NATURAL VENTILATION : A DISCUSSION OF ITS ADEQUACY IN WARM-HUMID CLIMATES

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ABSTRACT

Natural Ventilation in Warm-humid Climates has a three-fold objective. These are the provision of health ventilation, to keep levels of Carbon Dioxide, odours and harmful gases to a minimum; the Provision of adequate means of structural cooling; and lastly but most importantly for this climate, the provision of a means for physiological cooling in order to achieve thermal comfort within the ventilated space. This paper discusses these three aspects of natural ventilation and the adequacy of available wind to serve these functions. Conclusions are drawn based on available climatic data of a typical warm-humid region, that the ventilation required for health and structural cooling can be adequately provided for but as thermal comfort requires high levels of air movement in such climates, it is often difficult to rely solely on natural ventilation to provide adequate physiological cooling for occupants and artificially induced air movement has to be resorted to.

Natural ventilation, which has been defined as the intentional displacement of air through specified openings such as windows, doors and ventilators (1), has a three-fold aim. These are

a. Health ventilation; maintenance of indoor air quality
b. Thermal Comfort Ventilation; provision of thermal comfort through heat loss by convectin and evaporation.
c. Structural Ventilation; prevention of structural overheating.

The relative priorities of the three objectives mentioned above is dependent on climate.

HEALTH VENTILATION

The purpose of the supply of fresh air in order to maintain the indoor air quality has been described by Bouwman (2) as;

1. The prevention of Oxygen shortage
2. Counteraction of rise in Carbon-dioxide
3. Keeping contents of annoying and/or harmful substances emanating from building materials (radon, etc.) within acceptable limits
4. Prevention of great intensity of odour
5. Maintenence of desired environment in terms of temperature, relative-humidity and air-movement.

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It is obvious that the first three of the above-mentioned points are inter-linked and a satisfaction of the third point would ensure the satisfaction of the first two criteria.

Researchers have found a clear trend indicating that odour concentration in a space increases with increases in the CO_2 level above fresh air values (3). To keep odour complaints down to 5% of the occupants in a space, the minimum air supply was estimated at approximately 35 m^3/h/p, though acceptable levels are ultimately dependent on individuals and particular situations (4).
Minimum ventialation rates for different room usages have been set by authorities in different countries, either by specifying the number of air changes per hour or the quantitative airflow in m^3/hr or L/sec (Table 1) and it is clear that even in the absence of wind, there is sufficient air infiltration through door and window joints to fulfill minimum ventilation standards and only in the case of very effective weather-stripping, or where there is overcrowding resulting in excessive vapour production from cooking and laundering do special ventilation provisions have to be made to satisfy the health criteria.

In other words, there can be no doubt as to the adequacy of natural ventilation in its attempt to provide health ventilation under any climatic condition.

THERMAL COMFORT VENTILATION

Croome-Gale and Roberts (6) define thermal comfort ventilation as the air supply within a space through designed apertures. Its distribution can be controlled through design details, whereas infiltration, being the leakage of air due to imperfections in structure, cannot be controlled.

Though the ventilation existing in a room due to natural convection currents and infiltration may be sufficient for health purposes, it is not likely to be sufficient to provide the necessary air movement for a pleasant environment when temperature and humidity levels are high. Too much movement will cause draughts in cold climates, though in warm climates, there may never be too much. Too little movement in any climate will cause stuffiness, its extent being dependent on the degree of adverse conditions, elevating with rise in temperature and humidity.

Air movement can produce human comfort only within certain limits of air temperature and humidity. As long as the air temperature remains below skin temperature, air movement will always produce cooling, due to convection, irrespective of humidity levels. As the air temperature rises above the skin temperature, however, air movement produces cooling comfort as long as the evaporative heat loss

Table 1 Minimum Ventilation Requirements

1. If number of occupants is known

Room volume per person (m3)	Fresh air supply rate (l/s per person)		
	Minimum	Recommended	
		Non-smoking	smoking
3	11.3	17.0	22.6
6	7.1	10.7	14.2
9	5.2	7.8	10.4
12	4.0	6.0	8.0

remains higher than the conventive heat gain. In other words, even at very high temperatures, if the humidity in the air is relatively low, some comfort may be felt by air movement, provided enough moisture is present on the skin surface to enable evaporation and thus produce cooling. When air temperatures are below the thermal comfort level, air movement should not be perceptible and is considered unwanted.

