The influence of infiltration on air circulation in rooms.

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Abstract:

Many rooms equipped with a mechanical ventilation system do not have both inlet and outlet points.

What is required of the free open area between rooms equipped with inlet points and rooms equipped with outlet points, to obtain the desired air circulation within the building? How much of the exhaust air is infiltration air from outside?

These question are answered on the basis of measurements, made with tracer gas, in 4 mechanically ventilated buildings.

For example, measurements made in a building of flats with 48 flats, showed that only 60% of the air which was extracted from the bathroom and the kitchen came from the air injected into the living room and other rooms. The rest was infiltration air from outside.

Introduction

When a mechanical ventilation system is to be installed in a building, the solution chosen is often to place the air inlet and the outlet points in different rooms. Such systems have both advantages and drawbacks.

The most obvious advantage is the simple construction of the system; but it is also an advantage to the indoor climate to place the air outlet and inlet in different rooms, in a great number of cases.

An example is ventilation of dwellings where air preferably should be circulated from the living rooms to the more polluting areas such as kitchen and bathroom. This circulation of air will provide a considerable air change in all rooms, more outdoor air will be induced into the living rooms and the kitchen and bathroom will have a very high air change, removing moisture and odour. The fact that the air led into the kitchen and bathroom will not be "fresh" out door air, is normally not of any importance.

Another example to prove that the air can be used better if injected into one room and extracted from another is in day nurseries. In Denmark these normally have a communal room in the middle, surrounded by a number of group rooms, each of which has a toilet/bathroom where napkins are changed. The communal room and the group rooms are normally not used at the same time. If the air is injected into the communal room, led to the group rooms and finally to the toilets, the use of it is optimal.

The advantage of injecting the air into a room different from the one it is extracted from may be lost, however, if it is not possible to guide the air flow the appropriate direction through the building. This guidance can normally be obtained by apertures between the rooms to provide an unobstructed air flow.

The main drawback of the simple systems is the necessity of apertures between the rooms. These apertures may cause noise, draft and fire sectioning problems. In a many cases the apertures are therefore narrow, or are simply left out, in the believe that leakages in interior doors ensure the sufficient air flow.

In the following sections the calculation of these apertures will be treated as well as how to measure whether or not the air flows as desired. In the last section results from measurements in dwellings and day nurseries will be presented.

Calculation of aperture areas

To calculate the required aperture areas between the rooms, the air tightness of the building and the effects of the climate on the building must be known.

Additionally, it must be determined how large a percentage of the air injected into the building, should be returned to the ventilation unit through the extract duct.

After having determined these parameters the calcuations of flow can be carried out. These calculations are normally made as iterative processes, where first some aperture areas are chosen, secondly the pressures of the rooms are determined, and finally the air flows are calculated. The process is repeated until the equation of continuity is satisfied.

Figures 1 and 2 illustrate the results of rough calculations of a simplified singe-family house. The two buildings have different air tightness and the calculations have been carried out considering different wind directions outside.

The percentages of return air are 73 and 60 respectively. The percentage of return air is very sensitive to changes in air tightness of the buildings and changes in aperture areas of the partition walls.

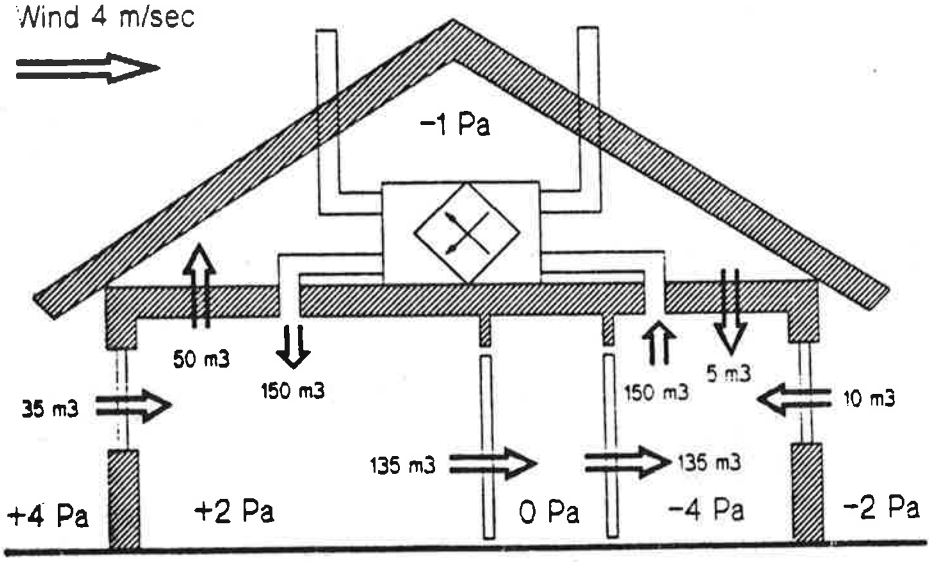

Fig. 1. Calculation of air flows in a building, with 3 rooms of 80 m^3, 10 m^3 and 20 m^3. The air tightness of the building is 3 air changes per hour at 50 Pa differential pressure over the climatic shield, corresponding to an equivalent aperture area of approx. 300 cm^2. The equivalent aperture areas in the two partitions are 400 cm^2 and 250 cm^2.

