EVALUATION OF A CONTROLLED NATURAL VENTILATION SYSTEM

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1. INTRODUCTION

The most commonly used form of ventilation of residential buildings in Sweden is passive stack ventilation. Its driving power is the temperature difference between internal and external temperatures and the wind. Other factors that affect ventilation rate are the airtightness of the building, the sizes and numbers of the outdoor air inlets and the sizes of the ventilation ducts.

Common shortcomings or problems in buildings with natural ventilation are:

* Varying ventilation flow rates over the year;
* Major variations in air flow rate from room to room;
* A significant effect of wind on the ventilation flow rate;
* Air leaks in the building envelope can cause uneven distribution of indoor ventilation.

When renovating older apartment buildings with passive stack ventilation, the choice of ventilation method is generally a compromise between various requirements and what is practicable at a reasonable cost. The costs of converting older passive stack systems can be considerable, as it is often decided to convert the system to a technically more complicated one with mechanical exhaust.

There is considerable interest today in finding simple system arrangements for use when renovating older passive stack systems. One such arrangement that has been discussed in Sweden is the fan-assisted passive stack ventilation system. This is based on the use of an auxiliary fan that maintains ventilation when the natural drive forces are insufficient. In order to minimise the effects of temperature on ventilation flow rate, systems are often fitted with temperature-controlled outdoor air inlets.

The project described in this paper has performed simulations using a multi-zone air flow model [4 (COMIS)] of three different passive stack ventilation systems. The objective of the simulation calculations was to evaluate system performances and to make suggestions for possible improvements of the systems.

2. THE VENTILATION SYSTEMS TESTED

Three different systems have been investigated, based on three renovation projects of passive stack ventilation systems in apartment buildings in Stockholm. The systems were inspected and the results recorded. A questionnaire survey [5] was performed in the three buildings, although the results are not reproduced here.

The first system (1) is a conventional passive stack ventilation system for residential buildings, with exhaust air ducts and controllable outdoor air inlets under windows.

The second system (2) was a fan-assisted passive stack ventilation system, based on the use of the existing passive stack ventilation ducts without extensive renovation. Reducing ventilation as a resulting of stack decreasing effect is steplessly and automatically compensated by an axial-flow fan at the top of the duct, speed-controlled by the ambient temperature (see Figure 2). The fan enclosure is designed to reduce the effect of the wind and can also be modified for heat recovery from the exhaust air. Fresh outdoor air is admitted through temperature-controlled and self-adjusting inlets in sitting rooms, bedrooms and larders. As the ambient temperature falls, the amount of outdoor air admitted is reduced. Ventilation air is exhausted from kitchens and bathrooms as normal.

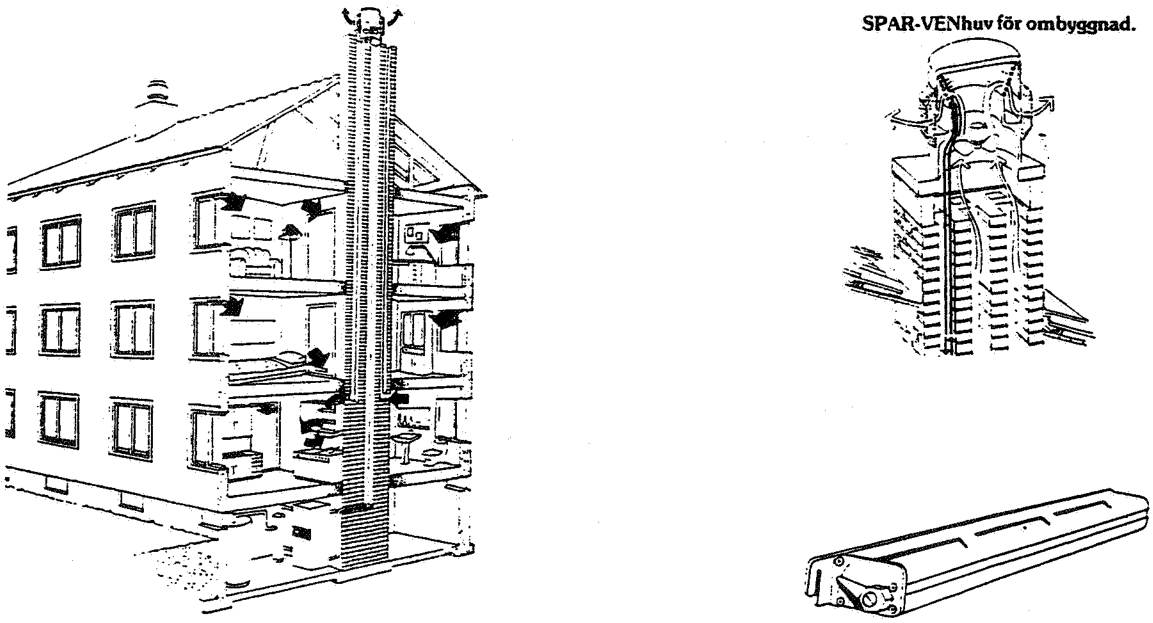

Figure 1. Components of the fan-assisted passive stack ventilation system.

