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Window Design for Natural Ventilation – Tropical Region

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I. INTRODUCTION

For town planning and design of building in tropics Architects, Planners 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 paper 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 paper, have been obtained by wind tunnel tests on models in CBRI as also elsewhere. These are applicable to normal rectangular rooms (with height about 3m) in which one of the indows is assumed to be in the wall facing the natural outdoor wind. The results obtained for different window combination aresummarized in the paper.

II.ROOMS WITH SINGLE WINDOW

A. 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.

*B.*The wind velocity at the points near the window is higher than the average wind velocity.

C. The Provision of single window does not serve any useful purpose regarding the improvement of indoor ventilation.

III. ROOMS WITH WINDOWS IN OPPOSITE WALLS

A. Effect of window size

1) The average indoor velocity does not change significantly if the width of inlet opening is increased while the outlet I 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.

2) 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 as 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

3) 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 is given in table - 1. It is observed that any increase in window height beyond a value 1.10 m. has a very small effect on the air movement in the normally occupied zone.

Fig. -1

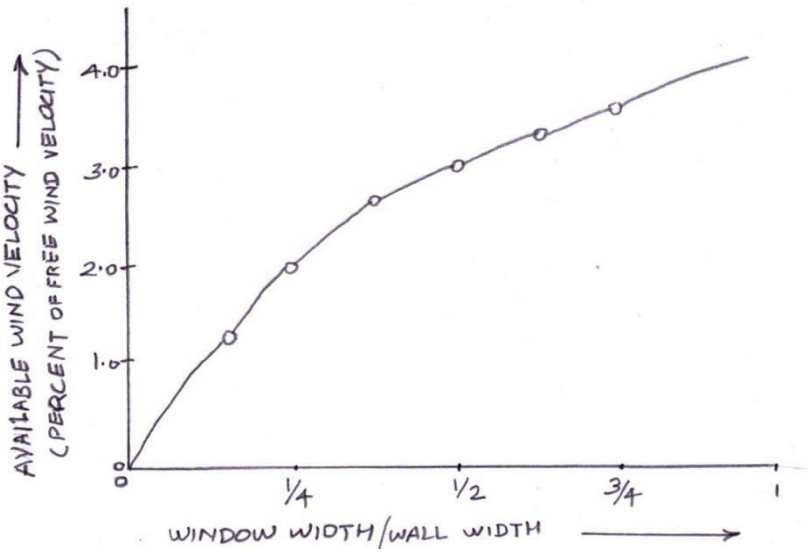
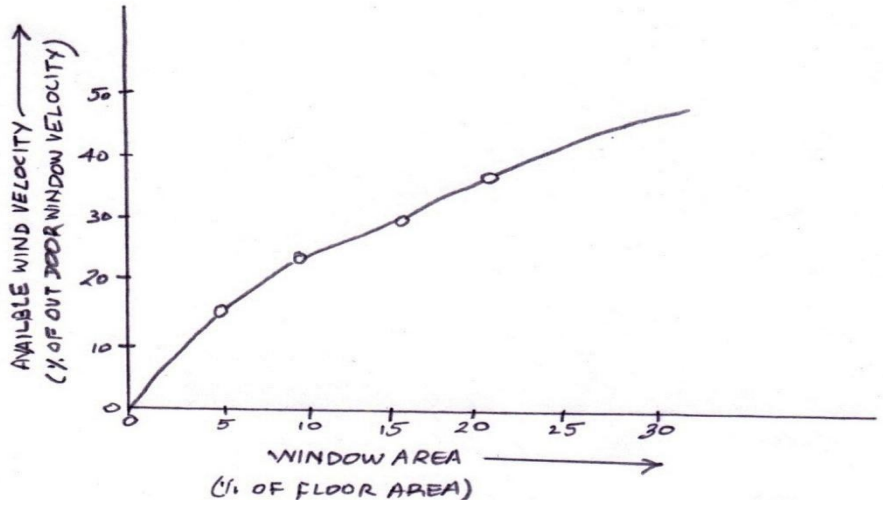


