DISCUSSION

Infiltration in israeli apartments has been shown to depend on the wind speed and the effective leakage area of doors and windows. The stack effect is usually small, due to the mild outside temperatures and is limited to low wind speeds. The energy losses also depend on the configuration of the staircase, the optimum solution being an open top staircase combined with a closed staircase door and windows.

Theoretically, considerable energy can be saved by weatherstripping the windows. However, at times of low wind speed, it is necessary to increase the supply of fresh air to obtain a reasonable IAQ. In the absence of mechanical ventilation, people have to open the windows for long periods, particularly in the inner coastal area during the night. However, even in the windy mountain region,effective weatherstripping aimed at reducing maximum peaks of energy demand can lead to poor IAQ during long periods. It appears that mechanical ventilation is the key to resolving the conflict between IAQ demands and the desire to save energy. The results of weather-stripping are, of course, different in the inner coastal zone, characterized by low wind during nights, and for the much windier mountain area, characterized by a large wind speed throughout most of the winter.

ACKNOWLEDGEMENTS

This work has been sponsored by the Ministry of Energy and Infrastructure of the State of Israel. Financial support of the Ministry of Immigration and Absorption is also acknowledged.

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EVALUATION OF MECHANICAL DOMESTIC VENTILATION SYSTEMS: THE FRENCH APPROACH

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ABSTRACT

In France, the ventilation must continuously supply fresh air to the habitable rooms and exhaust stale air from the service rooms. The ventilation rate should be adjustable to the needs of the occupants.

The requirements for the heat loss due to ventilation are set in the French regulation for new residential buildings. A simplified calculation method has been developed to take into account building characteristics (air leakage), ventilation systems and meteorological data. We describe how detailed numerical simulations, using CSTB tools, have been used to define such a method and to assess directly the performances of the innovative ventilation systems. Research is now going on for determining the best indoor air quality criteria, especially for DCV systems responding to airborne contaminants.

INTRODUCTION

Ventilation of buildings is necessary both to insure adequate indoor air quality and to protect the building itself against condensation and mould growth. On the other hand, ventilation rates must not lead to excessive energy consumption. Mechanical ventilation systems, which have been common in France since the sixties, comply with these requirements. These systems have been improved in recent years and new techniques such as humidity-controlled ventilation are widely used. This paper overviews the various mechanical ventilation systems in use in residential buildings and outlines their advantages and drawbacks. It also addresses the methods for efficiency assessment of these ventilation systems with regard to heat loss and indoor air quality.

MECHANICAL VENTILATION SYSTEMS

Since 1969, the French regulation on residential building ventilation is based on general and continuous air renewal. The air circulation in the dwelling must be arranged in such a way that fresh air comes into the habitable rooms (living room, bedrooms) by air inlets and contaminated air flows straight to the exhaust vents located in the service rooms (kitchen, bathroom, toilets). In this way, air is transferred from the rooms with a higher air quality to the rooms with a lower one (see figure 1).

Exhaust systems

The mechanical exhaust systems are composed of self-regulated air inlets, exhaust vents, an exhaust network and a fan to exhaust the polluted air out of the dwelling. The principle of a self-regulated air inlet is based on progressive modification of the air passage section of the inlet according to the pressure difference across the inlet. The change in section keeps the air flow constant over a wide range of pressure differences (see figure 2). These inlets, which have been in widespread use for more than fifteen years, help prevent uncomfortable draught when the wind pressure is too high [1]. Also, they help reduce heat losses due to cross-ventilation.

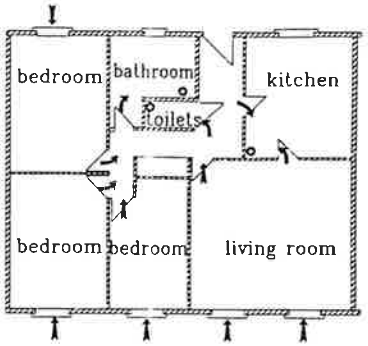


Figure 1. Air flow pattern in a dwelling.
Since service rooms are ventilated by exhaust vents, there usually are no ducted air inlets in these rooms.

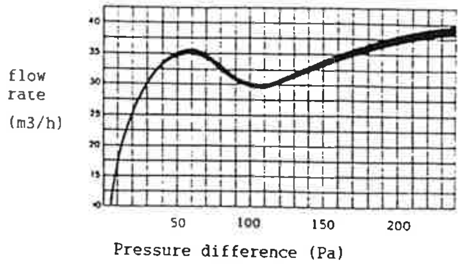


Figure 2. A characteristic self-regulated air inlet curve.

