PASSIVE HOUSE VENTILATION STRAGETIES: DEMAND CONTROL?

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ABSTRACT

Since insulation levels in a passive house context are very high, energy losses trough ventilation are of relatively high importance in the total energy balance of a passive house concept. Although fully mechanical ventilation systems are at the core of the this concept, enabling both regeneration and cheap space heating, it can still be optimized. With demand controlled systems, excess ventilation can be minimized, thus reducing both redundant ventilation losses and the accompanying electrical loads. This paper reviews the possibilities for a performance based optimization of ventilation systems for passive houses within the context of the Belgian legislation

1. INTRODUCTION

Passive houses achieve a low energy use compared to regular building practice. As a basis for the passive house concept, the total annual energy demand for heating is limited to 15 kWh / m². This is generally achieved by heavy insulation and a highly effective heat-recovery in the ventilation system.
Passive house standards recommend a minimal mean annual air change rate in a dwelling of about 0.4 [2], along with very strict airtightness guidelines. A fully mechanical ventilation system is used, mainly for heat recovery purposes, combined with a earth-to-air heat exchanger.
However, no guidelines are formulated on the control of this system. Several surveys [1] have indicated that most of these systems are equipped with a simple gradient switch, allowing for 3 operation modes. As is correctly assumed by the passive house standards, these surveys also show that in most cases, the users select the lowest possible mode or 33% of the maximum flow rate. Additionally, they hardly ever change the operation mode. The effect on Indoor Air Quality and the possible advantages of the application of demand controlled ventilation can easily be guessed.

2. ELABORATION

Demand Controlled Ventilation
Demand Controlled Ventilation is a term that is used for any ventilation system that is able to dynamically adjust the fresh air flow it provides to the demand existing at that specific time. Therefore it must be equipped with some kind of control strategy. Possible applications are time control, relative humidity based control, presence based control, carbon dioxide based control etc.

Energy
In the passive house standards [2], the following calculation of is proposed to estimate the annual energy demand of the building due to ventilation:

$$Qv = 0.34 * q * (1 - \eta) * \Delta t$$

In this equation q is the total ventilation rate per m² in m³. As was stated above, a building volume averaged, annual mean air change rate of 0.4 ACH is proposed and the height of the spaces is assumed to be 2.5m. The total ventilation rate per surface area q is thus 1 m³/m². η is the effectivity of the combination of the heat recovery unit and the earth-to-air heat exchanger. For this, a default value of 0.8 is proposed.

Calculation with this formula yields a resulting annual heat loss through ventilation of 5 kWh / m² or 1/3 of the total allowed energy demand for heating.

Indoor Air Quality

The Belgian standard NBN D 50-001 [3], is applicable to all residential buildings in Flandres, due to its attachement to the Energy Perfomance and Indoor Climate-decree of the Flemish government. In this standard, a minimal capacity of the ventilation system is proposed, that has to be met in every dwelling.

The airflow rates proposed in this standard are roughly based on the methodology proposed by FANGER in 1988 [4], which is incorporated in most of the currently available ventilation standards. This methodology introduces a correlation between the air quality percieved by an occupant upon entering a building and the ventilation rate (see Figure 1.). He demonstrates that he required ventilation rate is a function of human occupancy due to human generated pollution.

In the European EN 13 779 [5] standard for non-residential buildings for example, an air change rate of 36 m³ / h per person is proposed to achieve moderate indoor air quality. This corresponds to 20 % of dissattisfied occupants. This value is also used in the NBN D 50-001 standard. The occupancy level of the spaces is assumed to be related to its ground surface, with a 1/10 ratio. 1 Occupant is therefore assumed every 10 m². If all these assumptions are taken into account, the standard proposes a building averaged design air change rate for a dwelling of +- 1 ACH.

