OCCUPANT INTERACTION WITH VENTILATION SYSTEMS

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VENTILATION AND INDOOR AIR QUALITY IN NEW NORWEGIAN DWELLINGS

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SYNOPSIS

SINTEF, The Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology, has monitored a number of experimental low-energy houses, and also undertaken measurements in some other houses to establish the energy consumption, air tightness, ventilation rates etc. Some of the experimental houses are extremely air tight.

In connection with these measurements we have made some observations on the occupants behavior related to ventilation, and their satisfaction with the ventilation system.

Ordinary built houses

In 10 detached houses built in 1980 according to the present air tightness requirements ($n_{50} \leq 4$), we studied the use of ventilation during wintertime with outdoor temperatures -10 °C to -20 °C. The houses were equipped with exhaust ventilation system and vents in the windows. The use of vent inlets in the upper frame of the windows varied from 0 to 10 out of total 15 vent inlets. The mechanical ventilation was used only in 3 houses, in the rest it was blocked or switched off by the occupants. The occupants have made it possible themselves to switch the fan off. This together with changes in temperature and wind made the air change rate vary between 0.2 and 0.7 air changes per hour with an average 0.45. The n_{50} test gave an average of 3.9 for these houses.

Experimental, extremely air tight houses

The project consists of 11 low energy houses, with an average air change rate 0.85 h^{-1} according to the n_{50} test. The infiltration rates measured under normal winter conditions were lower than 0.1 h^{-1}. The houses have different ventilation systems. The best comfort conditions were observed in the houses with mechanical balanced ventilation system. In 3 houses with natural (buoyant) ventilation with outlet ducts over roof from kitchen and bathrooms and inlet vents in windows according to traditional practice problems with comfort, and condensation were observed. The measured ventilation rate, even in cold weather with all vents open, was very low. This was partly compensated by the occupants through opening of windows. These houses were prepared for mechanical exhaust which was installed after 2 years. The occupants noted a very considerable improvement in comfort after this modification.

Energy saving in households

In an interview investigation in 112 similar row houses in Trondheim (by Steinar Ilstad) a strong relationship between air infiltration/ventilation rates based upon different indicators, and annual energy consumption was established. The energy consumption varied from (average) 15600 kWh for "low ventilation index" to 19450 kWh/ for the winter period for "high ventilation index".

Our projects confirm that occupants behavior in relation to ventilation varies considerably. Many Norwegians sleep with open windows year round. Others shut down the ventilation by closing all vents or stopping the fans during cold periods. The habits are influenced by new building technology. More knowledge is needed for a complete picture of the users behavior, satisfaction and need for ventilation, and the efficiency and economy of different systems.

1. INTRODUCTION

In Norway today ventilation, indoor climate and air quality is one of the major subjects in research work related to environmental engineering. This concerns both commercial buildings, schools and dwellings. These subjects and problems are related to our work with energy conservation in buildings.

At SINTEF, The Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology, we have monitored a number of experimental low-energy houses, and also undertaken measurements in some other houses to establish the energy consumption, air tightness, ventilation rates etc.

In connection with these measurements we have made some observations on the occupants behavior related to ventilation, and their satisfaction with the ventilation system. In some houses we have also measured the indoor air pollution caused by building materials.

This paper describes two specific research projects. One project concerns ordinary built houses and another deals with experimental, extremely air tight houses. We focus on the results concerning air change rate, ventilation control, behaviour, comfort and air quality.

We also present some results from an interview investigation in 112 similar row houses concerning energy savings in households, and give some comments on Norwegian behaviour regarding window opening and ventilation control in general.

2. ORDINARY BUILT HOUSES

In January 1984 we measured the air change rate and heat loss factor in 10 identical detached dwellings. The main purpose of the project was to establish the relationships between the measured transmission heat loss factor, and the heat loss factor calculated according to Norwegian standard methods.

The houses were built in 1980 with a 100 m2 living area in detached 1 1/2 storey buildings. The houses are insulated with 150 mm mineral wool in walls and roof, and double glazed windows, figure 1. The houses are equipped with exhaust ventilation system and vents in the upper frame of the windows.

