PROGRESS AND TRENDS IN AIR INFILTRATION AND
VENTILATION RESEARCH

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AIR INFILTRATION AND VENTILATION.
PROGRESS AND TRENDS IN SWEDEN.

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1 BACKGROUND

The climatical conditions in Sweden are such that it has almost always been necessary to tighten the houses quite thoroughly in order to avoid cold-draught and to make as good use of the heating as possible. Devices for intentional ventilation, such as ducts for the exhaust of "used" air, have been installed in Swedish houses for centuries.

Thus the concept of infiltration and ventilation is not a new one. The more general introduction of central heating in the beginning of this century led to a relatively high degree of dependance on imported fuel. As a consequence of rising heating costs, aims to protect the environment, increased demands on indoor comfort etc. Steps to make houses more airtight and the ventilation more reliable and efficient have been taken during the last decades.

It was not until the seventies that a more systematic approach to the problems of airtightness and ventilation was undertaken. The Swedish Council for Building Research initiated the formation of the so called "Tightness group" in 1977. The group consisted of researchers in building physics and ventilation technology and practitioners - consultants and contractors.

Since the start in 1978, Sweden has been a member of the IEA annex V, Air Infiltration and Ventilation Centre. The collaboration between scientists and practitioners from the different countries in AIVC has proved to be successfull and of substantial value for Sweden, Boysen (1989).

2 AIR INFILTRATION

2.1 Air tightness of buildings

2.1.1 Benifits and drawbacks of airtight buildings

Nowadays, there is a consensus among researchers and practitioners in Sweden that there are a number of benifits of airtight buildings.

Airtight buildings

- are a prerequisite in order to make the ventilation of buildings perform well, thus having control of flow rates etc.
- prevent cold draught from air leaks.
- conserve <u>energy</u> because of low uncontrolled leakage flows.
- conserve <u>power</u> for heating in cold, windy situations.
- prevent rapid cooling of the indoor air in cases of heating equipment failure or uneven heating power deliveries e.g. in crisis situations.

- prevent moisture problems and -damages due to moisture convection (normally due to exfiltrated air).
- improve the acoustical properties of the building envelope thus preventing noise from the outside.
- are a prerequisite if heat is to be recovered from the ventilating air.

A drawback of airtight buildings may be that they demand a proper and well-performing ventilation system in order to guarantee a good indoor air climate, which leaky buildings don't.

2.1.2 Whole building measurements

The pressurization test of the airtighness of whole buildings was established in Sweden around 1975. Since then a certain - but unknown - number of buildings, mostly single-family houses, but also large buildings e.g. industrial buildings, have been tested in our country. The test results haven't been systematically assembled so an analysis of the trends isn't possible to perform.

The practical experience among contractors and building inspectors however is that the building code requirement of n50<3.0 ach is not very difficult to achieve in construction practise. However there have been some obvious problems to reach n50<1.0 ach, when this has been demanded by the commisioner of the building project.

2.1.3 Building components, measurements and calculations

For some specific building components - exterior doors and windows- quite extensive measurements have been done during the last 15 years in Sweden. This is primarilly due to the procedure of type approval of these products. The tests have normally been performed by the Swedish National Testing Institute. Brolin(1980 and 1984).

Measurements of the air tightness of whole building components, walls, roof elements etc, and connections between components have been performed only occasionally.

If leak paths can be described geometrically, it is possible to calculate the the air leakage characteristic of, for example, connections between building components. This is described in Kronvall(1980).

2.2 Driving forces for air infiltration

2.2.1 Wind

The wind climate of buildings has been investigated quite extensively in Sweden. Wind tunell measurements have been performed by the Swedish Institute for Building Research and others.

Until recently most investigations have concentrated on wind forces acting on buildings from the structural design point of view. However, during the last few years investigations with the aim of determining pressure coefficients for low-rise buildings have been performed. The results are suitable and useful for infiltration and ventilation calculations. Wiren(1985 and 1987).

Wind pressures on low-rise buildings have been studied by means of full-scale measurements by Gusten(1989). Mean values as well as fluctuations of the wind pressure have been investegated.

