COMPARISON OF THE USE TRICKLE VENTILATORS IN EUROPEAN RESIDENTIAL VENTILATION STANDARDS

Jelle Laverge¹, Arnold Janssens¹

¹Faculty of Engineering and Architecture, Ghent University, Gent, Belgium.

Abstract

The performance of exhaust ventilations systems is governed by several factors. The specifications used for the trickle ventilators, is one aspect that will determine the total airflow in the building. Therefore, correct sizing of the trickle ventilators is an important aspect in the assessment of the quality of a ventilation system. However, little agreement is found in European ventilation standards on the specifications for these components.

We modelled the performance of an exhaust ventilation system in a standardized detached dwelling according to the Belgian, Dutch and French residential ventilation standards in order to assess the heat loss and indoor air quality associated with the different specifications they represent.

In this paper we report the results of the simulations and assess the benefits and drawbacks of each of the approaches taken in the discussed standards.

Keywords: trickle ventilators, exhaust ventilation, standards, performance, IAQ

1 Contents

In the moderate climate zone of western Europe, especially in the Netherlands, France and Belgium, with about 2500-3000 heating degree days (Eurostat, 2010; ISO, 2007), the payback time for investments in heat recovery ventilation are long, especially in buildings with relatively low air change rates such as dwellings. Due to its competitive price setting as well as due to reports in popular media and scientific literature about possible health risks associated with heat recovery systems (Meijer, 2010) simple mechanical exhaust ventilation dominates the residential ventilation market (De Gids, 2003; Durier, 2008) in this region.

The performance of exhaust ventilation systems is governed by the sizing of its different components, mainly fan and ductwork, transfer devices and trickle ventilators (supply grilles). The Belgian (BIN, 1991), Dutch (NNI, 2006) and French (France, 1983) residential ventilation standards have very different prescriptions for the sizing of the trickle ventilators, ordering that they should be sized to deliver the design flow rate at 2, 1 and 10 Pa, respectively.

Because of the large differences in these prescriptions, this paper focuses on the impact of these differences on the overall performance of the exhaust ventilation system into which the trickle ventilators are integrated. The results were generated with the use of a multi-zone building model (Dols, 2001) of a statistically representative detached dwelling. The performance of the exhaust ventilation system is assessed both on the level of total heating season averaged convective heat loss through ventilation and on the indoor air quality (IAQ) level.

2 Methods

2.1 Building model

The geometry used in the model is based on a detached house that is statistically representative for the average Belgian dwelling. It has been designed for and used in several previous research projects (Verbeeck, 2007; Verbeeck, 2005; Janssens, 2009) and is currently used to assess the performance of residential ventilation systems in the EPBD framework in Belgium (Van Den
Bossche, 2007). Table 1. lists the dimensions (m²) of the spaces in the building model. Figure 1 shows the plan of the ground floor and 1st floor of the dwelling.

Each room in the dwelling was modelled as a separate zone. The air leakage of the building was modelled by introducing cracks at both ¼ and ¾ of the height of each wall in order to take into account buoyancy effects. The total leakage was varied between 12 (very leaky) and 0.5 (better than passive house standard) m³/h per m² of leakage area at 50 Pa in steps of 0.5. The indoor temperature is constant and set to 18 °C, which corresponds to the mean value measured in Belgian dwellings (CEN, 2004a; Laverge, 2010).

Since the goal of the paper is to assess the impact of the different sizing requirements for the trickle ventilators only, the other components of the system have to be identical for all of the simulations. Since the design flow rates of Belgian and Dutch standard are almost identical, the mechanical exhaust ventilation system is implemented according to the requirements of the Belgian residential ventilation standard (BIN, 1991). This standard imposes design flow rates for the main system components in an exhaust system. In general, the required flow rates are 3.6 m³/h/m² of floor area, with minimum values for wet spaces such as kitchen and bathrooms. The resulting design flow rates are also listed in Table 1.

The design flow rates used in the French standard are somewhat different, but the total exhaust flow rate for this building is comparable to that required by the Belgian and the Dutch standard. The total exhaust flow rate is 175 m³/h, which is about 0.5 ACH. As was mentioned above, the Belgian, Dutch and French standards require the trickle ventilators to deliver the design flow rate at 1, 2 and 10 Pa pressure difference over the component. The model was adapted to reflect each of these conditions. An additional condition was simulated where the trickle ventilators were omitted.

