The Applicability of Natural Ventilation

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Building Regulations Consultative Document 2009

Bad News for Natural Ventilation!

“It is likely to become more challenging to provide adequate ventilation rates using natural ventilation systems and this will give impetus to mechanical ventilation systems”.

[Image]
Building Regulations - 2006

More Bad News for Natural Ventilation!

Actively discriminates against natural ventilation as an “unintended consequence”

The Fundamental Flaw: Part L compliant air conditioned buildings can emit much more CO₂ than a notional (non compliant) NatVent Building.

![CO₂ Emission Graph]

- Best Practice 2002* (77.5) (28% Reduction)
- Notional Air Conditioned (Type 3*)
- Notional Naturally Ventilated (Type 2*)

*These data are based on the 2003 Edition of the EED Energy Consumption Guide 12 Energy use in Offices. The Notional Building Values represent those given for Type 2: naturally ventilated and Type 3: standard air conditioned Best Practice Values.

CO₂ Emission

A/C Part L
Compliant (55.8)
(28% Reduction)

Nat Vent Part L
Compliant (33.1)
(23% Reduction)

Notional
Air Conditioned
(Type 3*)

Notional
Naturally Ventilated
(Type 2*)

Royal Institution of British Architects attacks the Building Regulations as being “impenetrable and alienating for the lay person”

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2010 Building Regulations

Royal Institution of British Architects attacks the Building Regulations as being “impenetrable and alienating for the lay person”

Institutions call for more coordination of regulations

CIBSE is calling for a thorough review of the Building Regulations - 2010, to ensure that they can be read and understood with ‘user friendly guidance’

The fundamental flaw: Part L compliant air conditioned buildings can emit much more CO₂ than a notional (non compliant) NatVent Building.

Best Practice

- Best Practice
2002* (77.5)
- Notional Air Conditioned
(Type 3*)
- Notional Naturally Ventilated
(Type 2*)

Notional
Air Conditioned
(Type 3*)

Notional
Naturally Ventilated
(Type 2*)

Annual kgCO₂/m² of treated floor area
Case Studies of Mechanical Systems in Homes Show:

- **Airtightness with MV is not fail-safe**
  - 80% of the single-family houses monitored in Sweden did not meet minimum ventilation requirements;
  - A relationship between allergic symptoms and low ventilation rates has been observed (based on a medical study);

- **No Maintenance**
  - 12% systems not operating at all
  - over 50% of installations had dirty filters, cores and fresh air intakes – (subsequently shown to be a very common problem).

- **Appalling installation quality - Incorrect duct connections, lack of insulation, incorrect fans**
  - subsequently shown to be a very common problem.
  - R Lowe and D Johnson. "A Field Trial of Mechanical Ventilation with Heat recovery in Local Authority, Low Rise Housing, Final report, Centre for the Built Environment, Faculty of Health and Environment, Leeds Metropolitan University, UK. (1997)

- **Air supply ducts contaminated by moisture can be "virtual incubators for microbial pollutants such as mould and bacteria"**

The Netherlands:

Atze Boerstra and Jaap Balvers from BBA Indoor Environmental Consultancy in the Netherlands report that "There has been considerable media coverage in the Netherlands on the health effects of balanced mechanical ventilation in homes, including reports on public television linking energy efficient houses with balanced ventilation to negative health effects". They continue by reporting that numerous cases have been encountered and that "Investigation (inspection and measurement) supports the complaints and proves that the quality of the indoor environment is below standard."
“Thamesmead Ecopark – Case Study” reveals that, in this development of mixed heating and ventilation systems, energy measurements showed that the monitored dwelling fitted with MVHR had “the highest gas consumption” and that the heat recovery system “consumes more electricity than the fans” [of the other houses].

“Unable to demonstrate any effect of MVHR on overall energy consumption”

Therefore Natural Ventilation has a considerable (political) hill to climb.

However, the evidence base for mechanical systems, especially in housing, is poor.
Many UK Public Departments promote natural ventilation

The Carbon Trust: “A typical air conditioned building has double the energy cost and associated CO₂ emissions of a naturally ventilated building. It is also more likely to have increased capital and maintenance costs”.

The Commission for Architecture and the Built Environment (responsible for UK secondary school design): “Many basic issues of energy performance have been overlooked including the potential to minimise mechanical ventilation by using passive ventilation”.

The Department for Communities and Local Government: “More efficient systems and passive cooling are important options. Future Building Regulations should therefore consider a way of prioritising the reduction of energy demands through the elimination of active cooling”.

