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Air Infiltration and Ventilation Centre

Trends in the building ventilation market in England and drivers for change

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1 Introduction

This paper presents recent changes in building regulations affecting ventilation in England[1] . Regulations are the main drivers for change and have influenced the ventilation market. The paper addresses issues of IAQ, energy and air-tightness within the national regulations. It also presents case-studies from the school and office sector as indicators of current examples of successful materialised and monitored buildings.

In England and Wales, the Building Regulations underpin most of mandatory changes in the design and major refurbishment of buildings. The latest regulations were introduced in 2006 to take into account EPBD requirements. Mainly two parts of the regulations will be discussed here, Part F which deals with 'Means of ventilation' and Part L which deals with 'Conservation of Fuel and Power'.

[1] The Building Regulations in the UK are formulated in three sets, one for England and Wales, one for Scotland and one for Northern Ireland. There are many similarities in the Regulations but also differences to reflect regional references in construction methods and climate. When this document refers to Building Regulations it means the guidance within the Approved Documents (AD).

2 National trends in IAQ requirements and market characteristics

2.1 Ventilation building regulations

Part F of Building Regulations mainly deals with IAQ related ventilation requirements in buildings. Two major revisions were introduced in the last years; first in 1995 (amended in 2000) and the latest in April 2006. Both editions classify the buildings into dwellings and non-domestic buildings but the 2006 regulations introduce a separate section on *existing buildings*. Most importantly, 'it focuses on *performance based guidance* which suggests to the designer what levels of ventilation would be sufficient rather than how it should be achieved'. Therefore the use of innovative products and solutions is facilitated through the regulations which also include performance based criteria for acceptable levels of moisture and pollutants. *Control* of ventilation and types of controls are also included. Two new terms together with guidance are introduced: the *equivalent area* for ventilators and *ventilation effectiveness*.

In terms of energy conservation requirements and the EPBD, the ventilation regulations state that ‘ventilation also provides a means to *control thermal comfort* and this, along with other methods, is considered in Part L of the building regulations’. It also refers to ‘*purge ventilation*’ which ‘also can be used to improve thermal comfort and/or overheating of buildings in the summer’ again with a reference to Part L of the Building Regulations. These will be discussed in section 3.

Building air tightness and testing is specifically addressed within the 2006 ventilation regulations. The document refers to ‘a reasonable high level of air tightness (air permeability) which means a higher level than the target level recommended under Part L because all new buildings are expected to better the target value to some degree’. The regulations refer to the value of 3-4 m^3/hour per square metre of envelope area at 50 Pa pressure difference as the expected air permeability of the most airtight domestic and non-domestic buildings using normal construction methods. Hence, this is the air tightness value that the ventilation provision recommendations for IAQ are based on. Air tightness requirements and trends in the UK will be discussed in section 4.

2.2 Dwellings

Two methods for achieving ventilation requirements are outlined:

- Providing specific ventilation rates – these are whole building ventilation rates based on the number of bedrooms in the dwelling and ranging from 13 l/s for 1 bedroom to 29 l/s for 5 bedrooms. In addition extract ventilation is required in bathrooms, kitchens and utility rooms with flow rates depending on intermittent (30, 30, 15 l/s in kitchen, utility, bathroom) or continuous (13, 8, 8 l/s in kitchen, utility, bathroom), use of fans.
- Installing one of the four systems outlined; (a) background ventilators and intermittent extract fans, (b) passive stack, (c) continuous mechanical extract, and (d) continuous mechanical supply and extract with heat recovery. In addition, guidance on purge ventilation, suitable ventilator locations, and appropriate ventilation controls and performance test methods are provided.
- Installing other ventilation systems which satisfy the performance based criteria.

2.3 Non-residential

The guidance for non-domestic buildings focuses on office buildings and car parks. Specific mention is also made to historic buildings. Other building types are addressed by referring to appropriate standards.

The total fresh air supply rate for office buildings (no smoking and no significant pollutant sources) is 10 l/s per person. This can be achieved by natural ventilation of rooms and reference is made to (CIBSE, 2005a), mechanical ventilation or alternative approaches and reference is made to (CIBSE, 2005a, 2000, 2006 and 2005). It can also be provided by other ventilation systems provided that they meet specified moisture and air quality criteria (performance based ventilation).

3 National trends in energy requirements and market characteristics

Amendments to improve energy efficiency standards have been made in 1990, 1995, 2002 and 2005 with significant overall impact. Building Regulations related to energy consumption have been updated in 2006 and they are divided into four categories reflecting the specialization in the construction market: new and existing dwellings, new and existing buildings other than dwellings. With the 2006 amendment to the regulations, the standards will have been cumulatively raised significantly (compared to prior 1990 regulations), for example for new dwellings by some 70%, (ODPM, 2006).