TABLE – 1

WINDOW HEIGHT / HEIGHT OF WORK PLANE m	0.30	0.60	0.90	1.05	1.20	1.35	1.50	1.80
0.60	16.00	22.50	23.60	21.80	22.5	24.5	22.3	21.54
0.90	13.40	19.50	23.50	26.40	27.20	28.65	26.20	26.00
1.20	7.70	16.80	24.70	26.30	26.15	30.85	26.70	28.00
1.50	7.40	12.50	25.25	25.60	26.00	30.00	27.90	29.80
1.80	7.70	11.80	15.70	18.50	23.20	27.60	27.90	29.40
2.10	8.60	12.60	14.60	14.20	17.60	19.60	23.50	30.80

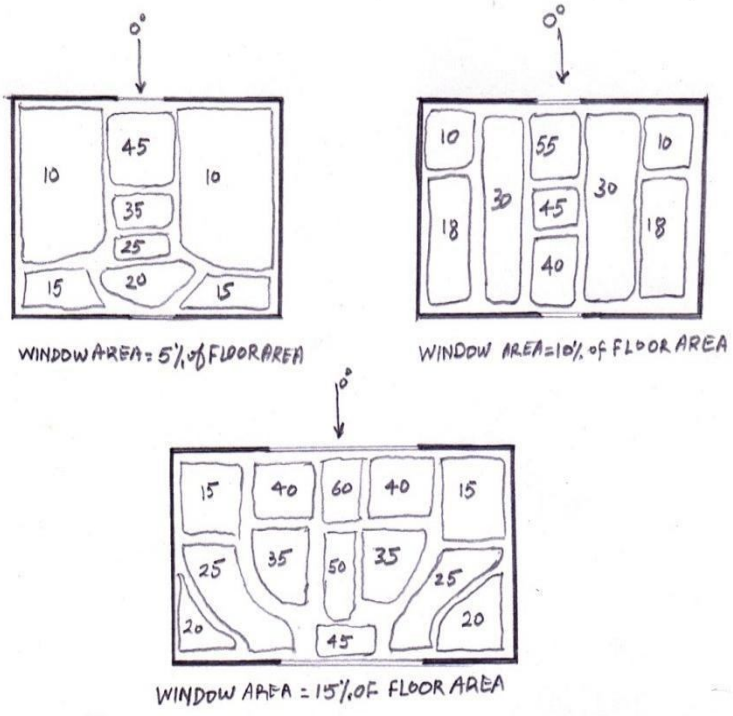
*a)*The variation of average indoor air velocity with the window area (expressed as percentage of floor area) is as in Fig. - 2. It is observed that the indoor air motion increases by increasing the window are up to 25 % of floor area, beyond which air motion is more or less independent of the area of openings.

Fig. 2



b) The wind velocity distribution pattern for window area equal to 5 %, 10 % and 15 % of floor area, are as 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.

Fig. 3 effect of window area on indoor wind pattern



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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 explain in details as under:

1) 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, 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 study of sill-height effect may be summarized as follows:

