Performance of decentralized mechanical ventilation in airtight homes

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Abstract. The main aim of this research was to establish if new-build dwellings fitted with dMEV systems in moisture producing rooms, coupled with a reduced area of trickle ventilation in habitable rooms of 2,500m², can maintain satisfactory ventilation in a real-life context. The study undertook a survey of 231 homes to ask occupants about their knowledge and operation of their ventilation system, and a subset of these (41 homes) were monitored to examine the actual ventilation performance and determine the factors that affect this. A further study was undertaken in a selected dwelling to experiment with different ventilation strategies using dMEV to identify key factors. The monitoring found over 50% of homes were poorly ventilated overnight and that bedrooms were a particular cause for concern. There were several variables that affected this. These included the nature of the trickle vents, the window coverings, the path between the room and the dMEV and the installation and performance of the system. Essentially homes with shorter, more open paths for air movement performed better, but rooms which relied on more remote dMEV systems frequently had poor ventilation. The findings suggest that whilst there are some situations where a dMEV system can assist with the ventilation provision of modern airtight homes, the ability to act as a whole house system is limited, particularly in larger more complex layouts, and where ventilation loads are high.

1 Introduction

The underlying context of this work is the potential implications of increasing standards of airtightness in construction resulting from mandatory requirements of Building Standards. Previous research has evidenced a lack of trickle vent use in contemporary housing and poor ventilation in practice [1]. IN 2010, a DCLG study concluded that to compensate for the fact that new homes are becoming more airtight, the size of trickle vents provided in the most airtight homes (≤4 m³/hr/m²) should be increased [2].

In 2015, changes to the Scottish Domestic Technical Handbook published by Building Standards Division [3] included the adoption of the European standard for sizing background ventilators using ‘equivalent area’, as opposed to geometric area. This was a subtle but important change that had significant implications, effectively increasing the requirements for trickle ventilation provision in Scottish housing. In response, manufacturers of dMEV units sought ‘type approval’ on their systems under the Scottish Type Approval Scheme (STAS), to demonstrate that their systems can be used with a reduced trickle vent equivalent area of 2,500mm² per habitable room. The Registered Detail can be provided as part of a building warrant application to demonstrate compliance. This was a significant reduction from the measures within the Technical Handbooks, which calls for trickle ventilators of 12,000mm² in habitable rooms and 10,000mm² in kitchens, bathrooms, utilities, toilets and shower rooms.

However, concerns have been raised by professionals and researchers alike regarding the ability of decentralised mechanical ventilation systems (dMEV) to act as ‘whole house’ ventilation systems in new-build housing with an airtightness of 3-5 m³/hr/m² @50Pa, coupled with reduced trickle ventilation of 2,500m² to habitable rooms. The concern was that whilst this strategy can potentially achieve satisfactory results in factory conditions and in modelling, there are several real-world situations arising which may compromise performance. These include the effects of internal layouts, size and placement of trickle vents, doors and windows, building form and location, and occupant behaviour. Sub-optimal performance could result in inadequate ventilation and associated indoor air quality problems. The use of dMEV is gaining in popularity due to its relatively simple requirements in increasingly airtight homes. However, the question remains whether these systems are delivering sufficient ventilation rates, particularly in rooms that may be at risk of being
bypassed and habitable rooms with limited cross ventilation, and this is the focus of this research.

1.1 Study aim and objectives

1.1.1 Study aim

The main aim of this research is to establish if new-build dwellings fitted with dMEV systems in moisture producing rooms, coupled with a reduced area of trickle ventilation in habitable rooms of 2,500m², can maintain satisfactory ventilation and IAQ in a real-life context.

