04

Urban Energy Technical Note

Natural Ventilation

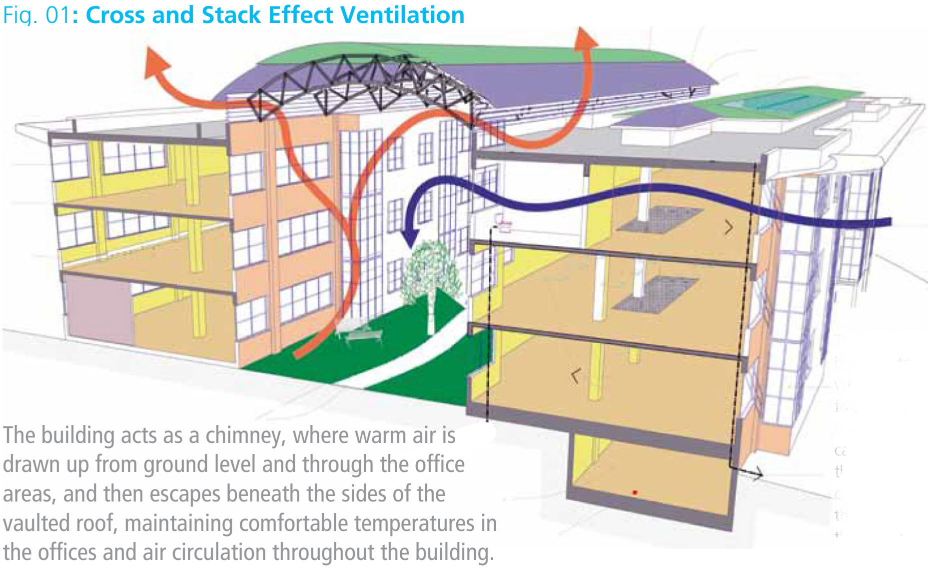
Thermal comfort in the built environment is affected by air temperature and air movement. Ventilation, which is simply the removal of stale indoor air from a building and its replacement with fresh outside air, has a great impact on thermal comfort.

Adequate ventilation is vital for pleasant, comfortable, internal conditions and suitable air quality in both domestic and non-domestic buildings. It is essential for the well-being of the occupants and for the fabric of the building itself. Too little ventilation puts the health and comfort of the occupants at risk, while too much results in energy losses with the consequent costs and possibly carbon emission penalties. Correct ventilation of domestic and commercial buildings is therefore critical.

Ventilation may be provided by natural or mechanical means, or by a combination of the two (mixed mode/ hybrid ventilation). It is important that ventilation requirements are met whilst minimising the energy consumption of the building. Mechanical ventilation, which can vary from a simple fan to full air conditioning, involves the use of energy, usually electricity. Electricity is generally an expensive form of energy and in most situations its generation results in carbon emissions, contributing to the problem of climate change.

This technical note describes how a building can be effectively ventilated using natural means.

Fig. 01: **Cross and Stack Effect Ventilation**



The building acts as a chimney, where warm air is drawn up from ground level and through the office areas, and then escapes beneath the sides of the vaulted roof, maintaining comfortable temperatures in the offices and air circulation throughout the building.

Section through the new office facility, UNEP and UN-Habitat Headquarters, Nairobi © UNEP and UNON

Natural Ventilation

This is the process of drawing in fresh air and discharging waste air from an indoor space without the assistance of powered components – fans or other mechanical systems. It uses the airflow caused by pressure differences between the building and its surroundings to provide ventilation and space cooling.

Air movement is a major factor that influences the indoor climate and should be taken into account in the planning, design and construction of buildings. It should be incorporated in the design concept, as properly designed and installed natural ventilation systems are considered to be the most energy efficient and healthy solutions. They are extremely economical as they provide ventilation at low or zero running costs. They are also efficient and require only minimum maintenance.

