OPTIMUM VENTILATION AND AIR FLOW CONTROL IN BUILDINGS

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WIND TOWERS - OLD TECHNOLOGY TO SOLVE A NEW PROBLEM

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Abstract

Wind towers (scoops situated on the roofs of buildings to catch the wind) have been in use for centuries in the Middle east and Pakistan, to provide ventilation and cooling with minimal mechanical plant. In Europe, the problem of cooling buildings has generally not been significant, but in recent years there has been a trend towards substantial increases in internal heat gains from IT equipment etc., and overheating in summer has become one of our major concerns. This has been dealt with by the use of air conditioning, but in many instances this could be avoided by making better use of natural ventilation through wind towers. This paper reviews the use of wind towers for cooling spaces, and reports on work currently being carried out, using wind tunnel tests on scale models, to examine the adaptation of these principles for use in modern office buildings, in order to avoid expensive air conditioning.

1. Introduction

Wind towers have been in use for centuries in the Middle east and Pakistan, to provide ventilation and cooling without using energy-consuming machinery. In Britain, the problem of cooling our buildings has never been a great one, until recently. The advent of IT and offices using ever larger quantities of electricity has made overheating in summer a serious problem. Last summer was one of the hottest on record in Britain, and emphasised the need for better cooling in offices. Air conditioning incurs both capital and running costs, and in many instances it could be omitted by improved building design. The use of opening windows is not always convenient, particularly in high-rise buildings where wind pressures may be high, and in cities, where traffic noise is excessive. Here, we review an alternative method of providing natural ventilation, an old technique used to supply cooling by means of wind towers, and examine how it can be exploited in today's modern office.

2. Historical background

The earliest examples of wind catchers are from Egypt where they are called *Malqaf*, and are known to us from drawings on papyrus dating from circa 1500B.C. These depict towers with only one windward opening, facing the prevailing North-westerly winds. The roof of the shaft is inclined at about 30° to force the air into the building, and a high central hall provides an outlet for the ventilation air.

The principle of a wind tower is simple. The tower is built on top of the building, has an opening to allow wind-driven air to enter, and is connected to the living space via an opening in the ceiling or a duct reaching to a lower level. Wind pressure forces air down into the building, providing ventilation air. The air may leave the building through open windows or gaps in the fabric. (Figure 1).

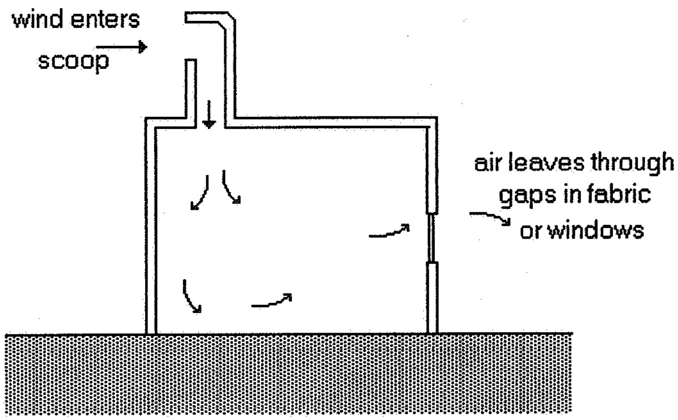

Figure 1. The Basic Wind Tower.

In areas where the wind is always in the same direction a simple uni-directional scoop may suffice, but in most regions the wind may come from any direction, and a scoop or head which can accommodate winds from all directions is required. An alternative which could be developed is a scoop which can be rotated to face the wind (Figure 2).

Variations on the basic wind tower principle include the use of tubes buried in the earth to provide additional cooling (Figure 3), or porous jars containing water to achieve evaporative cooling (Figure 4), and in some cases a combination of both.

