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Role and Tasks of Ventilation in Modern Buildings: A Case Study for Silesian Dwelling Houses

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Case Study of Silesian Dwelling Houses

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SYNOPSIS

The paper presents some selected results of evalution of improvement effectivenes of thermal insulation and tightness of multifamily dwelling houses located in the region of Silesia. The effect of the modernization work on heat consumption (to heat the buildings) and ventilation performance is discused. Attention is paid mainly to the sensations of the flat users connected with air flows and change. Prospects for effective implementation of thermorenovation of buildings are evaluated in the conclusions when taking into account predominating role of ventilation.

The present results of the pilot tests are a basic element of suggested changes of standards. They also represent a new approach to ventilation of dwellings.

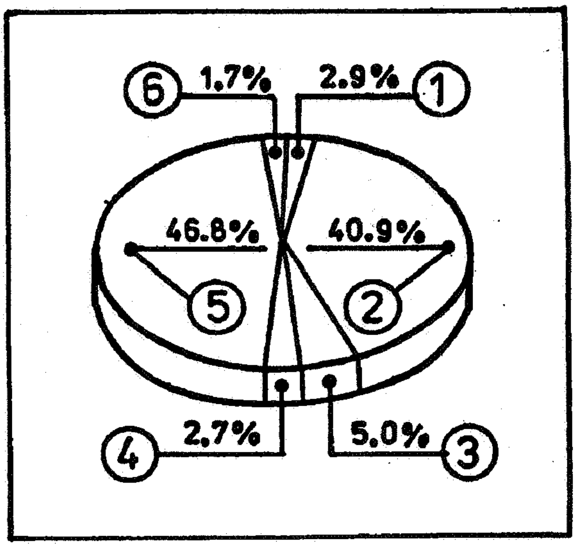
1. INTRODUCTION

Global energy use for heating, ventilation and hot water is presently about 45% of the energy balance of urban-industrial agglomerations of Silesia whereas heat losses of buildings are, on average, about 75% of the energy use [1]. The share of heat demand for ventilation purposes varies between about 25% and over 50%, depending on the size of building and thermal insulation of its walls.

Potential of energy use rationalization in buildings is significant. The evaluation carried out has proved that when thermal insulation and airtightness of buildings are improved, the energy use may be reduced by more than 45% (look Fig.1). In order to make use of that possibility, some thermorenovation work was carried out in a great number of buildings. At the same time, since 1983, new standards have been introduced successively. The standards have limited heat and air flow through the external partitions of buildings (e.g. the values of thermal conductivy coefficients for walls should not exceed 0.55 W/m^2K whereas before 1983 the upper limit was 1.16 W/m^2K).

Another characteristic example may be setting the maximum vallues of air leakage coefficients for windows (there were no limits before 1983). Presently the above coefficients should not exceed 2×10^{-4} m^3/ms at 1 Pa.

Better thermal insulation of external walls (including windows) is very much desired. However, reduction of air chanege rate by over - airtightening of external walls (above all windows) may be controversial [2].



1 - improvement of boiler house efficiency
2 - substitution of solid fuels with gas
3 - reduction of losses of district heating networks
4 - automation and regulation
5 - improvement of thermal insulation
6 - reduction of heating water losses

Fig. 1. Elements of energy saving potential

Unfortunately, the subsequent versions of the standards regarding thermal protection of buildings have not been accompanied by legat regulations in regard of ventilation needs. The results presented in the further part of the paper and, their discussion are the first in Silesia attempt to define to which extent the thermorenovation work already begun may results in undesirable sensations of the building users or even be harmful for their health.