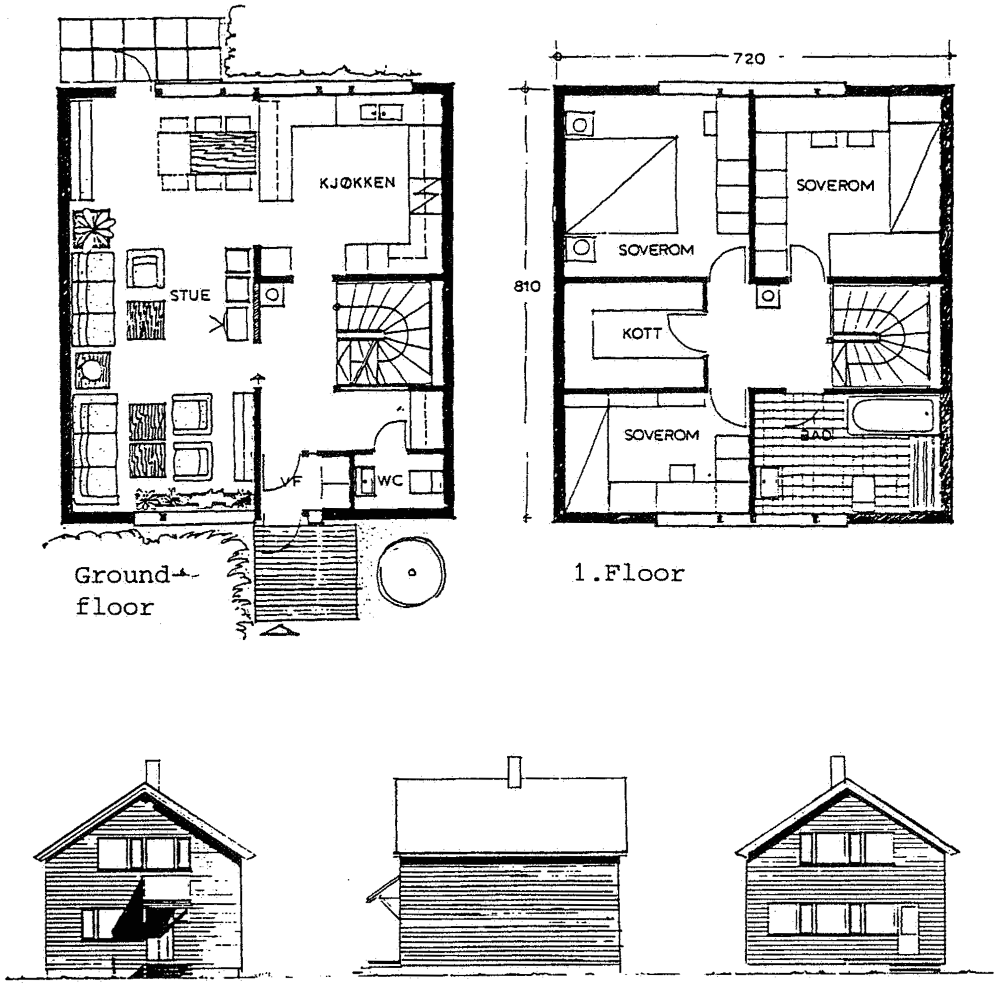

Fig 1 Ordinary built house (~100 m2)

We rented each house one day and measured
- temperatures (out- and indoor)
- wind speed
- energy consumption
- use of ventilation
- air change rate
- n_{50}-test

The air change rate was measured with N_2O (dinitrogen-oxyd) tracer gas with falling concentration.

During the measurement period the outside temperature and average wind speed varied considerably. The temperature varied from +4 °C to -20 °C.

Fig 2 Outdoor temperature during the measurements period

Each house was equipped with in all 15 vents in upper frames of the windows. The outlets are installed in kitchen, bathroom and WC, and are equipped with adjustable control vents.

Table 1 shows the connection between the use of the ventilation system, air change rate, outdoor temperature and windspeed, together with the n50 test-result for each house.

