THE PRACTICALITIES

OF

NATURAL VENTILATION

FROM

CONCEPT TO CONSTRUCTION

Tuesday 10 December 1996

in

The Building Services Engineering Centre

THE PRACTICALITIES OF NATURAL VENTILATION — FROM CONCEPT TO CONSTRUCTION

Tuesday 10 December 1996
at
the Building Services Engineering Centre, London

PROGRAMME

12.45 ***Registration and sandwich lunch***

13.30 **Opening comments by Chairman** — **Dr Earle Perera**
Building Research Establishment

Part I

Descriptive outline of Natural Ventilation Mechanism — **Dr Martin Liddament**
Head of Air Infiltration & Ventilation Centre
University of Warwick Science Park, Coventry

14.15 **Addressing Air Tightness — The Illusion & Reality** — **Mr Doug Lawson**
Managing Director, Building Sciences Ltd, Surbiton, Surrey

15.00 ***Mid afternoon refreshments***

Part II

Natural Ventilation Components — Present & Future — **Mr Peter Willan**
Chairman & Managing Director
Willan Building Services, Sale, Cheshire

16.30 **Discussion Forum**

17.00 **Close**

Part I

DESCRIPTIVE OUTLINE OF NATURAL VENTILATION MECHANISMS
by

Dr Martin Liddament
Air Infiltration & Ventilation Centre, University of Warwick Science Park.

1. Introduction - Natural Ventilation Techniques

Many buildings throughout the world are 'naturally' ventilated. Often this means little more than arbitrarily satisfying needs by a combination of uncontrolled air infiltration and window opening. Nowadays, ventilation needs can be very demanding and hence modern natural systems seek to provide much improved reliability by the careful sizing and positioning of air inlets and outlets. By careful design, it has been shown that natural ventilation can provide a satisfactory environment in even quite complex buildings.

2. Applications

Natural ventilation is most suited to buildings located in mild to moderate climates, away from inner city locations. Typical applications include:

- low rise dwellings;
- small to medium size offices;
- schools;
- recreational buildings;
- public buildings;
- warehouses;
- light industrial premises.

Specialised natural systems may be applicable to a wider range of climatic conditions and buildings including large commercial buildings.

3. Fundamental Design Criteria and Mechanisms

Natural ventilation is non-uniform with the rate of air flow responding to variations in temperature and wind velocity. Despite this variability of driving force, it is nevertheless possible for satisfactory design solutions to be developed. Key constructional aspects of any natural ventilation design include:

3.1 Driving Mechanisms

Natural ventilation is driven by wind and thermally (stack) generated pressures. Designing for natural ventilation is concerned with harnessing these forces by the careful sizing and positioning of openings.

- *Wind Pressure:* Wind striking a rectangular shaped building induces a positive pressure on the windward face and negative pressures on opposing faces and in the wake region of the side faces. This causes air to enter opening and pass through the building from the high pressure windward areas to the low pressure downwind. Normally very simplistic assumptions must be made about the wind pressure distribution. If more detail is required, such as the pressure distribution acting on complex structures, it may be necessary to resort to wind tunnel methods.

- *Stack Pressure:* Stack effect is developed as a result of differences in air temperature, and hence air density, between the inside and outside of the building. This produces an imbalance in the pressure gradient of the internal and external air masses which results in a vertical pressure difference. When the inside air temperature is greater than the outside air temperature, air enters through openings in the lower part of the building and escapes through openings at a higher level. The flow direction is reversed when the inside air temperature is lower than the outside air temperature. Calculation of stack pressure is based on the temperature difference between the two air masses and the vertical spacing between openings.