2. BUILDINGS AND METHODS USED

The tests begun in 1984 have been carried out in multifamily buildings used for 5 to 40 years. The buidings are of different shapes sizes and the inner structure. All the buildings have natural ventilation systems (ventilation ducts without fans) and individual water heating systems (gas heaters placed in windowless bathrooms, connected to waste gas ducts). Nine of the tested buildings are identical 11 storey houses of the same construction and with the same installations. Since they are typical of multifamily buildings in Silesia; most of the data presented in the paper refer to those nine houses.
The measurements consisted in continuous registration of thermal energy supplied to the building (in their heat centres). At the same time parameters of the outdoor climate and air temperature in about 75% of the indoor spaces were recorded. Thermovision and air flow visualization were also applied. That made it possible to select rooms for tests of airtightness (pressure method) and air change rate (tracer gas method with N_2O and SF_6 used as tracer gases). The data acquired was then used for computer simulation of air flows between seperate zones where the author's own computer code SYMWENT was applied. The tests were done before and after thermorenovation of the buildings. Inquiries were carried out in the similar way.
Two questionnaire types were used, worked out by local experts. The first one included more than 30 questions regarding thermal comfort, performance of heating and ventilation equipment, indoor air quality, etc. The other one asked the users to state the health problems related to the indoor environment conditions.

Detailed decription of the buildings, methods applied and results obtained were presented in some expert reports financed by the local administrative authorities and reports of the Silesian Technical University [3,4,5]. The paper presents only a part of the tests.

3. SOME SELECTED RESULTS AND COMPARISONS

Characteristic ranges of changes of heat loss balance parameters for the tested buildings are shown in Table 1. Apparently, significant reduction in air leakage coefficients for the windows has been acquired. The increase in airtightness of the windows (with no additional supply o-penings) resulted in 2-3 times reduction of air exchange with the outdoor environment. At the same time variability of air change rate, characteristic of natural ventilation was preserved both with time and in the indoor spaces. The variability is ilustrated by the data presented in Fig.2,3 and 4.

Table 1. Results of test of main components of the heat loss balance in the buildings

Description of parameter		Buildings built before 1950	Buildings bulit after 1980	
			Before thermo-renovation	After thermo-renovation
Thermal conductivity coefficients for walls (without windows), W/m^2K		$\frac{0.98}{1.46}$;(1.22)	$\frac{0.62}{1.70}$;(1.12)	$\frac{0.42}{1.08}$;(0.59)
Thermal conductivy coefficients for windows, W/m^2K		$\frac{2.90}{4.01}$;(3.20)	$\frac{2.48}{3.18}$;(2.80)	$\frac{2.22}{2.96}$;(2.68)
Air leakage coefficients for windows, m^3/mh dla 1 daPa		$\frac{5.41}{12.60}$;(8.61)	$\frac{2.16}{7.96}$;(4.62)	;$\frac{0.31}{0.92}$(0.48)
Air change rate, 1/h	-20°C, 0 m/s	1.76	1.6	0.49
	0°C, 0 m/s	1.48	0.91	0.37
	+10°C, 0 m/s	2.3	0.89	0.32
	+12°C, 0 m/s	0.99	0.48	0.21

Note:
(1) Thermal conductivy and air leakage coefficients - min/max (average)
(2) Air leakage coefficients include slots in the walls where the windows are mounted
(3) Air change rate is the results of numerical air flow simulation assuming real values of air leakage coefficient

In practice, the problem of air change rate variability is much more complex. The data shown in Fig 2,3 and 4 do not take into account room airing by opening the windows whereas in

practice due to window opening thermorenovation of the walls may be ineffective. This can be proved by the results shown schematicaly in Fig.5.
Apparently, the expected 35% reduction in the heat use was not achieved. The main reason for that was the necessity of permanent airing of the rooms which is also confirmed by the questionnaires.