Given the increased awareness of the cost and environmental impacts associated with mechanical ventilation, natural ventilation is the best method for reducing energy consumption and cost and for providing and maintaining a comfortable, healthy and productive indoor environment It saves significant amounts of fossil fuel based energy by reducing the need for mechanical ventilation and air conditioning which in turn reduces greenhouse gases released into the atmosphere from the electricity generating plants that produce the energy used for cooling buildings.

Categories of Natural Ventilation

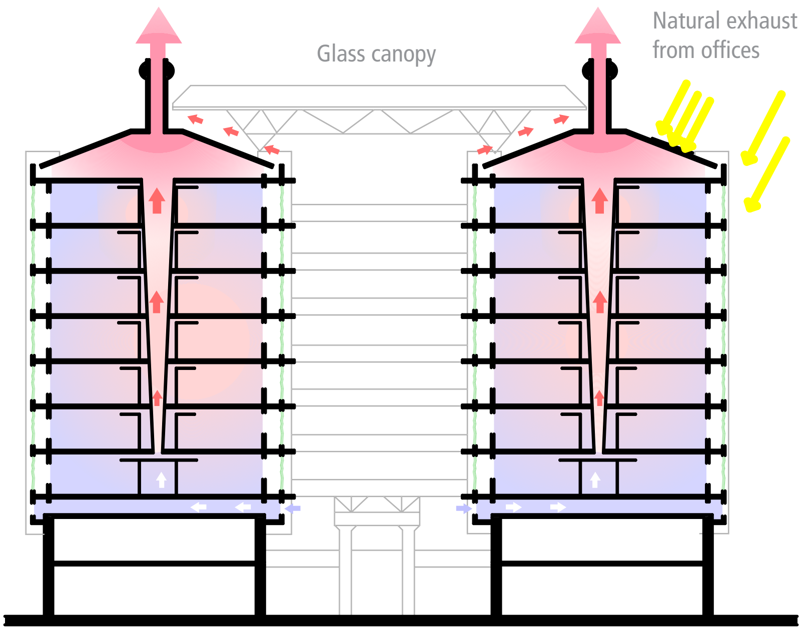
1. Cross Ventilation

This is a wind driven circulation of fresh air through open windows, doors, or other openings, which are in opposite sides of the room or rooms being ventilated.

Positive pressure on the windward side and negative pressure on the lee side of the building cause air movement across the room(s) from the windward to the leeward side, provided the openings on both sides of the room are open.

In order to achieve reliable air circulation, buildings must be designed for cross-ventilation. This allows for passive cooling and reduces reliance on air-conditioning. Incorrectly designed interior partitions impede cross ventilation by changing the air direction and speed.

Fig. 02: **Stack Effect Ventilation**



Section through the Eastgate Development in Harare, Zimbabwe by Architect Mick Pearce

2. Stack Effect Ventilation

The stack effect occurs when there is a difference between the inside and outside temperatures. It is brought about by warm air rising and escaping through high level outlets and thus drawing in colder, heavier air from outside.

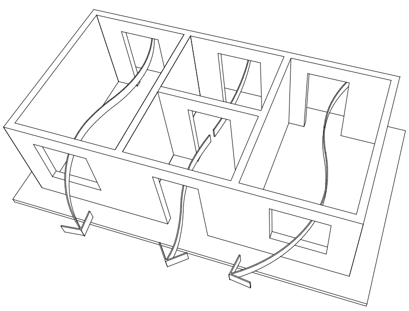
The stack effect can also be induced by placing openings near the floor and near the ceiling. It can be regulated by window shutters to obtain the desired heating or cooling effect. Outlets should be located on the opposite side of the room and at high level.

This effect increases when the difference between the internal and external air temperature increases and with an increase in the height of the building (i.e. the difference in height between the air inlet and the outlet.

