Naturally ventilating UK non-domestic buildings: current status and future policy

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Summary

Increased concern over the adverse environmental impact of energy use has encouraged the design and construction of energy efficient buildings, and many are suited to natural ventilation. In the temperate UK climate, naturally ventilated buildings can provide year round comfort, with good user control, at minimum capital cost and with negligible maintenance.

The principle of good ventilation design is to `build tight - ventilate right'. That is, to minimise uncontrolled (and, usually unwanted) infiltration by making the building envelope airtight, while providing adequate `fresh' air ventilation in a controlled manner. It is necessary to emphasise that a building cannot be `too tight' - but it can be underventilated.

This paper shows that there is considerable scope for making UK buildings tighter and indicates the level of benefits that will accrue. UK activity in this area is identified, including proposed statutory control in the form of revised Building Regulations for England and Wales, which will address issues of tightness for the first time.

Information is available on ventilation requirements necessary to satisfy safety and health criteria. However, criteria relating to comfort, especially those associated with odour, metabolic CO_2, and summer overheating are still being investigated. This paper sets out current thinking in this area, including policies relating to minimising effects of tobacco smoking in public and commercial buildings.

The paper concludes by identifying currently available UK design guidance on natural ventilation. Various instruments which are underpinning these changes, such as revisions to the Building Regulations for England and Wales, codes and standards, professional guidance and support for policy-interests are identified.

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Introduction

At the 1992 Earth Summit in Rio de Janeiro, the UK Government committed itself to limiting emissions of the main greenhouse gas - carbon dioxide (CO_2) - by signing the Climate Change Convention. Buildings-related emissions, as a by-product of energy consumption, contribute about half (over 260 million tonnes) of the UK's release of CO_2. Of this, nearly 90 million tonnes can be ascribed to usage in commercial and public buildings corresponding to a delivered energy consumption of 812 PJ [1].

Natural ventilation is firmly on the UK design agenda because of the potential impact that mechanically serviced buildings can have on environmental issues such as global warming (through emission of CO_2) and ozone depletion (through the use of CFCs and HCFCs). Natural ventilation also offers the potential bonus of providing greater occupant control and avoids the perceived health risks associated with some air conditioned buildings. As a result of these concerns, there are signs that, increasingly, UK clients and developers are seeking naturally ventilated solutions to building design.

Good design is based on the principle that adequate ventilation is essential for the health, safety and comfort of building occupants, but that excessive ventilation leads to energy waste and sometimes to discomfort. In a naturally ventilated building, air enters a building either by design (e.g. openable windows) or adventitiously from uncontrolled leakage (infiltration) through cracks and gaps in the building fabric.

The aim of good design is therefore to `build tight - ventilate right'. That is, to minimise uncontrolled (and, usually, unwanted) infiltration by making the building envelope airtight while providing the required ventilation with `fresh' air in a controlled manner. It should be emphasised that a building cannot be too tight - but it can be under-ventilated. For an overall successful natural ventilation strategy, the three issues of:

- Building tightness;
- Good ventilation for occupants;
- Natural ventilation design;

have to be considered together in an integrated manner.

Minimising infiltration

Field measurements show that there is considerable scope for making UK buildings tighter [2]. The average UK office building is twice as leaky as an average North American or Swedish. Buildings where staff dissatisfaction has been strongly expressed, and where internal areas are either too hot or too cold (depending on the outside air temperature) have been found to be four times as leaky.

Studies [3,4] have shown that infiltration in a (medium-sized) office with a leaky envelope can be three times that of an equivalent building with a tighter envelope. In terms of space-heating requirements during the heating season, this infiltration represents a loss of about 220 GJ (third of total) compared with 70 GJ (seventh of total) for the tight building.

Approximately three-quarters of the air leakage may be through background hidden paths (Fig 2) rather than through identifiable gaps and cracks in the envelope. Some benefits can be obtained by tightening existing buildings, but often post-constructional remedial measures may have only a minimal effect on an already leaky building. It is therefore more effective to design and construct tighter buildings than to carry out post-construction tightening.

The revised 1995 Edition of Approved Document Part L (Conservation of Fuel and Power) [5] of the Building Regulations for England and Wales contains new provisions for reducing air leakage at windows and doors and through the building fabric. To support this, BRE has produced a report [6] to give guidance on methods of reducing air infiltration in large, complex buildings like offices.

Unlike countries such as Canada, Netherlands and Sweden, the UK has no mandatory requirements for post-construction compliance testing. However, there are indications that some elements of the UK industry are setting voluntary standards as part of the commissioning process before `hand-over'. The simplest form of standard is that for a `tight' building, the whole-building leakage should not exceed 5 m^3/h (per m^2 of permeable envelope area) for an imposed pressure differential of 25 Pa across the envelope.

Good constructional practice, emphasised in the BRE guidance document [6], is the key to a tighter building. In the UK, there are good examples of tight buildings constructed according to these principles; eg. the purpose-built BRE Low Energy Office [7] and the low-energy housing development in Orkney [8].