Wind towers on houses are widespread in the Middle East, notably in Bastakia, Iran, where there are many such houses dating from the middle ages to as late as 1900, which represent a traditional style of building which developed over the centuries, and is appropriate to the local social and environmental conditions. These are large houses, designed to accommodate extended families of wealthy merchants. They are preferred by the older generation, who consider air conditioning to be draughty and noisy. The wind towers, known as *Badgeer*, are open on all four sides to catch the breeze from any direction and funnel it down to the occupants. In cool weather the vents can be closed off at the bottom with wooden traps [1]. In some Badgeer in Iraq, the duct is connected only to the room at the lower floor level and the cooled air is allowed to circulate to the upper rooms by natural buoyancy.

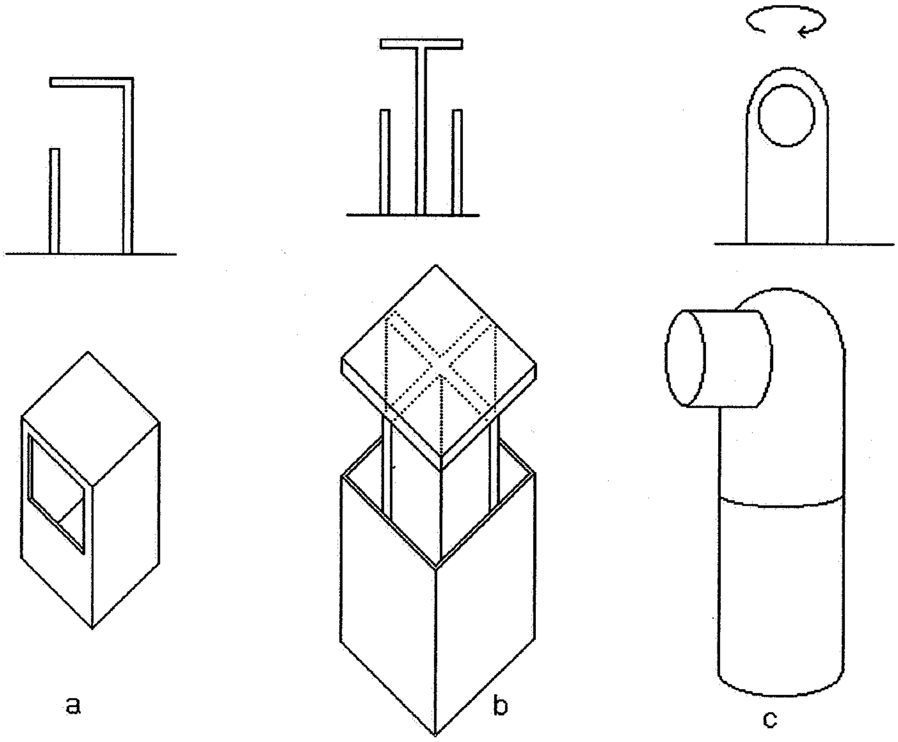

Figure 2. Range of Scoop Types. a. Uni-directional. b. Multi-directional. c. Rotating.

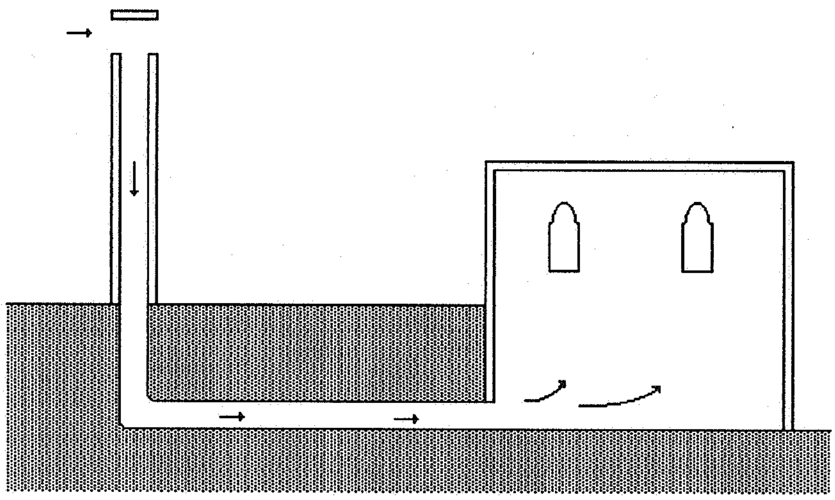

Figure 3. Additional Cooling Through Earth Tubes.

