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Tightness of Pre-fabricated Outer Walls and its Influence on Heat Demand in Apartment Dwellings

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Marian Nantka has been involved in air leakage and air infiltration studies at the Politechnical Institute of Silesia for a number of years. During this time he has made extensive measurements in single family dwellings and apartment blocks and has developed a mathematical model of air infiltration. In this article, Dr Nantka describes the results of some of his measurements and theoretical studies on apartment buildings.

Introduction

The Institute of Heating, Ventilating and Anti-Air Pollution is one of the few institutions in Poland engaged in the study of air infiltration through external walls constructed of pre-fabricated blocks. The project, which began before 1978, covers the following aspects:

- air infiltration through gaps in laboratory and site studies
- research and estimation of the climatic parameters in dwellings
- research and theoretical analysis
- heat balances.

Much of the work has been centred on large apartment buildings of pre-fabricated construction (Figure 1).

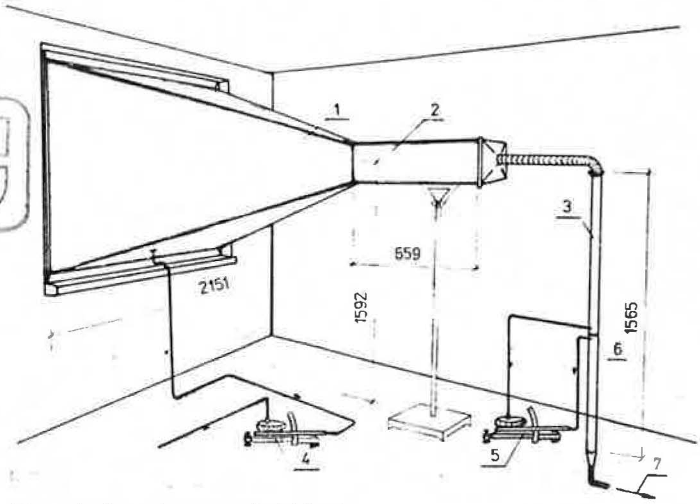
Figure 1. Types of buildings examined.

Air Leakage Measurements [1,2,3,4]

Measurements of air leakage have been carried out in inhabited buildings using the pressurization test equipment illustrated in Figure 2. Particular attention has been focussed on the measurement of air leakage through cracks around windows and doors and through joints between pre-cast wall slabs. Similar tests have also been conducted in the laboratory at the Institute. The laboratory studies indicate a power law relationship between pressure acting across the opening and flow rate given by:

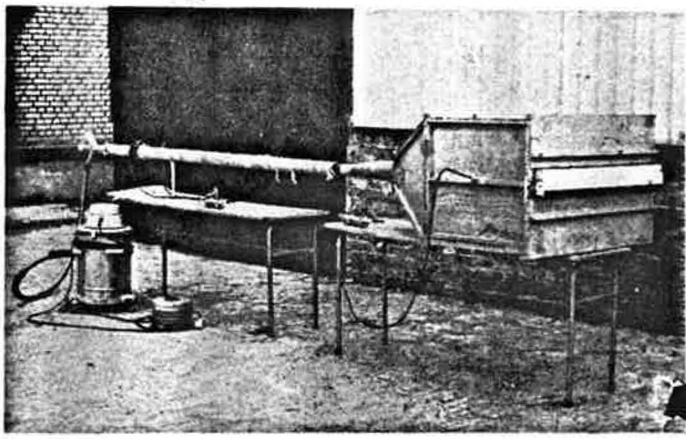
$$\dot{V} = a\Sigma\ell(\Delta p)^{1/n} \quad m^3h^{-1} \qquad (1)$$

where $\dot{V}$ = infiltration rate, m^3h^{-1}
Δp = pressure difference across opening, Pa
$\Sigma\ell$ = sum of gap lengths, m
a = airflow coefficient, $m^3m^{-1}h^{-1}Pa^{-1}$
n = power exponent



For windows in occupied blocks

1. *Airtight test chamber (1.8 x 1.5/0.2 x 0.2m)*
2. *Square-section duct (0.2 x 0.2m)*
3. *Measurements section (60mm dia.)*
4. *Micromanometer (for measuring pressure differences)*
5. *Micromanometer (for measuring air infiltration rate)*
6. *Gauge orifice (modulus m = 0.478)*
7. *To fan*



For laboratory tests on various components.

Figure 2. Experimental set-up for measuring component air leakage values.

