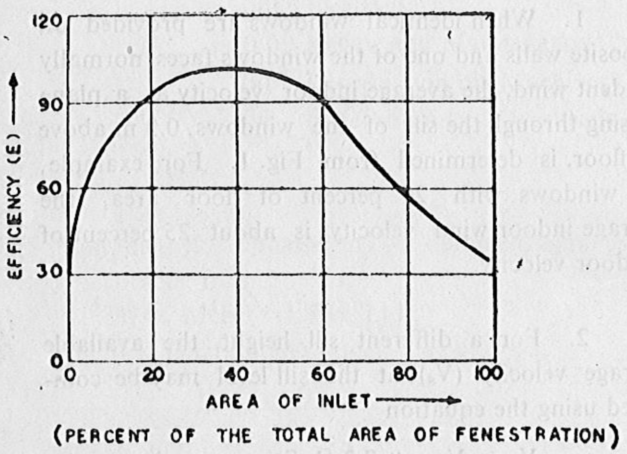


Fig. 2

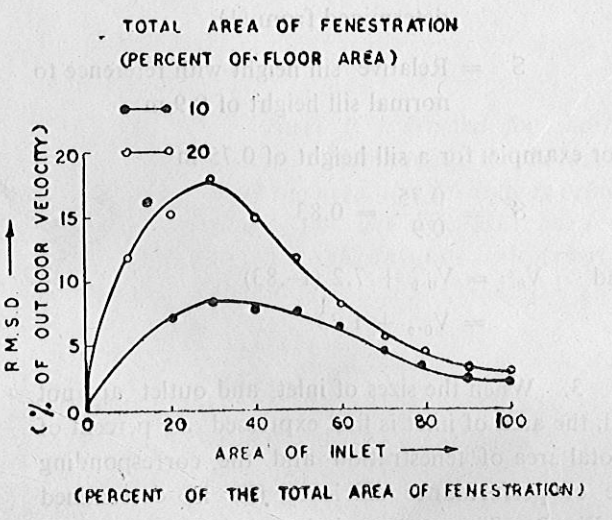


Fig. 3

then obtained by multiplying the value of E with that of V_s calculated in (2). The value of local velocity at different points shows a deviation from that of the average taken over the whole room area. For a given value of inlet size/total area of fenestration, the root mean square deviation (RMSD) of local velocity from the average value may be obtained from the relevant curve in Fig. 3.

4. For obliquely incident wind the value of V determined in (3) is multiplied by a factor given in Table 1.

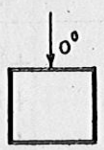
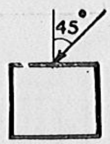
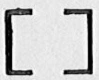
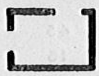
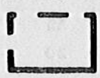
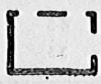
Table 1

Effect of Orientation on Indoor Air Motion

Relative size of openings	Multiplying factor for 45° incidence
1. Inlet > outlet	1
2. Inlet = outlet	Varying from 0.8 for fenestration area 25 percent of floor area to 0.85 for fenestration of larger sizes
3. Inlet < outlet	0.7

5. The value of V obtained above is considerably influenced by change in the location of openings with respect to the outdoor wind. The factors representing the changes in V, for some of the typical cases are given in Table 2. For a given window location and orientation, the average indoor

Table 2

ORIENTATION / NDOW LOCATION	CHANGE IN V (% OF V)	
		
	0	0
	− 10	+ 40
	− 10	− 15
	− 15	0
	− 15	0
	0	0
	− 10	+ 40
	− 10	− 15
	0	− 60
	− 20	− 10
	−20	− 60

wind velocity may be obtained by adding the corresponding factor to the value of V obtained in the foregoing steps.

6. Louvers which are provided for protection against rain and for preventions of direct entry of sun through the windows have a bearing on indoor air flow pattern. The influence of some simple types of louvers on room air motion is summarised in Table 3.

Table 3

Influence of Louvers on Indoor Air Motion

Type of louver	Change in V (percent of V) 0°	45°
Horizontal (sun shade)	−20	−20
L–type	+5	+10
Box type		
Contraction ratio 1:1	0	−25
Contraction ratio 2:1	0	0
Multiple Horizontal	−10	−13
Multiple Vertical	−15	−25

Thus the average indoor wind velocity in a room with louvered window is obtained by adding the corresponding correction factors to the value of V obtained in (5).

