VENTILATON RATES IN THE SWEDISH HOUSING STOCK

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ABSTRACT

This paper reports results from ventilation measurements in Swedish dwellings as part of the 1992 Swedish Energy and Indoor Climate Survey (the ELIB-study). Distributions of ventilation rates in single- and multi-family houses are presented and discussed.

INTRODUCTION

A nation-wide energy and indoor climate survey (the ELIB study) has been carried out. Indoor air quality variables such as indoor temperature, indoor relative humidity, ventilation rates and levels of radon, volatile organic compounds (VOC) and formaldehyde were measured in a random sample of 1200 single- and multifamily houses from the Swedish housing stock. All buildings were inspected in order to determine the status of the buildings and their installations. This paper reports the results from the ventilation measurements. For an overview of the ELIB-study, see the companion paper by Norlén and Andersson (1993) presented at this conference.

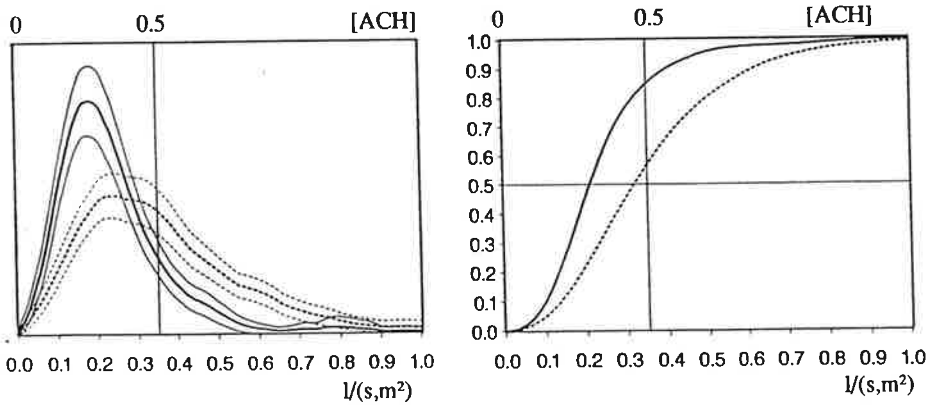

Fig.1 The frequency (left) and cumulative (right) distributions of the ventilation rate expressed as ventilation flow rate per square metre of floor area and air change rate (ACH) for single-family houses (solid line) and multi-family houses (dotted line). Thin lines for the frequency functions show the upper and lower limits for the statstical uncertainty

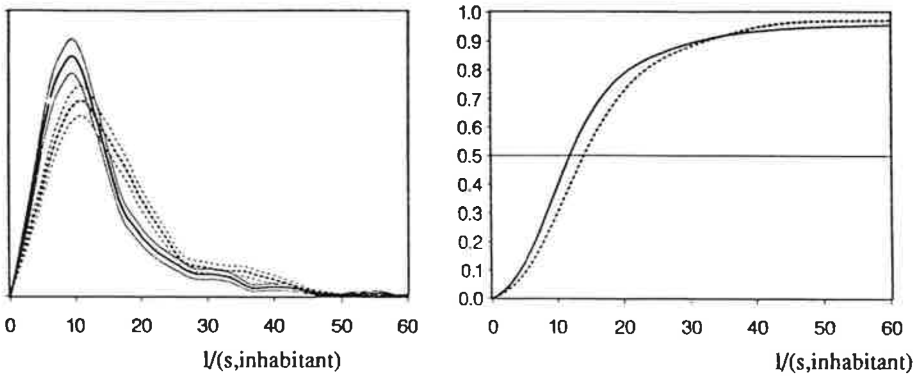

Fig.2 The frequency (left) and cumulative (right) distributions of the ventilation rate expressed as ventilation flow rate per inhabitant for single-family houses (solid line) and multi-family houses (dotted line). Thin lines for the frequency functions show the upper and lower limits for the statistical uncertainty.

In order to monitor the ventilation rate in a large number of dwellings, a simple but well-defined method had to be used. Measurements by means of a "passive" constant emission tracer gas technique were used, the so called PFT-method (perfluorcarbon tracers). The technique has been developed at the Swedish Institute for Building Research. In each dwelling one or two different tracer gases (miniature capillary diffusion source) have been used as emitters and as samplers, three to five diffuse air sampling charcoal tubes have been used. The quantity of tracer gases in the samplers have been analysed by means of gas chromatography. Before this large scale investigation, the method was validated in laboratory and field tests. The method is described in more detail in the paper by Stymne and Boman (1993) presented at this conference. For validation purposes, paralell short term measurements of the ventilation rates have also been undertaken by other methods in sub-samples (1).

For field application in this investigation the method has been applied as a single- or two zone model. Generally, in single-storey houses and in flats the single-zone model has been used, while in two-storey houses the two-zone model was used. During the ventilation measurements the indoor temperature has also been monitored. The measurements have been started by staff, specially trained at the Institute for Building Research, and finished by the tenants, who have been, after instructions by the inspectors, responsible for returning the measurement devices to the Institute for Building Research.