- *Complementary and Combined Use of Wind and Stack Pressures:* Systems need to be designed to ensure that the effects of wind and stack action complement rather than oppose each other. This is accomplished by understanding exploiting the pressure distribution developed by each mechanism and locating openings to best advantage. Passive stack and atria designs seek to accomplish this objective. Alternatively, the driving forces may be modified by careful inlet design or by providing a shelter belt to reduce wind effect. Ventilation rate at low wind speeds is dominated by the stack effect. As the wind speed increases, wind dominated ventilation takes over. At certain wind speeds, wind pressure may act in complete opposition to stack forces at specific openings, resulting in a small drop in the total ventilation rate. The application of 'network' calculation techniques, combined with representative weather data for the building locality, enables the natural ventilation performance of individual design solutions to be evaluated.

- *No apparent driving force:* It is theoretically possible for there to be no apparent natural driving forced although, in practice this is unlikely. In Winter, stack pressure is developed by indoor space heating, while in Summer, ever present turbulence, created by marginal differential air temperatures, will provide continuous air flow through open windows.

3.2 Building Airtightness

The building structure should be relatively air tight so that ventilation is confined to air flow through intentionally provided openings only. The philosophy is to 'build tight and ventilate right'.

3.3 The Space as an Air Quality Reservoir

For any given pollutant emission rate, the time it takes for the pollutant concentration to reach a given threshold concentration is dependent on the volume of the enclosed space. The enclosure therefore acts as an air quality reservoir in which the impact of a transient source of pollution can be initially accommodated by the enclosed air mass itself, despite the variable nature of the ventilation process. This is a key aspect of natural ventilation design since it enables good air quality to be maintained without the need for a constant rate of ventilation. Atrium ventilation systems, especially, take advantage of the reservoir effect. Other designs may incorporate high ceiling levels, but the resultant increased construction and space conditioning costs may prevent this from being a cost effective option.

3.4 Complementary Use of Wind and Stack Effect

Systems should be designed in which the effects of wind and stack action should complement rather than oppose each other. This can be accomplished by careful positioning of air inlets and outlets. Alternatively the driving forces may be modified by careful inlet design or by providing a shelter belt to reduce wind effect.

3.5 Sufficient Ventilation Openings to meet all Ventilation needs

Sufficient ventilation openings must be provided to meet all anticipated ventilation needs. The sizing of openings must take into account both need and variation in strength of driving forces.

3.6 Occupant Controls

Since the rate of ventilation is dependent on variable driving forces, provision should be made for the occupant to adjust openings to meet needs. A good design should have a combination of permanently open vents, to provide background ventilation, and controllable opening to meet transient demand.

3.7 Cross Flow vs. Single Sided Ventilation

There should be a clearly defined and unimpeded air flow path between the incoming and outgoing air streams which should pass through the zone of occupancy. This is known as 'cross flow' ventilation. Such an air flow pattern is impeded if the building is compartmentalised. Ventilation via 'single-sided' openings is still possible but relatively larger openings may be needed to secure an equivalent degree of air supply and mixing. Good air exchange is possible, for example, by window opening.

3.8 Maximum Room Depth

The maximum depth of a room from ventilation openings is often taken as 6 metres. Some research has shown that it might be possible to extend this to 10 metres.

4. Natural Ventilation Techniques

Natural ventilation techniques use combinations of the following elements:

- ***Trickle Ventilators:*** These are devices that promote the natural passage of air through a space to provide 'background' ventilation. They typically have an effective area of opening of between 4000 and 8000 mm^2. Ideally they should be tamper proof fixed openings although some incorporate manual adjustments. When used by themselves, trickle ventilators provide 'uncontrolled' ventilation. The direction and rate of air flow is a function of stack action, wind speed and wind direction. The stack effect may be enhanced by locating rows of ventilators at high and low level. This approach is often used in small industrial buildings in which low level wall ventilators are matched by roof apex openings.