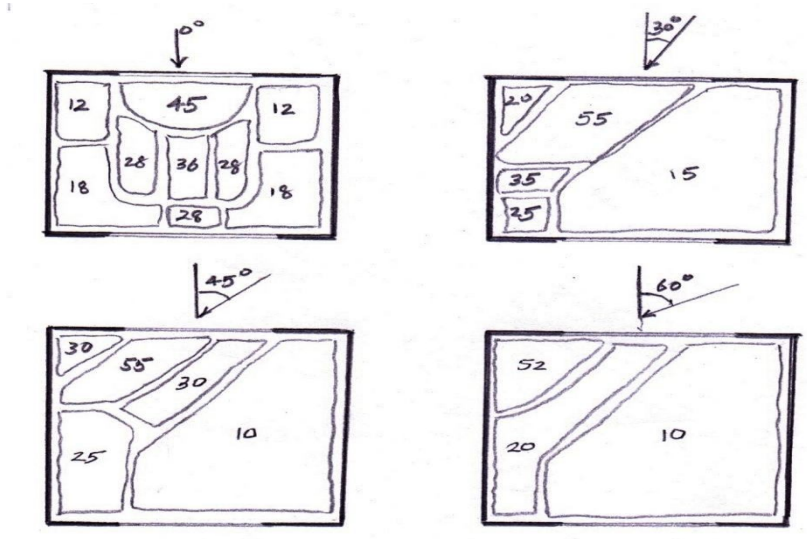
a) Sill-height must be kept at about 85 % height of the plane at which maximum air movement is desired.

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

Table – 3

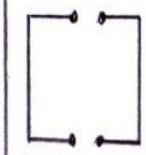
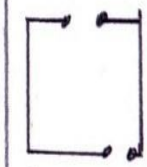
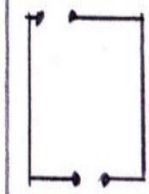
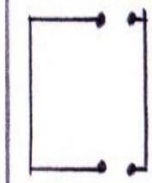
SILL HEIGHT → / HEIGHT OF WORK PLANE (m) ↓	0.60	0.90	1.20	1.50
1.20	21.30	23.20	24.50	17.30
0.90	22.50	25.50	21.20	14.10
0.60	26.80	23.70	17.80	12.70

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



2) Effect of window location along the length of the wall

Table - 3 depicts the available wind velocities for the following window locations:

ORIENTATION / WINDOW LOCATION	0	15	30	45	60	75	90
	23.60	24.80	22.30	18.00	16.30	12.50	10.00
	25.80	23.30	22.20	17.80	16.70	12.80	8.30
	21.40	19.20	16.30	15.60	13.50	11.40	8.60
	22.80	26.70	25.70	24.90	20.70	17.70	6.90
	22.50	25.80	29.00	26.70	20.60	11.70	10.30

a) Inlet and outlet in the centre of the corresponding walls;
b) Inlet in the corner and outlet in the centre;
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 patterns for some specific cases are as in Fig. - 4.1, 4.2 and 4.3. The 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 under:

Fig. - 4.2 wind pattern inside the rooms with windows in the centre of the opposite walls for different wind directions.