2.2.2 Stack effect

Systematic investigations of the stack effect in buildings have not been published in Sweden. However, at a seminar on moisture convection and pressure conditions held in Stockholm 1987, it was agreed upon that the stack effect in many cases had led to moisture damages in roof spaces, most commonly in buildings with high indoor moisture load, but also in "dry" buildings, such as tall office buildings, 1 1/2-storey single family houses etc.

2.2.3 Ventilation system

The pressure conditions due to the ventilation system in a building is of importance for air infiltration and exfiltration. In cases when outdoor air is led more or less directly into the house through supply-air vents, which is the case for naturally ventilated houses with ducts and exhaust fan ventilated houses, a certain part of the supply air is infiltrated through the building envelope. The percentage of infiltrated air compared to the air entering via vents is apparently high in untight buildings.

In mechanically exhaust and supply air ventilated houses it has been demonstrated that risks for indoor over-pressure is evident if the ventilation system is not thorougly adjusted and/or the cleaning of the exhaust air filters has been disregarded. The indoor over-pressure can cause severe moisture damages due to moisture convection.

3 VENTILATION

3.1 Ventilation systems

Today almost all newly produced buildings in Sweden - including single family houses - are equipped with mechanical ventilation systems. Heat recovery from the exhaust air is normal practice. In systems with exhaust fan ventilation the heat recocery is arranged by means of an air to water heat pump heating domestic hot water and/or water in a hydronic heating system.

In single family houses warm air heating is quite common today. The systems are normally exhaust-supply ventilation systems, where the warm air is blown into the different rooms in the house through terminal devices while the make-up air normally is exhausted through a centrally placed device. Recirculation of air is necessary in order to keep the warm air entering the room at a limited over-temperature and to maintain a good ventilation efficiency. However, the use of recirculated air could give indoor air pollution problems.

In multi-family houses, office buildings, hospitals, industrial halls etc. the ventilation system always includes exhaust and supply fan ventilation combined with some kind of heat recovery equipment.

3.2 Ventilation performance

The performance of ventilation systems has been studied early in Sweden. Studies from the late forties, Rydberg(1949), of ventilation in dwellings showed that the real performance of ventilation systems often differs from the intended behaviour. Later studies, especially on modern complicated systems, support this. An oftenly quated study, Allhammar & Sundell(1985), concludes regarding less than 10 years old ventilation systems:

- The flow rate through air terminal devices varied between + 50% and - 100% (i.e. zero) compared to design values.

- Every third fan was not performing well, which caused reduced fan capacity.

- More than 10% of the air heaters and filters were so dusty that the flow rates were reduced significantly.

- More than every tenth fan was not running, in some cases intentionally.

- Every tenth of the ventilation systems was running with 100% recirculated air.

- In almost every tenth of the ventilation systems filters in the supply air ducts were taken away or broken down in their suspensions.

The air flow field in a space, for example a room, could be studied in field, in a physical model or be simulated by means of computer calculations.

In the beginning of this decade equipments for continuous monitoring of ventilation were developed at the National Swedish Testing Institute and the Swedish Building Resaerch Institute. Both systems use a tracer gas and can be run in three different modes: constant concentration, constant flow or decay of tracer gas. Nine different rooms can be monitored simultaneously.

Quite a lot of measurements, combined with introduction of different air indices, such as air change efficiency, ventilation efficiency etc., have been carried out by M Sandberg at the Swedish Institute for Building Research. Most of the measurements have been carried out in a full scale apartment in the laboratory at the institute. There are many of reports, papers etc. describing this. A good summary and state of the art report is published in Swedish, Sandberg & Skåret(1989). This report will soon be published in English by the AIVC.

At Chalmers Institute of Technology, valuable additions to the knowledge of air flow fields in rooms have been brought about by means of computer calculations. Davidson(1989). The calculations are based on a modified k-epsilon turbulence model treating also complex geometries and low Reynolds number flow.