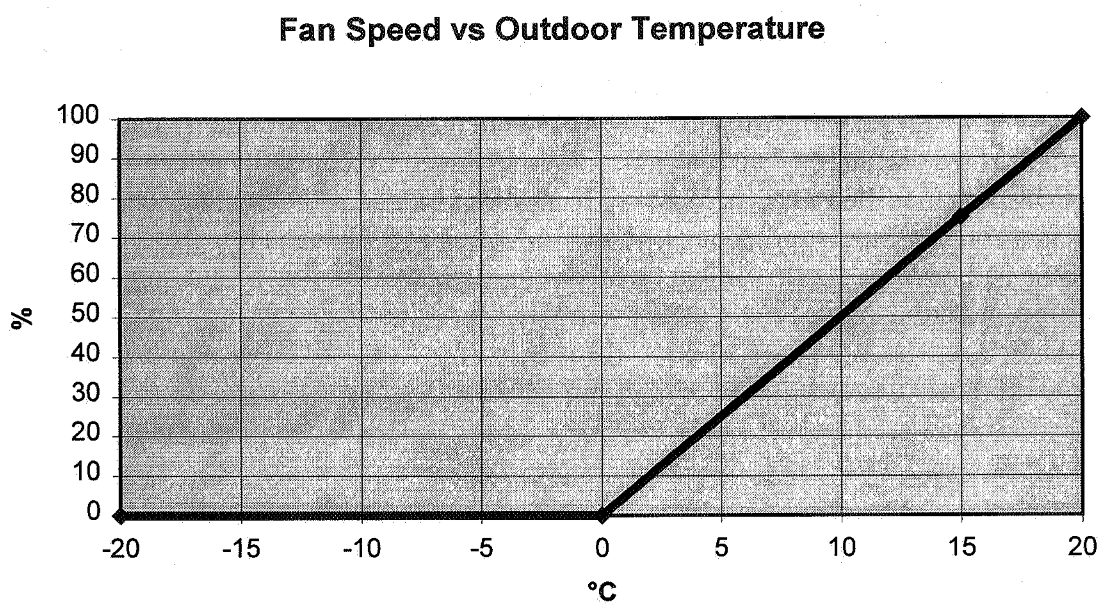

Figure 2. Fan control characteristic for systems (2) and (3).

The third system (3) that was investigated had outdoor air inlets as in a conventional Swedish system (1) and a fan and control system as in (2).

The apartment is in a residential area in a suburb of Stockholm, surrounded by buildings of the same height. The building is one of 13 in the area, containing a total of 189 apartments, with the distance to the nearest building being about 25 m. The buildings, which have three storeys and a cellar, date from the beginning of the 1940s. Indoor ceiling height is 2.7 m.

The simulations were performed for an apartment having the following characteristics.

Table 1. Differences between main features of the three systems

	Conventional passive stack system without fan (type 1)	**Fan-assisted passive stack ventilation system (type 2)**	**Conventional passive stack system with fan (type 3)**
Outdoor air inlets in rooms	Beneath windows: 1 in sitting room 1 in bedroom	Above windows: 2 temp. controlled in sitting room 1 temp. controlled in bedroom	Beneath windows: 1 in sitting room 1 in bedroom
Outdoor air inlet in larder	Disc-type inlet	1 temp. controlled	Disc-type inlet
Extractions	Kitchen and bathroom	Kitchen and bathroom	Kitchen and bathroom
Exhaust duct, pressure coefficient	-0.3	0	-0.3

3. WORKING METHODS

The objective of the investigation was to evaluate and compare the performance of a commercially available fan-assisted passive stack ventilation system with that of a passive stack system of the type that is conventional in Swedish residential buildings. The simulations compared the following parameters for both systems:

- ❑ Flow variations over the year
- ❑ Differences in ventilation performance in individual rooms
- ❑ The effect of wind on ventilation performance in individual rooms
- ❑ The effect of height above ground

A representative apartment, as in one of the buildings, was used as the model for all the simulations, being adapted in the model to incorporate the different types of ventilation systems as shown in Table 1. For the purposes of comparisons between the different systems, the apartment was assumed to be on the ground floor (level 1), but for the effects of height it was assumed to be on the second floor (level 3).

