Ventilation effectiveness comparison between extract ventilation and balanced ventilation in a scale model

Bart Cremers

Zehnder Group Nederland
Lingenstraat 2
8028 PM Zwolle, The Netherlands
bart.cremers@zehndergroup.com

ABSTRACT

The differences between extract ventilation and balanced ventilation are subject of many discussions in sales markets where both solutions have their share. Often, the differences are marked in terms of energy, because balanced ventilation is normally accompanied by heat recovery. But there is another difference in terms of the ventilation effectiveness of the system.

This document reports experiments in a scale model of a house showing the difference between extract ventilation and balanced ventilation in ventilation effectiveness, and therefore in achievable indoor air quality. The ventilation effectiveness is measured in terms of the cleaning time, i.e. the time it takes for smoke to be completely extracted from individual rooms.

The results indicate that for an undisturbed (design) system the cleaning time for individual rooms is independent on the ventilation system. But in disturbed situations like an open window or wind pressure on the building, the cleaning time is different for various individual rooms, and dependent on the ventilation system.

The conclusion is that for balanced ventilation, the ventilation effectiveness is not reduced by occupant behavior or wind conditions. On the other hand, for extract ventilation the ventilation effectiveness is lower in particular individual rooms as a result of these disturbances.

KEYWORDS

ventilation effectiveness, extract ventilation, balanced ventilation

1 INTRODUCTION

The differences between mechanical extract ventilation (MEV) and mechanical ventilation with heat recovery (MVHR) are subject of many discussions especially in the Dutch, Belgian and French markets where both solutions have their share. Often, the differences in terms of energy are marked. It is well known that heat recovery saves about 80-90% of the heating demand caused by the fresh air entering a building in the heating season.

But there is another difference in terms of indoor air quality, caused by the ventilation effectiveness of the system. In a monitoring campaign, these influences have been investigated thoroughly by Van Holsteijn et al (2015). This paper presents results of the differences in ventilation effectiveness concluded from scale experiments in a miniature house.

2 METHOD

For the scale experiments, the miniature house from fig. 1 was used. The house is 65 cm wide, 70 cm tall, and 25 cm deep. At the first floor, a master bedroom was modelled on the left, and a child's bedroom on the right, separated by a hallway. The hallway has three doors, of which two are leading to the master bedroom and child's bedroom. The third door at the back leads to a cavity at the back side of the house, modelling a bathroom. All three doors are made with a small slit underneath the door to allow cross flow between rooms even when the doors are closed.

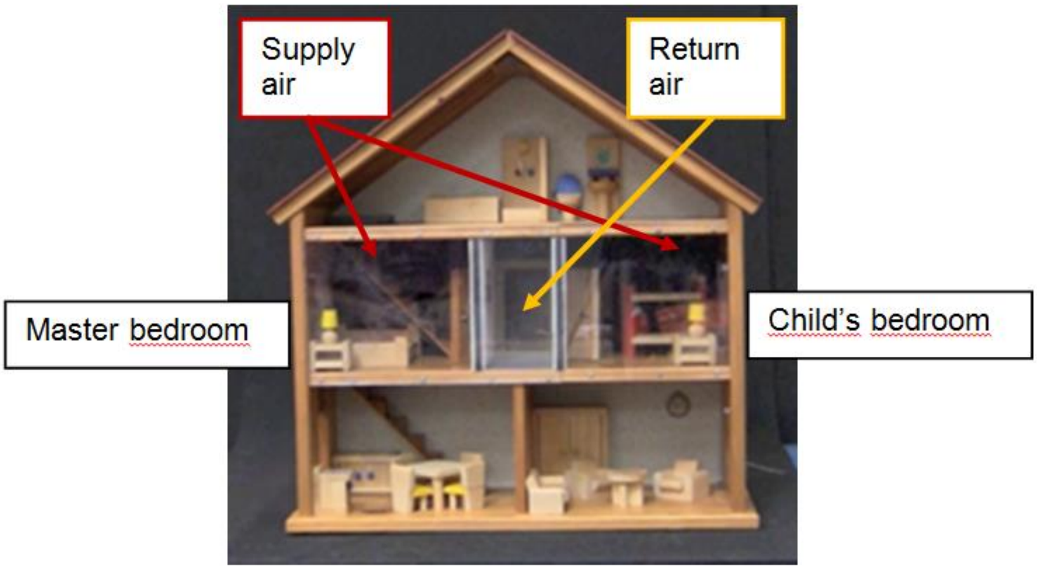


Figure 1. The miniature model used in the scale experiments.

The entire first floor has been closed air tight with glass. At the sides of the house, both in master bedroom and in child's bedroom are rectangular windows of 8 cm x 8 cm that can be closed or opened using tape. A small hole in the tape could be made to allow natural air passage (modelling a window grille).

