VENTILATION TECHNOLOGIES IN URBAN AREAS

19TH ANNUAL AIVC CONFERENCE
OSLO, NORWAY 28-30 SEPTEMBER 1998

IMPROVEMENT OF INDOOR CLIMATE AND VENTILATION SYSTEM IN A RENOVATED MULTISTORIED RESIDENTIAL BUILDING

Jari Palonen

HVAC-laboratory
Helsinki University of Technology, Finland

IMPROVEMENT OF INDOOR CLIMATE AND VENTILATION SYSTEM IN A RENOVATED MULTISTORIED RESIDENTIAL BUILDING

Jari Palonen
HVAC-laboratory
Helsinki University of Technology, Finland

Synopsis

The goal of this project was to improve the quality of indoor air in a multistoried residential building of 81 flats built in 1960. The building is located in a heavily built urban area of Helsinki. The building had a mechanical exhaust ventilation system without outdoor air inlets. A questionnaire was sent to occupants and a condition survey was made prior to renovation. The main indoor climate problem was draught with a prevalence of 60 %. Other almost as common problems were traffic noise also during nights and dust coming from the street. The ventilation system was fully unbalanced with reduced exhaust air flows partly due to uncleaned exhaust air vents. A new type of fresh air window with air filtration (EU 5) and good acoustic performance was developed. The sound insulation value measured in field was 42 dB(A). When these new windows were installed in the dwellings a new questionnaire was sent to occupants. The results showed clear improvement in all indoor climate related factors. The habitants were much more satisfied with the performance of ventilation system after the renovation measures.

1.0 Introduction

The design values for kitchen and bathroom exhaust air flows were 80 and 60 m^3/h in the 1960's, nowadays 20 and 15 l/s /1/. In small flats lower values are allow, but at least 0.5 ach is required 24 hours per day. Almost all mechanical exhaust ventilation systems in block of flats are equipped with a two-speed fan. The full speed is normally used about 6 hours per day /2/. When outdoor temperature falls under -12°C (in Southern Finland) fans are used only in half speed. In Helsinki there are about 350 such hours annually. Investigations /2/ concerning mechanical exhaust ventilation in block of flats built in the 1960's and the 1970's showed that when all the windows are closed, only one fifth of the exhaust air flows from kitchen or bathroom met the requirements of the National Building Code of Finland /1/. When exhaust fans are used in half speed, only 30 per cent of flats had an air change rate 0.5 or more per hour. In an other Finnish study the air-exchange rate over a two-week period 0.5 ach were reached in 40 % of dwellings with mechanical exhaust ventilation system /3/. The outdoor air inlets came obligate in new residential buildings without mechanical supply in the late of 1980's. There are still approximately one million dwellings in blocks of flats without outdoor air inlets.

2.0 Building and its environment

2.1 Building

The building built in 1960 is located in a heavily built urban area of Helsinki, Figure 1. The building is in the corner of two street with busy traffic. It has seven floors altogether with 110 habitants in 81 flats, most of them with only one or two bedrooms. The building is a condominium which means that most of flats are owned by the habitants. The building had mechanical exhaust ventilation system without outdoor air inlets. The exhaust air openings were placed in kitchen and bathroom. The exhaust air ducts and fan chambers were made from concrete. The exhaust air fan chambers are in the eight floor which is used also a storage room of the habitants. All flats have central heating system based on district heating. Windows were double pane type in original conditions with no outdoor air inlets.

Figure 1. Building in summer 1998 after the new windows have been installed.

No larger renovation measures have been made since 1960. In the year 1996 the condominium made a decision to renovate windows and ventilation system. The renovation costs of the new windows and ventilation system had to be kept at a level of 60 ECU/m^2.

2.2 Outdoor air quality

The nearest air quality follow up station locates only 300 m from the building in a similar urban environment. The yearly variation of inhalable particles is shown in Table 1.

Table 1. The daily means of inhalable particle concentration in each month of the year 1996.

Month	Concentration $\mu g/m^3$	Month	Concentration $\mu g/m^3$	Month	Concentration $\mu g/m^3$
January	35	May	40	September	50
February	75	June	30	October	35
March	98	July	25	November	40
April	90	August	50	December	40

The high particle concentrations are caused by accumulated sand spread on streets in order prevent slipperiness during the winter. The main outdoor air pollutants levels are; SO_2 negligible, NO_2 150 $\mu g/m^3$ (winter), 60 $\mu g/m^3$ otherwise, CO less than 5 mg/m^3.