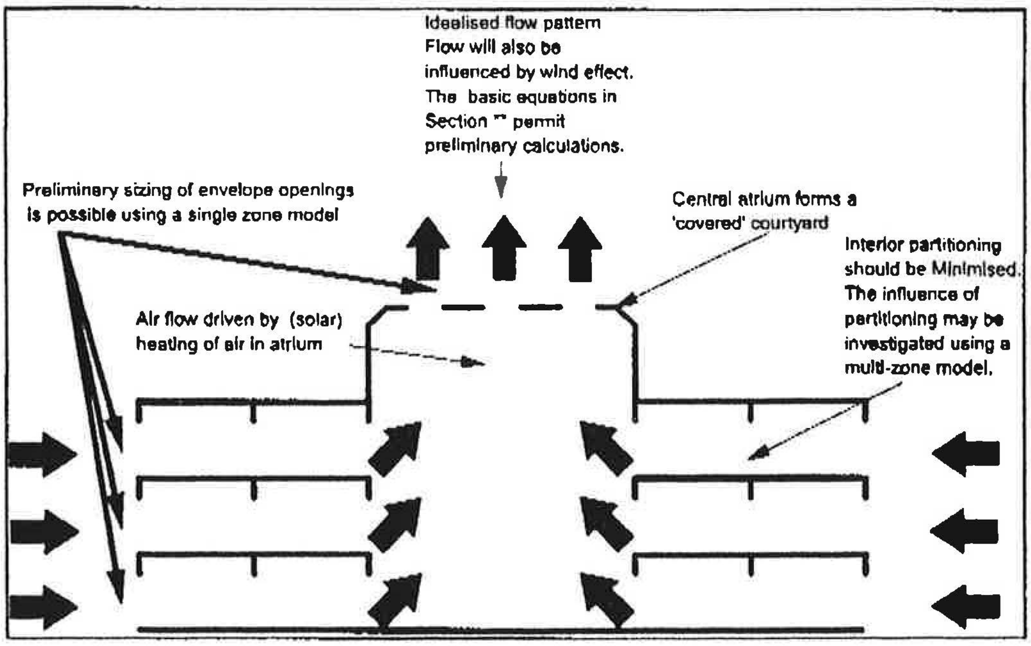
- ***Automatic Variable Area Inlets:*** Some air inlets have been designed to respond automatically to various air quality and climate parameters. *It should be noted that these inlets should not normally be used without a passive stack or mechanical extract system.* Automatic inlets are not in common use.

- ***Positioning of Trickle Ventilators and Air Inlets:*** Trickle ventilators and air inlets provide the supply air source to naturally ventilated buildings. The location of such ventilators is a critical aspect of design since they can be a source of discomfort through cold draughts. Ideally they should permit the entry and rapid mixing of outdoor air both to ensure the good air distribution and to prevent localised areas of cooling. To prevent discomfort, it is often recommended that such openings are located at a high level, i.e. above the window and possibly integrated into the window frame. Sometimes ventilators are located directly behind wall mounted heaters or even ducted directly to the heating system. This both prevents unauthorised access to the vents and enables the incoming air to be preheated before reaching the occupied zone.

- ***Openable Windows and Louvres:*** Openable windows are an essential component of natural ventilation. They permit the passage of large flows of air for purging or Summer cooling. They are also effective at providing air to single sided enclosures. Observations show that windows are popular and are used, even at moderately low outdoor temperatures. Many window designs are unsuitable for Winter operation because they provide inadequate control of opening. This results in cold draughts and high energy demand. To minimise draughts and energy waste, the extent of opening should be controllable. Vertical sash or sliding windows are able to provide air without low level draughting. Louvres and 'top hung' windows tend to provide a greater degree of flow control than large opening windows.

- ***'Passive' Stacks:*** Improved natural ventilation control is possible by incorporating passive stacks into the design. These are vertical ducts which penetrate a room or zone at ceiling level and terminate above roof level in the 'negative pressure' region. Stacks are typically used to service the 'wet' rooms of dwellings. They must not be branched and, hence, an individual stack is needed for each room. Air flow is driven through the stack by a combination of stack pressure and wind induced suction pressure. Thus the effect of stack action is reinforced by that of wind. Make-up air should be provided by trickle ventilators. Although the rate of air flow will still vary, the pattern of air flow is improved, with air predominantly entering through the air inlet and leaving through each stack. Occasional 'backdraughting' will occur when the pressure generated in the stack cannot overcome the static pressure of cold outside air sitting above it. This flow reversal, if it does occur, is normally temporary and should not present an air quality or health problem.