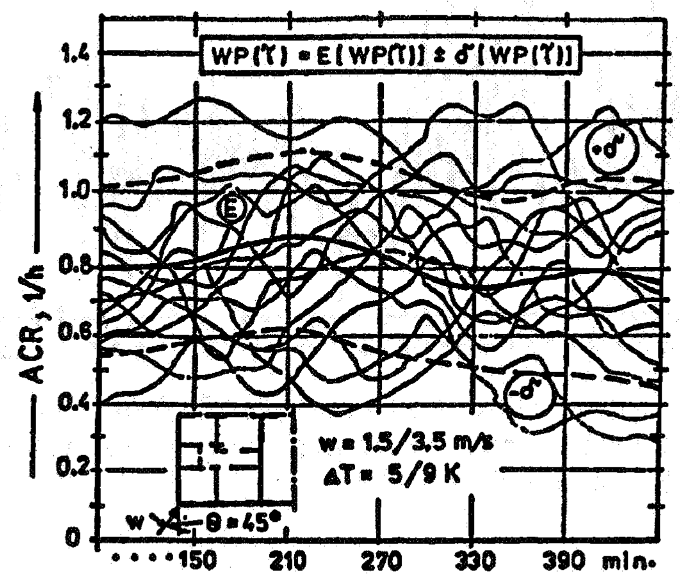


Fig.2. Variability of air change rate in a flat on the third floor of the tested building (measuremement results employing the method of NO_2 constant concentration and concentration and covering 14 four-hour period before thermorenovation)

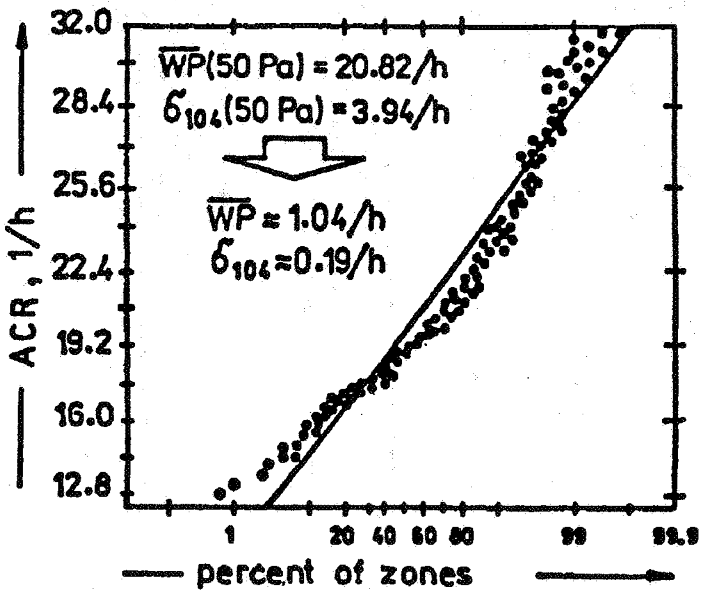


Fig.3. Normal distribution of air change rate for 104 zones located in one of the tested buildings (results of pressurization tests at Δp about 50 Pa - before termorenovation)

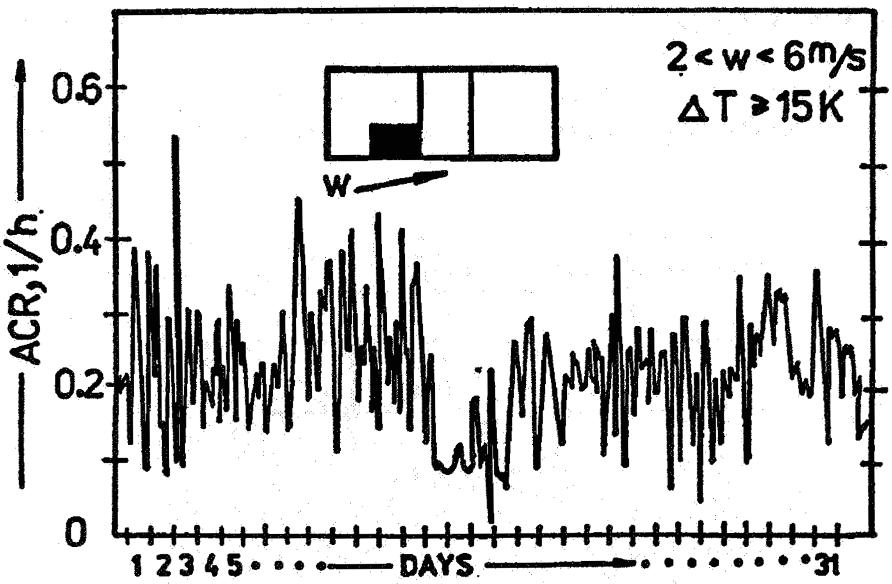


Fig.4. Variability of air change rate in a room on the fifth floor of one of the tested buildings after its thermorenovation (measurement results employing the method of constant SF_6 emission)