2. If number of occupants is not known

Room type	Number of air changes per hour
Kitchen, other than domestic	minimum 20
Kitchen, domestic	10
Laundry, boiler room, operating theatre	15
Canteen, restaurant, dance hall	10-15
Cinema, theatre, lavatory	6-10
Bathroom, bank hall, parking station	6
Office, laboratory	4-6
Library	3-4
Stair, corridor (non-domestic)	2
All other domestic rooms	1

Source: Szokolay, S. V., Environmental Science Handbook, p. 401

Ventilation requirements for thermal comfort can either be specified in terms of air supply or air change rate or alternatively in terms of preferable indoor velocity distribution pattern. For warm climates Givoni (7) favours the latter, as there is no direct relationship between quantitative flow and the ultimate velocity through the enclosure.

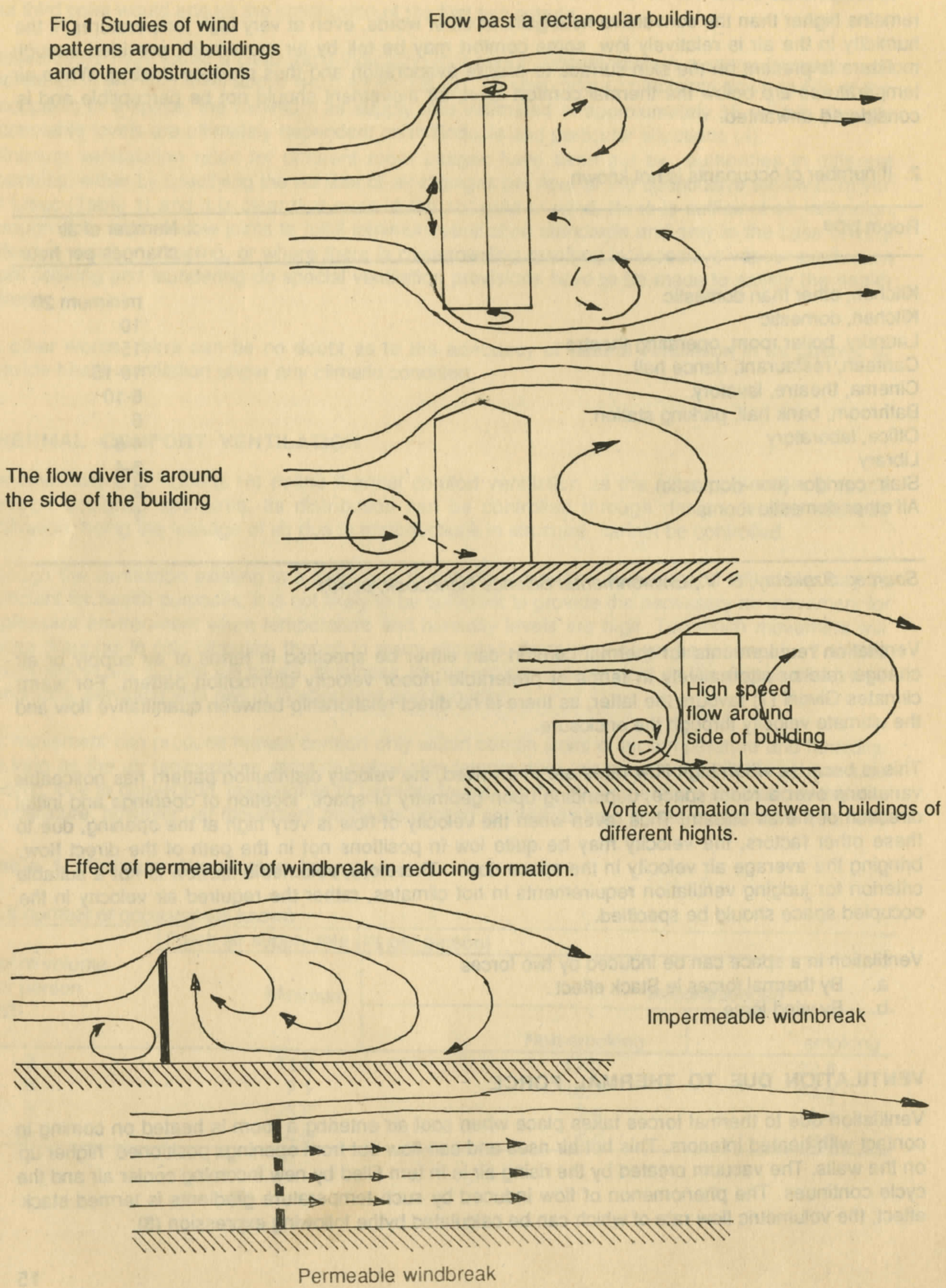
This is because when high flow rates are in involved, the velocity distribution pattern has noticeable variations over a room space, depending upon geometry of space, location of openings and initial direction of the air stream. Thus, even when the velocity of flow is very high at the opening, due to these other factors, the velocity may be quite low in positions not in the path of the direct flow, bringing the average air velocity in the space down. Therefore, volumetric air flow is not a suitable criterion for judging ventilation requirements in hot climates, rather the required air velocity in the occupied space should be specified.

