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Low energy house ventilation

Introduction

Today's houses are built or retrofitted to high standards of insulation and airtightness, limiting air infiltration and increasing the need for ventilation in order to keep good indoor air quality. Because of that, the percentage of energy losses through ventilation increases significantly. Therefore, there is a need to develop low energy ventilation designs, capable of supplying enough fresh air.

In this essay the different ventilation techniques are analyzed and their energy efficiencies compared. First, a definition of good indoor air quality is established, the advantages and drawbacks of natural and mechanical ventilation systems are explored and their energy efficiencies compared. Subsequently, some innovative techniques reducing energy use for ventilation are introduced. Finally, conclusions are drawn and the best practice is proposed.

Definition of good indoor air quality

Appropriate indoor air quality (IAQ) can be defined as the absence of air contaminants which may impair the comfort or health of building occupants (Rousseau, 2003).

Mawditt (2011) lists three requirements that need to be satisfied to maintain good level of IAQ: hygrothermal conditions, normal concentration of respiratory gasses and continuous dilution of pollutant concentration. The first factor is easily measurable, although temperature and relative humidity comfort zones and their ranges can differ depending on the climate and type of ventilation (Frontczak and Wargocki, 2011), so the conditions need to be established for each project individually. The two remaining requirements are much more difficult to assess but typically the concentration of CO_2 is used as a marker, providing an indication of the levels of other pollutants.

There are two ways of maintaining acceptable IAQ: minimizing the amount of pollutants that get to the indoor space and effective diluting of the pollution by ventilation. For the purpose of this essay I will focus on the latter aspect.

Can natural ventilation provide good IAQ?

Natural ventilation is induced either by thermal buoyancy (stack effect) or by wind (cross ventilation). It is facilitated by inlets in windows or walls (that can be humidity controlled) or simply by opening of the windows by occupants. Passive stack systems help to remove the stale air through the roof using vertical ducts. Natural systems often utilize small fans assisting air extraction, but they would be used only sporadically (intermittent fans) and locally – for example in bathrooms, for a short time after the bath.

These systems have the advantage of simplicity as well as low cost of installation and operation. The drawbacks of natural systems are: difficulty of controlling the air change rates and the fact that they don't have the capability of recovering heat – the fresh incoming air has to be heated and when it's leaving the house, the heat is lost.

A study described by Dubuisson (2011) was made using Siren software simulations on an example of a typical Irish house. It investigated how the performance of different ventilation methods depends on the house's airtightness level. A criterion used for verification was the UK Part F 2010 requirement for the system to supply enough air changes to keep the humidity levels below 75% for a certain number of hours during the heating season. According to the research, the natural ventilation of bathrooms without mechanical support would fail in any case. The system with air supply in dry rooms and exhausts fans in bathrooms are fulfilling the UK Part F 2010 requirements in house with airtightness exceeding 5ach @ 50 Pa, but in more airtight dwellings would fail as well. All mechanical systems (MEV, DC MEV, MVHR) were performing adequately in all houses, including those with increased air tightness (<3ach @ 50 Pa).

This study explores systems typical for Irish construction and focuses only on the problem of humidity levels, but proves that increased airtightness calls for more careful ventilation design. In the authors opinion mechanical systems are the easiest answer to the problem.

Another study (Simonson, 2005) verified the performance of natural ventilation system in a house in Finland. It was designed as a low energy, its airtightness was measured at 3.1ach @ 50 Pa. A natural ventilation system included passive inlets in windows and walls, and fan assisted passive stack extract from wet rooms. Simonson analysed the system by measuring the exhaust flow rates during different conditions, measuring CO_2 concentration during occupation and developing an equation to predict the ventilation rate as a function of outdoor temperature and wind speed. The measurements showed that bedroom concentrations of CO_2 (with open door) were between 800 and 1000ppm, ensuring good indoor air quality.

The relative humidity wasn't measured but the average ventilation rate through the ventilation system was expected to be 0.45 ach in winter – at a satisfactory level.

This study shows that a more careful approach in natural ventilation design can satisfy the ventilation needs even for well insulated and more airtight houses.

What are the problems with mechanical ventilation?

It is much easier to provide adequate levels of ventilation with easy to control mechanical systems that deliver fresh air and exhaust stale air using a central fan and a duct system. To drawbacks of this solution belong: high complication of the system (they are more difficult to install and are not always suitable for retrofit), their higher initial cost and embodied energy, and finally the use of energy to operate them. A typical mechanical system needs to run round the clock using electricity, the most expensive energy source. There are two types of systems that reduce the use of energy: heating recovery, which uses heat exchanger to recover energy from exhausted air (typically used in low energy houses), and demand controlled, that is turning on only when there is a need for air extraction.

Another problem with mechanical ventilation, not widely recognized, is how the occupants operate it. Macintosh and Steemers (2005) conducted a study that verified performance of the mechanical ventilation heat recovery (MVHR) system in a housing scheme in London. The authors concluded that it showed substantial savings when modelled at optimum performance but its actual usage was extremely inefficient – making the installation a failure. There were a number of reasons for the misuse of the system: the occupants felt it was very noisy (even though it was not confirmed by measurements), did not provide fresh air (as much as the air coming directly through the windows) and generally they did not understand what the ventilation system was for and when it should be used.