House	Open vents	Exhaust ventilation	Air change rate h^{-1}	Outdoor temp. °C	Wind speed m/s	n50 h^{-1}
1	2	on	0.6	4.6	6.0	4.8
2	5	off	0.3	1.5	4.2	3.3
3	1	off	0.2	0	4	3.8
4	0	off	0.3	-3.4	2.4	3.8
5	10	off	0.6	-7.2	2.3	4.5
6	1	off	0.2	-3.5	2	4.0
7	3	off	0.5	-2.5	3	3.4
8	6	off	0.6	-10.4	3	5.4
9	0	on	0.7	-18.2	0.2	3.8
10	0	on	0.5	-20.1	0.2	3.6

Tab 1 Relation between ventilation, air change and and outdoor climate

The use of vent inlets in the windows varied from 0 to 10 out of a total of 15 vent inlets. The ventilation fan was in the period actually running only in 3 houses. In the others it was blocked or switched off by the cccupants. The occupants had made it possible themselves to switch the fan off. (According to the code of practice this should not be possible). The windows were not opened during the measurements.

The air change rate varied between 0.2 and 0.7 air changes per hour with an average 0.45. This is caused by different use of ventilation together with changes in temperature and wind. The results from 3 houses (No. 4, 5 and 7) indicates an infiltration rate from 0.2 to 0.3 air changes per hour. We conclude that the occupants are satisfied with this low air change rate.

In the houses with the exhaust ventilation in use, none or only a few vents were open.

The n_{50} -test gave an average of 3.9 for these houses. Seven out of ten houses satisfies the present air tightness reguirements ($n_{50} \leqq 4$) for detached dwellings.

3. EXPERIMENTAL, EXTREMELY AIR TIGHT HOUSES

Description:

The "Heimdal-project" consists altogether of 14 low energy houses built 1980-81 as detached dwellings. The houses were planned and built in order to gain experience with different energy conservation systems. Three of the houses are passive solar houses with identical form and plan. The other 11 houses have the same form with about 120 m2 living area in 2 storeys. The houses are all occupied in a normal way.

The houses (not the solar houses) have different ventilation systems:
- 3 houses with natural (buoyant) ventilation with outlet ducts over roof from kitchen and bathroom and inlet vents in windows.
- 3 houses with exhaust ventilation from kitchen/bath and inlet vents in windows.
- 5 houses with different balanced mechanical ventilation systems combined with heat recovery systems.

Measurements of ventilation and air quality:

* We have measured the air tightness (n_{50}) in the houses twice. First time immediately before occupation and then one year after.

* The air change rate was measured with closed inlet vents, windows and doors and no use of mechanical ventilation. This was done in order to determine the infiltration rate under different windspeed and outdoor climate. In the 3 houses with natural ventilation measurements was also done with open inlet vents. We used N_2O tracer gas with falling concentration.

* Chemical pollutants (organic gasses, dust, formaldehyde and radon) are measured in unoccupied houseswith normal ventilation conditions.

* Use of window-ventilation is not systematically registred, but stipulated from interviewing the occupants.

Results:

The average air tightness for the 11 houses were 0.85 h^{-1}, with variations from 0.6 to 1.5 h^{-1}.

