ANNUAL VARIATION OF AIR DISTRIBUTION IN A COLD CLIMATE

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ABSTRACT

The airflows through a one family prototype building have been simulated. Supply openings in living room and bedrooms have a size of 200 and 400 cm^2 respectively. The ventilation system is a passive stack ventilation system, with ventilation chimneys from kitchen, WC and bathroom.

The following parameters have been studied: the supply opening areas and heights, the overflow opening areas between bedrooms and hall and between WC/bathroom and hall, the height of the ventilation chimneys and the opening and closing of living room and bedroom doors.

In this study a **supply efficiency** is calculated for each room and set of parameters. It is defined as the relative number of hours, during the heating season, when the actual airflow is equal to or higher than the design airflow. For living room and bedrooms the outside airflow is used while the exhaust airflow is used for kitchen, WC and bathroom.

With the basic configuration, the supply efficiency is as low as ca 2 % for the bedrooms and below 1 % for WC and bathroom. By modifying the parameters it is possible to increase the efficiency. Without fans it is however impossible to reach the design values during the whole period.

KEYWORDS

Natural ventilation, air distribution, multi cell program, one family buildings.

INTRODUCTION

The purpose of a ventilation system is to supply the building with the required amount of air at all times. Design values are given in national standards that vary between countries. In Sweden the value is given as a minimum outside airflow of 0.35 l/s, m^2. In addition to this, a bedroom shall have 4 l/s and bed. Bathroom, WC and kitchen shall have 10 l/s respectively. In practice this means that the outside air is supplied to bedrooms and living room and extracted from bathroom, WC and kitchen. We thus have an air distribution with airflow from “clean” to “dirty” rooms.

However, it is difficult for a ventilation system, mechanical, natural or hybrid, to achieve this goal at all hours during the year. It can, for example, be shown that a mechanical exhaust ventilation system, designed to give the desired outside airflow, is unable to do that in certain rooms at certain wind directions (Åhlander 1999). Measurements in one family houses show that the air exchange often is lower than requested (Blomsterberg 1990).

In Sweden there is now an increasing interest in using natural forces for ventilation, following a long period when mechanical ventilation has been the only solution. The natural forces are often combined with mechanical, either by installing low-pressure exhaust fans in the passive stack system or by using exhaust fans in bathroom, WC and kitchen. The combination of natural and mechanical forces gives a hybrid ventilation system (Heiselberg 1999).

Since the days when all residential buildings were naturally ventilated, the building technology has improved. This is most obvious when it comes to building tight houses. It means that we really don't know much about how natural ventilation functions in our modern buildings. This knowledge is necessary for designing both natural and hybrid ventilation systems.

In this study a two-story one family house is studied with respect to the air distribution between rooms. A building in a cold climate (Östersund, Sweden, latitude 63.18 ^{o}) is studied. For the calculations the summer months are excluded and only the heating season, September to May (6553 hours), is used.

The reason for this is that it is assumed that ventilation can be achieved during the summer months with window airing, without any comfort problems. No air conditioning is assumed while this is uncommon in this climate. The assumed window airing of course requires that the building is located in an area that allows such a ventilation method.

A climate file for Östersund from ASHRAE is used. The outside temperature varies between -25.8 and +26.5 ^{o}C during the year with the average temperature +3,1 ^{o}C. The wind velocity at 10 m height varies between 0 and 14.9 m/s with the average wind velocity 4,1 m/s. The average wind direction is 257,5 ^{o} , i.e. almost from west.

METHOD

The airflow through a prototype building is simulated using the multi cell program IDA Climate and Energy. The building is a two-story one family house with the total area of 84 m^2, which in Sweden is considered a quite small house. The building has living room, WC and kitchen at the lower floor and three bedrooms and bathroom at the upper floor. Living room, bedroom 1 and bedroom 2 are heading to the south, the other rooms to the north.

The leakages in the outer walls are assumed to be concentrated to two leakages in each room, 0.625 and 1.875 m above floor. The total leakage area is chosen to give 2.5 air changes an hour at 50 Pa pressure difference, which corresponds to the Swedish standard.

The air supply openings are located at 2 m level and have an area of 80 cm^2 in the living room and 40 cm^2 in the bedrooms. The overflow openings between the hall and surrounding rooms

have an area of 100 cm^2 except the opening to the bathroom that is 200 cm^2. These openings are located at floor level. The kitchen door is assumed to be open at all times.
The building is ventilated with a passive stack ventilation system. The ventilation chimneys from kitchen, WC and bathroom all origin from ceiling level and end 2.5 m above the upper floor ceiling. The inner diameter of the ducts is 150 mm in WC and bathroom and 200 mm in kitchen.