2.1 Assessment parameters

Through the correlation between excess CO₂ concentration and mean percentage of dissatisfied (CEN 1998) and Fanger’s Perceived Air Quality approach (Fanger, 1988), CO₂ concentration is now widely accepted as a proxy for perceived indoor air quality (CEN 2004), especially if the main pollution sources are related to the human metabolism. The production of CO₂ within the model is only related to the occupants’ metabolism and corresponds to their whereabouts. The production rate is, in accordance with EN 15251 (CEN, 2005), fixed at 19 l/h for an adult performing light work and 12 l/h for an adult at rest. A background outdoor concentration of 350 ppm is assumed. Within this paper, the average daily exposure to CO₂ concentration above 950 will be used as the assessment parameter for the indoor air quality. This represents the exposure to indoor air quality considered to be sub-standard (IDA 3 and 4 class) in EN 13779 standard (CEN, 2004b).

To assess the impact of the choice of trickle ventilator specifications on the energy use, the heating season averaged heat loss through ventilation was used.
Table 1: Floor Area (m²) and design supply/exhaust air flow rates (m³/h) of the spaces in the dwelling

<table>
<thead>
<tr>
<th>Ground Floor</th>
<th>Area</th>
<th>Supply</th>
<th>Exhaust</th>
</tr>
</thead>
<tbody>
<tr>
<td>Living room</td>
<td>35.7</td>
<td>128.4</td>
<td></td>
</tr>
<tr>
<td>Office</td>
<td>8</td>
<td>28.9</td>
<td>50</td>
</tr>
<tr>
<td>Kitchen</td>
<td>10.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Service room</td>
<td>7.7</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Toilet</td>
<td>1.7</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Hallway</td>
<td>28.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>First Floor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bedroom 1</td>
<td>17</td>
<td>61.1</td>
<td></td>
</tr>
<tr>
<td>Bedroom 2</td>
<td>18.2</td>
<td>65.6</td>
<td></td>
</tr>
<tr>
<td>Bedroom 3</td>
<td>18.3</td>
<td>65.8</td>
<td></td>
</tr>
<tr>
<td>Bathroom</td>
<td>8</td>
<td></td>
<td>50</td>
</tr>
<tr>
<td>Hallway</td>
<td>28.1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3 Results

The results for both heat loss and IAQ are shown in figures 2-3. The exposure to CO₂ reaches a maximum for each of the configurations. The leakage level at which this maximum is reached and the height of the maximum is dependent on the choice of design pressure difference for the trickle ventilators. Also note that the results for the configuration without trickle ventilators renders better results for the very tight cases.

Figure 2. IAQ results for the different configurations as a function of leakage. Note the maxima occurring for each of the configurations.

The heat loss results show parallel behavior. The heat loss is linearly correlated with the leakage level of the building for all the configurations, but levels off in the range that is tighter than the
leakage level at which the maximum in exposure is reached. Nevertheless, a constant value is only reached in the configuration where the trickle ventilators were omitted.

![Graph showing heat loss results for different configurations as a function of leakage.](image)

**Figure 3.** Heat loss results for the different configurations as a function of leakage. Note the deflections for the 10 Pa and No Supply configurations.

### 4 Discussion

The results show that the different specifications for the trickle ventilators have a significant impact on both heat loss and IAQ. The heat loss trough ventilation for the 2 Pa trickle ventilators is about 10% lower than that for the 1 Pa trickle ventilators at the best airtightness. The heat loss for the 10 Pa trickle ventilators is about 22% lower than that for the 1 Pa trickle ventilators at that leakage level. The heat loss for the 10 Pa trickle ventilators at the lowest leakage level is about equal to the constant value of the heat loss achieved by the system without trickle ventilators. In Figure 4, the heat loss for the 1 Pa trickle ventilators is shown, compared to that for the same ventilators, but with the exhaust fan shut down. 60% of the heat loss remains in the configuration without mechanical exhaust.