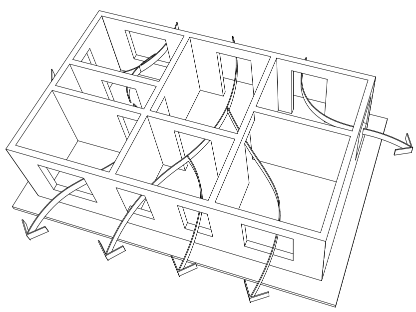
Stack effect ventilation can also be achieved by the use of solar chimneys and wind towers.

The rate at which air change takes place is determined by: temperature difference between inside and outside; the site, location and design of openings; and the distance between inlets and outlets.

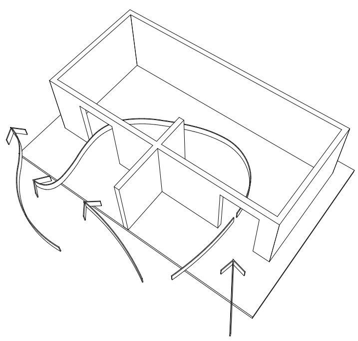
Fig. 03: **Cross-ventilation - importance of room configuration and position of openings for good air flow**



Cross-ventilation through a single banked room



Ventilation through circulation in linked rooms



Effect of external projections on the air flow patterns within a building

Design considerations for Natural Ventilation

The design of natural ventilation systems varies according to the type of building and the local climate. However, the careful design of internal spaces, and the size and placement of openings are critical to the amount of ventilation.

The Site

When designing for a particular site, it is crucial to interpret its wind data carefully. It is also important to check on local topography, vegetation and surrounding buildings. These have an influence on the local conditions.

Ideally, there will be some light winds in the hot season and in hot regions to provide sufficient internal air movement for thermal comfort in all conditions, and for night time cooling of the building.

Building Orientation and Planning

Buildings should be oriented to maximise their exposure to the direction of the prevailing wind. Rooms with a double orientation and with at least two walls facing externally but in opposite directions make for better ventilation.

Rooms should also be designed with a relatively narrow plan to facilitate air flow through the building (cross ventilation). However, single storey deep plans can be naturally ventilated through roof outlets.

Rooms should have inlet and outlet openings. The outlet should be located across from the inlet and high above it to maximise the stack effect. Whenever possible, an open plan design that minimises resistance to airflow, can be used to facilitate cross ventilation.

Openings – Size, Placement, Types

The size of the openings and their location influences the velocity of air circulation and its main route in the interior space. The larger the windows, the higher the indoor air speed; but this is true only when the size of both the inlet and outlet openings is increased. When a room has unequal openings and the outlet is larger, then much higher maximum velocities and slightly higher average speeds are obtained.

The location of openings may deflect the indoor air circulation. When the openings are placed asymmetrically in a facade, unequal pressure on both sides of the openings influences the airflow.

Openings should be located to receive the prevailing wind in hot conditions and, ideally, should be installed on both sides of the occupied spaces to provide cross ventilation.

They should be operable, oriented on opposite sides of the the room and offset from each other to maximise mixing of air within the room while minimising the obstructions to airflow within the room.

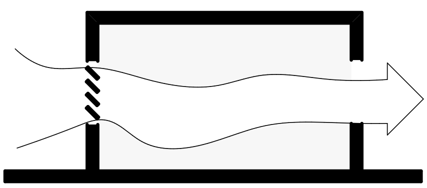
Operable windows or air outlets on the leeward side of the building are as important as those on the windward side. Incoming air slows down within the building and so, to maximise the ventilation, the total air outlet area should be larger than the air inlet area.

Ridge vents, vented skylights and clerestories provide openings for stale air to escape through stack effect ventilation.

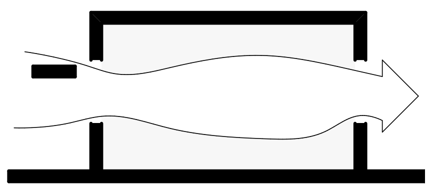
Casement windows on the windward side of the building offer some directional control of indoor airflow into occupied zones.