Ventilation in a space can be induced by two forces
a. By thermal forces ie Stack effect
b. By wind force

VENTILATION DUE TO THERMAL FORCE

Ventilation due to thermal forces takes place when cool air entering a room is heated on coming in contact with heated interiors. This hot air rises and can flow out from openings positioned higher up on the walls. The vacuum created by the rising air is in turn filled by new incoming cooler air and the cycle continues. The phenomenon of flow induced by such temperature gradients is termed stack effect, the volumetric flow rate of which can be calculated bythe following expression (8):

Fig 1 Studies of wind patterns around buildings and other obstructions



Q = 7A (h x t) m3/min/m2 of inlet area. where A is the area of opening his the vertical distance between the two openings tis the indoor-outdoor temperature difference.

The ventilation caused by stack effect is assumed to be negligible by Ali (9) in hot-humid climates, as buildings are usually built of materials with medium to high thermal resistance and low heat capacity and have shaded windows which bring daytime indoor temperatures to similar levels as outdoor shade temperatures.

As the air flow caused by stack effect does not induce perceptible air movement within a space, it cannot be an adequate means of providing thermal comfort, which happens to be the chief aim of ventilation in warm-humid climates.

VENTILATION DUE TO WIND FORCE

When wind flows directly into a solid object, there is a build-up of pressure on the windward face and the stream is deflected up and around the object, thereby creating a suction on the other faces. If openings were to be provided, joining the pressure and suction zones, a resulting flow from the high to low pressure through the interior of the object would result, its magnitude dependent upon the pressure difference. The flow would continue until this difference is neutralised. The air flow through a building on this principle depends on;

a. the initial windforce
b. the orientation of the building
c. the orientation of the openings
d. area of the openings
e. position of inlet with respect to outlet
f. detail of opening (frame, grille, screens, etc.)

Estimation of Natural Ventilation

Simple equations such as the following can be used to estimate volumetric airflow through an opening (10);

Q = E A V X 1000 lit/sec

where Q is the volumetric air flow

E is the effectiveness of an opening and has the value of 0.5 to 0.6 for perpendicular winds and 0.25 to 0.35 for diagonal winds.

A is the free area of inlet in m2,

V is the design outdoor speed in m/sec.

Fig. 2

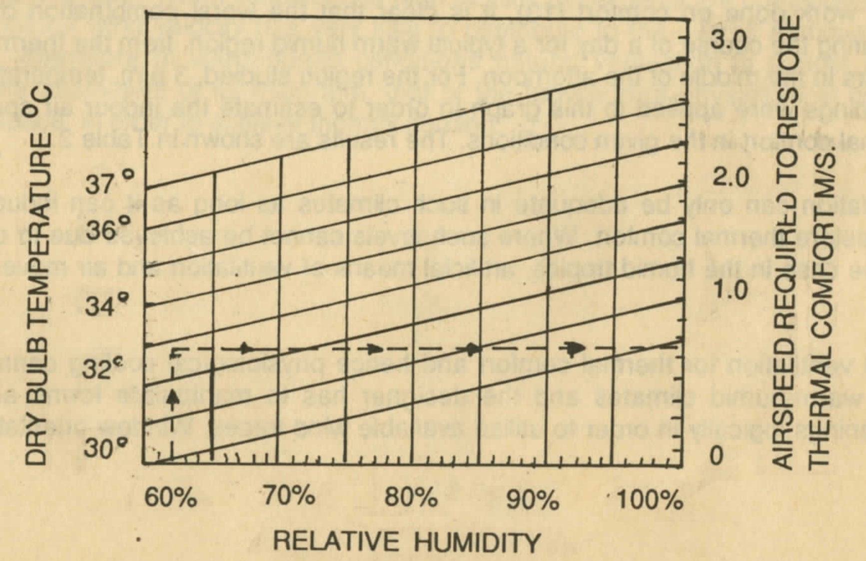


Fig : 3 Airspeed required to restore thermal comfort in warm-humid environments given DBT and RH