In the new regulations there is only one approach to show compliance with energy efficiency requirements (thus the elemental and target U-value methods are not included). This approach includes five criteria:

1. The annual CO_2 emission rate as calculated by approved methodologies should not exceed a target limit. For dwellings the approved methodologies are the Standard

Assessment Procedure for the Energy Rating of Dwellings (SAP 2005) and approved software applications of SAP 2005. For non residential buildings the approved methodologies are; the Government's Simplified Building Energy Model (SBEM, 2006), approved software interfaces to SBEM and approved Dynamic Simulation Model (DSM) software packages (DCLG, 2007).
2. Building fabric and services performance are with reasonable limits.
3. Solar shading and other measures to limit summer overheating are reasonable. Specific mention is made to non air conditioned non residential buildings which should not cause high internal temperatures in the summer as a result of excessive solar gains.
4. Fabric insulation and air tightness as built are as intended in design.
5. Satisfactory information must be provided enabling occupiers to achieve energy efficiency in use.

Two terms are used to describe the energy performance; BER is the Building CO_2 Emission Rate and TER is the minimum (Target) energy performance, both expressed in mass of CO_2 emitted per year per square metre of the total useful floor are of the buildings (kg/m^2/y). The term *asset rating* is introduced which refers to the banding system of building energy performance (eg energy certificate).

3.1 Non-residential

As mentioned before the target CO_2 emission rate, the calculated CO_2 emission rate and the asset rating of a building which is not a dwelling is calculated using SBEM or an approved DSM.

The ways of expressing the asset ratings and operational ratings of buildings which are not dwellings are being finalised.

During design of a building, its TER can be calculated by using the approved calculation methods to calculate CO_2 emission from a notional building and then adjust the TER according to specified correction factors. Air permeability is one of the prescribed parameters. Emission factors for CO_2 from different fuels are included in the regulations. It should also be noted that there is a LZC (Low Zero Carbon) correction which gives consideration to the incorporation of zero and low energy supply systems before construction start according to the EPBD.

In addition to the flexible approach based on the TER and BER values there are some individual targets for U-values, air permeability (discussed in more detail in section 4), and fixed building services (*controls* – separate zone controls, *energy meters* to monitor the performance of any LZC system and automatic meter reading and data collection for building more than 1000 m^2, heating and hot water systems, cooling systems, air handling plant (variable speed drives for fans rated at more than 1,100 Watts and ductwork air leakage), insulation of pipes etc, lighting efficacy and controls,).

In criterion 3, solar gains and summer overheating are addressed with a limit on solar and internal heat gains averaged over the working day of 35W/m^2 for non-air-conditioned buildings.

In criterion 4, quality of construction and commissioning are addressed. Particular emphasis is given to air permeability and duct air leakage and these are described in section 4 of this paper. Finally criterion 5 on information introduces the building logbook.

3.2 Dwellings

Dwellings are classified into two categories according to their size – less than 450 m^2 for which TER is calculated using SAP-2005 and those more then 450m^2 for which TER is calculated using SBEM. As in the case of non residential buildings, TER is calculated in two stages and some correction factors are applied. The five criteria limiting flexibility of TER are also specified.

In the case of dwelling progress has been made in expressing building energy performance in terms of asset rating. The asset rating of a dwelling, as calculated using SAP 2005 is expressed in two ways: as an Energy Efficiency Rating and as an Environmental

Impact (CO_2) Rating. Both indices are generated by SAP 2005:

- The Energy Efficiency Rating is an indicator of the energy costs associated with space heating, water heating, ventilation and lighting. It is expressed on a scale of 1 to 100, the higher the number the lower the running costs of the dwelling.
- The Environmental Impact (CO_2) Rating is an indicator of the annual CO_2 emissions associated with space heating, water heating, ventilation and lighting. It is also expressed on a scale of 1 to 100, the higher the number the lower the annual emissions.

Both ratings must be displayed on the graphic banding system shown in Figure 1.

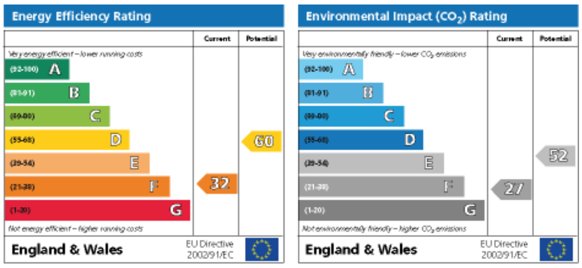

Figure 1: Graphic banding system of energy efficiency and environmental impact rating for dwellings.