Casement sashes or hinged doors can be up to 60% more efficient than other sashes or sliding doors on windward walls for capturing incidental air flow. Sliding windows are problematic in that only half of the window can be opened, and they cannot be adjusted according to the wind direction.

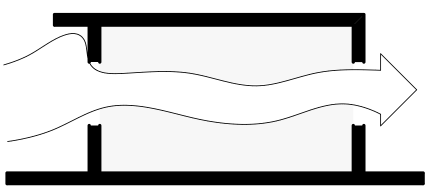
Fig. 04: **Effects of louvres and horizontal overhangs above windows**



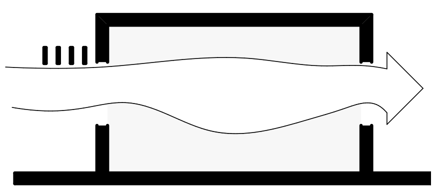
Louvres diffuse airflow



A slot between the overhang and the facade increases downward pressure and result in a more comfortable air flow within a room



Overhangs collect and breezes and enhance air flow within a space.



Louvered overhangs enhance downward pressure of air flow through a space

Climate and Natural Ventilation

The design of openings is greatly influenced by the prevailing climate.

Understanding the prevailing wind patterns of the site can be useful when designing ways to take advantage of natural ventilation or to protect the occupants from uncomfortable windy conditions.

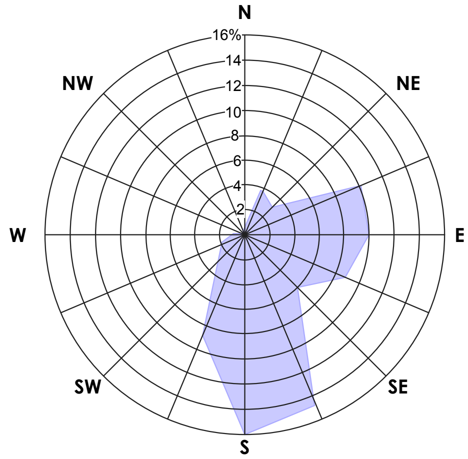
A **Wind Rose Diagram** is used to show wind speed and direction for a particular location and analyses the characteristics of the wind by indicating its strength and frequency over a specified period of time (month, season and year).

Hot and Humid / Great lakes zones

A climate characterized by high humidity and high temperatures makes provision of permanent ventilation essential. Natural ventilation improves indoor thermal comfort by reducing the effects of relative humidity above 60%.

Buildings should be oriented to capture the prevailing breezes. Open plan interiors promote natural cross ventilation. Carefully located wall openings allow breezes to flow through the interior. Internal openings should be included to encourage cross-ventilation.

Fig. 05: **Wind rose diagram for Mombasa, Kenya**



The longest spoke on the wind rose represents the greatest frequency of winds blowing from that particular direction over the specified time frame.

Windows with maximum open areas, such as awnings, louvres, and casements are recommended for these climates. Roof ventilation is essential in these zones.

Hot Arid, Hot Semiarid / Savannah zones

Buildings in hot, arid, desert climates can benefit from natural ventilation via the stack effect, to draw air through evaporative cooling systems or by wind pressure at night, to enhance night cooling of the building.

Natural ventilation during the daytime should be avoided unless it is through an evaporative cooling system, to ensure the temperature of incoming air is lowered and its relative humidity is raised.

Upland / High Upland zones

Maximum ventilation is not essential for comfort in these zones. However, it should be controllable.

Buildings should benefit from the winds during the hot months and so proper cross-ventilation is required. Shelter from the cold winds should be provided as well.

Windows should be of medium size with openings in opposite walls for proper cross-ventilation during the hot period.

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The purpose of this Technical Note is to call reader's attention to new technical issues in the field of sustainable human settlements development. They are not meant to be final or exhaustive. For more information, contact the Urban Energy Unit. Prepared by Vincent Kitio and Jerusha Ngungui