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Infiltration in Norwegian Houses

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Abstract

Air infiltration in Norwegian buildings has been an unknown parameter. This paper is based on results from measurements in nine different buildings in Norway. The measured parameters have been:

- infiltration
- wind velocity and direction
- pressure differences across the building envelope
- air humidity and temperatures on the inside and outside of the building

The infiltration has been measured continuously with tracer gas using the constant concentration method. In addition air tightness measurements and thermography have been carried out to establish the dimensions and the locations of the major leaks. In buildings with mechanical ventilation systems, the flow rate through the inlets and outlets have been measured.

The results from the measurements show a higher infiltration rate than expected. The two houses described in this paper show, without occupancy, an infiltration rate of 0,7 ach.

1.0 Background

The energy consumption in buildings consists of consumption to light, machinery, hot water, heating and ventilation.

The demand of energy to heating and ventilation can be divided into transmission loss, controlled ventilation and infiltration.

The magnitude of the infiltration loss has in many ways been unknown until now. Even if there over the recent years in many countries have been done substantial work to investigate the air infiltration in buildings the results can not be transferred from one country to another. The extent of the air infiltration depends on the different countries' regulations to air tightness of buildings, type of building construction, etc.

In Norway it has been common to calculate the infiltration loss to 0,3 air changes per hour (average) when building heat demands have been estimated.

To be able to build more energy efficient buildings it is essential to know the dimensions of the air infiltration and decide what should be done to reduce it.

By measurements of the air change rate in buildings without running the ventilation system the air infiltration can be stated.

2.0 Measurement Techniques

By using tracer gas measurement techniques the infiltration can be found. There are three different techniques in use.

- concentration decay method
- constant emission rate method
- constant concentration method

In this project we have used the constant concentration method.

- high accuracy
- real time

The disadvantage is

- expensive equipment
- time consuming setting up

The tracer gas used is sulphur hexafluoride SF_6 and a constant gas concentration of 5 ppm has been established in the building.

The tracer gas mass balance equation can be presented as

$$V\frac{dC}{dt} = Q\,[C_e - C_{(t)}] + F$$

Where

V = Effective volume of enclosure, m^3

Q = Specific air flow rate through enclosure, $m^3\,s^{-1}$

C_e = External concentration of tracer gas

$C_{(t)}$ = Internal concentration of tracer gas

F = Production rate of tracer by all sources within the enclosure.

The solution of the equation based on zero concentration of tracer gas at start will be

$$C_{(t)} = \frac{F}{Q}(1 - e^{-Nt})$$

Where

$N = Q/V$ Air change rate per unit time

If N remains constant, a finite time is required for the tracer concentration to reach equilibrium (determined by $(1-e^{Nt})$. Once the concentration has reached equilibrium the air flow rate is given by

$$Q=\frac{F}{C}(t)$$

Where

C = constant tracer concentration in the building (5 ppm)

$F_{(t)}$ = Production rate of tracer gas at time t.

The air change rate is proportional to the production rate of tracer gas.

The measuring equipment used in this report can do measurement in ten different rooms at the same time with an accuracy of ±10 %. The measurements are controlled by a computer and parallel wind pressure differences, temperatures, wind speed and direction and relative humidity be measured. The equipment calculates the air change rate and collects all analog data every three minutes. Any possible connections between the analog data and the change in air change rate can be found.

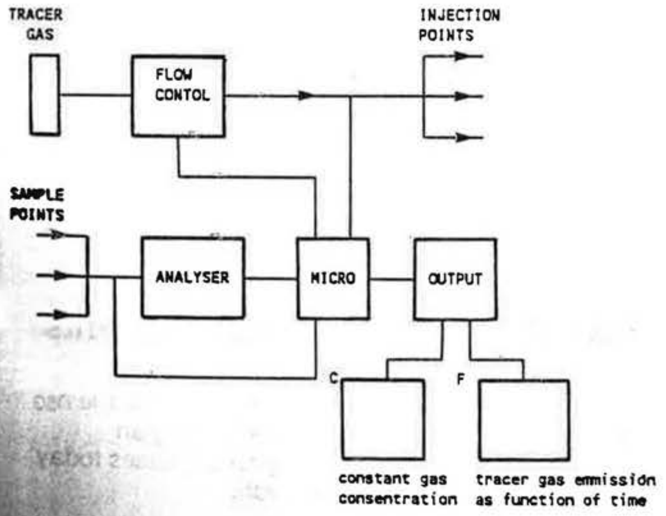

Figure 2.1 Schematic of constant concentration equipment

3.0 Results

From the nine buildings that are measured, detailed results are shown from two of them. One eight storey office building and one single family house.