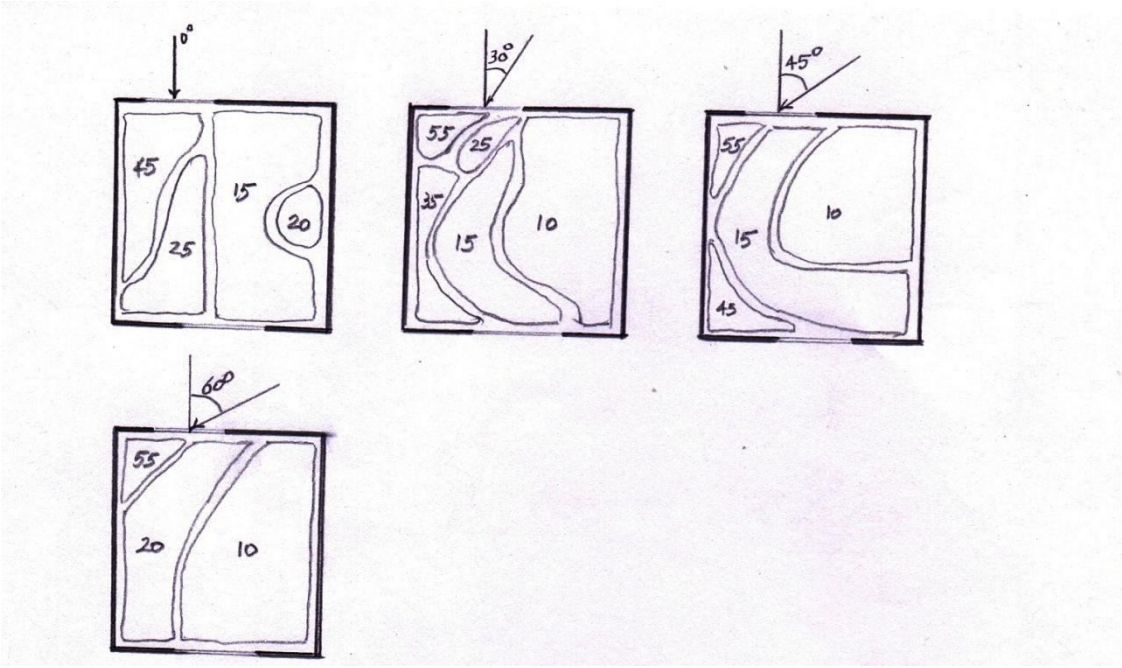
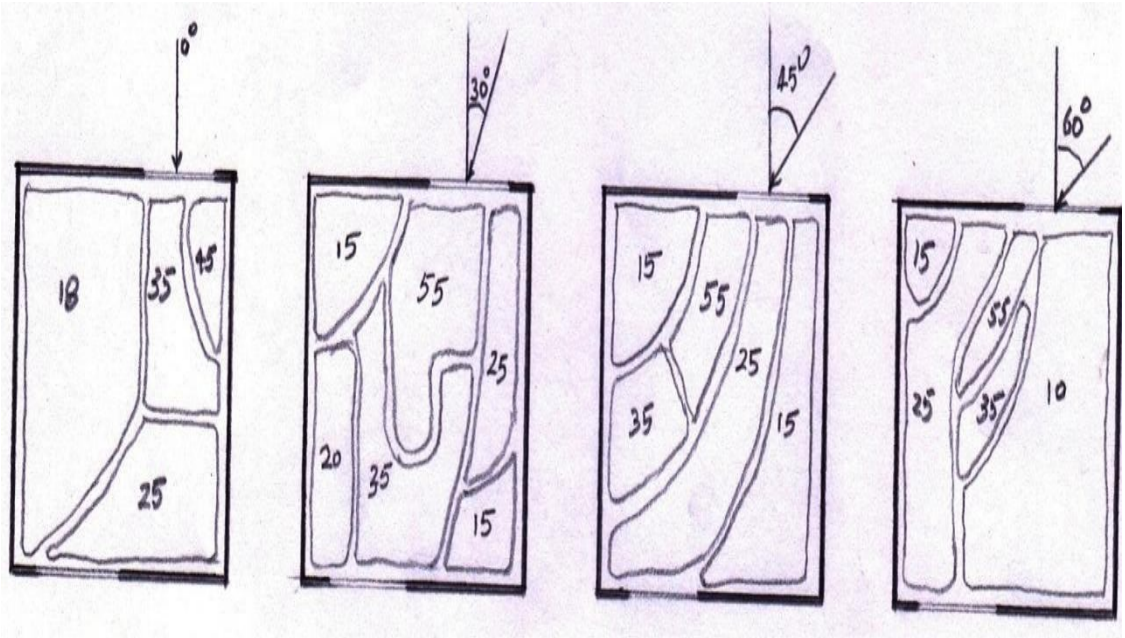


Fig. - 4.3 wind pattern inside the rooms with windows in the corners digonally opposite to each other of the wall, for different wind directions.