3.0 Definition of the problem

3.1 Questionnaire

A self-administrative questionnaire was distributed to the occupants prior to renovation in January 1997. In the questionnaire visible moisture and mold damaged, odors and their sources, airing habits, use of bathrooms for baths and laundry drying were asked. Also the prevalence of the most common indoor climate related problems and symptoms were asked. The response rate was 60 %. The main indoor climate problem was draught with a prevalence of 60 %. Other almost as common problems were traffic noise also during nights and dust coming from the street. There was urgent need for improving sound insulation and outdoor air filtration. Only 10 % of the occupants were satisfied with ventilation system and one third of the occupants were satisfied with the heating system. 38 per cent of the occupants said that their dwellings are comfortable. In 30 % of flats were reported problems with odors coming either outdoors, or other flats or staircases.

3.2 Condition survey

In the beginning of the project, a new Finnish guidelines for indoor climate investigations was conducted in the building before the main renovation work /4/, /5/. The guidelines consist of the measures and methods including measurement equipment needed in the investigations. The indoor climate investigations include the following steps:

- assessing of indoor climate problems by interviewing occupants and maintenance personel of the building
- examining of the performance, condition and balance of ventilation system and comparing them to the design specification
- examining of air flows, pressure differences and air tightness of the building
- examining of the performance, condition and balance of heating system

- examining of the condition of constructions, e.g. water damages and the effect of ventilation on them
- assessing of thermal conditions, humidity and pollutants
- measuring of indoor climate parameters (temperature, humidity, pollutants of indoor air, etc.)

Visible moisture damages were recorded with the help of the check list for mould problem investigations. The condition of old exhaust ducts were inspected with video camera recording. Altogether 58 exhaust ducts were inspected. The sound insulation of outer wall was measured.

Before the conditions survey, the cleanliness of exhaust air vents were checked in ten dwellings. 40 % of the exhaust vents were so dirty (crease and dust) that it was not possible to make any air flow measurements. The mean exhaust air flow of kitchen was 8.4 l/s and of bathroom 7 l/s. No kitchen hoods were found. The exhaust vents in the dwellings were cleaned before condition survey.

During the condition survey over 40% of the dwellings were found to have moisture damages, mostly in bathrooms due to low ventilation or pipe leakage. The exhaust fans were two-speed type. The full speed was in use between 8 and 9, 11 and 13 and 17-19 daily. The exhaust air flows were still after cleaning of exhaust air vents below the target values in many dwellings. The mean exhaust air flow of kitchen was 11 l/s and of bathroom 10 l/s with full fan speed. Those values are about 60 % of the building code level. The ventilation of the underground sauna department was in very poor conditions, the exhaust air flows were less than 5 l/s.

The video film of exhaust ducts showed several local damages, holes between ducts and tools left there during construction. The ducts were so clean that duct cleaning was not necessary.

The sound insulation values of the existing windows were 26-28 dB. The noise levels inside the dwellings were 39…42 dB(A). The Finnish guideline for the equivalent noise level in living and bedrooms is 35 dB(A) during daytime and 30 dB(A) during the night (5).

The following actions were recommended based on the condition survey:
- replacement of old exhaust air vents with adjustable air vents
- tightening of exhaust air chamber and improving of sound insulation
- modernisation of exhaust air fans
- adjustment of exhaust air flows
- fresh air inlets in staircases
- separate ventilation system for underground sauna department
- cleaning of outdoor air inlets of underground spaces
- adjustment of heating system after new windows installed and ventilation system adjustment
- installation of kitchen hoods where the exhaust air cleaned before recirculated back to the kitchen
- condition survey of water supply and sewer pipelines

4. 0 Window

The main design problem is to develop a solution for the outdoor air supply through window without causing any draught in the zone of occupancy. A new type of fresh air window with air filtration (EU 5) and good acoustic performance was developed. The acoustic performance of the new window and velocity and temperature field caused by outdoor air inlet were measured in the full scale test room built in the HVAC-laboratory.

Structure

The new window, installed in dwellings located in the street side of the building, consists of two parts, a three pane window and a separate airing shutter which can be opened in order to change the outdoor air filter or when airing is needed. The thickness of the glasses from outside to inside are 8 mm, 6 mm and 6 mm. The structure of the airing shutter from outside to inside is; 1.5 mm thick steel plate, 15 mm thick stone wool with covering against air, 25 mm air flow channel, 15 mm stone wool with covering against air, 15 mm + 15 mm gypsum board and surface plate.

The outdoor air is first cleaned by filter located at the bottom of the airing shutter. The filter is changed twice per year. The air flow from the bottom to the top side of the airing shutter via rectangular channel (25 thick and 200 mm width). The air is directed to indoor through a radial diffuser which spreads the air over the wall surface. The slot of the diffuser is partially covered in order to direct the cold supply air over the warm radiator under the window. The diffuser is widely used in Finnish dwellings as outdoor air inlet. The manufacturer notified that it can be supplied 8 l/s per vent and meet the requirements of the National Building Code of Finland /1/ concerning the maximum air velocities in the occupied zone.