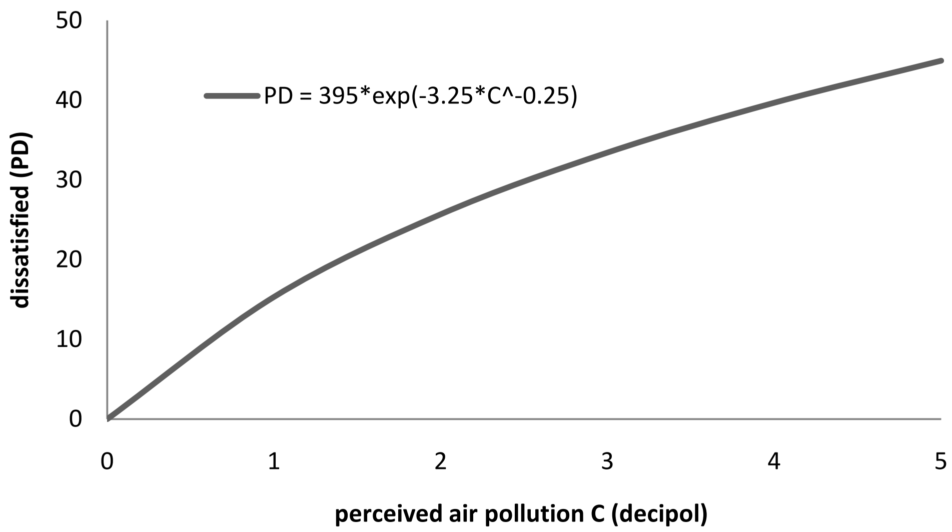

FIGURE 1: Percentage of dissatisfied occupants as a function of decipol (FANGER). 1 decipol is 36 m³ / h of fresh air per person

Note that this is significantly higher than the air change rate proposed by the passive house standard. 0.4 ACH corresponds rather well to the 1/3 average operation mode that was discussed above. Under the same occupancy assumptions, a building air change rate of 0.4 ACH would account for a percieved air quality jugged unacceptable by 36 % of the occupants. This is generally assumed to be unacceptable, for example in the European EN 13 779 standard.

The ventilation rate proposed by the passive house standard, firstly, is not based on an basic volume rate of 36 m³ / h per person, but rather on 30 m³ / h per person [2]. This corresponds with about 23 % of dissatisfied instead of 20%. Not really a dramatic deterioration one could argue. However, this would still yield a mean building air change rate of about 0.84 ACH if the same occupancy assumptions are made. The standard therefore assumes that this occupancy rate is only achieved 48 % of the time.

In the framework of the application of the equivalence principle on the performance of ventilation systems in a residential context, BBRI developed 100 multiperson family occupancy schemes for a detached house [6][7]. An analysis of this data demonstrates that a general occupancy fraction of 80% of a dwelling and a mean living surface of 32 m² per person are not so farfetched.

Combined together, this would result in an occupancy rate 74 % smaller than the one assumed in the standards. A serious margin of improvement would thus be available for demand controlled ventilation.

Control Strategies

The potential energy reduction that can be achieved with Demand Controlled ventilation, without reducing indoor air quality, is highly dependent on the control strategy employed. As was stated above, the general control strategy used by the occupants of a mechanically ventilated dwelling is semi-permanently choosing a low operation mode. However, occupancy is far from constant. The total number of occupants in the dwelling and their wherabouts in the dwelling are subject to considerable change. This can clearly be seen in figure 2., which depicts the mean occupancy of various rooms for the 100 families developped by BBRI during a weekday. The effect of this ill-adapted control strategy is a serious reduction of indoor air quality, often to an unexceptable extend, as was explained above.