RESULTS

The first simulation was made with the basic configuration of the building described above. The result gives an outside airflow to bedroom 1 that varies between 0 and 23 l/s with the average 2,7 l/s. The design outside airflow for this room is 7.4 l/s. The actual airflow is less than that for the major part of the year.

In this study a **supply efficiency** is calculated for each room and set of parameters. It is defined as the relative number of hours, during the heating season, when the actual airflow is equal to or higher than the design airflow. For living room and bedrooms the outside airflow is used while the exhaust airflow is used for kitchen, WC and bathroom.

With the basic configuration the supply efficiency is 38.8 % for the whole building,
2.5 % for bedroom 1 and 2 and 2.0 % for bedroom 3. For the living room it is 57 % and for the kitchen it is 96 %. The open door to the kitchen makes it impossible to have a correct air direction between hall and kitchen. During almost the whole year air from the kitchen is entering the hall. When it comes to WC and bathroom, which are assumed to have closed doors but overflow openings to the hall, the air direction is correct but the supply efficiency is lower than
1 %.

The results for bedrooms, WC and bathroom are of course not at all satisfying. The basic configuration must be modified. In order to increase these supply efficiencies, several parameters can be altered. The parameters studied in this paper are the height of the ventilation chimneys; the area and height of the supply openings in bedrooms; the overflow opening areas between bedrooms and hall, the overflow opening areas between WC/bathroom and hall and finally the opening or closing of living room and bedroom doors.

A first attempt to increase the airflow, is to lower the supply openings in the bedrooms from 2 m to 0.1 m height. This step is in accordance with the recommendations of the Nordic committee of building regulations (Bergsoe 1996). This step increases the supply efficiency in the bedrooms to 3.6, 3.0 and 3.9 % respectively. A positive change but of course not enough. The change to 0.1 m is kept during the following parameter studies.

The most effective way to increase the supply efficiency is to increase the chimney height, see figure 1. Since the extra chimney height means a big impact on the building architecture, its use is however limited.

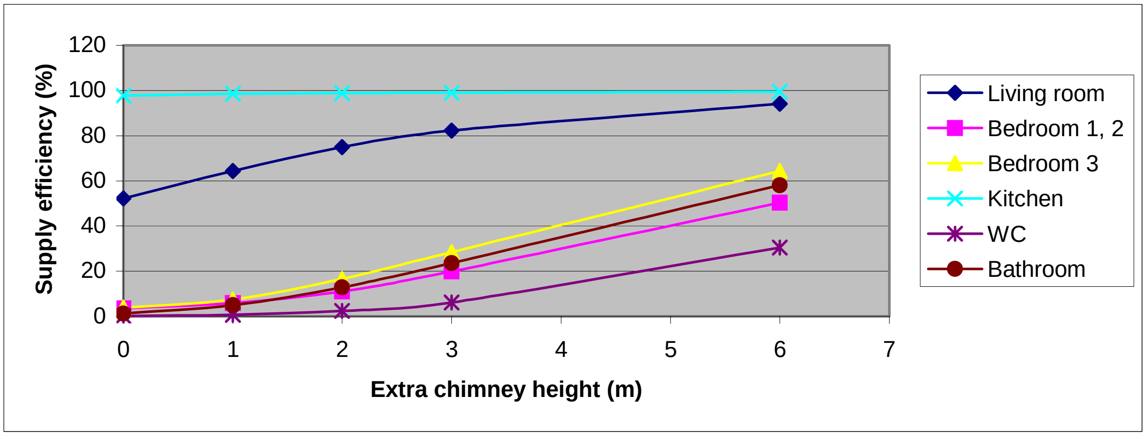
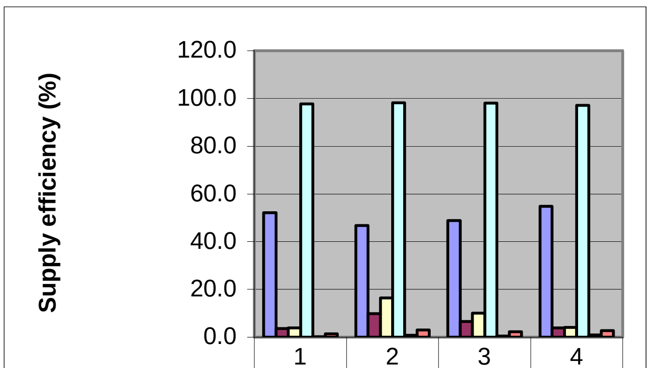


Figure 1. Influence of extra chimney height on the supply efficiency. Doors to living room and bedrooms closed.