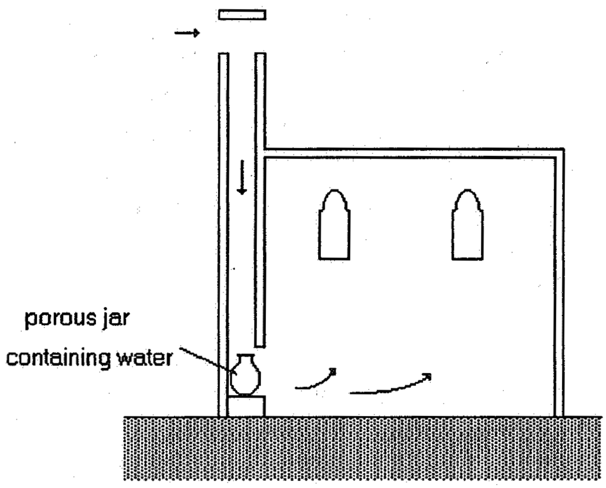

Figure 4. Evaporative Cooling.

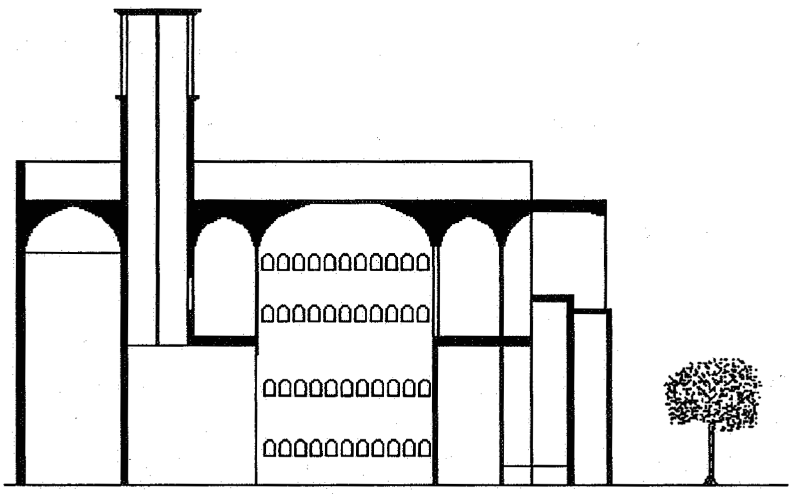

Figure 5. A Typical Badgeer on a House in Yazd, Iran.

In the town of Thatta in the Sind province of Pakistan, many houses have wind towers. The design here is different, and because the wind in the hot season is almost always from the south west, they are built to catch the wind only from that direction. These wind catchers in general have a square or rectangular plan, and are slightly enlarged at the top. The 'serviced' rooms (bathroom, kitchen) are all on the lee side of the building and wind tower. The wind tower is equipped with a metal grating to prevent entry into the house, and a trap door to close off the wind when not required. In this region, even some modern houses have wind towers - made from concrete rather than the traditional materials of wood and sun-dried mud-bricks. [2]. In Yazd in Iran, tall wind towers adorn some houses, with eight shafts to catch wind from all directions, and longer sides towards the prevailing north west and south east winds. (Figure 5) Felt hanging from the walls of the shafts can be watered for evaporative cooling, or pitchers of water made of porous stoneware. [3].

Each area using wind towers has evolved its own designs according to the requirements, the local climate conditions and local availability of building materials. Most wind towers today are on older buildings, although a number have been built in recent years, interest in wind towers having increased due to the mounting cost of energy, and greater concern for environmental considerations.

3. Mode of Operation

Wind catchers scoop the wind and drive it down through the building. Resistance to the flow of air through the building is created by friction against the walls of the tower or duct, with additional resistances at bends and from internal partitions. The mechanisms by which the air cools the building and its occupants are manifold.