“Buildings designed with passive ventilation have improved resilience to energy supply failure and are more energy efficient than mechanically ventilated buildings. In an acute hospital up to 70% of net floor space could be entirely or partially naturally ventilated”.

Ventilation and Climate

Once acclimatised to a particular climate it can be difficult to comprehend the differing needs of other climatic zones.
Unfortunately, much of the work that passes as architecture in the tropics today are unadulterated transplants from temperate countries.

Worth encouraging naturally ventilated design… Vernacular tropical architecture shows evidence that adaptive and innovative tropical building design can still obtain fairly comfortable indoor thermal conditions.

Worth remembering that, irrespective of climate, until 100 years ago there was only natural ventilation and passive cooling.
Natural Ventilation

- Driven by the natural driving forces of wind and temperature

Natural Ventilation cannot defy the Laws of Thermodynamics

- cannot be used to heat a space although can take advantage of “free heat”
- cannot be used to cool a space although it is possible to average out diurnal variations

Natural Ventilation provides fresh air
Natural Ventilation Mechanisms

- Cross Flow Wind
- Wind Tower
- Badgir (Wind Catcher)
- Stack Driven Ventilation
- Stack (Flue)
- Stack (Atrium)

Pressure of air increases closer to the ground due to the extra amount of air above.

The pressure gradient of air increases indoors because warmer air is less dense.

'Neutral' Pressure Plane

Air Pressure

Stack Height

The pressure between openings is given by $A = B$
Other Issues Passive Cooling – combining ventilation with thermal mass

![Graph showing temperature variation over time with external and internal temperatures marked]

Other Issues - Ventilation Rate vs Metabolic CO₂ Concentration

![Graph showing relationship between ventilation rate and CO₂ concentration]

- Minimum Ventilation for Offices 10 L/s.p 
  - 900 - 1000 ppm of CO₂

- Urban: 500 ppm
- Rural: 380 ppm
- Better Air Quality: CO₂ concentration range
- Poorer Air Quality: CO₂ concentration range

Typical control range
Some Case Studies

The principle purpose of the selected case studies is to highlight how concepts have been incorporated into both new and retrofitted buildings. Also some discussion focuses on the various problems experienced.

Case Studies buildings are taken from:

- The European NatVent study;
- Studies of the International Energy Agency’s (IEA) Implementing Agreement on Energy Conservation in Buildings and Community Systems;
- Studies reported by the CIBSE Natural Ventilation Group;
- Recent studies reported in the International Journal of Ventilation.

The number of case studies selected represent only a fraction of those included in the original investigations. Much useful additional material can be obtained by referring back to these studies.
This European funded study was carried out by a consortium of nine partners, across seven countries - Great Britain, Belgium, Denmark, the Netherlands, Sweden, Norway and Switzerland.

The main objective was to identify methods to reduce primary energy consumption in buildings by overcoming barriers which prevent the uptake of natural ventilation for office-type buildings.

The intended climatic range covered countries with low winter temperatures and moderate summer temperatures, particularly where summer overheating from solar and internal gains could be significantly reduced by good natural ventilation.

A key component of this study was to analyse the performance of 19 case study buildings.
The Probe Building of the Belgium Building Research Institute, Limlette, Belgium (continued)

Features – night cooling, thermal mass, ventilation louvres, solar shading, low internal heat gain, daylighting, demand control.

Results

• Occupants reported an important improvement to indoor comfort;
• Peak indoor summer daytime temperatures could be maintained at 4 K below peak outdoor temperature;
• During the monitoring period, the outdoor temperature reached 31°C while indoor temperatures peaked at 26-27 °C.

Enschede Tax Office, Enschede, Netherlands

Results

• Offices in this building accomplished temperature reductions of as much as 4 K during hot weather;
• At a peak outdoor temperature of 31°C inside temperatures varied from between 26°C to 28°C;
• Early problems related to commissioning and adjustment of the system to maximise summer cooling potential.

Features:
- Primarily naturally ventilated;
- High level, self regulating constant flow fresh air vents;
- Night cooling ventilation at 3.5 - 4 h⁻¹;
- Daylighting using light shelves;
- High mass construction;
- External shading;
- Low internal heat gains.
Design features include:

- Three storey, 1650 m² floor area, new building;
- Rural site, no external pollution or noise;
- Mixed mode (natural with fan assisted ventilation);
- Low level inlets to each zone in which supply air passes over ribbed heating pipes;
- North facing glazing to avoid high solar gain;
- Exposed high thermal mass;
- Open central stair way for air exhaust (with high level fan when needed);
- Demand Control CO₂;
- Night cooling air change rate of 3 h⁻¹;
- Rain wind and temp protection of vent openings.