Approximately 20 to 30 leakage measurements over a range of pressures were made on each component. The resultant combinations of Δp and $\dot{V}$ were analysed using the method of least squares to calculate *a* and *n*. Under these circumstances the precision of calculation was governed by the accuracy of measurement of Δp and $\dot{V}$ at the lowest range of measured values. Measurements of pressure down to 0.16 Pa were possible using a battery powered micromanometer and air flow measurements down to 0.6 x 10^{-3} m^3s^{-1} were achieved using an orifice plate or thermo-anemometer.

The results of these experiments are illustrated in Figure 3 and show that, at pressure difference of 50 Pa, the flow exponent for windows varies between 1.3 and 1.6. This has an important bearing on the calculation of air infiltration in rooms and can result in air infiltration overstepping expectation by an average of 30 to 50% for windows alone. In heat loss calculations, a similar allowance must also be made for leakages through joints in pre-fabricated elements even when they appear to be perfectly tight.

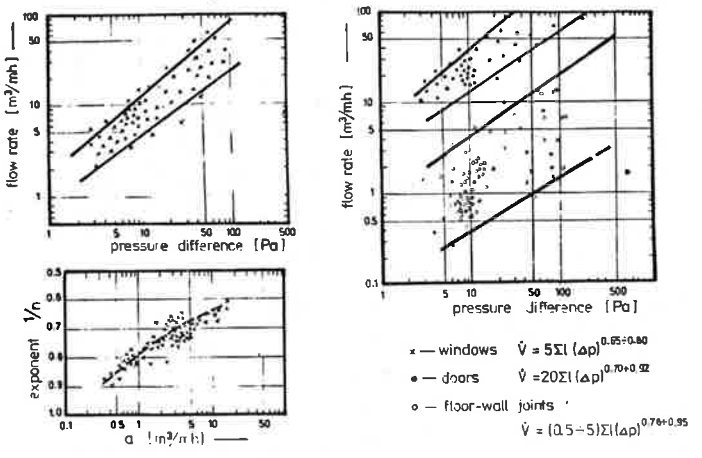
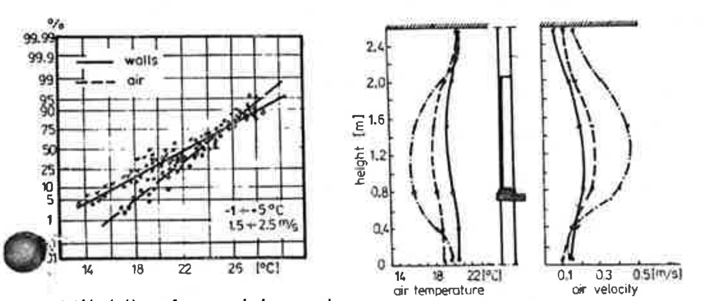


Figure 3. Comparison of air leakage rates through windows, doors and floor-wall joint in examined buildings and relation between exponents and coefficients for windows.

Estimation of Internal Climate Parameters[1,5]

In inhabited buildings, the essential parameters of climate are air temperature, wall surface temperature, humidity, and speed of air movement. These components have all been measured using traditional instruments. Many results were obtained over a two-year period, thus enabling a statistical analysis to be performed. Some typical results are illustrated in Figure 4. These show the wide variations in indoor climate that occur, with the result that it is difficult to make proper use of the rooms. The main reasons for the existing circumstances are lack of regulation of supply heat, insufficient tightness of building fabric and the existence of uncontrolled air infiltration.



(a) Variation of room air temperature and walls temperature in test dwellings

(b) Velocity and temperature profiles in a living room (for example). External temperature +1°C, mean wind speed 2 m/s.

Figure 4. Typical indoor climate data for flats located in test blocks.

Research and Theoretical Analysis of Ventilation and Air Infiltration[1,6,7,8]

A computer model was developed for studying the performance of natural ventilation in buildings. This was used to carry out a theoretical analysis of the performance of different kinds of ventilation system for a specific building throughout a one-year cycle of external climatic changes. The computer program calculates air infiltration by determining an internal pressure distribution such that air inflow is balanced by outflow. The accuracy of the calculation is dependent on precise measurements of internal/external air temperature, wind speed and direction, surrounding building obstructions, and the flow characteristics of ventilation shafts.

