

RARE Headquarters, Twycross, Leicestershire, UK

RESEARCH & DEVELOPMENT

Wind Towers for the article "The Design of Wind Driven Ventilated Buildings"

Wind is a powerful force that should be harnessed and harvested to maximise its potential positive contribution to the built environment.

In cold climates, wind has traditionally been seen as a negative force and buildings have been located and designed to minimise its effect.

Architecture is now being designed to use natural forces positively and utilise the free energy available from the environment. Instead of erecting an environmental barrier and cocooning ourselves within an artificial internal climate, we can make use of the building form to channel the positive natural forces into the building and reject the negative forces.

NATURAL VENTILATION

Natural ventilation is achieved by making use of the natural pressure differences surrounding a building, caused by the wind and stack effect. Air movement within the building may also depend on buoyancy (thermal forces). There will always be periods of calm when the wind speed is ineffectual, although these do not generally occur during hot weather. In these situations, buoyancy forces act alone. Natural ventilation is dependent on three climatic phenomena: wind velocity, wind direction and temperature difference.

1. Wind velocity - The direction of the wind and its velocity over the building create a pressure field around the building. It is therefore important that the wind tower or wind scoop is positioned to maximise the pressure differential between the inlet and the extract. This will increase the efficiency of the ventilation scheme, allowing reduced opening areas. Pressure differential around the building will always be the

predominant factor influencing natural ventilation, but this is reliant on the velocity of the wind. If this drops below a certain level, only then will stack effect (buoyancy) have any real bearing on the rate of ventilation. Wind ventilation is not effective unless wind speed is in excess of 2.5m/s; the average in the UK is 4.5 m/s.

2. Wind direction - The manner in which air passes through a building is fundamentally dependent on the direction of the wind. As the wind moves over the building it creates a varying positive and negative pressure field. Air will then flow from the positive pressure zones to the negative. It is important to note that as wind direction varies on a daily and seasonal basis, the pressure field around the building will also alter. An opening may therefore change from a positive pressure to a negative pressure from one day (or season) to the next.

3. Temperature differences - As the temperature increases, the density of air decreases and the air consequently rises. Temperature differences between the inside and outside of the building, and between different areas of the building, create pressure differences and, subsequently, air movement. This is known as 'stack effect'. A natural ventilation system should therefore also be designed to promote air buoyancy. It is desirable for the wind to apply its force in the same direction as the buoyancy force to avoid a condition in which the two forces cancel each other out. Buoyancy effects will, however, be exceeded by wind-generated pressures for wind speeds over 2.5 m/s.

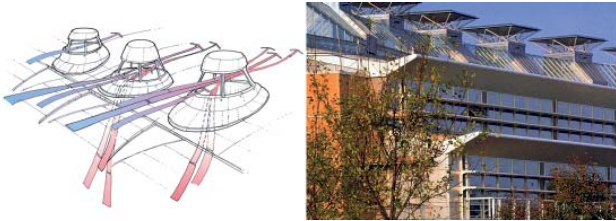
WIND-DRIVEN VENTILATION

Wind flowing around and across a building drives natural ventilation, and can be harnessed in a number of ways. Wind towers can be used to draw air out of the building, subsequently encouraging a natural air flow. Wind scoops can collect and deliver external air to the building, and a combination of wind towers and wind scoops can provide a natural form of air delivery and extraction.

Wind towers

The simplest design for a wind tower is a vertical construct that projects above its surroundings and has an open top. This will ensure

negative pressure and provide suction in all wind directions. If the ingress of rain is a problem, a cover can be placed above the top. Alternatively, an oast wind tower (L-bend) will reduce the effect of interference at the opening and provide a greater degree of protection from the weather. However, if an oast tower is to work in all wind directions, it must be omnidirectional and turn away from the wind, which obviously carries cost and maintenance implications. A number of other devices can be incorporated into the basic chimney design to create a greater negative pressure around the opening, but generally these must also be omnidirectional.



Wind towers at Ionica, Cambridge, UK

Wind towers and wind scoops

Wind scoops can be used in combination with wind towers to create a system by which cool air is provided by wind scoops and warm air is then extracted via wind towers. By collecting and extracting air at high level, rather than through the facades, there will be a greater pressure differential between the devices, producing more air flow through the building. Natural ventilation by means of a combination of wind towers and wind scoops can either be via two separate devices, or a single device with both inlet and extract.



