Revival

TECHNICAL**MONOGRAPH** 3

Natural ventilation strategies for refurbishment projects

This technical monograph is one of a set produced as part of the 'REVIVAL' project – an EU Energie Programme supported demonstration project of energy efficient and sustainable refurbishment of non-domestic buildings in Europe. The monographs explore some of the main energy and comfort issues which arose during the Design Forums held with each of the six sites. The four monographs are entitled:

- Thermal mass and phase change materials in buildings
- Adaptive thermal comfort standards and controls
- **Natural ventilation strategies for refurbishment projects**
- High performance daylighting

Refurbishment projects often involve changes to the ventilation strategy. Commonly this will include the reduction of uncontrolled infiltration, usually as part of a general upgrading of the envelope. The reduced infiltration will reduce heating loads, but may result in indoor air quality (IAQ) dropping below acceptable standards. This will often prompt the installation of mechanical systems as part of the refurbishment package.

▶ **Figure 1**
The Albatross building in Den Helder has an advanced passive ventilation system incorporated in a secondary glazed skin.

Furthermore, mechanical systems may often be installed to combat overheating, the result of poor design features such as large areas of unshaded glazing. An integrated approach to the refurbishment specification may allow natural ventilation, with the following advantages:

- Save electrical fan-power
- Reduce plant costs and maintenance
- Save space
- Improve health and well-being of occupants

Can we avoid mechanical ventilation?

Natural ventilation is becoming an attractive alternative to mechanical ventilation or full air-conditioning in new and re-furbished buildings. It is of course, a re-discovered technology, since before the 20th century all buildings were naturally ventilated. Furthermore, almost all residential buildings, and many non-residential buildings still rely on natural ventilation. Why the big issue then?

There are two important factors that have changed the situation. Firstly buildings have got much bigger and more complex, and secondly, the influence of energy conservation has required that wasteful over-ventilation is avoided.

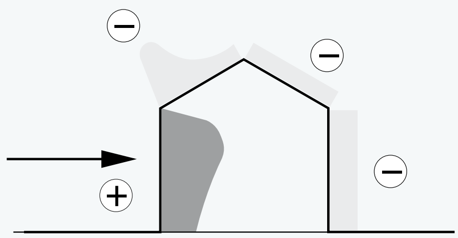
Traditionally buildings had leaky envelopes and this often provided a 'failsafe' for air quality. But with the growing trend to make air-tight envelopes to save energy, ventilation has to be designed more precisely. Three different purposes for ventilation can be identified and each needs to be considered separately although their provision may be by common elements:

Ventilation	Purpose	Ventilation rate
Minimal ventilation	To maintain air quality	Typical winter case 0.75 – 1.5 ac/h
Space cooling	To vent unwanted heat	Typical summer case 2 – 12 ac/h
Physiological cooling	To provide direct air movement to occupants	Typical summer case 0.5 – 1.5 m/s

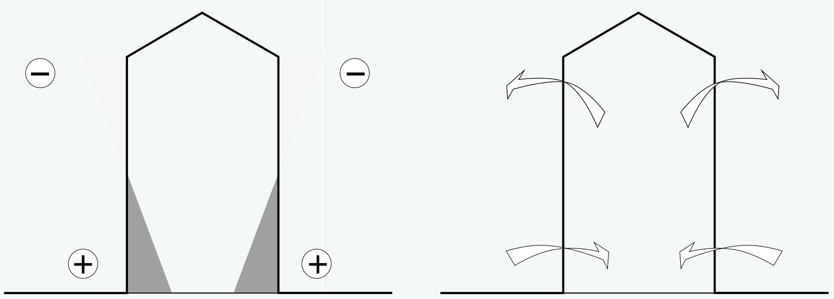
These purposes make very different demands on the building. In winter, the problem is to exchange just enough air to maintain sufficient air quality. “Build Tight – Ventilate Right” implies that the ideal is to have an airtight envelope with purpose made controllable ventilation openings, positioned to give the best mixing and minimise discomfort from cold draughts. Openings may be windows, or closable grilles or trickle vents. If they are windows only, they must be able to be set at a very small opening area.

The driving forces of natural ventilation

- Wind generates pressure differences across the building which cause air to flow through openings in the building envelope, figure 2.
- Temperature difference between inside and outside causes a vertical pressure gradient which causes air to flow vertically (upwards if building is warmer than outside). This is known as buoyancy flow or more commonly as the stack effect, figure 3.



▶ Figure 2
Wind pressure distribution. Airflow takes place between openings at different pressures.



▼ Figure 3
Temperature difference between inside and outside creates a pressure difference across the envelope driving airflow in through openings at the base and out the upper part of the building.

