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comfort and ventilation in an equatorial climate

INTRODUCTION

The equatorial climate, harmless and even pleasant in itself, provides a background of some difficulty for the ventilation of crowded buildings. In the absence of wind, which might give relief in fairly small buildings though it can hardly help in large ones, the only means of natural ventilation which can be relied on is the stack effect. A choice has to be made between this and air-conditioning in urban circumstances. The alternatives are discussed.

This subject was first considered by the writer in 1957, and what follows is no more than a belated postscript, hopefully overtaken by events. It seeks to define the purpose, scale and mechanism of natural ventilation in an equatorial climate, specifically that of the west coast of Malaya although similar conditions prevail elsewhere in low latitudes. Perhaps it may still serve as a starting point for discussion in spite of the lapse of time.

The climate and what it feels like

The equatorial or 'doldrums' climate, which is characteristically windless, warm, equable and moist, occurs over a belt several hundred miles wide which migrates with the sun's declination as far north as the Gulf of Iran and as far south as Australia. The daily pattern of warmth is that it feels neutral about an hour after sunrise, then warm with a peak of warmth about two hours after noon until it is neutral again at midnight. Finally it is cool in the early morning being coolest at sunrise. In the occasional sudden and brief squalls, convective by day or katabatic by night, it can feel really cold.

Outdoors in the shade the climate is enervating but harmless. Indoors, in a well-sited, well-designed and well-run bungalow with access to an open garden it is pleasant if monotonous. However, when people are crowded indoors, whether for entertainment, for shelter, or by force majeure, there is a warmth problem; one which would of course yield to adequate air-conditioning, flexibly controlled, if it were available. When air-conditioning is unavailable or inadequate the problem can become serious and the worst cases occur when numbers of people are casually and unexpectedly assembled with restricted access to the open air.

Frequently one comes across flats which are disliked by their occupants, and which become impossible if they try to hold a party. In the extreme case there are occasional incidents like that at Kosti in Sudan in 1958, when 300 rioters were locked up for the night, without serious overcrowding as it was thought, and by midnight 200 were dead. As far as the writer knows nodody has seriously considered large-scale deep shelters against air attack in S.E. Asia or India.

The permissible rise of temperature

The temperature itself is never extreme in an equatorial climate, the normal shade maximum being about 35°C. High humidities, however, begin to matter at about 25°C, are increasingly important in the 30 to 40°C range, and are finally dominant, saturation at 42°C being rapidly fatal. Relative humidities outdoors in an equatorial climate range from 70% to 100% by day, and saturation is general by night. Indoors the air is no drier.

The temperature rise accompanied by saturation which is bound to occur in a crowded building is at best unpleasant when the place is already warm; and a rise which in a cooler or drier climate would be thought moderate can here be potentially dangerous. With less than 10°C scope to reach the endurable limit obviously every degree counts, and one can usefully assume that the maximum permissible rise of temperature with saturation which can be accepted during the warm part of the day or evening is only about 2°C.

In the early morning hours the situation is different, and larger temperature rises are permissible, and even desirable. Probably few would complain if the bedroom temperature at dawn were 5°C above that in the street or garden outside.

The thermal function of a building

The thermal function of a building for human occupation in an equatorial climate is accordingly different from that of a similar building in a cooler or drier climate. Ideally it should on the one hand exclude almost all extraneous 'wild' heat viz. short-wave (solar) radiation whether direct, reflected or scattered. It should also exclude long-wave radiation from heated walls, roofs and the ground, and from cooking, laundry, artificial lighting and industrial appliances.

On the other hand the building must permit the dispersal of the body-heat of the occupants by ventilation, by refrigeration, less usefully by storage in the fabric, so that the temperature rise is limited to about 2°C.

Natural ventilation requirements by day and in the evening

As regards the warm period from about 9 am to 10 pm, it is possible to consider the effect of ventilation by itself, supposing that wild heat has either been excluded or is balanced by thermal storage. The ventilation task is then to remove about 100 watts per occupant by convection into the ventilating air without raising the air temperature by more than 2°C. The amount of heat to be removed will range from ½ kilowatt in the case of a family sitting quietly, through 1 megawatt for an excited audience at a badminton championship, to 10 megawatts or more in a packed covered stadium.

The necessary rate of air flow is surprisingly large viz. 10 000 cubic feet per hour per person and upwards. Such massive ventilation is rare indoors in other climates, and it obviously overrides the more familiar criteria of dispersing body-odour, cigarette smoke etc.