Innovative systems: SAP 2005 allows the energy performance of new technologies and advanced versions of existing technologies to be evaluated for inclusion in SAP assessments. The method for assessment and testing is specified in AppendixQ (2008). As specified, "in order for product specific data to be eligible for SAP Appendix Q data input, the product must have been tested to the approved testing methodology for that specific technology type. For entry to the SAP Appendix Q website database the tests must have been conducted by an approved test house. All test results should be submitted for assessment using the report templates supplied". Innovative ventilation systems tested according to this procedure are included in the SAP2005 calculations method.

Sustainable Homes Code (DCLG, 2006): In December 2006, the Code for Sustainable Homes - a new national standard for sustainable design and construction of new homes was launched. Since April 2007 the developer of any new home in England can choose to be assessed against the Code. In February 2008 the Government confirmed mandatory rating against the Code will be implemented for new homes from 1 May 2008. The Code measures the sustainability of a new home against categories of sustainable design, rating the 'whole home' as a complete package. The Code uses a 1 to 6 star rating system to communicate the overall sustainability performance of a new home. The Code sets minimum standards for energy and water use at each level and also specified minimum standards for materials, waste and pollution.

4 National trends in air tightness requirements and market characteristics

Previous regulations in 2002 specified that all commercial and industrial buildings with a gross floor area greater than 1000 m^2 to be tested for air tightness to a minimum standard of 10 $m^3/(h.m^2)$ at 50 Pascals (Pa). The new regulations introduced in 2006 extend this requirement to all sizes of commercial and industrial buildings and to new dwellings. The sections below outline the requirements.

4.1 Dwellings

In achieving the TER value (see section 3) the design air permeability may need to be better than the limit value. Significant better standards of air permeability are desirable in dwellings with mechanical ventilation, especially when using balanced systems with heat recovery. For such systems specifications exist within the regulations in terms of specific fan power (0.8 l/sW for continuous supply or extract and 2.0 l/sW for balanced systems) and heat recovery efficiency (66%). Additionally, reference to (GPG, 2006) is made where air permeability standards for different ventilation systems are outlined.

It is specified that for each new housing development air pressure testing must be carried out to demonstrate that the specified air permeability has been achieved. It is noted that if the design has specified low energy air permeability in order to achieve a better TER performance, the building will not fail to comply if the limit value for air permeability and TER are achieved. The regulations specify the number of tests required for two categories of development; those which have followed approved construction methods and those which have not. If satisfactory performance is not achieved in this sample testing then remedial measures should be carried out and a new test. There are exceptions for small developments of two dwellings.

No air permeability testing is required for refurbishment work carried out in dwellings but it is referred to in a paragraph about securing continuity of insulation and air tightness.

4.2 Non-residential

Air tightness for non-domestic buildings is also addressed in Part L of the building regulations where both envelope air permeability and ductwork leakage are addressed.

It is referred to in the sections on design standards in criterion 2 (design values) where a reasonable limit for design air permeability is set at 10 $m^3/(h.m^2)$ at 50 Pascals (Pa). It is also noted that better standards are technically desirable in buildings with mechanical ventilation and air conditioning.

It is also referred to in criterion 4 (quality of construction and commissioning) where testing of the building during commissioning is required and remedial measures are necessary if the limit value is not achieved. In addition, ductwork leakage testing should be carried out for systems served by fans with a design flow rate greater than 1 m^3/s.

5 School building design

In the last few years, there has been an initiative for building new schools for secondary education. The inclusion of school building in the building regulations meant that specific guidance needs to be included. This task has been undertaken by the Department responsible for school buildings and recommendations were published (DfES, 2006) together with spreadsheet tools to help sizing openings (in terms of equivalent area) and also avoid overheating through ventilation. In terms of recommended environmental conditions relating to ventilation the following values are stated:

- The maximum concentration of carbon dioxide should not exceed 5000 ppm during the teaching day.
- At any occupied time, including teaching, the occupants should be able to lower the concentration of carbon dioxide to 1000 ppm
- In terms of air flow through natural ventilation a minimum of 3 l/s per person, and a minimum daily average of 5 l/s per person should be provided
- Additionally, the capability of achieving a minimum of 8 l/s per person at any occupied time. Additional ventilators could be used to provide this extra ventilation e.g. supplementing windows with the addition of louvres or stacks. This ventilation may not be required at all times of occupancy, but it should be achievable under the control of the occupant.
- If a mechanical ventilation system is specified, it should be commissioned to provide a minimum daily average of 5 l/s per person. In addition, it should have the capability of achieving a minimum of 8 l/s per person at any occupied time.