The control of ventilation rate

For much of the time both of these forces are present simultaneously. The problem is that both are highly variable. Overall air change rate on a cold windy day will be many times that on a warm calm day, unless the openings respond to change the flow resistance, figure 4.

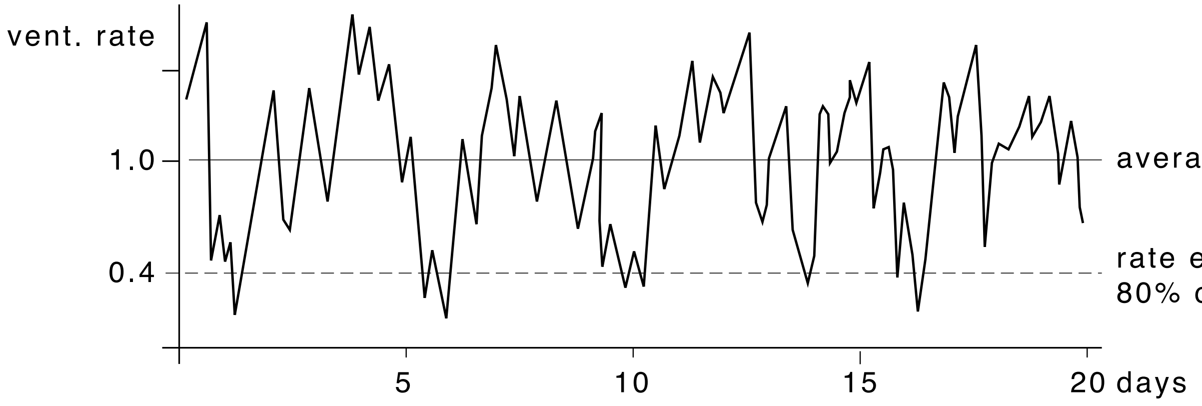
Rules for winter ventilation

- Openings should be small and controllable to account for different wind strengths and temperature differences.
- Openings should be high up in the external wall of the room to encourage mixing and minimise draughts.

If only fixed trickle vents are provided, they have to be large enough to cope with the worst conditions – i.e. no wind and small temperature differences. This will lead to over-ventilation in conditions of significant wind and large temperature differences, and hence wasted energy, for much of the time. Automatic vents are now becoming available, which close up as the pressure differences get greater, thereby stabilising the air-flow rate. Or active ventilators under BMS control can be modulated in response to temperature and wind speed, or indoor air quality (IAQ).

Rules for summer ventilation

- Openings should be large and easily controllable (good access to handles, stays, locks etc)
- Openings should be well distributed



▲ **Figure 4**
Due to the variability of the driving forces, fixed openings sized to provide sufficient minimum ventilation will result in over ventilation (and energy waste) when driving forces are large.

vertically and horizontally to encourage flow between parts of the façade at different pressures (see figures 6 and 7).

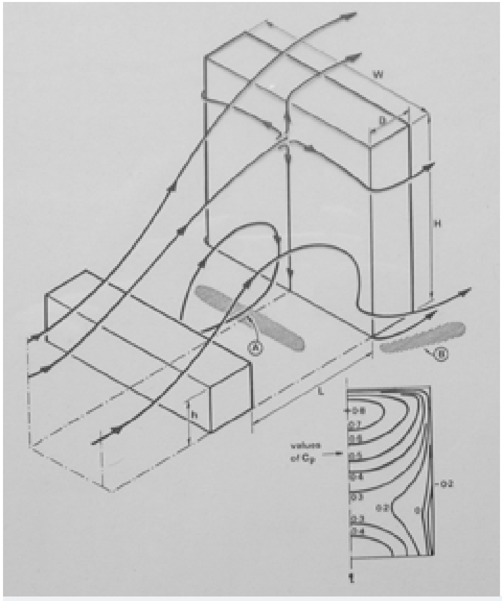
- Consideration must be given to how the incoming air will affect the occupants.
- Shading devices must not block summer ventilation openings (see Tech. Mon. 4)
- Openings may require special design features to reduce transmitted noise.

In both cases, consideration must be given to the distribution of fresh air within the space. Different distributions of openings allow different depths of floor plan to be naturally ventilated. The following table (figure 5) gives a rule of thumb.

Note that the depth of effective ventilation is dependent on floor to ceiling height. The removal of a suspended ceiling may represent a refurbishment opportunity for improving natural ventilation (and daylighting), provided other problems such as servicing and acoustics can be solved.