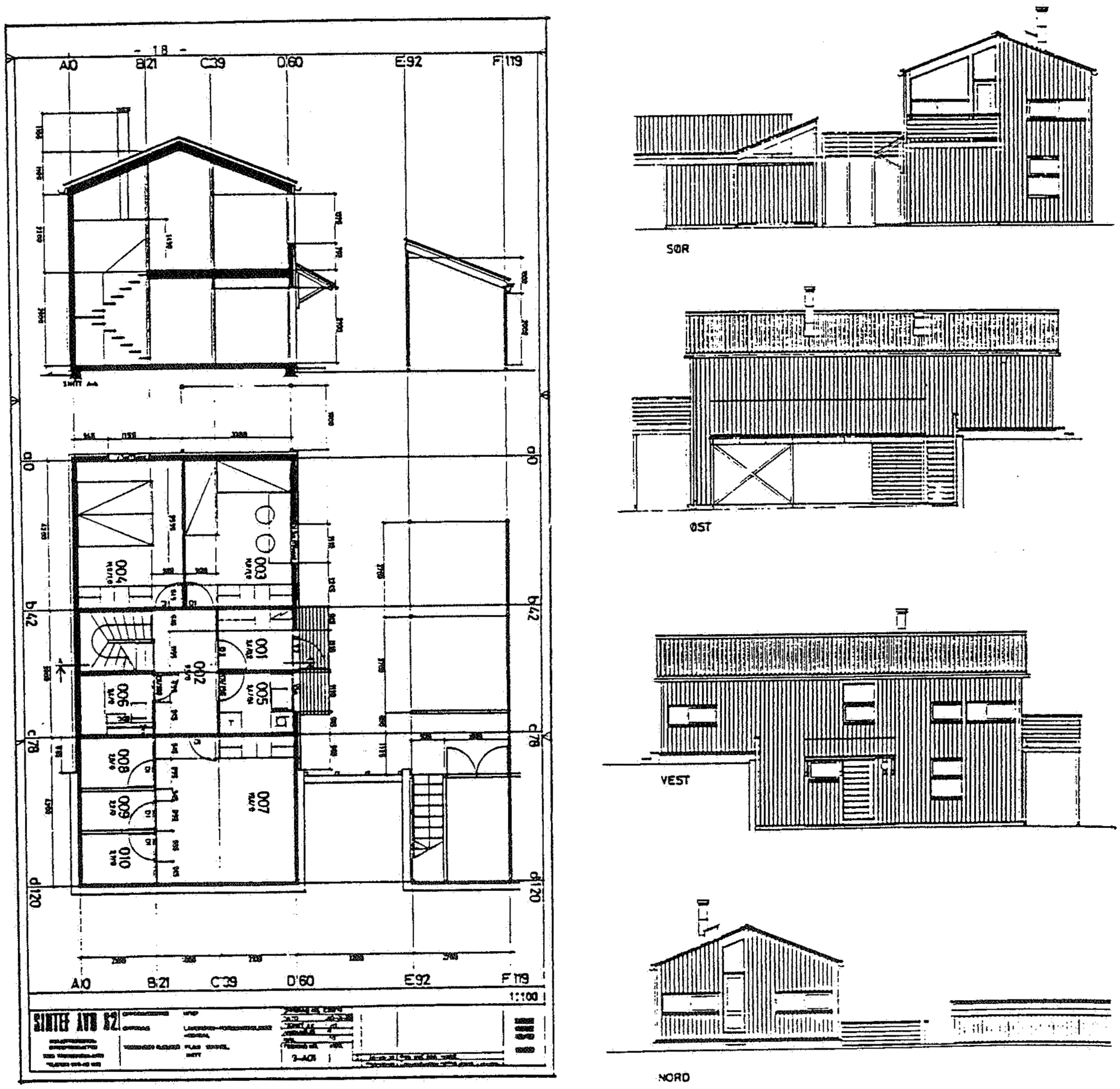

Fig 3 Low energy house

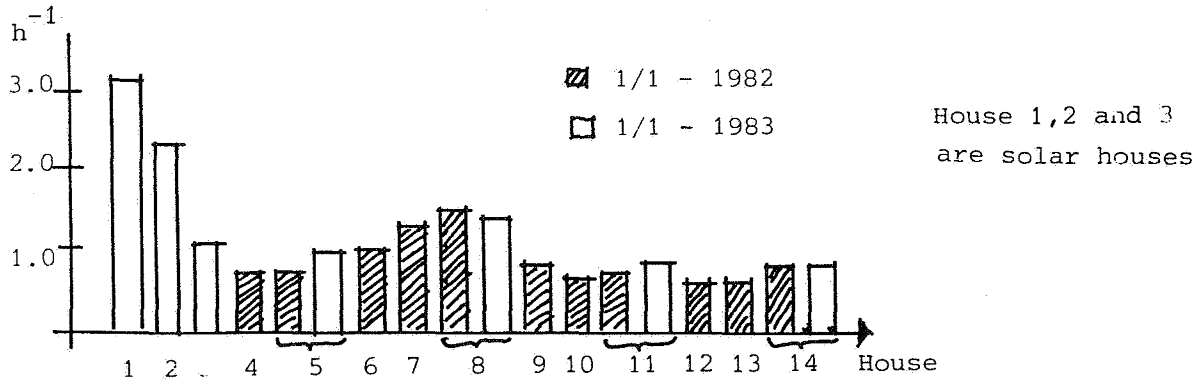

Fig 4 Air change rate n_{50}-test

The infiltration rates measured under normal winter conditions varied from 0.03 to 0.11 h^{-1} with an average of 0.05 h^{-1} for 7 houses.