About 60% of newly-built dwellings are equipped with a mechanical exhaust ventilation system. Ventilation plants are different according to the type of dwellings. In the single-family dwellings, the exhaust fan is located in the attic and each exhaust vent is linked to the extract fan unit by an individual flexible plastic duct. In the blocks of flats, the network is generally composed of several vertical ducts which end in horizontal ducts located on the roof of the building and linked to the extract fan unit. Vertical ducts act as collector ones to gather individual air flows from several dwellings.

The French regulations have allowed the use of variable exhaust air flow systems, controlled by indoor relative humidity, in order to limit heat loss due to ventilation, in dwellings. These humidity-controlled ventilation systems, which reduce the ventilation rates during lower occupancy, must be assessed by an "Avis Technique" (technical approval) with regard to heat loss and indoor air quality. The air passage section of air inlets and exhaust vents is a function of the room air relative humidity, in order to increase air change when relative humidity is too high (see figure 3). About 20% of flats and 5% of houses (newly built) are equipped with such demand controlled ventilation (DCV) systems.

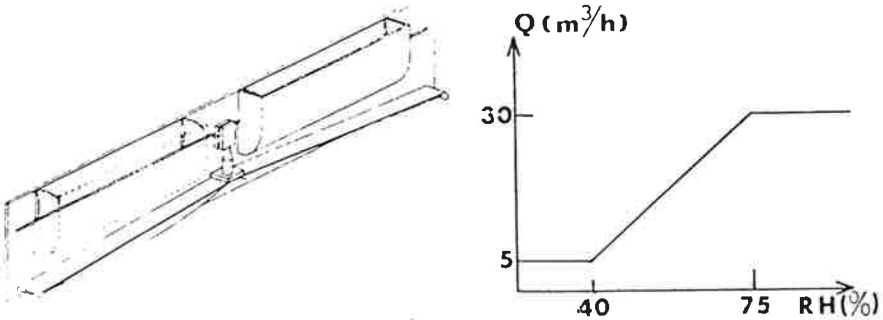


Figure 3. Example of humidity-controlled air inlet. The curve depicts the flow rate as a function of the room air relative humidity when the pressure difference is 10 Pa.

Balanced systems

In France, the balanced system is less common than the exhaust system; only 6% of the new single-family dwellings is equipped with it. Nevertheless, the balanced system has numerous advantages. In comparison with the exhaust only systems, the balanced systems control air flow rate in each room of the dwelling and therefore provide a better ventilation efficiency, prevent discomfort due to cold air draught, acoustic annoyance due to noise, and due to pollutants (e.g. dust, radon,...) from outside. Additionally, the balanced ventilation systems make it possible to adjust ventilation rate according to needs, by transferring air flow from a room to another one, and to save energy thanks to the heat exchanger. However, the dwelling equipped with such a ventilation system must be sufficiently airtight in order to limit the heat losses due to cross-ventilation, and particular attention must be paid to the installation maintenance to fulfil the energy saving potential.

QUALITY ASSESSMENT OF VENTILATION SYSTEMS

Regulation approach

In France, the key feature of the ventilation is the synergy between the evolution of techniques and regulations [2]. As an example, the 1969 regulation required to continuously provide one air change per hour in each habitable room this led to the start of central mechanical ventilation. Conversely, the development of new products, such as DCV systems designed to optimize air renewal, led French authorities to amend some mandatory provisions relevant to minimal ventilation rate. By the early seventies, the French thermal regulation required to include the energy loss due to ventilation in the total energy loss of the building. In order to assess the performance of ventilation systems - and more particularly the amount of heat loss due to air change - methods based on computer models were derived. These models make it possible to compute the heat loss as well as the condensation hazards and the air quality level. Two methods are used to assess the ventilation systems. The first one is a simplified method [3], derived from the numerical simulations, and applies to usual ventilation systems. The second one, so-called "Avis Technique", is straight based on simulation and experiment results obtained in accordance with a specific technical procedure [4], and applies to new materials (in this case, DCV systems).