- ***Atria:*** An atrium is essentially a glass covered courtyard which provides an all weather space for building occupants. They are popular for buildings such as offices and shopping malls, and feature in 'passive' low energy building designs. Natural ventilation is sometimes applied by using the atrium itself as a passive stack. In this case, the atrium is normally extended above the occupied zone by several metres so that the air temperature at the apex can rise considerably, without causing discomfort at lower levels. This inflated temperature assists in developing stack flow. Initial sizing of opening can be accomplished using the simplest of calculation methods. Some form of thermal modelling will also be necessary to identify the total heat gain, while some designers may choose to use computational fluid dynamics to attempt to understand the air flow pattern within the structure.



Stack Ventilation Applied to Atrium Building

5. Robustness of Design

Natural ventilation solutions must be shown to be robust and capable of matching all design requirements for health and comfort. Therefore design analysis needs to look at the requirements for air change over the full range of local climatic conditions. For example, it will normally be necessary to identify the minimum Winter ventilation rate necessary to satisfy occupant needs and the maximum Summer ventilation rate necessary to satisfy cooling needs. Both conditions must be matched against the relevant driving forces, so that the sizes of openings under each set of conditions can be determined. The mechanisms by which openings are adjusted to satisfy need must also be determined. For example, the Winter condition may be met by fixed trickle ventilators while the Summer condition may be met by window opening.

6. Conclusions

Natural ventilation is very common and is likely to continue to dominate as the primary approach to ventilation for many small to medium sized buildings located in mid climatic areas. It is made attractive by its low cost and low maintenance needs. Natural ventilation is not normally suited to large buildings or to buildings located in extreme climatic zones. It may also be unsuitable for urban or industrial areas where noise may be intrusive and outdoor air quality may be poor. Poorly designed systems can be energy wasteful, especially if the only mechanism to provide Winter ventilation is by window opening. It is normally incumbent on the occupant to adjust ventilation openings to meet varying needs.

7. For Further Information

A more detailed account of ventilation techniques, including an extensive bibliography and discussion on design, measurement and calculation methods is presented in the AIVC Guide to Ventilation (available from the AIVC).

ADDRESSING AIR TIGHTNESS — THE ILLUSION & REALITY

by
Mr Doug Lawson
Building Sciences Ltd

A good level of envelope air tightness is critical to the achievement of effective natural ventilation. Acceptable tightness is necessary to:

- Control the accidental background air change due to fabric leakage.
- Permit ventilation air to be introduced via intentially positioned/sized openings.
- Permit occupier control of the ventilation air flow through the intentional openings.

Acceptable envelope tightness levels can be 'judged' by various means, e.g. building operational performance, an inspection by infra red scan, tracer gas decay measurements or fan pressurisation tests.

Fan pressurisation is the most common method of testing with various tightness 'standards' being applied in the UK, but all based upon measuring envelope leakage against a specification of $Xm^3/hr/m^2$ of envelope area at a specific differential pressure across the fabric. As stated the standards being applied vary with some tests based upon 50Pa differential pressure and others at 25Pa. However, referencing these all to 25Pa in order to gain a clearer impression of the range of tightness specifications being used, the applied standards vary between $3.3m^3/hr/m^2$ and $6.5m^3/hr/m^2$ of envelope area.

From prior and current fan tests undertaken it is clear that many of our building are very leaky with offices typically 2 to 4 times more leaky, and factories around five times more leaky than their North American and Swedish equivalents. In addition where tightness standards are being applied many new building are repeatedly failing fan test with some continuing in a permanently leaky condition.

A lack of acceptable envelope tightness results in excessive air leakage through the building fabric. During winter on a moderately leaky building this could result in all of the air required for ventilation arriving into the heat space via accidental leakage, whereas on a tightly constructed building this accidental infiltration could be reduced to a level representing a minor element of the air flowing through the intentional ventilating opening. Clearly if the ventilation system is to perform as planned delivering air in the intended volume and locations, then accidental leakage through the fabric must be kept to a minimum.