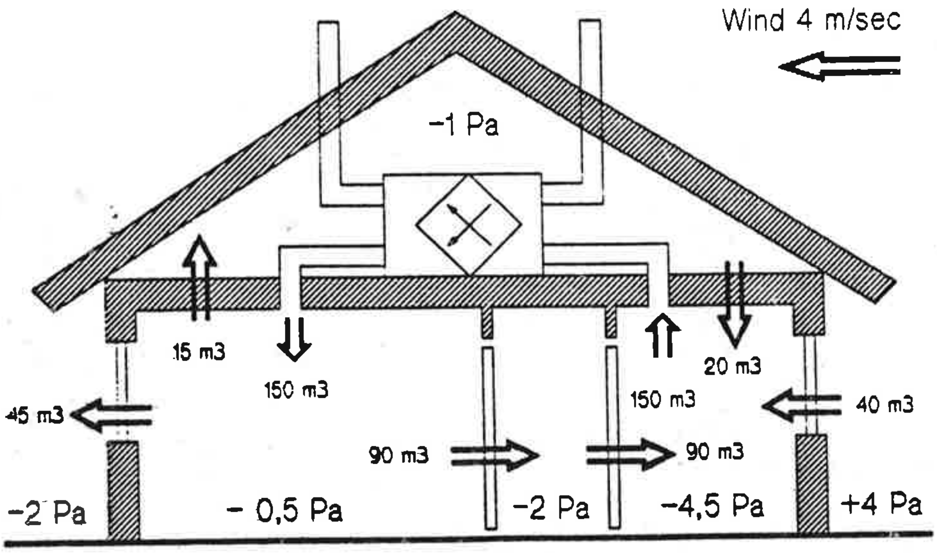

Fig. 2. Calculation of air flows in a building, with 3 rooms of 80 m^3, 10 m^3 and 20 m^3. The air tightness of the building is 5 air changes at 50 Pa differential pressure over the climatic shield, corresponding to an equivalent aperture of approx. 500 cm^2. The equivalent aperture areas in the two partitions are 400 cm^2 and 250^2.

One of the main resons for leakages in the partitions are the interior doors. In Denmark an interior door will typically have a 2 mm opening between the door and the panel. The open area will total to 110 cm^2 and the equivalent open area of the door is approx 75 cm^2. The equivalent open area of a door may vary considerably from door to door, and between doors of different make.

When comparing the equivalent open area of a door with the areas used in example 1 and 2, it can be seen that the fact that the air will flow unhindered through interior partitions should not be relied upon. Normally, it is necessary to make apertures in partitions or doors if a ventilation system with injection in one room and extraction in another is to function satisfactorily.

Measuring method

To test whether or not air flows from the injection rooms to the extraction rooms tracer gas can be used.

When a constant dose of tracer gas is added to the injection air and when measuring the quantity of extracion air and the concentration of tracer gas in the latter, the percentage of returned injection air can be calculated.

Percentage of return air:

$$100 \times \frac{\text{quantity of extracted air x concentration of tracer gas}}{\text{dose of tracer gas in injection air}}$$

The measurement can be difficult to carry out if the flows of injected air and extracted air are changed during the measurement. In such a case it is preferable to keep the concentration of tracer gas in the injection air at a constant level and additionally measure the injected air volume, the extracted air volume and the concentration of tracer gas in the extracted air, continuously.

Measurements with a contant concentration in the injection air flows demand somewhat more of the measuring equipment, than the measurement with a constant dose.

Measurement of the air change in the building by means of the "constant concentration of tracer gas method" can also be used to calculate how much of the injected air is present in the extracted air. The necessary data for this calculation are the volume of injected air, the volume of extracted air and the air change for each room in the building. The procedure is to calculate how much the injected air is diluted with infiltration air in each of the rooms. This method, however, is not as accurate as when the injected air is marked with tracer gas.

Measurement results

Measurements have been carried through in a 13 floors high rise, and 3 day nurseries.

The high rise had 96 apartments each with 2 or 3 rooms. The measurements were carried out in the northern half of the building, serviced by a ventilation plant situated on the roof of the building. The ventilation plan injected air into the living room and other rooms of the apartments and extracted air from the kitchen and bathroom. The plant was equipped with a heatrecovering system transferring energy from the exhaust air to the injection air.

The measurement was carried out by adding a constant dose of tracer gas to the main inject duct and measuring the concentration and the flow in the main extract duct.