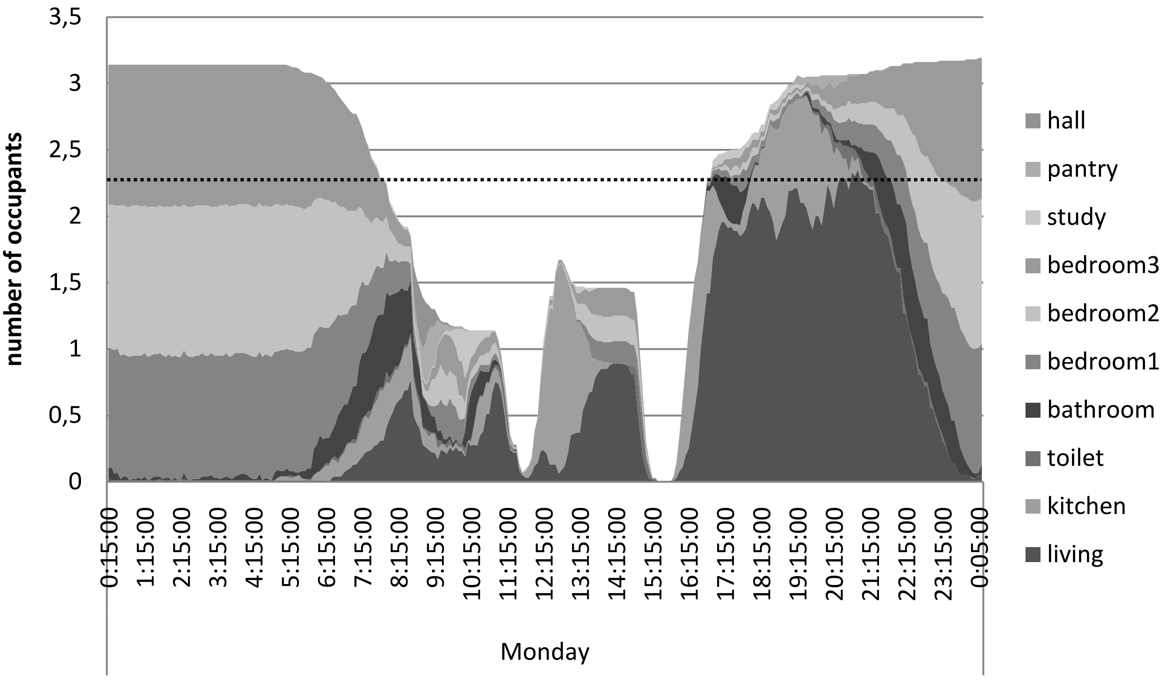

FIGURE 2: Occupancy in a dwelling on a weekday, based on 100 families developed by BBRI

In a fully mechanical ventilation system, 2 main control strategies are available: central flow rate control or de-central flow rate control (or a combination of both).
Central volume rate control will reduce the total air volume rate that is supplied to the building in function of the known or measured total occupancy. As can be seen in figure 2, this can reduce the daily mean airflow rate by about 25 % (The mean is depicted by the dotted line). However, this can only be done effectively in combination with de-central air flow control.

De-central volume rate control implies that the airflow is directed to where it is needed. Most residential ventilation systems don't offer the possibility to adjust the airflow separately in each room. Without this feature, the system needs to deliver the highest proportional flow rate demanded at that time to all rooms. This too can easily be seen in figure 2. For example, at noon, the kitchen demands full capacity. If no local air flow control is available, the whole system will have to operate in maximum capacity mode, while the total flow rate demand is only half of that. The combination of both strategies will enable a reduction of the total mean air flow rate with about 74%.

In addition to these 2 strategies, a minimal flow rate must be guaranteed at any time. In European standards and in assessment criteria used in the Belgian equivalence procedure, 10% of the nominal air flow rate is considered to be a lower limit of total air flow rate reduction. This is due to the fact that control systems are not equipped to detect every kind of pollution. A minimal air flow rate thus insures that these undetected pollutants cannot build up due to a system shut down, rendering a total possible flow rate reduction of about 70%, without compromising indoor air quality. Compared to the currently used calculation procedure, this would be equal to a 1.9 kWh / m² reduction of the annual heating demand.

In addition, not only the heating demand will go down because of this. Electrical energy needed to power the fan will drop in an equal amount, although this is a rather small amount of energy to begin with.

Integration with heating

In a passive house, the ventilation and heating system are usually fully integrated. A heating coil is inserted into the ventilation system. Due to the high levels of insulation, air tightness and heat recovery in the ventilation, the ventilation flowrate is large enough to heat the building within all comfort restrictions.

If the total flow rate is reduced, as described above, this could endanger the heat supply to the dwelling on cold winter days. On the other hand, reduced ventilation with a demand controlled ventilation system means low occupancy. Therefore, if decentralised air flow control is implemented, the heated air can be directed to the spaces that are occupied, thus guaranteing thermal comfort in these spaces. A more costly choice to tackel this problem would be to implement decentralised heating coils in the system, combined with a recirculation unit.

3. CONCLUSION

The currently used calculation procedure in passive house standards uses rather limited ventilation rates. Moreover, it assumes a rather effective control strategy, while no requirements are set for this. This may easily result in poor indoor air quality.
Demand controlled ventilation systems offer an effective way to further reduce the annual heating demand of passive houses by about 2 kWh / m². In addition to that, they do so without compromising indoor air quality, as is the result of ill adapted control strategies now commonly found in dwellings with mechanical ventilation systems.

4. DISCUSSION

This paper explored the potential of demand controlled ventilation in passive houses. It demonstrated that these systems can have a serious impact on the total energy demand of passive houses.
Future research might be oriented to the calculation of economical viability of these concepts and to assess their performance in real applications.
Especially the technical implementation of control mechanisms and the integration of a fully functional ventilation system and an equally functional heating system is still open to a lot of research.

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