Except in the quoted family case, horizontal ventilation by wind or by fans is out of the question. Vertical ventilation by the stack effect is, however, available and can be very effective. To remove the warmed air from the vicinity of the occupants at the required rate needs an air velocity of only a few centimetres per second, which apart from its cooling effect is imperceptible.

It is tempting to compare rates of air-change, and in those terms the rate would be about one change per minute, but the air-change concept must break down if there is not time for the air to be thoroughly mixed throughout the space to be ventilated. For the same reason it is necessary that the ventilation should be uniform all over the occupied space, without dead spots and unventilated corners. Again since the air movement is upward the temperature will be higher at head level, and this will necessitate a somewhat higher rate than otherwise.

If the stack effect is doing the job then wind may not help. The arrival of a light breeze can only give a slight bonus of extra ventilation on the windward side of the building, and it may hamper and reduce the stack flow. It can even in a certain case oppose and prevent stack ventilation.

To encourage the stack effect large openings are required, on a scale of 10 square feet per person or more, half the area of opening being in or through the floor, or at least very close to floor level; there should be minimal obstruction to uniform vertical flow; and the upper openings should be high.

The natural ventilation requirement of bedrooms

The ventilation requirement of a bedroom is more modest. Most of the daytime forms of wild heat are absent, body-heat is at a minimum of 60 watts per person, and a temperature rise of 5°C is desirable by dawn. Squalls need to be excluded, and ventilation should be by stack effect only, at not more than 3000 cubic feet per hour per person. In the past bedrooms have often been designed to be over-ventilated, to the extent that the occupants have been driven to block up the ventilators.

There is the complication that some, e.g. children, the sick and those who merely keep early hours, will be in bed during the evening or the day. Bedrooms should be sited for daytime coolness, and there is a case for air-conditioning to be switched off and the ventilators opened at midnight.

The area of the ventilation openings need be only 2 square feet per person.

The traditional solution

Traditionally the designed buildings, with their very large but heavily shaded ventilation openings, were quite successful thermally. Colonial-period buildings copied many of their features in more permanent materials, and were reasonably so. Both are out-moded for modern urban living, but it may be useful to consider how they worked thermally, whether one aims to increase comfort or to economise on air-conditioning in the modern equatorial city.

The traditional style of building, of which the fisherman's or rice-farmer's dwelling and the older of the sultan's palaces were examples, was clearly designed to minimise the entry of wild heat and to encourage ventilation by the stack effect. The floor was several feet above ground level, so that the incoming air would be relatively dry and cool, and was itself permeable to air. The living space was high, and opened without ceiling into a high sloping roof also permeable to air. There were louvred openings at floor level, under the deeply overhanging eaves, and in the gables and the ridge. In the larger buildings rattan blinds hung from the eaves in place of walls, while in the smaller the walls were thatched, plaited or loosely boarded, and had small windows shaded by a thatched, plaited or louvred shutter. No glass was used.

There was a core of bedrooms etc. surrounded by a wide verandah, the eastern end of which was preferred for sitting. The whole plan was orientated on an east-west axis to minimise the overall solar load, and if possible sited on rising ground open to the south. Cooking and laundry were done outside the house, in the open or elsewhere.

Measurement of the openings showed that the stack effect would be quite adequate for any probable number of occupants.

The urban situation

In a modern equatorial city there is a change in the balance of advantages and disadvantages, the fundamental ventilation problem staying the same as before. Solar heat is often more difficult to exclude by shading, and there may be cooking and laundry to be done inside the dwelling. There may be only one or two outside walls on which to site ventilation openings, ceilings are low, and the ventilating air may be quite warm. On the other hand buildings are higher, have a higher thermal capacity and better insulation, and air-conditioning is more readily available.

So there is a greater need for ventilation, and what there is is less effective. It would be fortunate if air-conditioning be used to supplement and improve the effectiveness of ventilation, as it can in desert climates, but this is not the case. A choice has to be made, and there is much to be said for air-conditioning in cities.

There have been two questions in the mind of the user of air-conditioning: how cool should the conditioned room be; and what does one do when the conditioning fails, or is overpowered by the entry of a lot of people. There seems to be no basic reason why it should be much cooler than the environment found to be thermally neutral locally at an hour after sunrise, or at about midnight. And in a building designed for conditioning there is no prospect, when it fails, of restoring comfort by natural, or even forced, ventilation. The only immediate answer is to go elsewhere or out of doors.

Taking the two questions together, there seems to be a case for a double installation, comprising a small plant for lenient conditioning when the building is sparsely occupied and a large back-up plant for when it is occasionally crowded.

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