4. RESULTS

General input data for the simulations

Apartment's airtightness	1.9 air changes/h at 50 Pa negative pressure
Building pressure coefficient	As described by [1]
Internal duct dimensions	120 x 250 mm
Friction coefficient/for ducts	0.0042 [2]
Air leakage through closed larder door	As described by [3]
Inner doors:	Bathroom door closed, others open
Weather data	Stockholm, 1971

Flow variation over a year

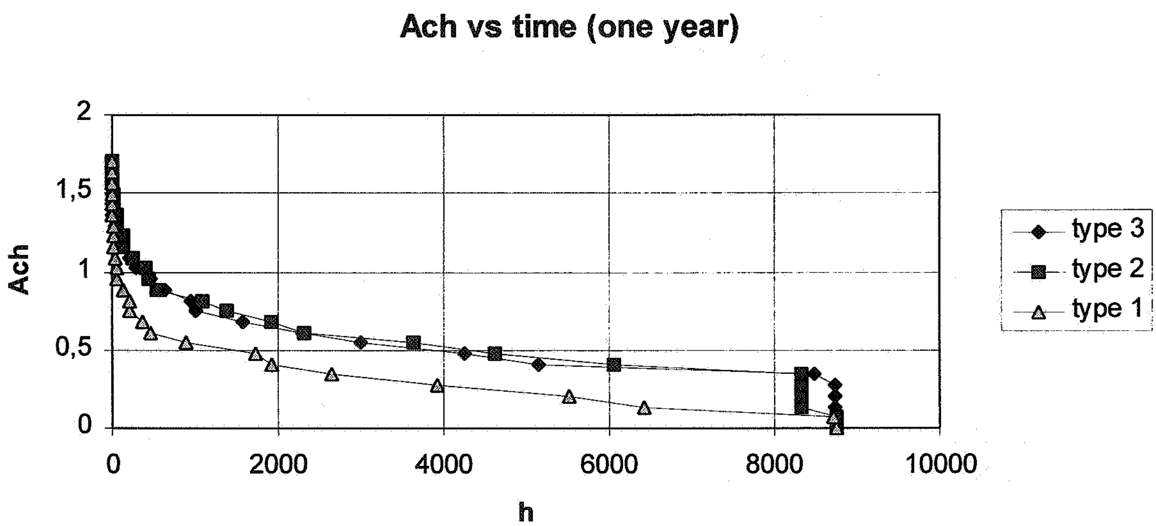

Figure 3. Air changes per hour over a year with the three different systems

Table 2. Air change rates per hour for the different systems

System type	Mean annual hourly change rate	Proportion of the year during which air change rate is within 20 % of annual mean value
Fan-assisted passive stack (type 2)	0.56	32
Passive stack with fan (type 3)	0.54	38
Passive stack without fan (type 1)	0.29	26

Despite the fact that System 2 (see Figure 3) incorporates temperature-controlled fresh air inlet fittings, the flow rate varies during the year just as much as it does in System 3, which does not have temperature-controlled inlets. The temperature-controlled inlets, in other words, have not succeeded in stabilising the air flow rate.

It can be seen from Table 2 that the proportion of the year during which the air flow rate is within ±20 % of the mean value is somewhat higher for System 3 than for System 2. This, too, shows that the temperature-controlled fresh air inlets have not had any effect in terms of stabilising the flow rate over the year.

The temperature-controlled fan, on the other hand, has increased the flow from 0.29 air changes/h to 0.54-0.56 air changes/h.