Similar conclusions were drawn from a study by Isaksson and Karlsson (2006) who concluded that appropriate information about functionality of the ventilation and heating systems is vital in achieving desirable goals.

This shows that calculated and actual performances of mechanical systems can be very different due to occupant's unexpected behaviour and how important it is to train the final users.

Which system is more energy efficient?

The trade-off between natural and mechanical heat recovery systems include the amount of energy for heating of the incoming air for the first case and electricity use for running the mechanical fan in the second one. Studies show that in certain examples the two can be balanced and the running cost of both systems can be the same. Simonson (2005) compared energy use for natural and MVHR ventilations in his case study house and found out that the natural ventilation system increased the space heating energy by 15 kWh/m^2a (because there is no possibility for heat recovery from the ventilation air) but saved electrical energy of 5 kWh/m^2a (because of no ventilation fans). Assuming that 1kWh of electrical energy requires 2.5kWh of primary energy, the primary energy use for the first house was 171 kWh/m^2a, and for the second one 166 kWh/m^2a, making them nearly identical for both cases.

Generally, it is very difficult to decide which system would be more energy efficient as a lot depends on the individual situation. As described by Maier et al. (2009) in his study comparing 22 houses with different systems, both natural and mechanical approaches depend on occupant's behaviour that can influence their performance. In case of natural ventilation there is a danger that the user will block the vents or neglect to open the windows, what can lead to inadequate levels of incoming air. Regarding the mechanical ventilation – its misuse can cause great energy losses that could undermine the whole idea.

Mahdavi and Doppelbauer (2010) raised an issue of embodied energy for the mechanical ventilation system in their comparison of two types of apartments: better insulated ones, with heat recovery ventilation, and less insulated ones - with natural ventilation (humidity sensitive inlets in windows + mechanical extracts in wet rooms). That investigation showed that while providing better performance in relation to CO_2 concentration levels and relative humidity, the amortization time for the additional (embodied) energy for apartments with heat recovery would be only about 2 years. It was shown that despite of using more electricity for the operation of ventilation system, the apartments with heat recovery system were still using less primary energy than the ones with natural ventilation.

This contradicts the Simonson's (2005) findings described earlier, probably due to a different climate data and building's details, and proves again that the energy performance of natural and mechanical ventilation depend on an individual case.

Innovative methods that can help reduce energy use for ventilation

There is an ongoing research in direction of improving performance of ventilation systems. Natural ventilation methods supporters look for ways of enhancing the controllability and incorporating heat recovery solutions without the need for power. An excellent example was set out by the passive heat recovery ventilation system in Bed Zed development in London (Twinn, 2003). It works like an active ventilation system - it has dedicated inlet and outlet ducts and a 70% efficient heat recovery system but instead of using electrical fans to drive the air flow it incorporates wind cowls on the roof, which create both positive pressure at the inlet and negative pressure at the outlet ensuring air movement. In low wind conditions it would continue to produce reasonable ventilation levels through a stack effect.

Such approach combines the best features of the two systems providing heat recovery with no demand for electrical energy. However it was difficult to find out the initial cost of that system and also any data verifying its performance in relation to delivered air rates. This solution might also prove problematic from the aesthetical point of view, for example in conservation areas.

Another inventive approach has been demonstrated by McEvoy and Southall (2004). They tested a new low-energy whole-house ventilation system (WHOLE-pvs), which combined supply air windows with passive stack ventilation. A supply air window consists of an outer pane of glass spaced away from the inner glazing. The air is drawn through vents at the base of the outer sash. It is warmed as it rises within the cavity by solar gain and the reclaimed heat from the room, and is delivered into the room as pre-warmed background ventilation. The performance was tested in 3 sets of houses in different climates and compared the new ventilation system with locally used ventilation methods. The measurements showed savings in energy use of up to 15%.

A good example of energy use reduction method by ventilation system was shown in a study by Woloszyn et al. (2009). Performance of constant air flow ventilation system was compared to a relative humidity sensitive (RHS) system while keeping the same relative humidity levels. It was found that the use of the latter one reduced mean ventilation rate by 30-40% in the cold period and generated 12-17% savings. The study also confirmed that the use of moisture buffering materials (such as wood fibreboard compared to gypsum board) is a very efficient way to reduce the amplitude of daily moisture variations. It was possible to keep the indoor RH at a level of 43-59%.

Conclusion

To summarize, it was established that ventilation is a key factor in maintaining good indoor air quality. The advantages and drawbacks of both natural and mechanical ventilation systems were reviewed and their energy efficiencies compared. Finally, some examples of innovative approaches in the topic were introduced.

It is generally acknowledged that the heat recovery mechanical ventilation systems are more suitable for low energy buildings and they are commonly used for passive house buildings (Feist et al., 2005). However, based on the examples presented, it is more appropriate to say that natural heating systems can perform equally well both in terms of providing adequate indoor air quality and maintaining low energy consumption. Especially innovative approaches, utilising wind cowls or pre-heating supply air windows can easily compete with MHRV systems.

There is however still a need for research in both directions – making the natural ventilation more controllable and reducing energy use in mechanical equipment. The systems could also be combined to further optimise ventilation performance. Perhaps more efficient fusion of mechanical and natural systems could be developed.

This essay is limited by the lack of definite conclusion as to which ventilation system is the most energy efficient. It proved to be impossible to establish because of the dependence of each example on the individual circumstances – the building's design, the occupier's behaviour etc.

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