3.1 Office Building

The office building is an eight storey building with brick walls and concrete floors. There is a lift and a stairway that forms a shaft in the middle of the building. We measured one separate part of the seventh floor which was divided into seven zones, one for each room, (See fig. 3.1.1). Dosing and sampling were done in each zone. In addition the gas concentration in the corridor was measured. The building has a balanced ventilation system with inlets and outlets in each room. The volume flow for each inlet and outlet were measured.

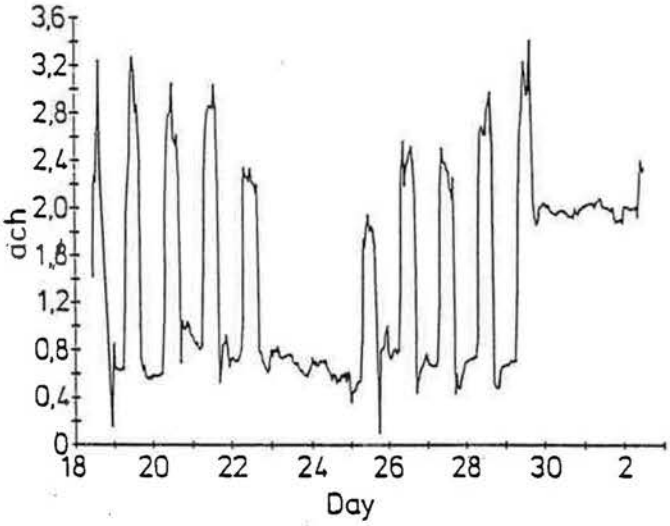

Figure 3.1.1 The average ventilation rate measured in the office building on the seventh floor. The measurement was carried out for a period of two weeks. During the first week the internal doors were closed and during the second week all internal doors were kept open.

All the offices were occupied during daytime on weekdays but not on Saturdays and Sundays. The ventilation system was turned on at seven a.m. and shut off at four p.m. on weekdays. Usually the ventilation system is off during the weekends, but during the last weekend it was running.

From the measurements we can conclude with the following key figures:

	Min	Average	Max
	ach	ach	ach
Total air change rate, daytime	1.9	2.8	3.4
Infiltration, vent. syst. running	0.6	0.7	0.8
Ventilation through windows	0.0	0.8	1.3
Ventilation through ducts	1.3	1.3	1.3
Infiltration, vent. syst. off	0.6	0.7	1.0

3.1.1 Discussions

There were big differences from one zone to another in airing through the windows. The total air change rate rise, in one zone, 6 ach in average because of airing through windows.

The ventilation system was running only one weekend without any occupancy. For that period we have studied the influence of the weather conditions on the air change rate, which in this case is the infiltration rate. During this period the wind velocity was low (the average was about 3 m/s). The variations are mostly due to the difference in the outdoor and indoor temperature. The indoor air temperature was stable about 23°C and the outdoor temperature varied from -3 to +5 ° C. This caused the change in the infiltration from 0.8 ach to 0.55 ach.

The wind velocity was not measured continuously for this period. However, we have information about the wind velocity 4 times a day and also continuous measurements of the pressure differences across the building envelope. From this we can see a slight rise in the infiltration rate when the wind increases, but significant figures can not be stated for this building.

3.2 Single Family House

3.2.1 Air Change Rate Measurements

This 260 m^2 house, which is from 1973, consists of two stories. It has walls of wood frame construction, natural ventilation with four outlets, one from each wetroom and eight inlets on the first floor. The size of each outlet was about 50 cm^2 when it was open. The inlets were shut during the measurements.