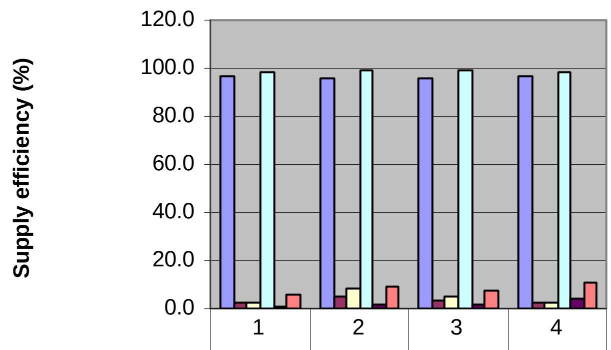


	1	2	3	4
Living room	52.2	46.8	48.8	54.8
Bedroom 1, 2	3.6	9.9	6.6	3.9
Bedroom 3	3.9	16.4	10.0	4.1
Kitchen	97.7	98.2	98.1	97.1
WC	0.2	0.7	0.4	0.9
Bathroom	1.3	3.0	2.2	2.7

Figure 2. Effect of doubling outer and inner opening areas. 1) Basic opening areas 2) Supply openings to bedrooms doubled 3) Overflow openings to bedrooms doubled 4) Overflow openings to WC/bathroom doubled. Living room door closed.

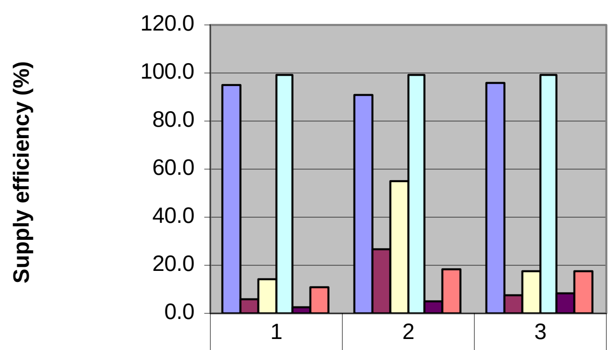
The effect of doubling the areas of the supply openings in bedrooms, the overflow openings between bedrooms and hall and the overflow openings between bathroom/WC and hall is shown in figure 2. The airflow is changed in all rooms except the kitchen with its open door.

If the door to the living room is open, which is common in Sweden, the airflows in the different rooms will change. It will increase in living room, WC and bathroom but decrease in the bedrooms. The effect of changing the inner and outer ventilation openings will differ from the case with living room door closed. The airflow in the living room as well as in the kitchen is now almost unchanged, see figure 3.



	1	2	3	4
Living room	96.7	95.9	96.2	96.8
Bedroom 1, 2	2.6	4.7	3.7	2.8
Bedroom 3	2.7	8.1	5.3	2.8
Kitchen	98.7	98.9	98.8	98.6
WC	1.1	1.8	1.4	4.0
Bathroom	5.8	9.2	7.9	11.0

Figure 3. Effect of doubling outer and inner opening areas. 1) Basic opening areas 2) Supply openings to bedrooms doubled 3) Overflow openings to bedrooms doubled 4) Overflow openings to WC/bathroom doubled. Living room door open.



	1	2	3
Living room	95.0	90.7	95.9
Bedroom 1, 2	6.0	27.0	7.7
Bedroom 3	14.3	55.3	17.1
Kitchen	98.9	99.2	98.9
WC	2.2	5.3	8.1
Bathroom	10.6	18.7	17.8

Figure 4. Effect of doubling outer and inner opening areas. 1) Basic opening areas 2) Supply openings to bedrooms doubled 3) Overflow openings to WC/bathroom doubled. Living room and bedroom doors open.

If, finally, both the living room and the bedroom doors stand open the doubling will have the effect shown in figure 4.

Combining a doubling of all the ventilation opening areas, a lengthening of the ventilation chimneys with 2 m and assuming that living room and bedroom doors are open, gives a supply efficiency for the bedrooms between 52 and 80 %. For WC and bathroom the corresponding figures are 47 and 65 %. The efficiency for the whole building will be 97 %.

CONCLUSION

The chimney heights and opening areas in the basic configuration give unsatisfying supply efficiencies. As long as the bedroom and WC/bathroom doors are closed, even a doubling of the ventilation openings is insufficient. An effective way to improve the efficiency is to lengthen the ventilation chimneys. Since this makes a big impact on the building architecture, one has to increase the ventilation opening areas.

To achieve the requested airflows during the whole heating season, the overflow openings to bedrooms and WC/bathroom must be as large as possible. Still it will probably be necessary to use exhaust fans in WC and bathroom or low-pressure fans in the ventilation chimneys.

Since the proposed changes increase the airflows, the time of the year when the airflows are too high will increase. Temperature controlled supply openings may therefore be necessary.

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