Wind scoops at Bluewater Shopping Centre, Kent, UK

Again, the wind scoop should be omnidirectional, and if a combined device is used, an omnidirectional wind tower can also be employed. An alternative device may be installed, however, to eliminate the necessity for scoops and towers to be orientated into the wind. A chimney is divided by partitions into four shafts, each open to a different direction, and regardless of the wind direction, one of the shafts will catch the breeze and the others will act as oast wind towers. This method was first adopted in Iran in the design known as the 'badgir'.

The design of wind towers and wind scoops is based on historical examples from the Middle East. These devices can be deployed to take advantage of particular site conditions, collecting cool winds, promoting cross-ventilation through the building and encouraging the extraction of excess warm air. Their application and design parameters will be studied to show how traditional devices can be adapted and improved in order to provide a simple and effective means of ventilation for even the most demanding buildings of the future.

WIND TOWER DESIGN

The effectiveness of wind towers is dependant upon producing the maximum pressure difference between the air inlet openings and the wind tower. The air movement around the building will determine the size and position of the wind tower and openings (and in some cases the actual building form), so as to maximise the pressure difference.

The effects of resistance to the internal air movement can also dictate the internal layout.

Suitable building form

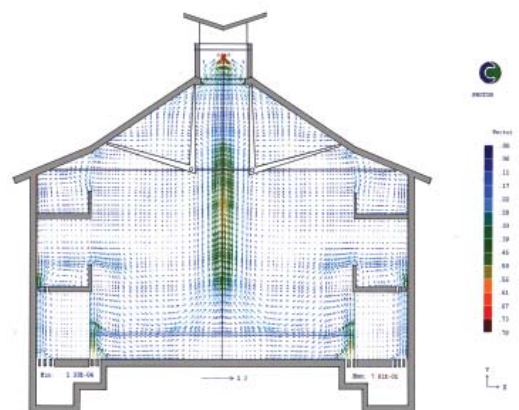
A pressure differential is created by a building in the path of an air stream. A positive pressure will be exerted on the windward face of the building, and a negative pressure will form over the roof and leeward face. The greater the restriction of air flow due to the building form (for example an elevation facing directly into the wind), the greater the positive pressure at the windward face. This will also produce a more powerful negative pressure over the roof and the wind tower. Additionally, the wind tower itself will act as an obstacle to the air flow, creating an area of positive pressure in front of the device, and a negative pressure over the opening of the chimney. Alternatively, the building can be aerodynamically shaped to encourage an increased velocity air stream over the building. This improves the 'draw' and therefore the performance of the wind tower. The use of a wind tower allows the building to be orientated regardless of the wind direction. It can therefore point south to provide good solar access, even if the prevailing wind is from the east or west. This may not be possible with traditional cross-ventilation.

Optimum opening positions

The 'leading edge' of the building is the edge between the windward facade and the roof or sides. This is where the maximum positive pressure occurs on the windward facade and the maximum negative pressure occurs on the roof (see figures 46 and 47).

A wind tower is at its most effective at the windward edge of the roof (where the negative pressure is greatest), and is least successful at the leeward edge. The ideal position, which can harness winds from all directions, is therefore at the centre of the building. The position of the inlets is less crucial since it is the wind tower that will drive the air through the building. The ideal position for inlet openings is along the windward facade, where the positive pressure is at its greatest. However, the change of wind direction makes this difficult to obtain without a complex building-management system that can open and close windows/vents, and it is therefore better to have openings on all facades.

The positive pressure against the vertical facade increases with height. However, placing the openings at low level gets better results, allowing air flow to act in the same direction as internal stack effects and to circulate throughout the building.



CFD analysis of the wind tower at Gresham School Theatre, Norfolk, UK

Wind-tower height

The extrusion of a chimney produces the same effect as the building form by creating an obstacle and producing a negative pressure over the opening. The wind tower may be combined with the lift motor room, but it must be sufficiently high above the building to avoid any turbulence around the roof. Its height will also affect the ventilation rate: a taller tower will have stronger winds passing over it, creating a greater negative pressure. This must be weighed up against aesthetic concerns and planning restrictions.