Observations

- Building air quality was perceived to be good;
- For more than 95% of the monitoring period CO₂ concentration was less than 460 ppm above ambient (approximately 800 ppm total);
- Fan energy consumption was very low at 1.7 kWh/m².year.

Example Building: Grove House
Thames Valley University, UK

Features:
• Retrofit building in urban area;
• Lecture theatre, laboratories and offices;
• Need to dissipate heat from computer equipment;
• Natural ventilation stack ventilation with mixed mode support;
• Stairwell used as extract route;
• Extract unit placed on roof incorporating a low energy fan;
• Night cooling and day ventilation provided by large, above window air inlets;
• Fresh air enters above a suspended ceiling and is in direct contact with thermal mass;
• Air also discharges through ceiling diffusers;
• System controlled by temperature sensors and timers;
• Air from rooms discharges into stairwell through high level transfer grilles that incorporate fire dampers.

Performance:
This building was found to operate very satisfactorily without the need for mechanical cooling and achieved an energy efficiency accreditation.

Other Case Studies (from CIBSE and IJV)

1 Coventry University Library
(Frederick Lanchester Building)

Key Features:
• University library opened in 2000;
• City centre location;
• Deep plan (50mx50m) building;
• Natural ventilation (no hybrid fans);
• Thermal mass for night cooling;
• Daylighting and solar shading;
• Combined heat and power;
• Under building air supply plenum ducting air to supply atria;
• Perimeter ventilation exhaust stacks combined with central exhaust atrium;
• Zonal control system based on CO2 and temperature monitoring;
• Air conditioning only in computer suite.

Occupant Reactions:
Simons et al (2003) report on occupant comfort and noise monitoring of this building and conclude that it has proved to be very popular with its users. Some noise propagation through the library is reported.
Natural Ventilation and Climate – Examples for all Climates

Case Studies Presented in Tokyo December 2005

Montreal, Canada
Tokyo, Japan
Annapolis, USA
Tuborg Havn, Denmark

For all climates there is often potential for maximising the use of natural ventilation and thus reducing periods of mechanical cooling.

Design and Operational Problems

The case studies presented above represented buildings that largely performed as designed. In reviewing the various case studies, however, some buildings problem buildings were found. It is not intended to specifically identify these buildings but, instead, to outline the types of problems that occurred since important lessons can be learnt from these.
Overheating occurred in some buildings. Reasons included:

- Improper estimation of heat gains;
- Inadequate cooling measures including insufficient contact with thermal mass and inadequate solar shielding;
- Not constructing the building as designed. In one building that overheated a simple assisting fan, designed to overcome low summer airflow rates, was left out of the construction as a cost saving measure;
- Winter heating system not being turned off resulting in space heating operating during night cooling periods (not uncommon);
- Failure of components or systems.

**Problem Buildings - Overheating**

**Typical result - thermal retention**

**Reasons:**

- Night cooling ventilation has not been implemented (low ventilation rate);
- Thermal mass and insulation is retaining heat as if for winter performance.
Various air quality problems were reported including:

- Ingress of vehicle emissions;
- Odours;
- Noise from outdoors or transmitted through the building;
- Cold draughts through incorrect operation of system;
- Cold draughts through inadequate pre-heating.

Reasons for problems included:

- Air intakes too close to main roads;
- Courtyard intake zone turned into a car park and loading zone;
- Failure to pre-heat supply air.
Design and Operational Problems

3 - Failure of Components and Controls

Reported problems included:

• The incorrect operation of actuators which resulted vents not correctly opening and closing, incomplete closure, distortion and eventual fracturing of vents and windows;
• Failure of motorised dampers which eventually seized in open and closed positions. While such dampers could easily have been placed within occupant reach they were instead located in an inaccessible area and eventually abandoned;
• Structural failure of components resulting from wind damage;
• Inadequate provision for maintenance;
• Poor operational instructions.

Conclusions - Problems to Avoid

- Politically, natural ventilation is experiencing a high degree of negative discrimination;
- Outside the legislative structure there is still much demand for natural ventilation;
- Well designed case studies are shown to be effective;
- Problems are invariably associated with inadequate design, implementation and/or maintenance. In reviewing a wide variety of case studies major problems included:
  • Over heating as a result of inadequate assessment or treatment of heat loads and poor interaction with thermal mass;
  • Operational faults – failure of controls, actuators and dampers;
  • Inaccessible components;
  • Conflicting control strategies such as winter heating being left on in summer;
  • Outdoor air quality problems, including the ingress of fumes and noise;
  • Structural failures – component breakages and serious wind damage.