Modelling

In order to assess the performances of the traditional ventilation systems we used a single-zone air flow model, developed at CSTB [5], which takes into account the combined effects of driving forces such as wind-induced pressures, thermal buoyancy and mechanical systems. The air change due to cross ventilation was calculated over the heating season using climatic data and for ventilation installations and buildings with given characteristics. Dimensionless pressure coefficients used in this model were derived from pressure field measurements performed in a boundary layer wind tunnel on a scale model. An experimental validation of this model has been undertaken by measuring air change rate in the CSTB's full-scale rotating house [6].

A multi-zone air flow model, developed at CSTB [7], was used for the assessment of DCV systems. It is a 5 min time step model which uses climatic data and building and ventilation systems characteristics for computing, throughout the entire heating season, the air flows in a dwelling, taking into account the hygroscopic inertia of the dwelling. The theoretical air quality level is also evaluated thanks to indicators. Different air quality indicators have been considered: mean concentration of carbon dioxide as an indicator of human bioeffluents, frequency of condensation on the windows, mean relative humidity in rooms, which is expected to be correlated with mould growth hazards.

Method applied to traditional systems

The calculation rules, so-called "Règles Th-G" [3], describe how to calculate heat loss due to ventilation. They apply to all traditional ventilation systems i.e. systems which are not innovative. Heat loss due to air renewal can be expressed by:

$$DR=0.34(Q_V+Q_S) \qquad (1)$$

Where DR= heat loss due to air renewal (W/°C), 0.34= the value of the specific heat capacity of air (Wh/m^3°C), Q_V= air flow rate due to ventilation system operation (m^3/h), Q_S= air flow rate due to cross ventilation (m^3/h). For the dwellings having a mechanical exhaust ventilation system, the air flow rate Q_V is the sum of the flow rates of each exhaust vent. The flow rate exhausted by a vent q_V depends on its low and peak values and variation in time of the vent operation :

$$q_V=(1-a)q_m+a*q_p \qquad (2)$$

Where q_V= specific flow rate of the exhaust vent (m^3/h), q_m= low flow rate (m^3/h), q_p= peak flow rate (m^3/h), a= modulation factor.

a=1 when the aperture area of the vent is fixed
a=1/12 when the modification of the area is operated by manual control
a=1/24 when the vent is time controlled (peak time of 30 minutes).

The low and peak flow rates have to be at least as great as the values allowed by the building regulation, these last ones being dependent on the number of habitable rooms.

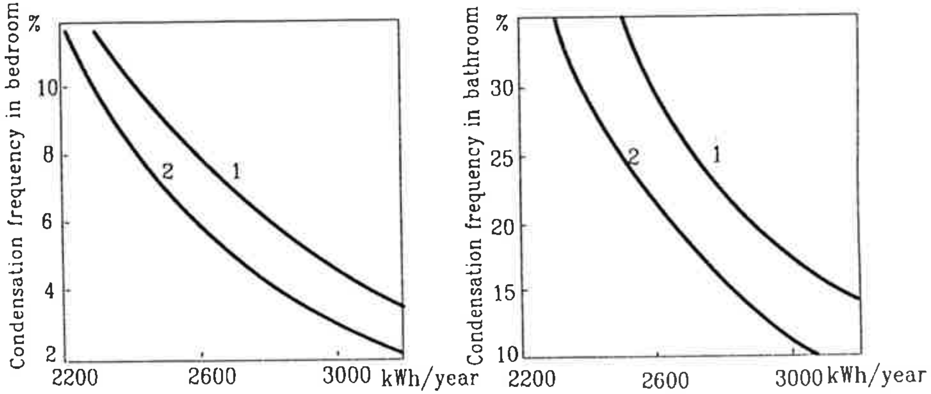
In case of balanced ventilation systems, the supply and exhaust flow rates of the whole dwelling are calculated in the same way from formula (2); then, the specific air flow rate of the dwelling Q_V is the greatest value of both. It is obvious that cross ventilation induced by wind effect depends on numerous factors such as air tightness level of the building envelope, shielding of the surroundings and pressure inside the building due particularly to the operation of the ventilation system. Using computer code which includes climatic data, a new way of calculating cross ventilation flow rate was derived, according the following equation:

$$Q_S = \frac{P \times e}{1 + \frac{d}{e}\left(\frac{Qi - Qe}{P}\right)^2} \qquad (3)$$

Where Q_S= flow rate due to cross ventilation (m^3/h), P= flow rate through cracks and purpose provide openings in the building envelope when the pressure difference is 1 Pa (m^3/h at 1 Pa), Qi= total supply flow rate (m^3/h), Qe= total exhaust flow rate (m^3/h), d=1.55 for dwellings with only one exposed façade and 1.15 for dwellings with more than one exposed façade, e= shielding coefficient which depends on shielding class and building exposure type. In the case of exhaust only ventilation systems, the supply flow rate Qi is equal to zero and the exhaust flow rate Qe is equal to the specific rate Q_V. This formulation of the cross ventilation rate has been accepted as an informative annex in the European standard on the calculation simplified method of thermal performances of buildings [8].