In the dwellings facing the yard similar windows except for the airing shutter being a three pane window were installed. The outdoor air inlet was ordinary an slot-type adjustable vent with much lower sound insulation value. The slots were installed in the upper frame of the window. The slots also have filters inside, but with lower efficiency than filters in the street side.

Sound insulation

The sound insulation value was measured in the building after some windows were installed on the street side of the building. The sound insulation value was now 42 dB. The measurements were slightly disturbed by internal noise from other dwellings and plumbing systems. That means that even better sound insulation value could have been obtained if the temporary internal noise sources could have been eliminated.

5.0 Results and discussion

New windows were installed in the dwellings between February and April 1997. The exhaust air flows were measured with full fan speed after the windows were installed. The mean exhaust air flow from kitchen was 12 l/s and from bathroom 9 l/s and from cloakroom 12 l/s. Those values are about 60 % of the building code level except cloakroom. Air exchange rates were 1.0 ach in single room flats, 0.7...0.9 ach in double room flats and 0.7 ach in three room flats. The air exchange rate was 0.5 or greater almost in all flats.

A self-administrative questionnaire was distributed to the occupants after one year of the installation of new windows in April 1998. The questionnaire was shorter than in 1997, moisture and mold damaged were no more asked. The response rate was now 72 %. In Table 2 the prevalence of indoor air related problems before and after the renovation measures are shown.

The measurements in the dwellings before and after the renovation showed that the deviation of room temperatures between single dwellings decreased remarkably. Before renovation the mean value of the room temperature was 22.4°C (20-25°C) and after renovation 22.0°C (21.0-23.4°C). The percentage of complaints concerning main indoor related problems like traffic noise and draught decreased to a great extent. Also indoor air quality were judged now much better than earlier. Now 27 % of the occupants were very satisfied with ventilation system and 43 % of the occupants were very satisfied with the heating system. 50 per cent of the occupants said that their dwelling is comfortable. The percentage of dissatisfied with ventilation system decreased from 30 % to 12 %.

Table 2. The prevalence of indoor air related problems before and after renovation measures.

Problem	Prevalence in 1997 %	Prevalence in 1998 %
Too high room temperature	4.2	6.9
Too low room temperature	42.6	31.0
Unstable room temperature	34.0	12.1
Draught	61.7	22.4
Cold floors	36.1	25.9
Dry air	38.3	24.1
Humid air	4.3	3.4
Stale air	31.9	10.3
Unpleasant odor	23.4	13.8
Insufficient ventilation (winter)	34.0	13.8
Insufficient ventilation (summer)	42.6	24.1
Dusty air	38.3	22.4
Dust in surfaces	53.2	39.7
Noise from ventilation system	4.3	3.4
Other noise (traffic etc.)	53.2	17.2

In 43 % of flats were reported problems with odors coming either outdoors, or other flats or staircases. That was only problem with increased prevalence after renovation measures. Due to better indoor air quality the habitants may detect easier temporary odors than earlier.

Airing frequency decreased after new windows were installed. Especially the percentage of habitants airing several times daily decreased from 36 % to 15 %.

Winter 1997 was slightly milder than winter 1998. The weather conditions were not reason for the decreased percentage of the habitants feeling draught after new windows were installed. It is very important to take care of the whole ventilation system when conducting a large window renovation project in a blocks of flats. Otherwise the ventilation in flats will decrease.

The poor conditions of exhaust air ducts made from brick or concrete limits often possibilities to renovate or improve existing ventilation system with reasonable costs.

Further actions

During August and September 1998 exhaust air fans will be modernized, fan chambers tightened, new exhaust air vents installed and the exhaust air flows balanced. The aim is to increase the mean value of exhaust air flows by 20 %.

Acknowledgements

The window was designed by acoustical consult, architect Alpo Halme, who made also sound insulation measurements. This study was financed by Ministry of the Environment and by the condominium Fleminginkatu 23.

References

1. National building code of Finland, D2. Indoor climate and ventilation of buildings. Regulations and guidelines 1987. Helsinki, Finland: Ministry of the Environment; 1987.

2. Performance of ventilation systems in blocks of flats. (In Finnish Asuinrakennusten ilmanvaihtoselvitys). City of Helsinki 1993.

3. Ruotsalainen, R., Ventilation, indoor air quality and human health and comfort in dwellings and day-care centers. (Doctoral Thesis). Helsinki University of Technology, Laboratory of Heating, Ventilating and Air Conditioning, Report A1, Espoo 1995.

4. Building Renovation Program 1992-1996. Results of the development projects in the building sector. The Finnish Environment 119. 1997. (in Finnish)

5. Palonen, J., Seppänen, O., Jokiranta, K., Ruotsalainen, R., Guidelines for indoor climate investigations in residential buildings. CIB World Building Congress 1998, Gävle, Sweden, 7-12 June.

6. Directive of indoor climate. Ministry of Social Affairs and Health. Guides 1997:1. ISBN 952-00-0261-8. Helsinki 1997.