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

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

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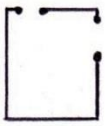
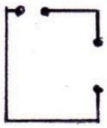
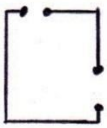
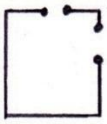
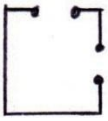
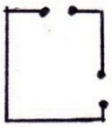
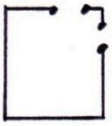
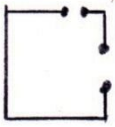
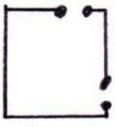
TABLE – 4

ORIENTATION → / WINDOW LOCATION ↓	0°	15°	30°	45°	60°	75°	90°
	22.08	16.12	9.88	10.76	16.88	22.60	22.08
	19.96	14.88	09.88	08.88	13.64	20.96	25.36
	21.36	14.68	09.56	08.28	10.76	17.24	22.52
	24.16	21.80	11.76	08.96	17.84	23.48	26.12
	23.80	20.24	10.08	08.28	13.68	21.60	27.04
	22.20	19.20	12.48	08.44	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

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

3) Rooms with windows in adjacent walls: The average indoor wind velocity resulting from the various combinations, locations and orientations of windows are as in table - 4. The indoor wind velocity distribution patterns for some typical cases are as in Fig. - 5.1 and 5.2 in a manner similar to Fig. - 4. Following are the important conclusions:

Fig. – 5.1 wind pattren indide rooms with windows in the centre of the adjacent walls, for different wind directions.

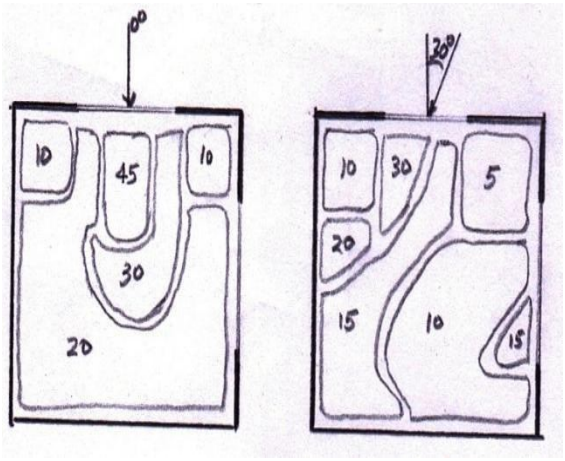
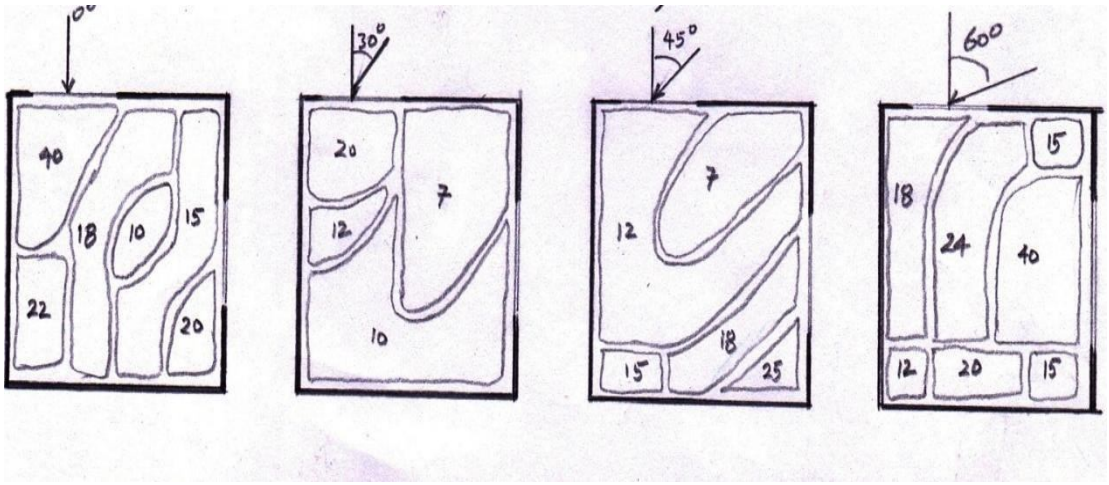


Fig. - 5.2 wind pattern inside rooms with inlet in the corner & outlet in the centre of the adjacent walls for different wind directions.



a) If the wind is incident normally, the average indoor wind velocity is more or less independent of the location of openings.
b) Indoor wind velocity is minimum, when wind isincident 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 directions.