Two identical small axial fans with a diameter of 75 mm are mounted at the sides of the cavity at the back side of the house. One of the fans (the 'return' fan) extracts air from the house via the bathroom. A second fan (the 'supply' fan) brings 'fresh' air into the building via two plastic ducts with internal diameter of 5 mm. One duct ends in the master bedroom and one duct ends in the child's bedroom. The ends of both ducts stick out of the back wall of the rooms for about 2 cm and are located 1 cm from the ceiling and 7 cm from the exterior wall.

The following special arrangements have been taken in preparation of the experiments. All of these arrangements are necessary in the scale model as well as in the real world for a normal building.

1. In order to have an air tight house, the cracks in interior and exterior walls were sealed.
2. In order to have balance between return air and supply air, the return flow was partly obstructed to match the resistance of the supply flow.
3. In order to have equal supply air volume in master bedroom and child's bedroom, the lengths of the supply ducts have been made equal to match each other's resistance.

The ventilation effectiveness of a ventilation system under various conditions has been investigated by injecting smoke to the master bedroom and the child's bedroom. Just after the bedrooms have been filled with smoke, the ventilation system is started. For MEV, only the return fan is started, and for MVHR both fans are started. Figures are shown for three conditions with MEV on the left of the figure and MVHR on the right of the figure.

The first condition is without disturbance, the second condition is with open window in the master bedroom and the third condition is with wind pressure on the façade of the building where the master bedroom located. The ventilation effectiveness of a system is expressed with the so-called "cleaning time", defined as the time it takes for a room to be fully clean (i.e. without smoke).

The exact amount of the air flow rates are unknown. But we can make an estimation of the used ventilation rate in the scale model. In real world ventilation, a typical cleaning time for an individual room is about 4 hours. In the scale experiments, the cleaning time of the undisturbed condition is about 10 minutes. This means that the ventilation rate in the scale experiments is about 24 times as high as in real life.

Note that the term MVHR is used in this document to indicate a system with mechanical supply of fresh air as opposed to natural supply of fresh air. However, in the scale model, there is no heat exchange taking place because the energy implication are out of scope for these experiments.

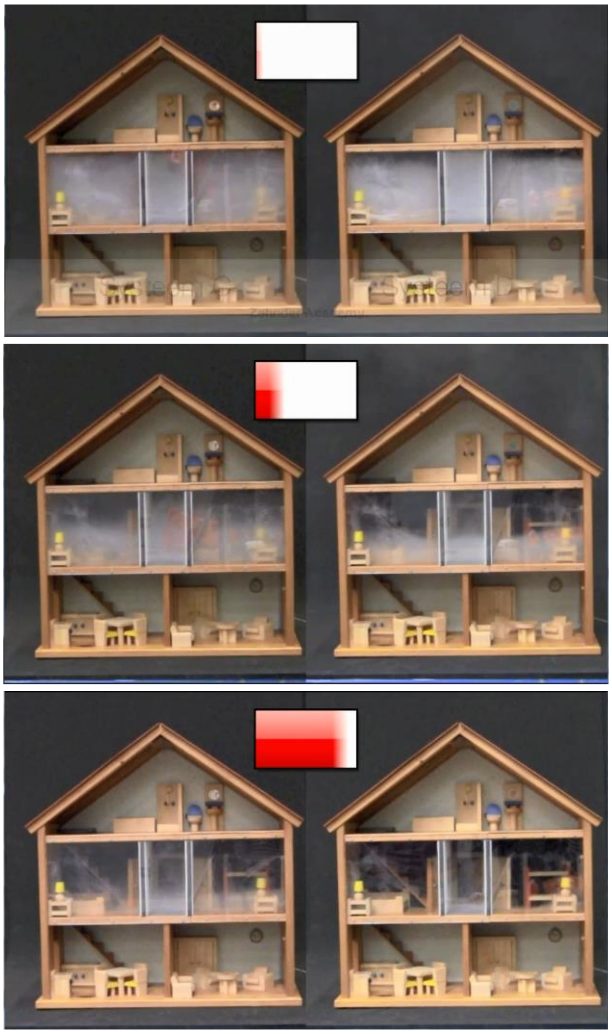
3 RESULTS AND DISCUSSION

Condition 1: Without disturbance

The first comparison is made without disturbance, i.e. the situation as intended in the design phase of a ventilation system. Figure 2 shows that after the start of the ventilation system, stale air in the bedrooms is replaced for fresh air. For MEV the fresh air is entering via the window grills and for MVHR the fresh air is entering via the supply tubes.

The cleaning time for both bedrooms and for both ventilation systems are all equal. It can be concluded that, without disturbance, the cleaning time depends only on the fresh air flow rate.