Table 2
3 pm Temperature and Relative Humidity Conditions and Indoor airspeed needed to restore comfort

Month	Temperature °C	R H. %	Airspeed for comfort m/sec
January	25.3	69.4	-
February	28.0	62.4	-
March	32.5	59.0	0.6
April	34.2	70.0	1.35
May	32.9	78.4	1.22
June	31.3	86.5	0.85
July	30.9	86.3	0.77
August	30.9	85.9	0.73
September	31.3	85.9	0.80
October	30.7	83.0	0.64
November	28.7	77.5	-
December	24.4	75.4	-

However such methods of estimation do not predict whether this volume of air entering is sufficient to provide thermal comfort to the occupant or not. In other words, the quantity of incoming air may be determined by such equations but the quality and effect of the air stream has to be assessed by other means.

Various studies have been undertaken in an attempt to establish links between temperature and humidity levels in warm-humid climates and the air speed required to achieve thermal comfort at these variables. Fig 3 shows graphically the airspeed necessary to restore thermal comfort in such climates for given combinations of dry bulb temperature and relative humidity (11, 12).

From recent work done on comfort (13), it is clear that the worst combination of environmental conditions during the course of a day for a typical warm humid region, from the thermal comfort point of view, occurs in the middle of the afternoon. For the region studied, 3 p.m. temperature and relative humidity readings were applied to this graph in order to estimate the indoor air speed required to restore thermal comfort in the given conditions. The results are shown in Table 2.

Natural ventlation can only be adequate in such climates as long as it can induce the airspeed required to restore thermal comfort. Where such levels cannot be achieved due to calm conditions, as is often the case in the humid tropics, artificial means of ventilation and air movement have to be employed.

Thus natural ventilation for thermal comfort and hence physiological cooling cannot be taken for granted in warm-humid climates and the designer has to manipulate forms and spaces and orientate openings logically in order to utilise available wind forces. Window orientation thus attains

great significance both in its ability to encourage breezes, as well as its importance with respect to the avoidance of solar input.

VENTILATION FOR STRUCTURAL COOLING

The function of ventilation which takes care of cooling the interior of a building and with it more importantly the structural elements, can only be performed when there is a favourable difference in the levels of temperature of indoor and outdoor air (14). This temperature difference can generally be induced by one of three main sources;

a. A high diurnal range of temperature, which is not the case in warm humid climates.
b. From heat gains from the exterior, ie excessive solar radiation on roof or particular walls. This is particularly significant in hot dry climates, though not in warm-humid climates, when quite a number of the daytime hours remain cloudy, thus obscuring the sun.
c. internally generated heat gains. This is quite significant in industries, kitchens, laundries, etc. and in spaces with overcrowding.

In warm humid climates, which necessitate the use of wide openings for thermal comfort, indoor outdoor temperature levels are generally almost at par and structural overheating is highly improbable in climatically designed spaces. In a space which is thermally comfortable the adequacy of ventilation for structural cooling is unquestionable as indoor-outdoor temperature difference remains insignificant.

CONCLUSIONS

From the above discussion, it is clear that for warm-humid climates, such as we experience here in Bangladesh for quite a substantial part of the year, there can be no doubt that natural ventilation is absolutely adequate for two of its three main purposes, viz. health ventilation and that required for structural cooling.

However, in such climates thermal comfort requires high levels of air movement and studies show that it is often difficult to rely solely on natural ventilation to help induce indoor air speeds of comparable levels. Not only is the prevailing level of outdoor wind speed quite low, but wire netting for mosquito prevention which is an absolute necessity in the. humid tropics further impedes what little movement is available. When conditions of high density settlements are compounded on these conditions the natural wind velocity has very little to contribute to the overall airmovement pattern within a space. Therefore in warm-humid conditions natural ventilation is almost always quite inadequate in the attainment of its main aim, that of the provision of physiological cooling to the occupants of a space in order to achieve thermal comfort.

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