Ventilation requirements

With tighter buildings, greater attention has to be paid to providing adequate ventilation and a correct balance has to be struck with energy efficiency. To do this, it is necessary to identify the role played by ventilation with respect to the following criteria:

- Safety;
- Health;
- Comfort.

Associated with each is an energy cost, either for space heating in the winter or, in certain instances, for cooling in the summer. The basis of good design is to identify the requirements that need to be satisfied, and to provide the necessary `fresh' air ventilation in an appropriate and controlled manner, i.e. in an optimum manner.

Safety criteria relate mainly to eliminating or minimising the risk of explosion resulting from airborne contaminants. The risk levels are set by the higher and lower explosive limits; values for gases and vapours are published by the UK Fire Protection Association when such guidance is necessary.

Ventilation necessary to satisfy health criteria is mainly set by the requirements for:
- Human respiration; and
- Dilution and removal of contaminants generated within the occupied space.

Common pollutants generated within buildings can include the naturally occurring gases (eg. CO_2, ozone, water vapour, methane), products of combustion (eg. carbon monoxide, oxides of nitrogen and sulphur), volatile organic compounds (eg. formaldehyde) and particulates and fibres. Within this, environmental tobacco smoke (ETS) could be considered another pollutant.

An over-riding principle in 'ventilating right' is that ventilation should be for people - not for the building. A common misconception is that dilution ventilation is the only way to remove harmful contaminants from within the occupied space. The UK Committee on Substances Hazardous to Health (COSHH) Regulations lists [9] the following methods (in order of preference) to ensure maintenance of good indoor air quality:
- Eliminate the substance;
- Substitute the substance for another less hazardous;
- Enclose the process;
- Partially enclose the process and provide local extract ventilation;
- Provide general (dilution) ventilation; and
- Provide personal protection.

In the office environment, generation of internal pollution should either be avoided (eg. low-emitting furnishing and carpeting) or controlled locally (eg. by local extract ventilation near photocopying machines). If this strategy is carried out, ventilation through fresh air is then only needed to:
- Provide sufficient oxygen for breathing;
- Dilute body odours to acceptable levels; and
- Dilute to acceptable levels the concentration of CO_2 produced by occupants and combustion.

Consequently, the following fresh air levels (per person) of ventilation are required:
- 0.3 l/s as the minimum necessary to provide oxygen for life;
- 5 l/s to satisfy the current CIBSE (Chartered Institution of Building Services Engineers) recommended minimum ventilation rate;
- 8 l/s as identified in the new 1995 edition of Building Regulations Approved Document (AD) Part F (Ventilation) for England and Wales [10] provision for 'rapid' ventilation (ie. to rapidly dilute when necessary, pollutants produced in habitable rooms); and
- 16 l/s in the same Regulation's provision for rooms designed for 'light' smoking.

Depending on the proportion of occupants smoking, ventilation requirements can not only be doubled, but can be quadrupled. A no-smoking policy or smoking in a restricted zone (ventilated separately) may be appropriate in these instances. The UK government's Code of Practice on smoking in public place [11] contains suggestions on ventilating smoking areas and rooms.

Design for natural ventilation
Natural ventilation is the movement of air through a building driven by wind and buoyancy induced pressures. Wind-induced pressures on a building depends on wind direction, itsspeed and the shape of the building and wind speed; they are also affected by the surrounding built/natural environment. Air density differences between inside and outside air (caused by air temperatures) induce buoyancy forces. These independent forces interact to produce the ventilation air flows.

Some simplified guidance on designing for natural ventilation is given in the revised AD Part F. This provides guidance on the use of permanent background ventilators with an openable area of 400 mm2 per m^2 (of floor area) to meet occupant health requirements (of 5 l/s per person), usually in winter. Similarly, guidance is given on the sizing of windows - the most obvious controllable opening for natural ventilation, especially in summer. The recommendation is for an openable area of at least 1/20th of the floor area for 'rapid' ventilation.

Until now, Building Regulations only dealt with provision for ventilation in domestic buildings. The revised AD Part F now addresses ventilation in non-domestic buildings as well. As a result, and because there was no authoritative guidance on providing natural ventilation in non-domestic buildings, BRE joined with the CIBSE Natural Ventilation Group to produce a new BRE digest [12] on 'Natural Ventilation in non-domestic building'. The digest is the precursor of a more detailed and comprehensive joint CIBSE/BRECSU (Building Research Energy Conservation Support Unit) Applications Manual to be published next year. These two guidance documents are intended to make existing knowledge more widely available.

Research is under way in the UK to address many of the technical issues that currently limit the use of natural ventilation in buildings. In particular, the Department of the Environment's Construction Sponsorship Directorate, in collaboration with BRE, has launched the Energy-Related Environmental Issues (EnREI) research programme to address a range of key issues in the design and management of non-domestic buildings and their services. It includes some 20 different research projects such as:
• Energy-efficient ventilation of large buildings;
• Design and control of night cooling; and
• Energy-targeting strategies for non-domestic buildings, with many of them in collaboration with industry.