In terms of overheating the following are stated :

- There should be no more than 120 hours when the air temperature in the classroom rises above 28°C during occupancy hours
- The average internal to external temperature difference should not exceed 5°C (during the summer).
- The internal air temperature when the space is occupied should not exceed 32°C.

These recommendations together with the calculation tools have underpinned the inclusion of innovative ventilation systems in many recently constructed school buildings. Further regulation on acoustic performance was introduced to take into account external noise and noise from building services. In a classroom the noise level must remain below 35 $L_{Aeq30min}$.

Two building case-studies are described below to illustrate these developments. Data are taken from (Pegg et al, 2007). These case-studies are included in the project Building AdVent (2008).

5.1 School case-study A

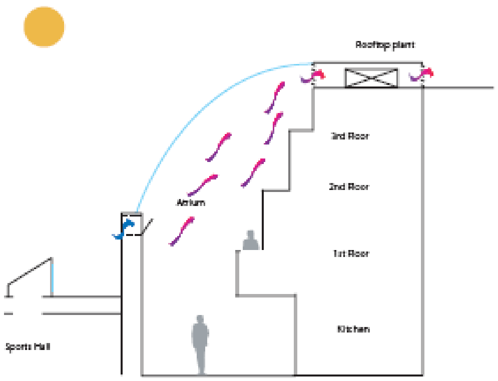

Figure 2: Schematic of the ventilation system in the school

The design team intended the building to be completely mechanically ventilated due to the road noise from the west of the site. Tender returns were higher than expected and therefore much of the design was altered to enable natural ventilation. The ETFE (ethylene-tetra-fluoro-ethane) atrium (Figure 2) is naturally ventilated on the south side and extracts at high-level on the north facade, through an external plant room. The vents were initially intended to be automatically operated, however this became manual after value engineering. The halls in the basement of the school are mechanically ventilated, incorporating heat recovery and demand controlled ventilation based on CO_2 levels in the space.

The ICT space, music practice rooms and server rooms have mechanical supply and extract with room Fan Coil Units.

Cooling is supplied via a Variable Refrigerant Flow, heat-recovery air-source heat-pump. This allows heat to be effectively moved between zones and suits a simultaneous heating and cooling demand. Science and technology rooms on the ground and first floor teaching blocks are mechanically ventilated to reduce noise ingress, however the second and third floor classes are naturally ventilated due to a dispensation to save money.

5.2 School case-study B

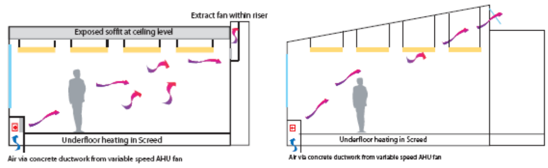

Figure 3: Schematic of the ventilation system in the school

The approach to ventilation is driven by acoustic constraints. The new acoustic guidance (BB93, 2003) was introduced when the building was onsite and therefore classrooms were required to have a sealed façade. A hybrid ventilation strategy was implemented (Figure 3); this consist of:

1. natural ventilation through windows and small supply and extract fans in the ground floor classrooms activated by a PIR sensor and
2. natural ventilation through windows in the first floor classrooms and extract through motorized openings at high level.

Because of the acoustic regulation, some classrooms have a natural ventilation supply via a buried concrete pipe (to pre-heat/cool the air) with a mechanical extract on the ground floor and natural extract on the first. For special rooms (ITC and music rooms) cooling is provided from split systems.

5.3 Energy consumption

The energy consumption in school A is 89.9 kWh/m^2 normalised gas consumption (of which 77.2 kWh/m^2 for heating) and 66.2 kWh/m^2 electricity consumption. The good practice benchmarks are 112 and 31 kWh/m^2. Therefore heating and hot water consumption is very low but the same does not apply to electricity. On closer look, it was found that most of electricity consumption is due to lighting (and its controls) as well as the increased use of IT facilities in this modern school in comparison with the benchmarks which represents the situation of a few years ago.

The energy consumption in school B is 64.1 kWh/m^2 normalised gas consumption (of which 52.5 kWh/m^2 for heating) and 67.4 kWh/m^2 electricity consumption (including 2.5 kWh/m^2 generated on site). Therefore heating and hot water consumption is lower than best practice benchmarks but the same does not apply to electricity for similar reasons as for building A.