Method applied to DCV systems

Heat loss due to air renewal in dwellings equipped with humidity-controlled systems is straight calculated using computer code. The air quality level obtained with the DVC system is evaluated using some indicators in comparison with the results of a standard mechanical systems. As an example, comparative results between DCV and standard systems are given in figure 4. This figure shows the condensation frequency in a bedroom and in a bathroom as a function of the annual heat loss by air change. These results were obtained by running the model many times with the variations in system dimensioning. It was shown that, for a similar level of air quality, the DCV system can reduce the heat load by about 400 kWh/year, depending on indicator selected.



1 Standard mechanical ventilation system

2 Humidity-controlled

Figure 4. Performances of a DCV system compared with a standard system
1: standard mechanical system
2: humidity-controlled system

Additionally, in order to assess the efficiency and reliability of these ventilation system components, testing was performed in laboratory and field investigations were undertaken in occupied dwellings. These investigations made it possible to know the actual performances of the systems with regard to ageing and fouling hazards [9].

CONCLUSIONS

In France, dwelling regulation has enabled the development of efficient ventilation systems. These have to be assessed with regard to heat loss. Performance assessment is an important issue as it may ease the development of new systems with a better efficiency. Nowadays, about ninety percent of new-built dwellings are equipped with mechanical ventilation systems (exhaust systems, balanced systems, DCV systems). The efficiency of different ventilation systems is assessed by methods using computer models which require some assumptions relevant to the occupancy schedule of each room and the virtual pollutant emission rate. Results have shown that the performances of ventilation systems depend on the selected indoor air quality indicator ; research is needed in order to determine the relevant indicators to assess the performance of systems.

ACKNOWLEDGEMENTS

The authors wish to thank Messrs Francis LALBA and Redwan MOUNAJED for their assistance in the development of computer models. The participation of ADEME (Agence de l'Environnement et de la Maîtrise de l'Energie) and MELT (Ministère de l'Equipement, du Logement, et des Transports) is gratefully acknowledged for the research support.

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VENTILATION RATE AS A DETERMINANT OF SYMPTOMS AND UNPLEASANT ODORS AMONG WORKERS IN DAY-CARE CENTERS

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ABSTRACT

The objective of this study was to assess the occurrence of symptoms related to the sick building syndrome (SBS) and unpleasant odors among day-care nursing workers, in relation to air flows and ventilation rates in day-care centers. A random sample of 30 day-care centers in the city of Espoo was selected for the study. The study population consisted of 268 female nursing workers, who filled in a questionnaire. Ventilation system in most of the day-care centers (63%) was mechanical supply and exhaust, and the rest of the centers (37%) had mechanical exhaust only. The exhaust air flows in the children's rooms varied remarkably, the range being 0-11 L/s per person (average 4.0 L/s per person). The ventilation rate varied from 0 to 5 m^3/hm^3 (average 1.6 1/h). No consistent associations were observed between the magnitude of air flows or ventilation rate and the occurrence of symptoms or unpleasant odors experienced by the workers. The results indicate that relatively low mechanical ventilation rates are not associated with SBS symptoms and unpleasant odors, in conditions where the potential sources of odor are strong and air exchange is not totally dependent on mechanical ventilation (windows are openable).

INTRODUCTION

It has long been known that infectious diseases are more common among children in day-care centers than among children in other forms of care (1, 2). Inadequately low ventilation rates and high concentrations of CO_2 and chemical and biological pollutants have been measured in day-care centers in the Nordic countries and North America (3-9). However, the effects of different indoor environmental factors and especially ventilation rates have not been sufficiently studied.

A similar set of symptoms experienced by office workers has been called the sick building syndrome (SBS). The objective of this study was to assess the occurrence of SBS symptoms and unpleasant odors among day-care nursing workers in relation to air flows and ventilation rates. This association has not been reported earlier in a day-care center environment, where approximately one third of the Finnish preschool children are enrolled. The hypothesis of the study was that SBS symptoms as well as perceived unpleasant odors are more commonly related to low ventilation rates.