RESULTS

Overview

The results of the long-term PFT-measurements are summarized in figures 1 and 2. The method used for estimating the distribution functions is described in the paper by Waller and Högberg (1993) presented at this conference. For each dwelling the measurement was performed during approximatel one month in the period November 1992 - April 1992. The ventilation rate in a multi-family house is estimated as the average of the ventilation rates determined for the two apartments selected for the measurements. No attempt has been made to normalize the measured values with respect to weath influence during the specific measurement period for each building. An attempt to perform such normalization, (the method described in (2)) will be carried out during the spring of 1993.

Ventilation rates in residential buildings of different types and ages

In figures 3 and 4 the average ventilation rates in the Swedish housing stock are presented for different types and ages of residential buildings.

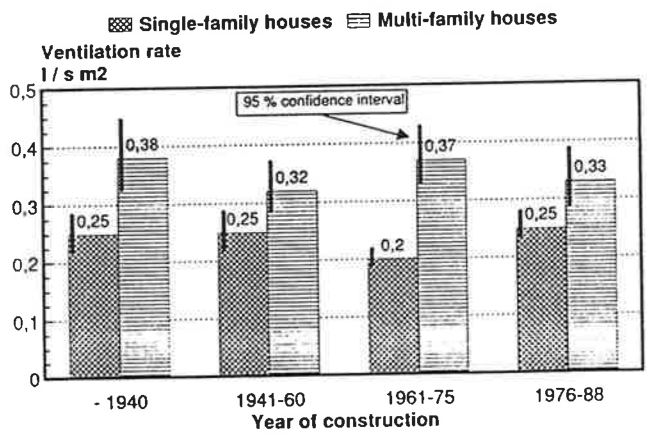

Fig.3 Average ventilation rate (l/(s,m²)) in the Swedish housing stock by type of building and year of construction. 95%-confidence intervals of the averages are indicated.

Based on these diagrams some obvious observations include:

- The variation in average ventilation rates (based on l/(s,m²), is very large; it ranges from an average value of 0.20 for single-family houses built in 1961-1975 up to a value close to twice as large (0.38) for multi-family houses built up to 1940.

- Compared to the prescribed ventilation rate for dwellings of 0.35 l/(s,m²), as stated in the Swedish building regulations from 1975 and onwards, the average for all single-family houses of all ages fall below. This is the case for most multi-family houses too, except för the group with the oldest houses and the group built in 1961-75.

- Generally the average ventilation rates in multi-family houses are higher than in single-family houses. There is no exception in any age-group.

- When the average ventilation rate based on number of inhabitants (l/(s,inhabitant)) is considered the variation is small, both between different age-groups of the same type of house and between different types of houses

The estimates of the ventilation rate in litres per second and square metre (fig 3), depends on , e.g., area figures obtained from the inspections. A further analysis of these area values for single-family houses is currently being carried out.

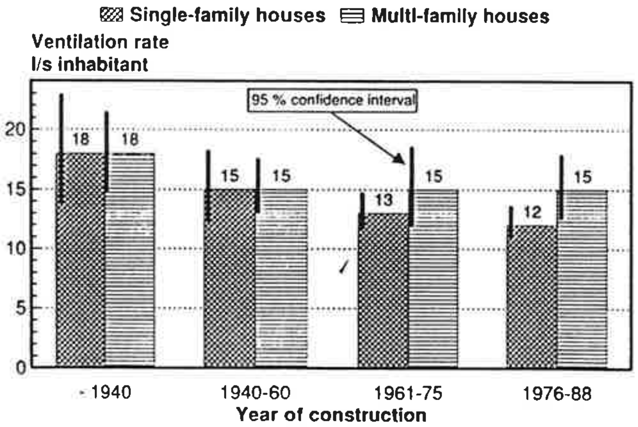

Fig. 4 Average ventilation rate (l/(s,inhabitant)) in the Swedish housing stock by type of building and year of construction. 95%-confidence intervals of the averages are indicated.

DISCUSSION

Analyses are currently being performed of correlations between specific characteristics of the buildings e.g. age, status of reconstruction, type of ventilation system, airtightness geographical location etc, and the ventilation rate. From the results it will be possible to predict estimated values of average ventilation rates for arbitrary combinations of the characteristic factors mentioned above.

These analysis will be based on the following hypotheses.

Variation in average ventilation rate between different types of houses

It is obvious that multi-family houses have higher ventilation rates, measured by (l/(s,m²)), than single-family houses. Reasonable explanations for this are:

- For older houses of both categories natural ventilation is the most common ventilation strategy,(see table 1). The driving forces especially the stack effect, are stronger in multi-storey buildings and this results in higher ventilation rates.

- For newer houses of both categories mechanical ventilation is common, (see table 1), so it would be expected that the ventilation rate should be close to the design value (0.35 l/(s,m²)). This is more or less the case for the multi-family houses but not for the single-family houses. The design, construction performance and maintenance are probably better for the multi-family houses.