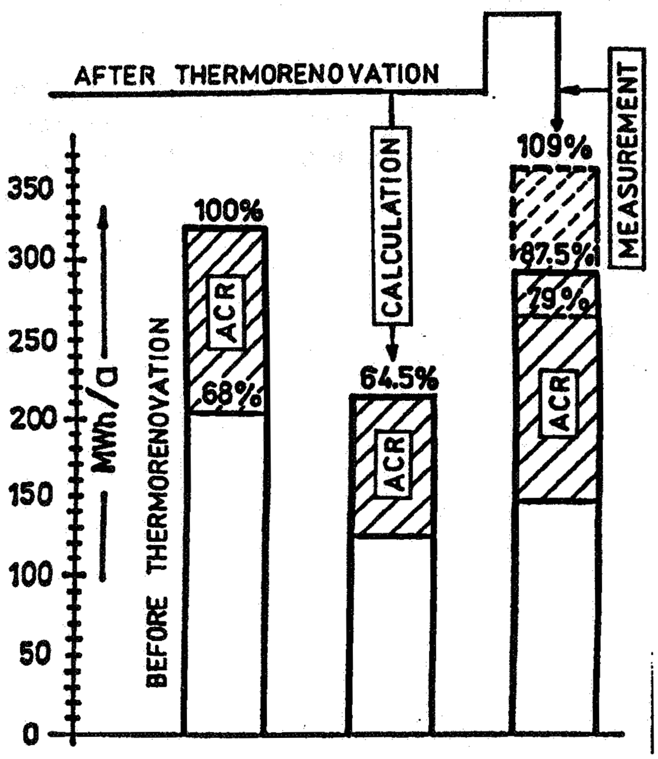


Fig5. Comparision of heat amounts used to heat 9 identical multifamily buildings .(calculations were made by means of TRYNSYS and SYMWENT)

Table 2. Number of total health symptoms and their occurrences reported by inhabitants (building with sealed windows)

SYMPTOM	DWELLING HOUSES			
	Built before 1950 (481 respondents)		Bulit after 1980* (658 respondents)	
Eye irritation	(63)	13,1%	(228)	34,6%
Dry/sore infection	(8)	1,7%	(50)	7,6%
Irriative cough	(37)	7,7%	(161)	24,5%
Excessive phlegm	(59)	12,3%	(108)	16,4%
Sinus infection	(2)	0,4%	(16)	2,4%
Bronchial pneumonia	(17)	3,5%	(21)	3,2%
Asthmatic attacks	(41)	8,5%	(54)	8,2%
Headaches	(216)	44,9%	(410)	62,3%
Dizziness	(193)	40,1%	(272)	41,3%
Unusual fatigue	(182)	37,8%	(200)	30,4%
Difficulty in sleeping	(31)	6,4%	(112)	17,0%
Nasal irritation	(50)	10,4%	(108)	16,4%
Nosebleed	(3)	0,6%	(21)	3,2%
Nausea	(40)	8,3%	(103)	15,7%
Vomiting	(18)	3,7%	(68)	10,3%
Abdominal irritation	(40)	0,8%	(18)	2,7%
Whole body ache	(23)	4,8%	(71)	10,8%
Fever	(11)	2,3%	(38)	5,8%
Stuffy/"bad" air	(33)	6,9%	(59)	9,0%
Average number of symptoms per person	2.1.		3.2.	

More than 70% of the whole number of the respondents mentioned the unpleasant sensation of overheating of rooms and lack of ventilation (air change). It should be pointed out that the percentage was less that 25% in the same buildings but before thermorenovation.
An increase in the number of health symptoms reported by the inhabitants of the buildings of reduced heat losses is also a characteristic change. Table 2 shows a comparisons of the health symptoms and includes data regarding more than 45 multifamily buildings.
The comparision shows that the total number of symptoms per person, reported by the questioned inhabitants is higher in modern (or modernized) buildings than in old dwelling houses. The highest frequencies are reported for headaches, dizziness, eye irriatation and even vomiting. The last symptom refers mainly to the users of buildings with windowless bathrooms with gas heaters of water. When air leakage coefficients for windows are low, phenomena of

backward operation of ventilation and waste gas ducts, characteristic of natural ventilation, increases. It has been confirmed by the results of air flow simulation employing the allthor's own simulation codes SYMWENT and SYMPOLL [5,6]. In result, the risk for the occupants' health increases significantly.