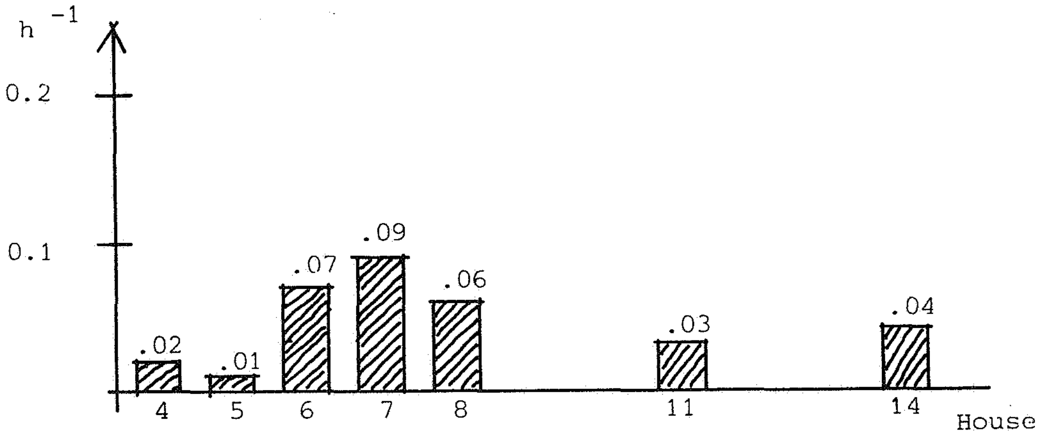

Fig 5 Infiltration rate

For one house we measured the infiltration rate under different climatic conditions. We had only small variations with different outdoor temperature and wind.

By use of natural ventilation and open inlet vents we measured a total ventilation rate of 0.2 h^{-1} in average. The low rate was partly compensated by the occupants by opening windows at irregular intervals.

In the 3 houses with natural ventilation we observed problems with comfort and condensation. These houses were prepared for mechanical exhaust which was installed after 2 years. The occupants noted a very considerable improvment in comfort after this modification.

The analysis of chemical pollutants showed:
- the presence of organic gasses to be inversely proproportional to the air change rate
- high airchange rate gives high dust concentration, i.e. the outdoor concentration is higher than indoor concentration

- low concentration of formaldehyde < 0.1 mg/m3 (mostly used plasterboard inside)
- radon concentration indoor similar to outdoor concentration

The ventilation rate (total) varied between 0.2 and 0.7 h^{-1} during these measurements.

Interviews with the occupants showed that ventilation through open windows is used during wintertime even in houses with excellent ventilation systems. The variations between occupants are considerable.

4. ENERGY SAVINGS IN HOUSEHOLDS

This was an interview investigation carried out by Steinar Ilstad, ORAL, University of Trondheim. The purpose of the study was to investigate how differences in total energy consumption between apartments can be explained by differences in the occupants behaviour (habits, attitude, social control).

The study comprised 112 similar row houses with 100 m2 living area heated by electricity. The data collection procedure included reading the electric meters in September and April, and systematic interviews with each family, on habits concerning indoor temperature, ventilation, hot water use, use of electric appliances etc. In relation to ventilation they were asked about use of inlet vents, air humidity, open windows during night and during day.

The relationship between air infiltration/ventilation rates and different indicators on ventilation habits was established. The energy consumption varied for the heating period from (average) 15600 kWh for "low ventilation index" to 19450 kWh for "high ventilation index". This means 25% higher energy consumption caused by different use of ventilation.

Some details from the interview investigation:

- 30% close all inlet vents during wintertime, 20% keeps all open
- 40% sleep with no open windows at night, 55% open 1 or 2 windows
- 35% open 1 or 2 windows during a part of daytime, 20% open 3-4 windows

In a similar investigation in 97 apartments it was found less use of open windows.

5. CONCLUSIONS

* Our projects confirm that occupants behavior in relation to ventilation varies considerably. Many Norwegians sleep with open windows year round, others shut down the ventilation by closing all vents or stopping the fans during cold periods.

* We have no problem with condensation in normal new dwellings with only simple ventilation systems. According to interviews condensation problems only exist in older not sufficient insulated houses.

* In extremely air tight houses mechanical exhaust ventilation is needed to give satisfactory comfort.

* Chemical pollution seems, even in extremely air tight houses, not to be a problem in houses with normal use of building materials and low ground radiation as in the Trondheim area.

* More knowledge is needed for a complete picture of the users behavior, satisfaction and need for ventilation, and the efficiency and economy of different systems.

6. REFERENCES

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