Differences in ability to ventilate individual rooms

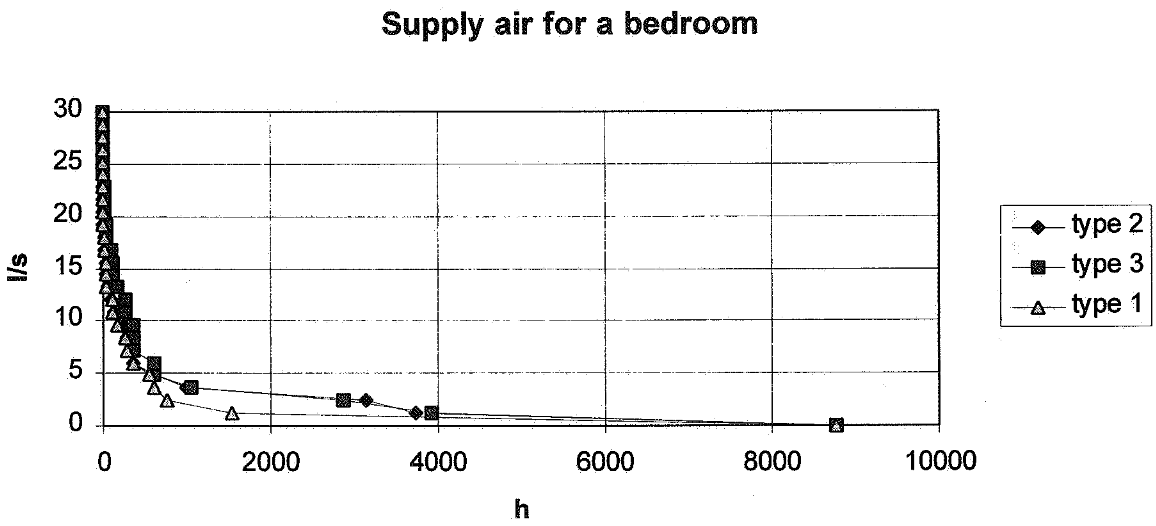

Figure 4. Supply air flow rate to the bedroom in the three different systems

Table 3. Average supply air flow rate over a year to bedroom for the three different systems

System type	Fresh air flow rate, l/s (mean value over the year)
Fan-assisted passive stack (type 2)	1.8
Passive stack with fan (type 3)	2.2
Passive stack without fan (type 1)	1.3

Swedish building regulations require the fresh air flow rate to a bedroom to be at least 4 l/s per person. It can be seen from Table 3 that none of the systems investigated meets this requirement. Systems 2 and 3 fulfil it for a lesser part of the year (< 1000 hours), as shown in Figure 4. For most of the year (> 4600 hours), there is no greater difference between the three different types of systems.

The effect of wind on ventilation of individual rooms

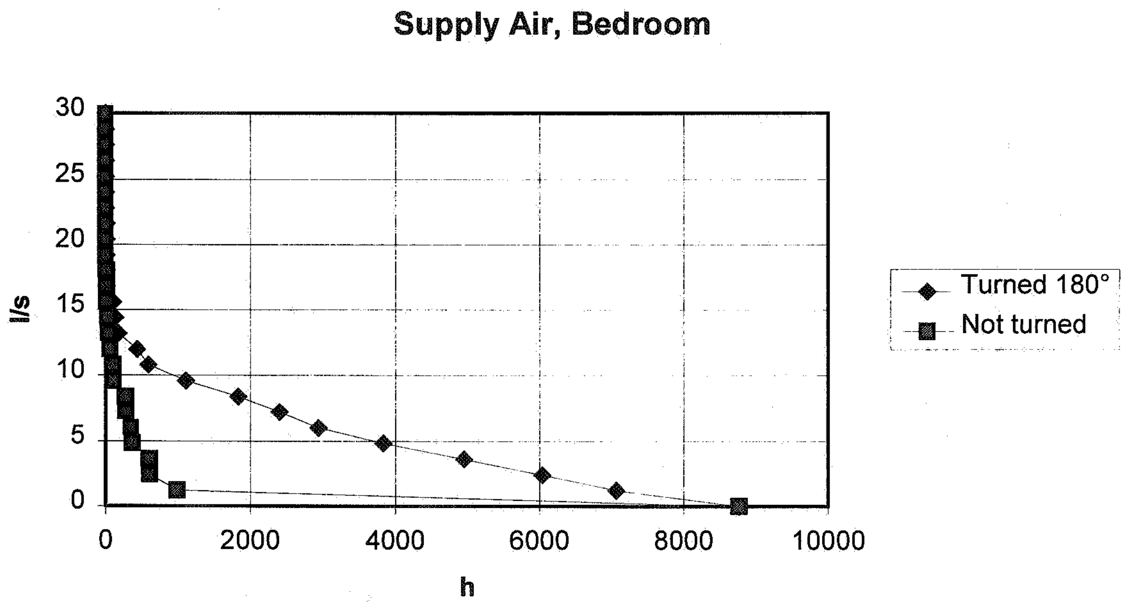

Figure 5. Outdoor air flow rate to the same bedroom with two different wind directions. Comparison performed for system type 1.