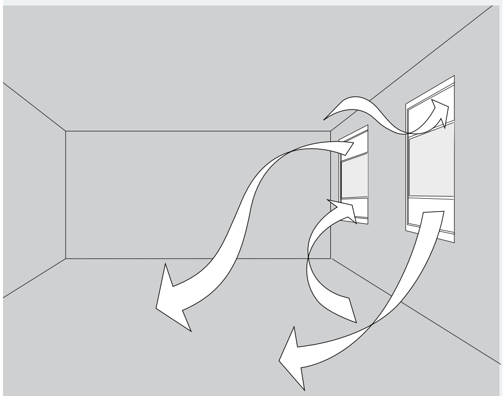
▼ **Figure 5**
Depth of effective natural ventilation in rooms from side openings

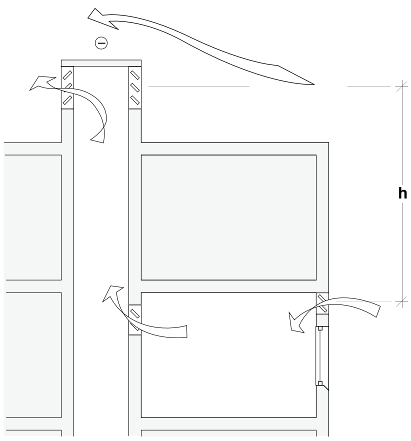
	Single-sided		Double sided (cross ventilation)
	Single opening	Multiple openings well distributed vertically and horizontally	
Depth of floor in units of floor to ceiling height h	2h	3h	6h

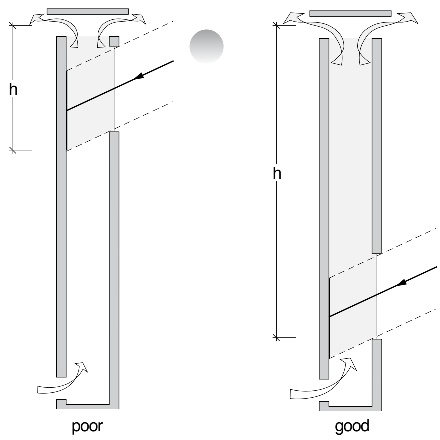


▲**Figure 6**
Wind generates complex pressure distributions on buildings, particularly in urban environments. This assists ventilation, provided that openings are well distributed and flow paths within the building are available.

▼**Figure 7**
For a given total area, ventilation is improved when openings are well distributed vertically and horizontally. This is because air flows at different pressure between openings. It also leads to a better distribution within the room.







▲ **Figure 8**
Stacks can ventilate a deep plan building; wind and buoyancy forces both create negative pressure causing fresh air to flow in from the perimeter

▲ **Figure 9**
Solar chimneys use solar gains to heat the air column. However, the driving force is dependent on the height of the warm air column and the average temperature difference. It follows that it is no good heating up the air at the top only.

Advanced ventilation techniques

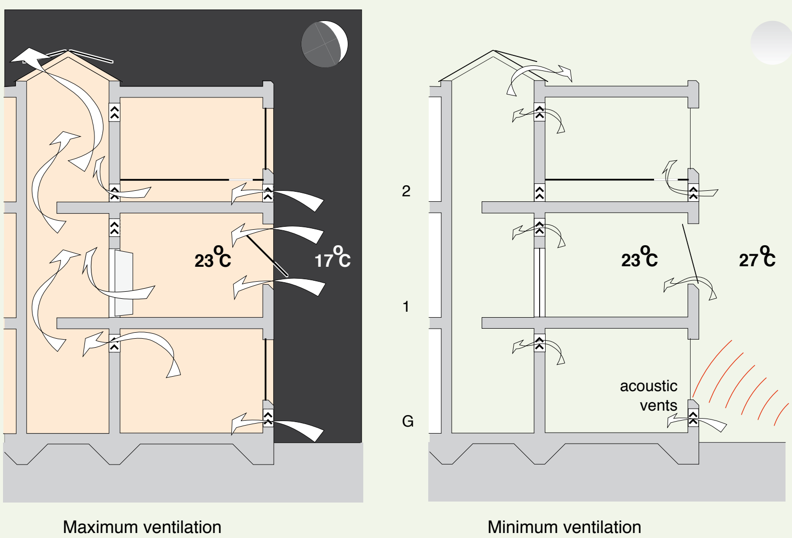
Ducts and chimneys
So far this guidance has considered ventilation provided by openings in the facades of the building, and usually doubling up as windows. This imposes some limitations on plan depth and layout. To get sufficient quantities of air in and out of an existing deep-plan space, ducts and/or chimneys may be provided, figure 8.