4) How to proceed for window design: The design of windows for good natural ventilation involves the following steps:
The first step is to have knowledge about the climatic design date 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 to Table - 5 which is based on an effective comfort temperature of 24°C. Thus knowing the free wind velocity and desired wind velocity, the size of the openings can be determined from Fig. - 2.

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Table 5 Desired Wind Speed for Comfort
(Effective Temperature 24°C)

Dry Bulb Temp. °C	R.H. %	Desired wind speed m/sec
27	60	0.25
27	65	0.55
27	70	0.75
27	75	1.00
27	80	1.25
27	85	1.45
27	90	1.70
30	30	0.30
30	40	1.00
30	50	2.00
30	60	3.00

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.

5) Example – 1: The windows of a habitable room are to be designed on the basis of the following climatologically design data.
Dry Bulb temperature
= 30°C
Relative Humidity
= 40%
Prevailing outdoor wind speed
= 12Km/hr
Prevailing wind direction
= SW
Find out the size and location of window for optimum ventilation:

*6) Solution:*The desired wind speed and determined from Table - 5 = 1 m/sec. = 3.6 km/hr.

——————— 100 = ——— = 30

Now from Fig. - 2 corresponding to 30% available wind velocity, the window area = 15 percent of the floor area.
Thus, windos each having area equal to about 15 percent of floor area should be provided in walls facing SW and NE walls.

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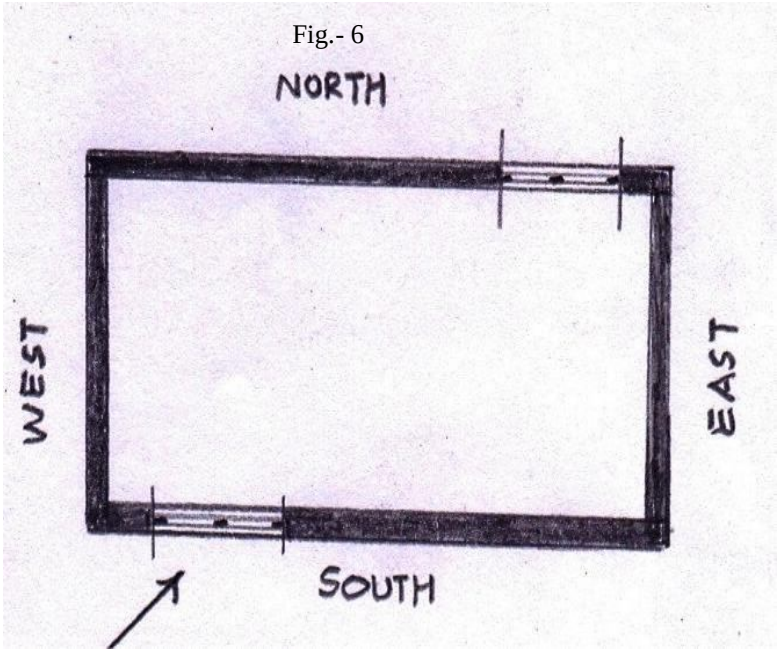
7) *Example – 2:* If in the above case the building is oriented with it longer sides facing North & South, instead of SW & NE, what must be the location of windows?
8) *Solution:* An analysis of Fig. - 4 and Table - 3 suggests that in case the wind is incident at an angle 45° to the window as in the present situation, the windows must be placed diagonally opposite to each other as shown in Fig. - 6.

Fig.- 6



IV. CONCLUSION

It shows the window design for natural ventilation in tropical region as per angle & direction, location & position of the building. The case to case the conclusions has been mentioned. With introduce the examples, the calculations & conclusions are more clear & practical orientation.