7. The presence of a verandah on windward or leeward side of a room influences the room air motion. Table 4 shows the effect on average indoor wind velocity of some of the common types of verandah.

To get the value of average indoor wind velocity for the given type, location and orientation of a verandah, the correction factor may be taken from Table 4 and applied to the value of V obtained in (5). The value remains almost unaffected in case the verandah height is lower than that of the room.

8. The type of interconnection between the different rooms and the location of the intermediate door play an important role in the establishment of indoor wind pattern. The value of average indoor wind velocity in a room of a multi-room house is determined by subtracting from V an appropriate value given (as % of V) in Table 5 and 6.

Illustrative Example : To find out the probable average indoor wind velocity in the living room of a two-roomed house (Fig. 4.) when wind is incident normally on the exposed side of the room.

Solution :

(i) Referring to Fig. 4:

Size of inlet $= 1.6\ m^2$

Size of outlet $= 1.9\ m^2$

Floor area $= 11.3\ m^2$

∴ Total area of fenestration $= 3.5\ m^2 = 31\%$ of floor area

∴ Average indoor wind velocity, (V_I) from Fig. 1 = 32 percent of outdoor velocity (V_o)

Table 4

Effect of Verandah on Indoor Air Motion.

Type of Verandah	Location	Change in V (Percent of V) 0°	45°
Open on three sides	Windward	+15	+10
	Leeward	+15	+10
Open on two sides	Windward	0	0
	Leeward	0	0
Open side parallel to the room wall	Windward	—10	—10
	Leedward	0	0
Open side perpendicular to the room wall	Windward	—50	—30
	Leeward	0	+15

Table 5

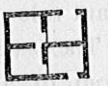
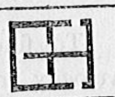
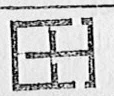
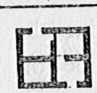
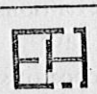
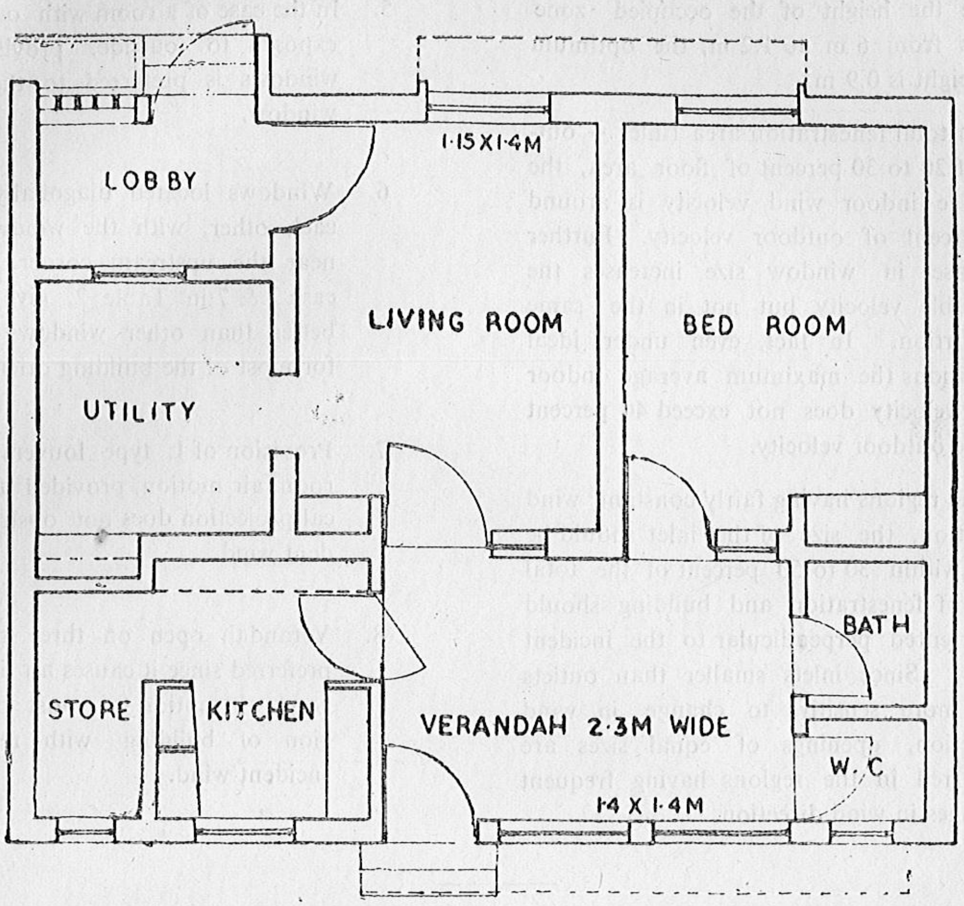
REDUCTION IN V (% OF V)	LOCATION OF INTERMEDIATE DOOR	REDUCTION IN V (% OF V)
40 25		40 20
50 25		20 20
40 30		45 20
40 30		25 25
30 55		50 20
55 55		35 15
30 45		45 20
30 35		35 20