Large vertical ducts can generate larger airflows, by the so-called 'stack effect', than can be obtained in a single room by side openings, because of their greater height. Furthermore, when the wind does blow, there is always a negative pressure across the top of a building; thus the wind driven and stack driven flows complement each other. In order to keep flow resistance low, the cross-section must be quite large, typically between 2% and 5% of the floor area they are serving, assuming a similar area of inlet is available at the perimeter.

This may be difficult to provide in an existing building, although use of existing light wells or redundant lift shafts might be a solution.

The performance of the stack can be enhanced by heating the air in the stack by solar energy, but the air must be heated from the bottom, not just as it leaves the stack, since it is the height of the warm column of air that drives the flow, figure 9. These elements are often referred to as solar chimneys; they may have problems in cold and sunless weather when the poorly insulated glass, cools the air and generates reverse flow. Because they need to be heated for the height of the column, they cannot be located in the centre of a deep plan building, unless the solar part protrudes a long way above the roof level.

▼ **Figure 10**
Night ventilation can reduce daytime temperatures by as much as 4˚K. However it only works where there is thermal mass available internally, and high rates of nighttime ventilation.



Night ventilation
The thermal mass of buildings can be used to soak up heat gains in the day, thus reducing peak temperatures, figure 10. But the heat has to be taken out of the building at some time. This is done most efficiently by maximising the ventilation rate at night. This technique can be so successful that the daytime temperatures in the building can be considerably lower than the peak outdoor temperature (up to 3 or 4ºC). In this case it pays also to reduce the ventilation rate in the day when (and if) the outdoor temperature is above the indoor temperature.

In night ventilation strategies the following should be considered:

- Provide openings which can be left open at night, but maintain security.
- Consider how large volumes of air will flow through the building, from room to room and floor to floor.

- Thermal mass is only effective if it is coupled to the occupied space, and to the night ventilating air. Lightweight internal finishes to heavyweight buildings makes them behave as lightweight buildings – the benefit is lost. Consider exposing massive elements if covered – e.g. suspended ceilings.
- In lightweight buildings, consider adding thermal mass (e.g. new partitioning) or even phase change materials (see Tech Mon 1).

Note that refurbishment may involve the application of insulation internally to solid masonry walls. This will significantly reduce accessible thermal mass. If this has to take place, ensure that internal partitions, and if possible floor slabs, are heavyweight and not isolated.

Hybrid systems

Natural and mechanical ventilation need not be mutually exclusive. Obviously, certain spaces in a naturally ventilated building can be mechanically ventilated if they are internal or have high ventilation demands, such as toilets or kitchens.

Much fan power is wasted ventilating unoccupied or lightly occupied spaces. Demand control is where fans are only run when the air quality (as detected by CO_2 levels) is deemed unsatisfactory. CO_2 detecting controls are now cheap and reliable. Fans can be used to supplement natural air-flow in ducts and chimneys when the wind and buoyancy forces are too weak. This function also needs to be activated by a control system which detects a reduction of air-flow or a fall in air quality.

The arguments for and against hybrid systems are:

For – Passive systems would have to be oversized in order to cope with 'worst case scenarios – by accepting mechanical intervention, with appropriate controls, an optimum balance between energy efficiency and comfort can be struck.

Against – Necessitates the capital expense and maintenance of two systems

One technique where a small amount of mechanical power can be used with great effect is the use of ceiling or desk fans. These devices provide air movement but not fresh air. The air-movement can make a reduction in the effective temperature, i.e. as perceived by the occupants, of as much as 3°C. Although they improve thermal comfort, they do not improve air quality.

Summary conclusions

Natural ventilation can achieve high level of comfort, However, it requires considerable co-operation from the occupants and management, so it is important that both understand the principles and are aware of the problems.

Natural ventilation cannot provide such consistent and uniform conditions as mechanical systems. However, the positive side of this, is that there is growing evidence that variation in indoor conditions is tolerated and even enjoyed, provided the occupants are in control (see monograph "Adaptive thermal comfort standards and controls"). Other factors which have to be considered include the outdoor conditions, for example natural ventilation may be impractical in very noisy or polluted environments. However, it is observed that even in noisy urban environments, people will open windows, trading thermal comfort for traffic noise.

It is important to consider the effect of the whole package of refurbishment measures since they interact with on and other. For example, a building where air-conditioning had been identified as the only solution to comfort problems, might provide a satisfactory environment with natural ventilation, provided measures such as shading and fabric improvement were also carried out.

Hybrid systems should be considered where mechanical systems act as 'failsafe', activated only when air quality or thermal comfort falls below an acceptable level.

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