4. DISCUSSION

Most people spend major part of their lives in closed spaces. It is therefore of special importance to maintain air quality which does not impair comfort and health. Progressive increase in the cost of heating within the last years has become a reason for seeking ways to reduce heat use. On of the simplest ways may be increase of thermal insulation of buildings by thermorenovation of their walls.

When different building types are considered, dwelling houses and especially multifamily houses, present particular problems. Those problems are very complex and require simulataneous solution of seyeral components.

The test show that in spite of significant improvement of thermal insulation and airtightness of the walls, the energy use to heat the buildings is only slightly lower or even is not reduced at all. At the same time both the heat losses and the indoor environment conditions very much depend on air change rate and ventilation processes. A characteristic feature of basic heat losses of modern (or modernized) dwelling houses, presented in Fig.6, is that it is dominated by

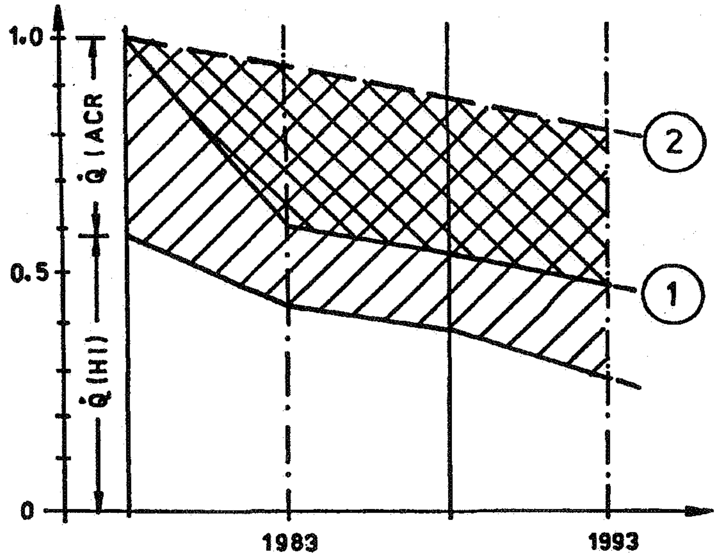


Fig.6. Changes of ventilation heat demands in the balance of basic heat losses (1983, 1993 - years when new standards were introduced)
Notations: (HI) - heat insulation, (ACR) - air change rate; 1 - according to the calculation for standard values of air leakage coefficients; 2 - as above

ventilation heat demand (see line 2). Ventilation plays particular rote in dilution and removal of pollutants within occupied spaces. Minimum requirements can be set to meet the metabolic needs of occupants. In real situation, added to such requirement are those need to dilute other sources of pollutants such as moisture, tobacco smoke, cooking, building materials, heating

appliances, furnishings, fittings, etc. At the same time, increased awareness of the potential health risks associated with outdoor (most important problems in Silesia) and indoor air pollutants should stimulate studies of ventilation systems and ventilation functioning in Poland.
The test show that the use of natural ventilation not only in small detached houses but also in multifamily (often high) buildings is inappropriate as a basis for indoor air quality and health control.

5. CONCLUSION

The attention paid to ventilation and indoor air quality in Silesia is rather new. For the last five years, research concerning building airtightness from energy point of view has been done. Basing on the results of measurements and questionnaires it may be concluded:

- Air change rate in flats and rooms located in modern or modernized dwelling houses are very small; this is a result of excessive airtightness of external walls, especially windows.
- The most significant health symptoms are headaches, dizziness, unusual fatique and eye irritation; the number of these symptoms per person appears to increase with decreasing heat consumption of the building.

In the next stage of the study, the research will include on-site measurements of air polltants in new dwelling houses. Presently research has been started on natural and mechanical ventilation efficiency both in situ and at laboratory stands. It is also expected that the research on ventilating air quality and elimination of the risks occurring in existing and actually buit buildings will be continued.

6. REFERENCS

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