Results of these calculations (for example, Figure 5a) have reaffirmed the inferences of the experiments carried out in the inhabited buildings regarding the influence of uncontrolled air infiltration on room heat demand. It is only possible to eliminate such problems by installing mechanical ventilation to supply the necessary quantities of outside air (Figure 5b).

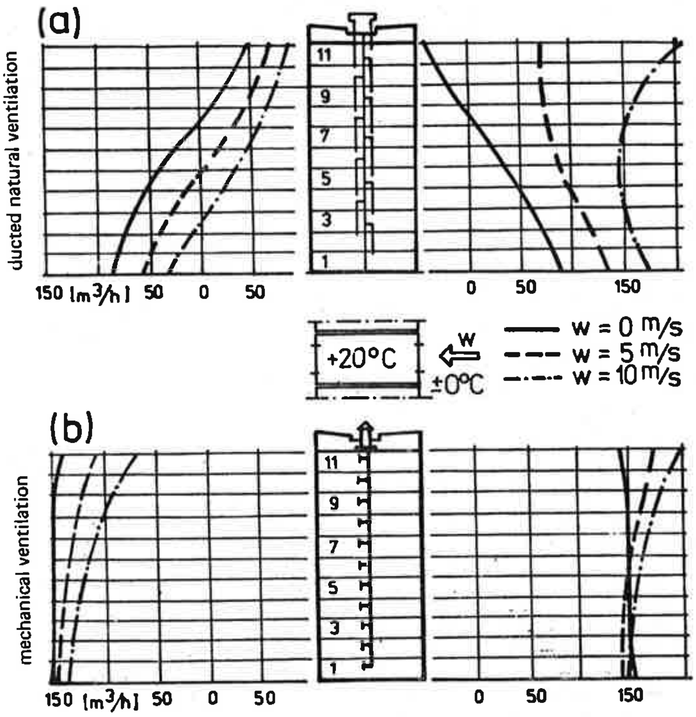
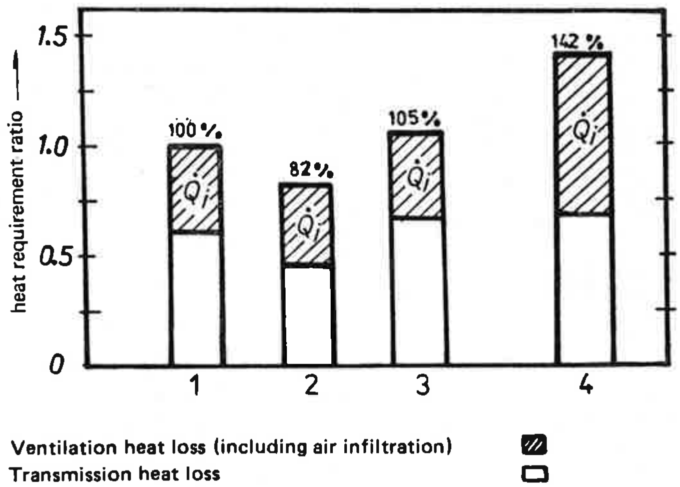


Figure 5. Influence of heat demand of types of ventilation systems in blocks of flats (results of computer calculated mean air leakage values).



1. *Calculated according to the Polish Standards (k-values = max, air infiltration = min.)*
2. *k-values and air infiltration – based on technical data for buildings*
3. *k-values from measurements; air infiltration = min.*
4. *from measurements*

Figure 6. Heat losses for different conditions.

Building Heat Balance[8,9,10]

Excessive air infiltration is the reason for a need of extra heat in buildings. To assess the true value of heat loss through external wall elements, several measurements of heat transmission have been carried out. Continuous measurements have been made of the thermal resistance and internal/external temperatures of the slabs. These measurements have shown that the values of heat transmission fluctuate between limits of 1.2 to 1.5 $W/m^2 K$ for walls and 2.8 $W/m^2 K$ for windows.

Taking into account the air infiltration measurements, it was possible to determine the real heat requirement in buildings. The results of comparisons of these requirements with the calculated values are shown in Figure 6. These results show that the real heat requirement is about 40% larger than the calculated values. For natural ventilation systems the combined ventilation and air infiltration heat loss accounted for between 50 to 60% of the total building heat loss.

Summary

To date, this research has provided clear indications on how to overcome ventilation problems associated with air infiltration in apartment buildings. The Institute of Silesia in Gliwice is now preparing test rigs and measuring apparatus to monitor air exchange rates in apartment buildings as well as in other houses.

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