In both schools, ventilation energy is mainly used to heat the air and therefore energy consumption is very good. In terms of electrical energy for pumps, fans and control related to mechanical ventilation the consumption is 66kWh/m^2 and 21 kWh/m^2 for schools A and B respectively. The low consumption in school B was achieved by using two strategies;

1. 15 rooms were provided fresh air via buried concrete ducts. Air was supplied via a single 4 kW variable speed controlled fan. Each room had a damper that opened and closed based on the time-table of the room. The fan speed was controlled, based on the number of rooms occupied, down to a minimum of 40%, at which time 6 of the rooms were provided with air, regardless of occupancy (due to the perception of problems of harmonic interference using equipment at motor frequencies lower than 20Hz).
2. Other spaces using mechanical ventilation utilized fans controlled by PIR sensors. Logs of 'ON/OFF' times of plant indicated that some classrooms were utilized as little as 2 hours per day.

In school A strategies run equipment at full loads for between 8 and 10 hours per day.

6 Urban Heat Island

6.1 Urban Heat Island

Research and application studies have been carried out to investigate the effect of urban heat island, mainly in London and other cities including studies on the implications in the design of urban buildings and ventilation strategies. A report was published by the Greater London Authority (GLA, 2006) with some practical guidance for the development of the city and mitigation of the UHI in London.

The most recent quantification of the UHI was carried out in 2000 and some results are presented in Figure 4. Work continues on developing modelling techniques to predict weather conditions within the UHI of London (LUCID project, 2008). Apart from the obvious mitigating strategies for urban planning (cool and green roofs, cool pavements, planting trees and vegetation, sky view factors, and strategies for heat prediction and preparedness for general population in the city) , specific guidance has appeared for building services engineers in the form of correction factors for air temperature in three zones in London to be applied to standard weather files used for building simulations. (CIBSE 2006). These summer weather files can be used to correctly access the design and ventilation strategies and components and in particular passive ventilation strategies such as night purging.

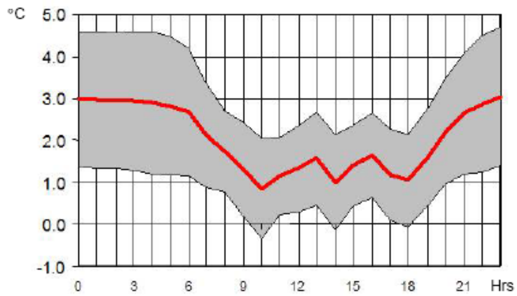

Figure 4: The variation in the UHI intensity for London over 24 hours for summer 2000. (source GLA 2006).

6.2 The role of the client

In the UK, there exist well documented materialised built examples of low energy offices which are mainly driven by the desire of clients to incorporate low energy and natural ventilation strategies. One such building is the Red Kite house, offices of the Environment Agency in Oxfordshire, England (BSJ, 2008).

The client wished for a naturally ventilated building which was achieved by optimising the building form at early design stage with the architect Scott Brownrigg working together with the engineer Hoare Lea. The building has a narrow plan on an east-west axis so that prevailing winds from south west can be exploited. Solar shading is used to reduce solar gains together with a night ventilation strategy with exposed soffit thermal mass. The normalised measured gas (heating) consumption is 66 kWh/m^2 (less than good practice benchmark) and electricity consumption is 127 kWh/m^2 (higher than both good practice and typical practice benchmarks). As in the case of school buildings, this is probably due to high occupancy density together with IT and office appliances. There is no sub metering in the building which is a requirement under the new Part L (2006) regulations for a building of its size. Monitoring of environmental conditions in the summer of 2006 show good performance while a users' survey carried out puts the building at the 80 percentile in a benchmark comparison of 50 buildings recently surveyed by BUS (2008).

Figure 5: Red Kite House office building

7 Conclusions

This paper has reviewed recent changes in the Building Regulations in England and Wales introduced in 2006 to facilitate the implementation of the EPBD. The paper covered changes in building ventilation and energy performance including envelope air tightness and duct air leakage considerations.

The case of school buildings was highlighted as stringent regulations (eg acoustics) have affected the installed ventilation systems and strategies. The role of the client driving natural ventilation strategies despite design restriction imposed by regulations was described in the form of a successfully built and operated non urban office building.

The need for post-occupancy studies of buildings for assessing their performance and establishing up-to-date benchmarks is proposed.

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The Air Infiltration and Ventilation Centre provides technical support in air infiltration and ventilation research and application. The aim is to promote the understanding of the complex behaviour of the air flow in buildings and to advance the effective application of associated energy saving measures in the design of new buildings and the improvement of the existing building stock.