Table 1 Estimated number of dwellings in thousands, in the Swedish housing stock

Type of residential building Ventilation system	Year of construction -1940	1941-60	1961-75	1976-88	All	%
Single-family houses						
Natural	523	324	435	71	1353	80
Extract	2	<2	46	163	211	12
Supply and extract	2	<2	18	111	131	8
Multi-family houses						
Natural	232	463	136	6	837	42
Extract	124	257	459	69	909	45
Supply and extract	9	26	104	116	255	13

Variation in average ventilation rates between different ages of the same type of houses

Single-family houses

The variation in average ventilation rate (l/(s,m²)) in single-family houses of different ages is small. However it should be noted that older houses (-1940 and 1941-60) have a somewhat higher average ventilation rate (0.25) than newer ones. This is probably due to the fact that old houses generally are quite leaky, thus giving rise to substantial degree of infiltration through the envelope of the houses. Houses built in the sixties and the beginning of the seventies have the lowest average ventilation rates (0.20). The main reason is probably that this generation of houses are more airtight, due to improved construction technique. Furthermore, most of them are naturally ventilated and not until the Building Code of 1975 was it prescribed that they should be equipped with special devices for outdoor air supply. A sign of this is that it is generally experienced by building consultants and other professionals that many of these houses suffer from problems with high indoor relative humidity. Thus, in many cases during winter, inhabitants complain about condensation on windows etc.

Multi-family houses

The variation in average ventilation rate in multi-family houses of different ages is moderate. However, as for the single-family houses, the ventilation rate tends to be higher in older houses.

Ventilation rate expressed as (l/(s,inhabitant))

For both single- and multi-family houses the average values of ventilation rate (l/(s,inhabitant)) are very even, ranging from 12 to 18 l/(s,inhabitant) (fig 4). The larger variation in ventilation rate expressed as (l/(s,m²)), (fig 3) is counteracted by the fact that occupants in single-family houses have access to larger livingspace than those in multi-family houses (fig 5).

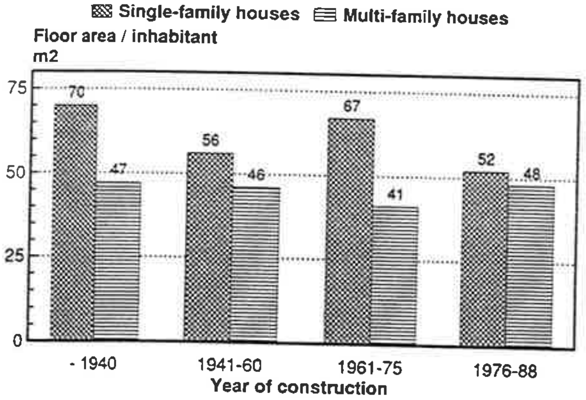

Fig 5 Residential floor area per occupant in Swedish dwellings.

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THE POLLUTANT CONTROL INDEX: A NEW METHOD OF CHARACTERIZING VENTILATION IN COMMERCIAL BUILDINGS

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ABSTRACT

In many buildings, the traditional indices of ventilation rates are very difficult to measure. The measured indices usually represent only a short time period. Seeking to overcome these limitations, we introduce the local and global pollutant control indices (PCI). These parameters quantify the effectiveness of ventilation in controlling the concentrations of a simulated indoor-generated air pollutant. In the proposed measurement procedure, an indoor pollutant source is simulated by deploying multiple passive emitters of tracer gas throughout the building. Using a programmable sampler, time-average tracer gas concentrations are determined during occupancy periods near locations where occupants breathe. The PCIs are based on the measured tracer gas concentrations and the total tracer emission rate. A new type of passive tracer source has been developed for measurement of PCIs. Further research is needed to evaluate the accuracy of sampling and sample analysis procedures and the reproducibility of measurements within buildings

INTRODUCTION

Traditionally, the rate of ventilation in buildings has been characterized by the rate of outside air supply, normalized by either the indoor volume, the floor area, or the number of occupants. Measurements of these ventilation rates in commercial buildings generally serve one of the following purposes: (a) to determine air flow rates for use in energy-related calculations; (b) to determine if the ventilation rate is adequate for controlling indoor pollutants; and (c) to evaluate the spatial distribution of ventilation within a building. Research on the relationship between ventilation and occupant health in commercial buildings is another, but less common, application for ventilation rate measurements.

Existing techniques for determining ventilation rates in commercial buildings include tracer gas decays or stepups (1), measurements of post-occupancy carbon dioxide (CO_2) decay rates (2), measurements of air flow rates (3), and mass-balance estimates based on measured CO_2 concentrations and estimates of the rates that occupants generate carbon dioxide (2). Although ventilation rates may be temporally variable and long-term average ventilation rates are often desired, none of these measurement techniques provide an average ventilation rate for an extended time period (several days), unless the measurement process is repeated many times. Only the tracer gas and CO_2 decays account properly for air infiltration and exfiltration. The tracer-gas techniques are very labor intensive, impractical to implement in many buildings, and require stable ventilation rates because the processing of tracer gas data is based on steady-state mass balances (1). Direct measurements of air flow rates, for example using flow