- Air movement against the body creates a fresher feeling, even though the air may not be cooler.
- If the air is cooler than that inside, it may directly cool the occupants and the building fabric.
- At night, the air will cool the building fabric and make it pleasanter the next morning.
- The air may also be drawn over jars of water and produce evaporative cooling.

4. Existing Performance Data

The design of wind towers in Sind and the Middle east developed over the centuries to suit the local climate, social conditions, and available materials, as the best building practice should. The traditional approach to design through rule of thumb and experience unfortunately leaves us with little record of the process by which the shape and size of the towers were reached. Proper, quantitative design processes and guidelines need to be developed for today's environment, where the users' demands on the building are greater. Today's urban environment is much more crowded, space is limited, and there are limits to the height of towers we can erect determined by structural considerations, aesthetics, overshadowing of nearby buildings, and so on.

There is relatively little quantitative data on the performance of existing wind towers. Such data as there is suggests that the air speed at the outlet of the scoop is between 8 and 15% of the wind speed at the inlet. In a room 5m by 3m by 3m with a 1m x 1m duct, at a wind speed of 10m/s the speed of the air in the room was 1m/s [4], but no record of the overall ventilation rate was made. This air movement increases the acceptable maximum temperature by approximately 2.0°C at 45% relative humidity.

5. Variables Affecting the Performance of Wind Towers.

The chief environmental variables are the wind speed and direction, and for a given design and orientation there should be a fixed relationship between the wind speed and ventilation rate. The nature of this relationship is affected by:

- Tower dimensions in relation to room below.
- Form of tower and scoop head.
- Presence of internal obstructions which create a resistance to air flow.
- Effect on local wind patterns of nearby structures.

Further, the cooling effect that ventilation has on the fabric of the building and the internal air is a function of;

- The ventilation rate.
- The air temperature.
- The relative humidity.

6. Experimental work.

A 1:100 perspex model was constructed as shown in figure 6, representing the top storey of an office building, and was tested in a wind tunnel at a range of simulated wind speeds, with the wind direction parallel to the long axis of the model. The opening in the wind tower and the roof of the building represented 0.5% of the floor area, equivalent to a 0.075m^2 duct (27cm x 27cm) 1ft by 1ft in a 5m x 3m room .

Three sets of tests were carried out:-

a. Air movement tests using anemometers.
These measurements enabled the air velocity within the room to be measured. The air velocity at the outlet was also measured and correlated with the wind speed (Figure 7). This gives an overall mean ventilation rate throughout the space, but does not indicate the actual ventilation rate at particular locations.

b. Flume tests using coloured dyes.
These were carried out to evaluate the ventilation distribution in the model. They showed that the turbulence induced as the air entered the "room" created a wide spread of ventilation air throughout the room, and that ventilation air reached every corner of the room, using the vent position shown.

c. Vent rate tests using SF_6.
These were carried out using standard tracer gas decay technique. The detector location was centrally in the room. The ventilation rates achieved in the centre of the room are shown in Figure 8.

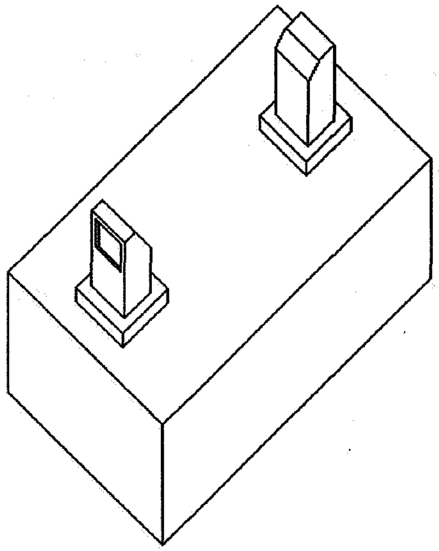

Figure 6. The model building used in the wind tunnel tests.

8. Results

The mean ventilation rate within the model should clearly be some function of the wind speed, for a given set-up. However, due to turbulence, the ventilation rate at particular locations may vary from this, due to changes in air flow mechanisms at different wind speeds from laminar flow to turbulent flow. The overall ventilation rate is roughly given by the air speed at the "exit" duct and shows good correlation.