An important aim of the UK research programme is to ensure that all the findings and new technologies are absorbed into practice as soon as possible. This is done in a variety of ways:
• Technical input into revisions of the Building Regulations, especially into Approved Document Part F (Ventilation) and Part L (Conservation of Fuel and Power);
• Influence on the developments of national and international codes and standards (eg. CEN and British Standards);
• Input into consensus professional guidance such as CIBSE Guides and Codes; and
• Dissemination via technical authorities of national standing; eg. through BRE Reports and Digests and Energy Efficiency Office Best Practice Guides.

Dissemination through articles in technical and professional journals,seminars and demonstration projects for:
• developers of new buildings;
• owners of existing buildings;
• their professional advisers;
• property agents and managers;

• helping market mechanisms to bring about improved environmental performance; eg. through initiatives such as the BRE Environmental Assessment Method (BREEAM) for assessing the environmental quality of buildings; and
• providing input to ENBRI (European Network of Building Research Institutions) and CIB (Construction du Batiment Internationale) initiatives on environmental issues.

Conclusions

Ventilation is of fundamental importance in securing a healthy environment within buildings. However, ventilation air must often be conditioned by space heating or cooling. This is an energy intensive process which is estimated to account for between a third and a half of all energy consumed in buildings. Excessive or uncontrolled ventilation, therefore, can be a major contribution to general global pollution.

This paper has emphasised that a strategy of designing for natural ventilation needs to go hand-in-hand with that of 'build tight - ventilate right'. The issue of providing ventilation for occupants rather than for buildings was emphasised.

Building design must be appropriate and sympathetic to the client's needs. Good design techniques and practice are essential key factors to a wide and successful uptake of natural ventilation buildings. It is therefore essential that an overall strategy be developed to ensure that the appropriate research is targeted and disseminated within various instruments which underpin this uptake. This includes legislation, codes and standards, professional guidance as well as good-practice initiatives providing the 'pull' (through high-profile energy-efficient and environmentally-friendly buildings) to complement any statutory 'push'.

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Fig 1

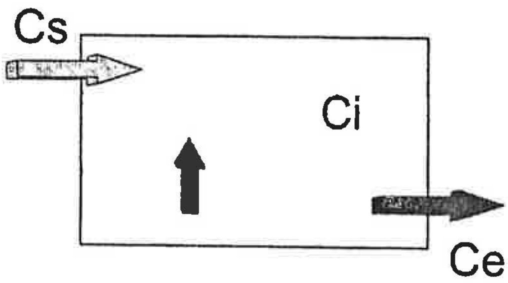
Design criteria for the indoor environment
Thermal state of the body as a whole

PPD (percentage population dissatisfied

category		PPD
	A	< 6 %
	B	< 10 %
	C	< 15 %

Fig 2

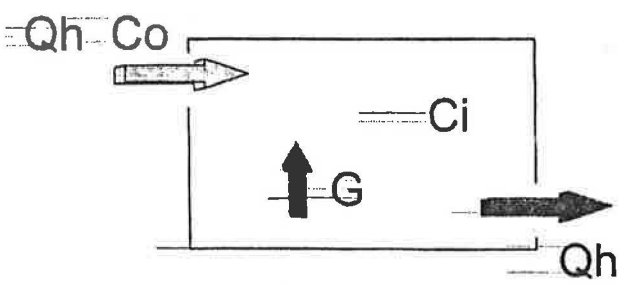
Ventilation effectiveness



$$Ev = \{(Ce - Cs) / (Ci - Cs)\}$$

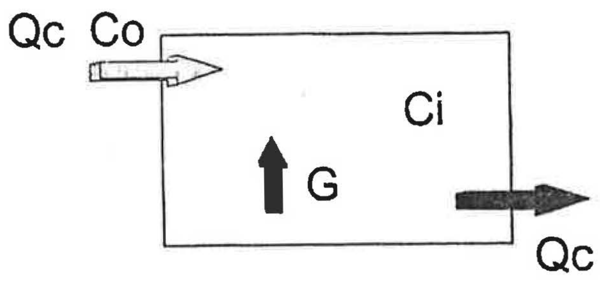
Fig 3

Required ventilation rate - health



$$Qh = G / [(Ci - Co) Ev]$$

Fig 4 Required ventilation rate - comfort



$$Qc = 10\, G / [(Ci - Co)\, Ev]$$

Fig 5 Design criteria for the indoor environment

Landscaped office

category		ventilation rate l/s/m.sq	sound pressure dB(A)
	A	1.7	35
	B	1.2	40
	C	0.7	45

Fig 6 Required ventilation rate per occupant - l/s

	% smokers			
category	0	20	40	100
A	10	20	30	60
B	7	14	21	42
C	4	8	12	24

Fig 7

Design criteria for the indoor environment

Landscaped office

mean air velocity (m/s)

category		summer	winter
	A	0.18	0.15
category	B	0.22	0.18
	C	0.25	0.21

Fig 8

Design criteria for the indoor environment

Landscaped office

operative temperature

category		summer	winter
	A	24.5+/-0.5	22.0+/-1.0
category	B	24.5+/-1.5	22.0+/-2.0
	C	24.5+/-2.5	22.0+/-3.0