The smoke can be observed to disappear as a layer of smoke on the floor that is decreasing in height as time goes by. Although the ventilation rate in the scale experiments is high, it appears that the smoke is not mixed in a uniform way in a bedroom. This is likely to be caused by the high density of the smoke compared to the density of clean air. In real life, the mixing of fresh air with stale air in the room is much more apparent.



a)

b)

c)

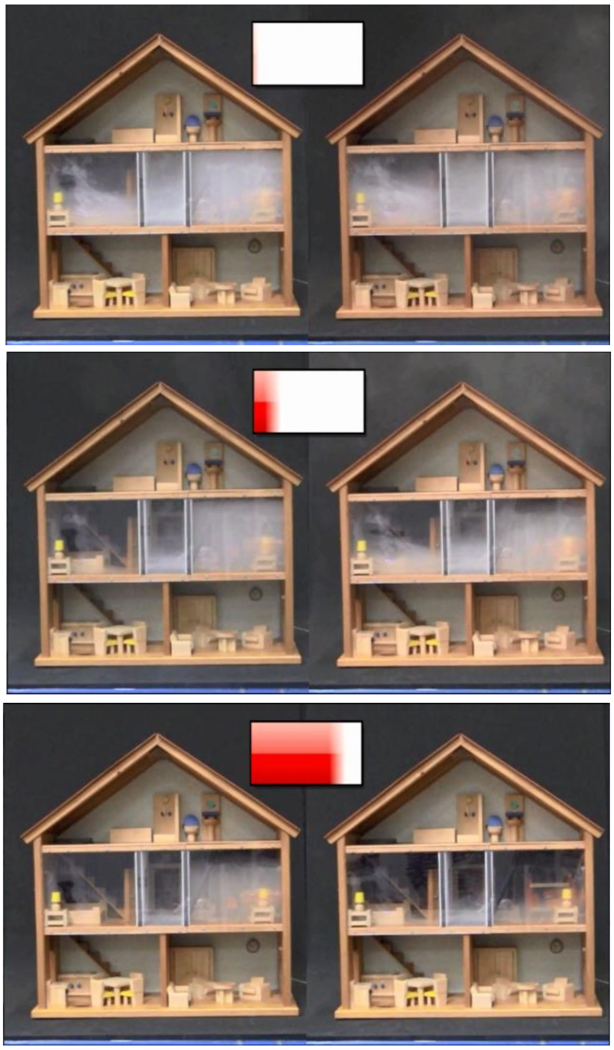
Figure 2. Frames of the situation without disturbance 1 minute (a), 3 minutes (b), and 10 minutes (c) after start of the ventilation system. In every frame left is the house with MEV and right is the house with MVHR.

Condition 2: Open window in the master bedroom

The second comparison is made for occupant behavior during a typical winter night situation. For both MEV and MVHR, the parents leave the window half open to allow fresh air to enter the bedroom (on top of the fresh air brought by the ventilation system). For the MEV case, the window grille in the child's bedroom is closed to avoid direct draught and the internal door is closed to ensure a silent, good sleep for the child.

Figure 3 shows that the cleaning time in the master bedroom is decreased because the half open window is increasing the amount of fresh air coming into the room. In the child's room the closed window grille is obstructing the incoming flow of fresh air and consequently the cleaning time increases with respect to the intended situation in the design phase.

For MVHR, the cleaning time of the child's room is still equal to the cleaning time of the undisturbed condition. It means that the supply of fresh air into a room never gets smaller by the opening of windows or doors in other parts of the house.



a)

b)

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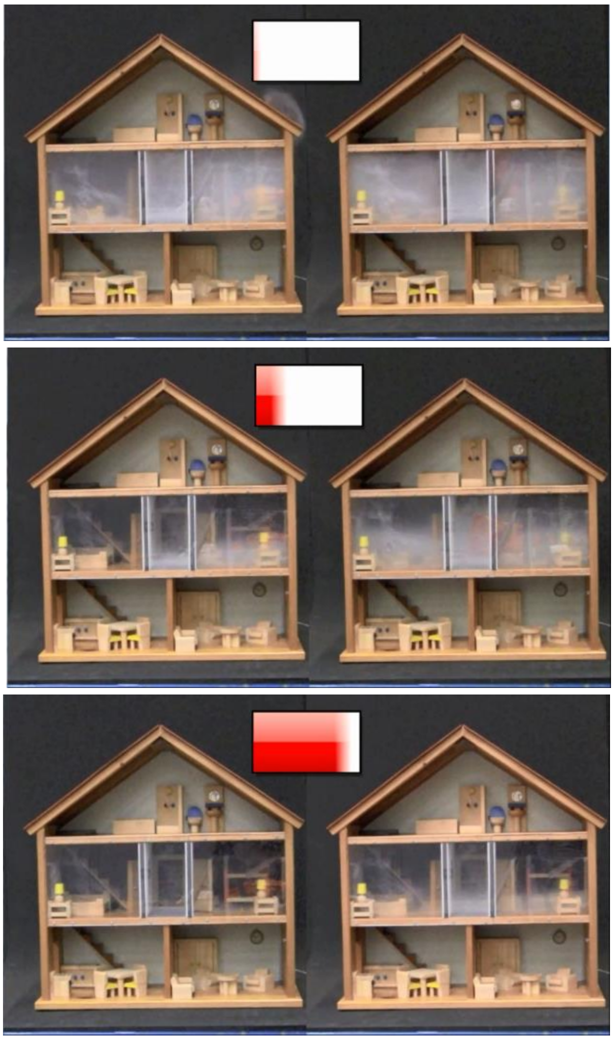
Figure 3. Frames of the situation with an open window in the master bedroom 1 minute (a), 3 minutes (b), and 10 minutes (c) after start of the ventilation system. In every frame left is the house with MEV and right is the house with MVHR.