3.3 Ventilation and air infiltration

Ventilation and air infiltration must be considered simulaneously in order to reach a complete understanding of the total thermo-dynamical and indoor climatical behaviour of a building.
In order to study this system-behaviour, (computer) simulations and field measurements are essential components.

Different computer programs for such analyses have been produced in Sweden during this century. The latest and most promising one, MOVECOMP, Herrlin(1988), is currently used by several researchers, e.g. Blomsterberg(1989) who also compares the calculation results with measurements.

The Swedish researcher in the COMIS-group is responsible for the flow calculation algorithm.

4 NATIONAL REGULATIONS AND STANDARDS

4.1 Air tightness

For a building as a whole the Swedish Building Code(1988) states that the air tightness of the building envelope, tested in accordance with the Swedish standard SS 02 15 51, must not exceed 3 m3/(m2h) for dwellings and 6 m3/(m2h) for other buildings. No specific demands regarding the air tightness of different building components are included in the building code any longer.

For ventilation equipment and -ductwork there are certain air tightness demands in the Building Code.

4.2 Ventilation

Regarding air exchange the following is quoted from the Swedish Building Code(1988):

A room should have a continous air exchange. This should be arranged so that emissions from people and building materials, moisture, air pollutions, odour and health affecting substances will not be accumulated.

The flow rate of outdoor air into rooms with normal height, where people are present more than occasionally, should be at least 0.35 l/(sm2 floor area). For dwellings, this demand regards the dwelling unit as a whole as well as the different rooms. Rooms demanding a higher degree of ventilation should have at least the ventilation capacity shown in the table below. Spaces where people are present only occasionally should have a ventilation in such a manner that no health risks occur and that damages to the building and it's installations are prevented.

Table (shortly abbreviated)

Dwellings, hotels etc.

Bedroom	4.0 l/(s*person)
Kitchen	10.0 l/s
Kitchenette	15.0 l/s
Bath room	
with openable window	10.0 l/s *)
without "- "-	15.0 l/s *)
WC	10.0 l/s
Laundry room, drying room etc	10.0 l/s *)

Workplaces, conference halls, shops etc.

Rooms for sedentary work	5.0 l/(s*person)
Rooms for mobile work	7.0 l/(s*person)
Rooms where smoking could be expected	10.0 l/(s*person)
WCs	15.0 l/(s*WC-unit)
WCs for the public	20.0 l/(s*WC-unit)

If the floor area is greater than 5 m2, the ventilation should be increased by 1 l/s for each m2 exceeding area.

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5 PROSPECTS FOR THE FUTURE

General development:

Due to the general interest in the country regarding indoor air quality it could be expected that:

- routines for quality assesment and -control of air-handling systems will be established and used.

- the control of building materials and other possible pollutants indoors will be intensified.

- ventilation-, heat recovery- and heating systems which are more energy efficient and reliable from performance point of view will be developed.

- the technology for control, service and maintenance will be more adopted to man than is the case today.

- the demands on good performance and efficiency of ventilation in individual rooms will increase.

- the demands on airtight building envelopes will increase.

Research:

Research fields likely to be dealt with in the future are:

- Development and use of techniques for computer simulations of air flow patterns in rooms and between rooms in a building, thus providing a better understanding of ventilation performance.

- Air quality studies on emissions in the indoor environment, human ventilation demands, feasibility of different ventilation strategies and -equipment.

- Moisture convection, it's dependence on indoor over-pressure, air tightness and moisture in indoor air.

- Measurement technique. Development of refined tracer gas techniques.

- Development of heating and ventilation strategies for energy- and other crises.

Industrial and/or scientific development:

Important areas which regard attention are:

- Development of equipment for automatic control and supervision of complicated house installations. (Smart houses)

- Developments of better manuals, hand books etc. for heating and ventilation equipment.

- Development of equipment for human and technical demand control for heating and ventilation.

- Development of less expensive and reliable warm air heating systems for houses.

- Development of electricity efficient heating and ventilation equipment

- Development of outdoor supply air ventilation devices causing less discomfort (especially in the winter time) than existing ones.

- Development of hard- and software for tracer gas measurements.

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