Table 6

		← ORIENTATION → LOCATION OF INTER CONNECTING DOORS		
			7.5 7.5	15 15
—	—		10 20	45 15
80 80	75 75		15 25	45 15
35 15	15 20		15 20	50 15
45 30	20 20		20 20	55 30
— 20	— 45		10 25	45 35
50 35	45 25		— 25	— 15
30	45		25 25	30 15
55 35	40 25		40 20	55 20
25 15	15 15		15 30	40 15



PLAN

Fig. 4

(ii) $\frac{\text{Size of inlet} \times 100}{\text{Total area of fenestration}} = 45\%$

∴ Performance efficiency, from Fig. 2 = 100

∴ $V_i = 0.32\ V_o$

(iii) Sill height in the present case = 0.76 m

∴ Average indoor wind velocity (V_i') at a plane passing through the sill of window is given by

$$V_i' = \left[0.32 + \frac{7.2}{100}\left(1 - \frac{.76}{.9}\right)\right] V_o$$

$$= 0.331\ V_o$$

(iv) Since the wind is incident normally and inlet is located almost in the centre of the wall, no correction is needed (Table 2).

(v) Since the window is provided with a horizontal louver, the reduction in V_i' as determined from Table 3 is 20 percent.

$$\therefore\ V_i'' = \left[0.331 \left(1 - \frac{20}{100}\right) \right] V_o$$

$$= 0.265\ V_o$$

(vi) In the present case, the reduction in room air velocity due to series connection (as determined from Table 6) is – 20 percent

∴ Final value of average indoor wind velocity

$$= 0.265 \left(1 - \frac{20}{100}\right) V_o$$

= 21.2% of outdoor wind velocity

Concluding Remarks

The correction factors given in different tables are applicable for the window sizes mostly used in practice. In case the building design details are not directly covered by the digest, an appropriate value of the correction factor may be obtained by the intrapolation of the relevant data. The following guidelines are recommended for designing buildings for the best possible utilization of outdoor wind :

1. Atleast one window should be provided on the windward wall and the other on the leeward wall.

2. Maximum air movement at a particular plane is achieved by keeping the sill height at 85 percent of the height of the plane. However, for the sitting and bed

where the height of the occupied zone varies from .6 m to 1.2 m, the optimum sill height is 0.9 m.

3. For a total fenestration area (inlet + outlet) of 20 to 30 percent of floor area, the average indoor wind velocity is around 27 percent of outdoor 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 wind velocity does not exceed 40 percent of the outdoor velocity.

4. In the regions having fairly constant wind direction, the size of the inlet should be kept within 30 to 50 percent 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 the regions having frequent changes in wind direction.

5. In the case of a room with only on exposed to outside, provision windows is preferred to that of window.

6. Windows located diagonally oppo each other, with the windward wi near the upstream corner, as shov case 2 & 7 in Table 2, give perforn better than other window arrangei for most of the building orientations.

7. Provision of L type louvers increases room air motion, provided that the ve cal projection does not obstruct the i dent wind.

8. Verandah open on three sides is to preferred since it causes an increase in room air motion for most of the orien tion of building with respect to incident wind.

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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 100th 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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