Condition 3: Wind pressure on the master bedroom

The third condition is the occurrence of wind, with the master bedroom at the windward side and the child's bedroom at the lee side. In the scale model, the wind is made by a table fan placed approximately 2 meters from the scale house. For MEV, all window grilles are open. For both ventilation systems all windows are closed and all internal doors are halfway open.

Figure 4 shows that for MEV, the open window grilles at the windward side and the lee side allow a cross flow through the house. Stale air from the master bedroom is flowing to the child's bedroom. Figure 4 also shows that for MEV the natural air flow through the window grille is taking place in the reversed direction (!) as intended in the design phase, so that indoor air with smoke flows out of the house via the grille. Unlike a typical night, in the scale model there is no continuous source of contamination (CO_2, moisture, etc.) in the master bedroom. However, one can conclude from the figures that he cross flow through a house with MEV causes an increased fresh air supply in rooms at the windward side and a decreased fresh air supply in rooms at the lee side of the house. The cross flow also has its effect on draught experiences in the master bedroom and on the entire energy consumption to heat the building but these energy implication are beyond the scope of these experiments.



a) b) c)

Figure 4. Frames of the situation with wind attack on the master bedroom 1 minute (a), 3 minutes (b), and 10 minutes (c) after start of the ventilation system. In every frame left is the house with MEV and right is the house with MVHR.

4 SUMMARY OF RESULTS

The comparison between MEV and MVHR can best be seen in table 1. This table summarizes the cleaning time in the child's room for the experiments with the scale model. The cleaning time is used as a measure of the ventilation effectiveness, with obviously cleaning time decreasing when ventilation effectiveness for an individual room is increased.

Table 1. Cleaning time of the child's bedroom.

	MEV	**MVHR**
No disturbance	8 minutes	8 minutes
Open window in master bedroom	20 minutes	8 minutes
Wind on master bedroom	1 minute	8 minutes

The cleaning time of a room is increased by an open window elsewhere in the house. Contrary to people's belief that windows may not be opened for an MVHR ventilation system, it is shown that the ventilation effectiveness of an MEV system may be negatively influenced by open windows somewhere in the house.

The cleaning time of a room at the lee side of the building is seemingly decreased by the wind in the scale experiments. However, with a continuous source of contamination elsewhere in the house, the room at the lee side does not get a supply of fresh air via the window grille, but is filled with stale air from elsewhere in the house. Because of the air tight envelope of a house with MVHR, the cleaning time of both rooms is not influenced at all by wind around the building.

In real life the number of conditions is much larger. Depending on the outside temperature and wind conditions, and on the specific position of grilles, windows, internal/external doors, the driving force and the air flow paths change in a drastic way. With natural supply of air as in MEV ventilation systems, the corresponding ventilation effectiveness for an individual room is largely influenced by the combination of all these conditions.

The conditions as shown in these scale experiments are merely chosen as examples of the negative influences they can have. The real life effect of all these conditions can be seen in large monitoring campaigns as in Van Holsteijn et al (2015).

5 CONCLUSIONS

For an air tight house with MVHR (mechanical extract and mechanical supply), the ventilation effectiveness is neither changed by the occupants' behavior nor by wind effects around the building. The mechanical supply in a room is therefore necessary to maintain a continuous supply of fresh air into the room. The conclusion is that the mechanical supply in MVHR systems (as opposed to the natural supply from MEV systems) lead to a constant indoor air quality regardless of occupants' behavior or wind effects around a house. Another advantage is the obvious energy saving by the heat recovery of MVHR ventilation systems.

6 REFERENCES

Van Holsteijn RCA, Li WL, Valk HJJ et al (2015) Improving the energy- and IAQ performance of ventilation systems in Dutch residential dwellings. Proceedings of the International Conference Healthy Buildings 2015 Europe, 18-20 May 2015, Eindhoven