1.1.2 Research objectives

The research objectives were to:
- Identify a sample of new-build (post 2012) housing developments in Scotland with a designed airtightness of between 3-5 m³/hr/m² @50Pa that are ventilated using dMEV systems, with a reduced trickle ventilation provision of 2,500m² in habitable rooms
- Investigate how occupants interact with dMEV systems, trickle ventilators and other components in their home, their awareness of these systems and controls, their perception of IAQ, and their willingness to participate in the monitoring study, through a household survey
- Establish ventilation levels in selected homes with dMEV systems and reduced trickle ventilation during winter, based on measured CO₂ levels
- Identify the hygrothermal conditions in these homes based on measured temperature and humidity together with relevant contextual information
- Examine the airflows including potential for short-circuiting of fresh air from trickle ventilator(s) by the dMEV unit, through a review of the design, as-implemented and as-used systems coupled with analysis of airflow pathways using smoke testing and simulation tools
- Draw together data from the household survey, monitoring study, detailed measurements and modelling to examine and fully comprehend the nature of ventilation provision and use
- Assess the implications for future design, legislation and advice, and identify any issues concerning current regulatory standards and/or practices and options for improvement.

2 Methodology

This study was commissioned by the Scottish Government Building Standards Division (BSD) to examine the real-world performance of modern homes with dMEV systems. A survey of 231 homes was conducted to ask occupants about their knowledge and operation of their ventilation system, and a subset of these homes were monitored to examine the actual ventilation performance and determine the factors that affect this. A further study was undertaken in a selected dwelling to experiment with different ventilation strategies using dMEV to identify key factors.

2.1 Project development

Suitable new-build dwellings with dMEV systems (in Scotland) were identified. A review of current building standards was performed to provide a detailed understanding of the current context relative to national regulation and policies.

2.2 Household survey

A survey of 223 homes was conducted between December 2017 and February 2018, to gather information on occupant use and awareness of ventilation within their home. A professional survey company conducted the doorstep survey, with the surveyors being briefed by the project team. The survey was also used to identify locations for follow-up sample monitoring.

2.3 Monitoring study

A sample of 41 dwellings with dMEV systems were selected for detailed monitoring. These included a range of house types that represent new-build stock, including differing building typologies, tenures and varying aspects. The survey required access to the houses to undertake a building survey and measure ventilation performance in practice. Environmental monitors that record temperature, relative humidity and carbon dioxide were installed in living room, kitchen and bedrooms over a one-week period. This monitoring took place between December and March 2018.

2.4 Analysis of ventilation effectiveness

Analysis was undertaken to examine the nature of occupancy, ventilation provision and use. The CO₂ data was analysed with reference to recommended guidelines (i.e. 1000ppm), to provide an indication of ventilation performance. Detailed analysis of air change rates (using the constant injection method) was also performed.

2.5 Detailed monitoring study

In this section of the project, more detailed testing was undertaken in a selected dwelling where several scenarios were tested using simulation software to examine the impact of air flow pathways.

2.6 Analysis and dissemination

On completion of field work, data from the household survey, monitoring study and detailed measurements were collated and analysed.

3 Results
3.1 Household survey

71% of households surveyed reported closing the bedroom door at night (Figure 1), while 95% reported closing curtains/blinds, which signifies a particular challenge to providing a whole house ventilation system where dependence is placed on trickle vents and open doors at night.

Fig. 1. Reported bedroom door opening at night

Overall, the survey found that although there was good awareness of the presence of ventilation provisions, there was a lack of knowledge regarding how these systems were controlled. For instance, only 48% of households reported the presence of switches to boost the ventilation rate. Where boost switches were not reported, households were asked how the ‘boost’ mode was controlled; the majority of which stated they were not sure (85% - see Figure 2).

Fig. 2. Awareness of boost mode function on dMEV systems

Most households stated they did not feel the need to boost the ventilation rate in the dMEV system (96%), and a lack of engagement with trickle vents was also clear (39% of households reported adjusting trickle vents less than once a month).

3.2 Monitoring study

The monitoring found that over 50% of homes appeared to have poor ventilation overnight (where carbon dioxide levels exceeded 1,000ppm for most of the time), and that bedrooms were a particular cause for concern. There were several variables that affected this. These included the nature of the trickle vents, the window coverings, the path between the room and the dMEV (including the door opening or undercut, and the arrangement of the home) and the installation and performance of the system. Essentially homes with shorter, more open paths for air movement performed better, but rooms which relied on more remote dMEV systems frequently had poor ventilation.