Gas was injected in seven zones and the concentration was sampled in 10 zones. The measurements were carried out for a period of two weeks where the results from the first week are infested with some uncertainties. During the first 5 days of the last week the occupants were not at home. The 4 outlets were open 2 days of this period.

When the occupants were not at home we can observe the immediate reaction in the infiltration rate caused by changes in the weather conditions, (See fig. 3.2.1).

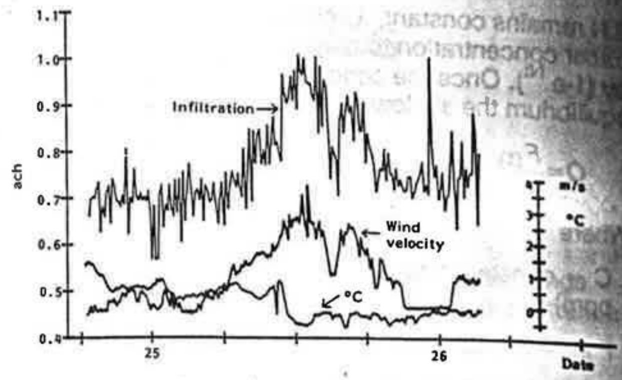

Figure 3.2.1 The influence of the wind velocity on the infiltration rate (the whole house). Inlets and outlets were shut and the occupants came home late in the evening the 25th.

From the measurements we can conclude with the following key figures for the single family house:

	Min	Average	Max
	ach	ach	ach
With occupancy:			
Total air change rate 4 outlets open (200 cm^2)	0.7	0.8	1.3
Without occupancy:			
Total air change rate 4 outlets open (200 cm^2)	0.7	0.8	1.1
Infiltration (no vents open)	0.6	0.7	1.0

3.2.2 Air Tightness Measurements

Air tightness measurement was carried out and the n_{50} - value was found to be 6.9 ach. The Norwegian building code requires for new detached houses today the n_{50} - value to be less than 4.0 ach.

3.2.3 Discussion

During the first 10 days all the ventilation inlets and outlets were shut. The measured air change value for this period is the same as the infiltration rate. In average the figure was 0.7 ach which is more than needed for ventilation pruposes. The outside temperature was higher than normal and the wind velocity was lower.

4.0 Air Change Rate Measurements in Seven Buildings

The other seven buildings differ from the two reported here in size and form.

Type of building	Year of constr.	No of storeys	Measured storey	Inf. rate v.sys. off	Tightness n_{50}
Office building	1943	3	All	0.8	-
Office building	1965	4	1st floor	0.7	-
Office building	1985	3	1st floor	0.4	-
Row-house	1960	2	All	0.7	7.8
Single family house	1982	3	All	0.2	2.2
Apartment building	1960	2	2nd floor	0.5	7.6
Kindergarten	1968	1	1st floor	0.5	11.6

The infiltration rate depends on several parameters. The results presented above are average values when the ventilation systems were off. If the building had natural ventilation system the inlets and outlets were shut and no occupants were in the building.

5.0 Conclusions

Both the buildings reported in this paper had a higher infiltration rate than expected. In both cases the figure in average, without occupancy, was about 0.7 ach. The office building has a balanced ventilation system which means that all leaks represent an energy loss.

The single family house has a natural ventilation system with 4 outlets and 8 inlets. The air change rate without the vents open (Infiltration rate) is more than needed to ventilate the building in average. the outlets in the bathrooms are recommended to be kept open for humidity control in these rooms. the major leaks found by thermography, are recommended to be sealed in order to make the houseowner able to control the air change rate better and to reduce the energy loss.

Eight of the nine buildings had a higher infiltration rate than needed for ventilation purposes, therefore it is of big importance to make tighter buildings in order to reduce energy consumption and to get better indoor climate.

References

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Acknowledgements

The project reported in this paper was supported by the Norwegian Council for Scientific and Industrial Research (NTNF). The authors would like to thank Oddmunn Hansen, Bernt Heggly, Ketil Gorm Paulsen and Magne Gjerde for helping to carry out the measurements.

This paper was presented at the symposium "Building Physics in Nordic Countries", held in Trondheim, Norway, 20-22 August 1990.