Cleary the relationship between the internal ventilation rate and the wind speed is affected by a number of factors, including the vent size and shape. The results presented thus refer only to this particular combination., and a mathematical model will be developed in due course.

9. Conclusions.

Natural ventilation is becoming increasingly attractive to users wanting improved air quality and lower energy bills. Wind-driven ventilation from roof-mounted towers has been used successfully for centuries, with little attempt to date to quantify the effects or develop scientifically-based design guidelines. This work represents the initial stages in developing a fuller understanding of this form of ventilation. There was some correlation between wind speed and internal ventilation rate, and ventilation air was well distributed.

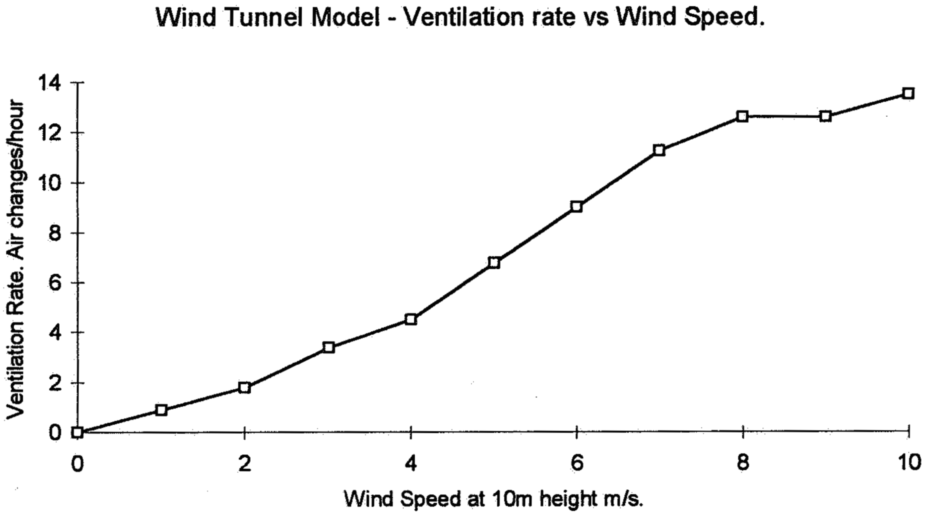

Figure 7. Results of Anemometer Measurements.

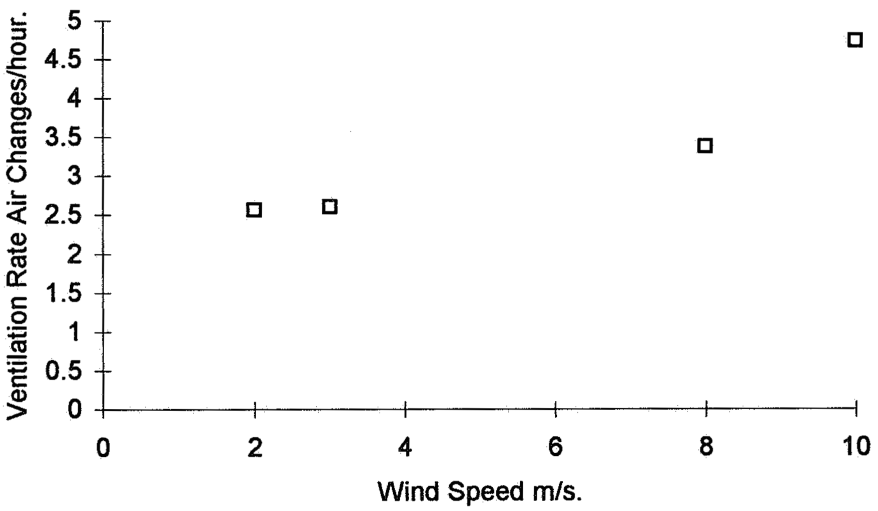

Figure 8. Results of Tracer Gas Ventilation Rate Measurements.

9. References

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3. Von Hardenberg, J.G. "Considerations of houses adapted to local climates." Energy and Buildings. Vol 4, No. 2. 1982.

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