Fig. 3. Measured airflow rates in ensuite dMEV systems

Inspection of the monitored homes found a high number of installed dMEV systems (42-52% - depending on location) were sub-optimal (exceeding recommended airflow rates by >15%), or non-compliant with the guidance (17-48%), see Figure 3. Flow rates were highly variable, sometimes this was due to the system setup and commissioning, but some systems had provision for occupant control. Given that bedroom doors were often closed (41%) due to occupant preference or fire requirements, the strategy relies on door undercuts, but these were undersized in 20% of properties.

Fig. 4. Example of short-circuiting in bathroom

There were several homes (51%) where trickle vents were installed in wet rooms with dMEV systems (e.g. see Figure 4). Whilst this may improve the efficacy of extract and moisture control in these rooms, this undermines the ability of the system to assist with ventilation in more remote rooms.

Whilst dMEV systems in ensuite bathrooms provided the best outcomes for adjacent bedrooms, problems with systems being disabled were encountered in 56% of homes and the predominate problem was one of noise. The physical monitoring found a much higher incidence of this than the overall survey.

3.3 Detailed monitoring study

In the test house several different ventilation scenarios were tested over a week. The detailed monitoring scenarios clearly illustrated the weaknesses of the system as installed.

Whilst ventilation levels in the bedroom with an ensuite performed reasonably well, the bedroom which relied on a remote dMEV only achieved good
ventilation when the windows were open at night. The next best scenario was when the occupants left the bedroom door open overnight. Subsequent modelling suggests that air flows from door undercuts are less effective.

The current requirement for ventilation is based on the specification of trickle vents, undercuts and extract systems, but this does not vary depending on the layout of the building or the occupancy load. Buildings with complex paths are therefore at greater risk of having isolated rooms, as illustrated in Figures 5-7. Whilst provision of dMEV systems in en-suite bathrooms produced better results for the attached bedrooms, this does not appear to provide a whole-house solution.

![Fig. 5. Ensuite condition (section and axonometric)](image)

![Fig. 6. Single storey non-ensuite (section and axonometric)](image)

![Fig. 7. Multi-level condition (section and axonometric)](image)

These issues with sizing of trickle vents strongly suggest that the effectiveness of a ‘whole-house’ dMEV system is more influenced by the provision for air movement rather than the size of the trickle vent opening. As such, a working dMEV system that provides a mechanical driver for air movement would have some advantage over entirely natural ventilation strategies, as long as the air movement is available in all habitable rooms, and the system is running.

4 Discussion

The findings would suggest that whilst there are some situations where a dMEV system can assist with the ventilation provision of modern airtight homes, the ability to act as a whole house system is limited, particularly in larger more complex layouts, and where ventilation loads are high.

Although trickle ventilation provision in habitable rooms did not appear to be a major determinant of carbon dioxide concentrations in the monitored dwellings, these results should be interpreted with caution, given the small sample size and large number of confounding variables identified. It is likely therefore, that the impact of reduced area of trickle ventilation was overshadowed by other key components such as air flow pathways, pressure differentials, dMEV extract rates etc. As such, the system, as a whole, requires careful design, taking into account the house layout, paths for air movement (including undercuts and pass vents), the nature of the mechanical system, and consideration of remote rooms. The system will only be effective when these are optimised.

5 Conclusions

The use of dMEV as a strategy to assist ventilation in low energy airtight homes can provide good levels of ventilation in certain circumstances. However, greater attention is needed to the design of the overall system, the interaction between elements of the system and the installation and maintenance of the system.

The following recommendations are provided, to help ensure effective ventilation of homes with dMEV systems:

- Better design of ventilation strategies using dMEV as a component of the system and accounting for other key components,
- Improved standards for commissioning and testing in use, including measurement of noise post-installation,
- Better design of touchpoint controls and interfaces of the mechanical ventilation system, in particular the boost mode function and other control elements,
- Better ventilation advice an information for occupants about the ventilation strategy, how to use the system and any requirements for maintenance,
- Fall-back strategies for ventilation, in cases where mechanical ventilation systems may fail or become sub-optimal over time.

The research team would like to acknowledge the households who participated in the study and the Scottish Building Standards Division who commissioned the study.

6 References

2. DCLG, 2010, Ventilation and Indoor Air Quality in Part F 2006 Homes, BD 2702