Table 4. The effect of wind direction on supply air flow rate to bedroom, system type 1

System type	Fresh air flow rate, l/h (mean value over the year)
Passive stack system (type 1)	1
Passive stack system with building rotated through 180°	4

It can be seen from Figure 5 and Table 4 that the wind direction has a considerable effect on the ventilation of individual rooms. Turning the building through 180° increases the fresh air flow rate from 1 l/s to 4 l/s, expressed as mean values over the year. Figure 5 shows that the fresh air flow rate through the bedroom is less than 1 l/s for over 6000 hours of the year. Any fresh air inlet device or fitting that is intended to compensate for the natural drive forces in the system must be able to compensate both for temperature and for wind.

The effect of height above ground

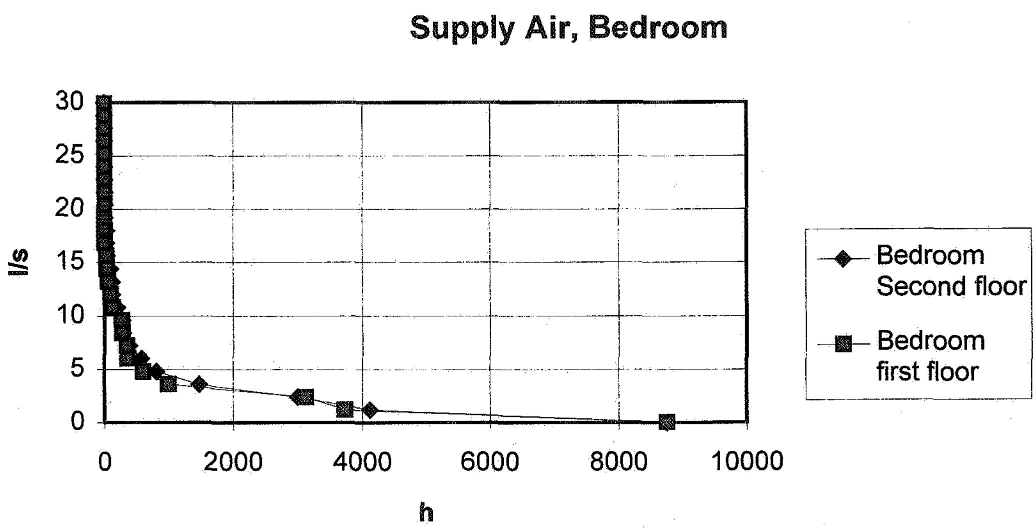

Figure 6. Supply air flow rate to a bedroom on the ground floor (level 1) and on the second floor (level 3), system type 2.

Table 5. Mean annual flow rate to a bedroom on the ground floor (level 1) and on the second floor (level 3), system type 2.

	Mean annual flow rate, l/s
Ground floor bedroom	2
Second floor bedroom	2

That there is virtually no difference between the outdoor air flow rates on different floors is explained by the pressure drop in the ventilation duct. At the ground floor, there is greater stack effect than on the second floor. However, as the ventilation duct is also longer, there is also a greater pressure drop, which more or less cancels out the effect of the greater stack effect so that the flow is approximately the same on both floors.

5. CONCLUSIONS AND RECOMMENDATIONS

System analyses with computer simulations have shown themselves to be a valuable aid in assessing total ventilation performance and how the systems operate. The quality of the input data is the prime determinant in deciding how closely the simulated results agree with real conditions. For more accurate investigations, it will be necessary to complement the computer simulations with actual measurements of the indoor climate conditions, airtightness of the building envelope, performance of the ventilation system and energy use.

The technology of fan assistance of passive stack ventilation systems needs to be further developed. As expected, the systems in this investigation with ancillary fans handled higher ventilation flow rates than unassisted passive stack systems, but are hardly more stable than them, as shown, for example, in Figure 3.

The temperature-controlled outdoor air inlets do not affect the outdoor air flow rate to make it more constant over the year in the apartment investigated here (compare curves 1 and 2 in Figure 3).

The effect of wind on the flow rate to individual rooms is considerable, as shown in Figure 5. Although the total fresh air flow rate to the apartment is acceptable, there is a problem in ensuring that the air enters each individual room.

The fact that the difference in air flow rate between the floors is only slight is explained by the pressure drop in the passive stack ventilation duct. The more powerful stack effect for the ground floor apartment is offset by the greater pressure drop in the duct due to the longer length of duct. This means that there is no greater difference in outdoor air flow rate between apartments on the ground floor and on the second floor.

If the systems are to be improved, it will be necessary to improve the performance of the components. If designs are to be improved, it will also be necessary to improve the technical specifications of the components. Finally, adjustments of the air flow rates in the systems must be improved in order to make the ventilation flow rate more uniform throughout the year.

6. REFERENCES

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