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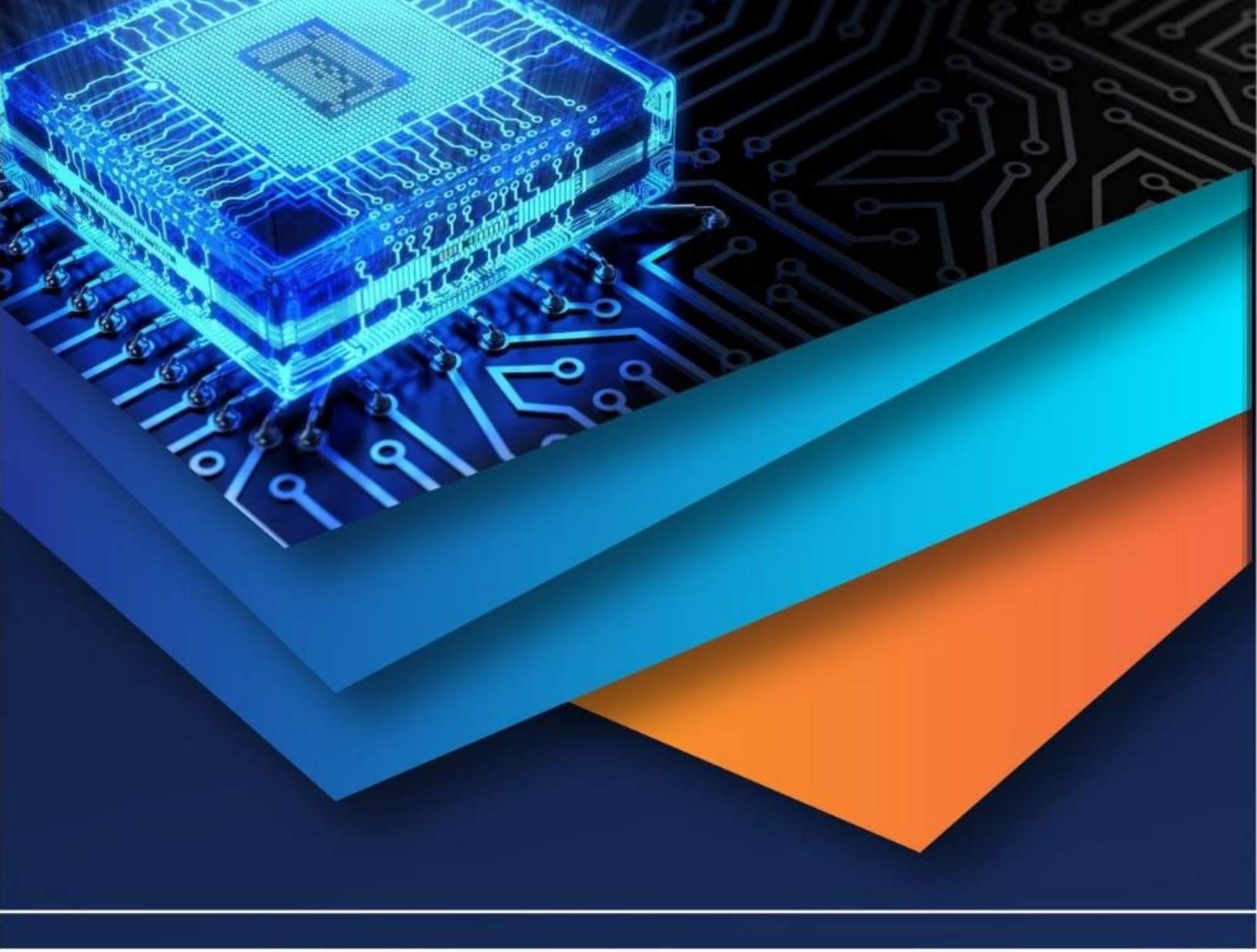

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