The result of the measurement is illustrated in fir. 3. The percentage of return air is 72%, a percentage that has been obtained solely because the quantity of extracted air is somewhat bigger than the injected. Examining the return air alone, it is seen that this contains but 59% injection air.

The measurements were carried out while the apartements were occupied and the occupant could thus open both windows and interior doors. It is not possible to calculate infiltration and exfiltration flows exactly since the concentrations of tracer gas in the respective room have not been recorded.

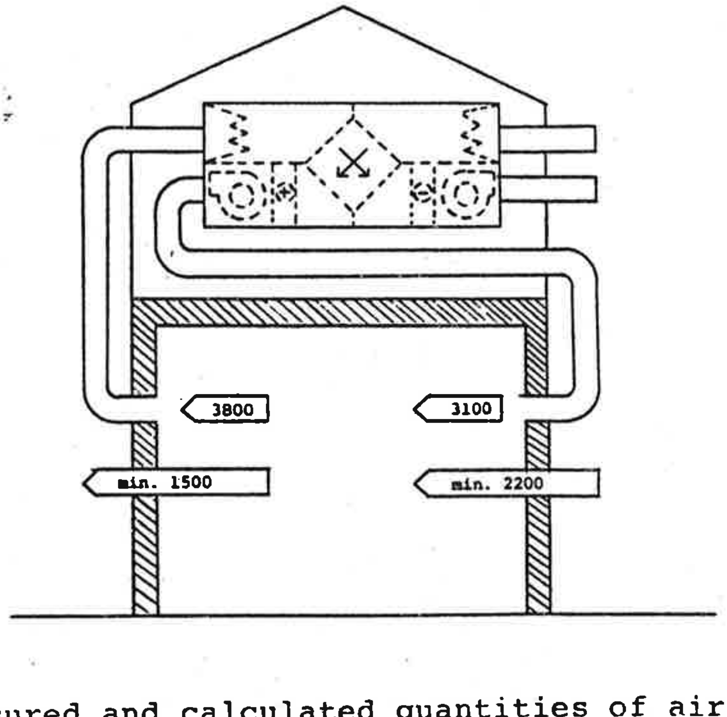

Fig. 3. Measured and calculated quantities of air in m^3/h, of the 48 dwellings in the building.

The three nurseries in which measurements were made were equipped with mechanical ventilation systems which gave approximately one air change every hour. The measurement results can be seen in Fig. 4. In the stated aperture areas, the leeks are not included, only the established holes.

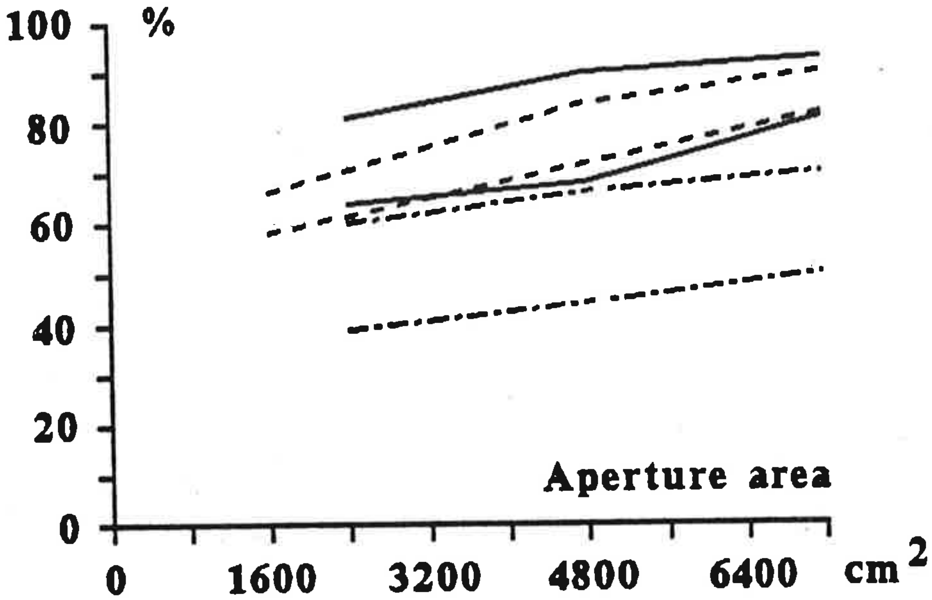

Fig. 4 Percentage of the injected air returned to the ventilation system as a function of the aperture area in walls between the rooms with air injection and those with air extraction. The three nurseries are drawn with different lines and with curves for both high and low performance of the ventilation system.

Conclusion

The measurements show that to a certain degree it is possible to direct air through the building as desired by establishing apertures in the partitioning walls. Of the air injected into the building between 40% and 90% was refound in the extraction duct. This percentage is very much influenced by the air tightness of the building and the aperture areas in the partitioning walls, plus the outdoor climate.