Our buildings have become excessively leaky partly due to changes in construction practices which include:

- More complex building geometry/detailing.
- A move away from masonry and plaster construction to a more fragmented process with many subcontract packages.
- Often no one responsible for the interface between the subcontract packages.

In spite of much evidence to the contrary there continues to be an illusion held widely across the construction industry at 'our' buildings are really quite tight and this encourages the continuation of prior practices. This illusion tends to be broken when one or more of the following occurs:

- Building of more complex geometry/detailing.
- Poorer than normal construction standards.
- Building in more exposed location.
- Building close to a pollution source.
- More demanding occupants.
- Building to a tightness specification.
- The acid Test — Fan Pressurisation.

Slides showing examples of more complex building geometry/detailing demonstrated how these issues could impact the complexity of the air barrier design. Slides showing a wide variety of typical envelope defects showed significant air leakage occurring.

The building envelope has to perform various functions including providing an efficient air barrier. To be effective an air barrier specification must address the following issues:

- Be air impermeable.
- Be continuous around the envelope.
- Have acceptable mechanical strength.
- Be readily installed.
- Be durable or accessible for maintenance.
- Can be located on hot or cold side of the assembly.

As many of our buildings seem to be very leaky how can acceptable air tightness be ensured? For new buildings, envelope design stage and construction phase reviews should be undertaken which specifically address the issues of air barrier effectiveness and continuity. A decision has to be made as to the pre hand over inspection/test requirements. This could involve either a step by step quality control process through the design and construction phases, an infra red scan/inspection or where a quantitative test is required, a fan pressurisation test. For existing buildings an envelope air leakage audit can be undertaken followed by remedial sealing works and if necessary, a final inspection/testing exercise can be carried out.

The essence of this seminar can be summarised as follows:

- Good air tightness is essential for effective ventilation.
- Good air tightness levels are readily achievable.
- A building cannot be over sealed it can only be under ventilated.
- The message is — ***Build Tight — Ventilate Right.***

THE PRACTICALITIES OF NATURAL VENTILATION — FROM CONCEPT TO CONSTRUCTION

Chairman & Speakers' Biographical Notes

Dr Earle Perera
Building Research Establishment

Principally involved in research into ventilation of non domestic buildings and wind environment around buildings. He represents the UK on the IEA Annex 5 (AIVC) steering group.

Dr Martin W Liddament
Head of Air Infiltration & Ventilation Centre
University of Warwick Science Park

Dr Liddament graduated in Applied Physics from the University of Lancaster in 1971 and received his doctorate at the University of Manchester Simon Engineering Labs in 1975. He joined the British Water Industry in 1975 and in 1980 became senior scientist at AIVC responsible for conducting a program of ventilation model validation. He recently published "A Guide to Energy Efficient Ventilation" as well as a wide range of technical notes and papers.

The AIVC is an international institution established in 1979 and funded by the Governments of 12 countries including the USA. It is currently undergoing growth by securing funding from more than 20 countries. The purpose of the Centre is to provide technical support in air infiltration and ventilation research.

Douglas Lawson
Building Sciences Ltd

After training as a Mechanical Engineer, Doug was a line manager principally in industrial companies heading up various functions including engineering, sales and marketing before general management. Doug held general management posts in the UK and North America with a major US corporation before switching careers to establish Building Sciences Ltd with the aim of improving the performance of UK building envelopes via our range of envelope consultancy services.

Doug is a member of the Natural Ventilation Group Management Committee and editor of the Group Newsletter and an occasional speaker at seminars. He has written several articles for various journals.

Peter Willan
Chairman, Managing Director, Willan Group

Joined the family business after leaving school in 1971. He founded Willan Building Services in 1980. The company specialises in natural ventilation and roofing products. During this time, he has been involved in several research projects on energy conservation.