The configurations without trickle ventilators and without mechanical exhaust represent two extremes that are both associated with a different overall flow regime in the dwelling. The configuration without trickle ventilators creates a large underpressure in the building due to the absence of large inlets and the forced mechanical exhaust of 0.5 ACH. For the tightest case, this underpressure amounts to 50 Pa. This is of course not very realistic in a real building, but in this case flow regime in the dwelling is fully governed by the mechanically induced exhaust flow and is flowing from the living spaces (with the larges leakage area) to the ‘wet’ spaces where the vent holes are located. This regime is achieved from a leakage rate of 2 m/h at 50 Pa on, as can be seen in Figure 3. This corresponds to an underpressure in the building of 6 Pa. If we take the fact that the trickle ventilators are sized to the design flow rate specified for the living spaces and not to the exhaust flow rate, the underpressure generated by the exhaust flow system in the tightest case of the configuration with 10 Pa trickle ventilators, amounts to 3 Pa, so it is getting close to this regime. This can be seen in the deflection of the heat loss curve in the low leakage range.

The configuration without mechanical exhaust corresponds to the other extreme, where no underpressure at all is generated and the flow in the dwelling is only driven by thermal buoyancy. The air is now entering the dwelling at the ground floor trickles and exits through the first floor trickles.
Next to thermal buoyancy, wind will induce cross ventilation in this case causing fresh air to enter the building at the windward side and exit through the trickle ventilators at the leeward side. The combination of buoyancy induced flow and wind induced flow is a ‘natural ventilation’ regime.

The flow regimes created by the configurations with the 1, 2 and 10 Pa trickle ventilators are combinations of these two extreme regimes. As underpressure due to mechanical exhaust flow builds up, an ever greater portion of the cross ventilation and buoyancy driven flow will be redirected to the vent holes. This explains why the heat loss for these configurations is somewhere between that of the individual extremes and their sum.

The exposure for the configuration without mechanical exhaust flow is higher than that with mechanical exhaust and rises sharply in the tight range, peaking at about 2500 ppmh for the tightest case. The IAQ associated with the higher pressure drop trickle ventilators is worse than that reported for the 1 Pa trickle ventilators (Figure 2.). This is also caused by the combination of the two flow regimes. Especially at the first floor, where the occupants spend the majority of their time in the dwelling, two driving forces (underpressure from the exhaust flow and buoyancy) are opposite. The resulting pressure drop over the trickle ventilators will be seriously reduced, thus causing low ventilation rates in the bedrooms and higher exposure. Once one of the driving forces dominates, the flow rates increase and the exposure decreases, explaining the peak exposures seen in Figure 2.

The height of this peak exposure is also influenced by the overall leakage level of the dwelling and the internal flow resistances caused by internal separations and transfer devices. Because of these resistances, the underpressure generated by the exhaust flow will not be spread evenly through the building, creating lower fresh air supply in the living spaces, where exposure is therefore high, due to ‘leakflows’ in the ‘wet’ spaces where the vent holes are located, where exposure will be lower, but will have little influence on the overall exposure due to the little amount of time spent in these spaces.

Based on the heat loss results, one would argue that the higher the design pressure drop for the trickle ventilators, the better, since this cancels to some extent the influence of the leakiness of the building. Additionally, if the generated underpressure is high enough, the IAQ results show that this can even lead to lower exposure. Nevertheless, the underpressure needed for this is unrealistically high (> 30 Pa).
5 Conclusion

Three design pressure drops for trickle ventilators were tested, corresponding with the Belgian, Dutch and German residential ventilation standards. The results showed that the sizing of the trickle ventilators has a considerable impact on the flow regime inside the dwelling. For leaky buildings, the influence of the trickle ventilator sizing on the IAQ is rather limited, and considerable energy savings can be achieved by selecting smaller trickle ventilators. In the medium leakage range, which corresponds to the majority of dwellings, the use of a design pressure drop of 10 Pa for the sizing of trickle ventilators will result in both energy saving but also in poor indoor air quality. This effect disappears only at extremely low leakage levels (better than passive house standard air tightness).

6 References

Cen. (2005) Criteria for the indoor environment, including thermal, indoor air quality, light and noise, EN 15251.