PRESSURISATION TESTS OF SELECTED APARTMENTS AS A BASE FOR ANALYSIS OF NATURAL VENTILATION IN MULTI FAMILY BUILDING

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ABSTRACT

The paper presents a study on application of pressurisation tests of selected apartments as a base for analysis of natural ventilation in multi-family building. The analysis has been performed for 5-floor building constructed in late sixties. 10 apartments from total number of 45 have been selected for pressurisation testes. The discussion presents estimations of windows' air tightness, the influence of additional air sealing on windows' infiltration coefficient and flow rates at reference conditions. Faults of the ventilation systems operation and deviations from requirements of Polish building code and Polish Standards have been reported. The conclusions highlight the importance of such a simple evaluation tool for Poland where the stack ventilation in most popular type of ventilation, but is not a subject of individual analysis during designing process.

INTRODUCTION

Vast majority of Polish residential buildings is equipped with stack ventilation. Unfortunately, this type of ventilation is not a subject of any calculations during the designing process. Cross sections of stacks, the type of ventilation grilles, air tightness of envelope components are selected by a rule of thumb or are no taken into consideration at all. Great action of energy conservation, supported by the Government, advises air sealing of the building envelopes. However, very often it results in very negative consequences related to decreasing of ventilation intensity. As gas appliances with open flame are still used in number of Polish apartments for preparing hot water or cooking, an inadequate ventilation is not only a problem of comfort or long term illnesses. It can create direct risk for occupants' health or even life. One may expect (unluckily there are no official statistics) that each year there are 600-800 cases of carbon monoxide poisoning, many of them with mortal end.

In that situation there is a great need for implementation of quite simple tests of ventilation systems. The aim of presented study [1] was to check the technique of pressurisation test in specific Polish conditions and to provide the expertise to the owners and organisations promoting energy conservation actions. The analysed building had also been tested with tracer gas techniques. The comparison of results, as well as general evaluation of these two procedures, is performed at present.

METHODS

Analysed building, located in small town in south-western part of Poland, is quite typical for the Polish building industry in late sixties. 45 small apartments have been located at 5 floors in

3 staircases A, B, and C. One may recognise two types of apartments (see table 1) categorised for the purpose of this paper as type I and II.

The construction of the building is quite heavy. The walls are made of brick and concrete with heat transfer coefficient U $\approx$ 1.0 W/m^{2}K. The building has been equipped with natural ventilation (stack ventilation). It has been assumed that air would infiltrate through cracks in double glazed wooden frame windows (typical solution in that time in Poland) and that air would be removed from the apartments by grilles located in kitchens and bathrooms. The grills have been connected to the stacks. Kitchens or bathrooms located at first floor have common stack with corresponding volumes at third floor (similarly grilles at second and fourth floor are connected to the same stack). Only apartments located at 5 floor have individual stacks equipped with special H shaped fittings to minimise the risk of back – draughts.

Table 1. Basic characteristics of the analysed apartments

	Unit	Type of apartment	
		I	II
Total area of apartment	m^2	43.16	39.06
Bathroom area	m^2	3.25	3.32
Kitchen area	m^2	7.23	8.30
Height of apartment	m	2.5	2.5
Length of cracks in windows	m	21.46	15.35
Area of external walls	m^2	26.77 or58.67*	19.3

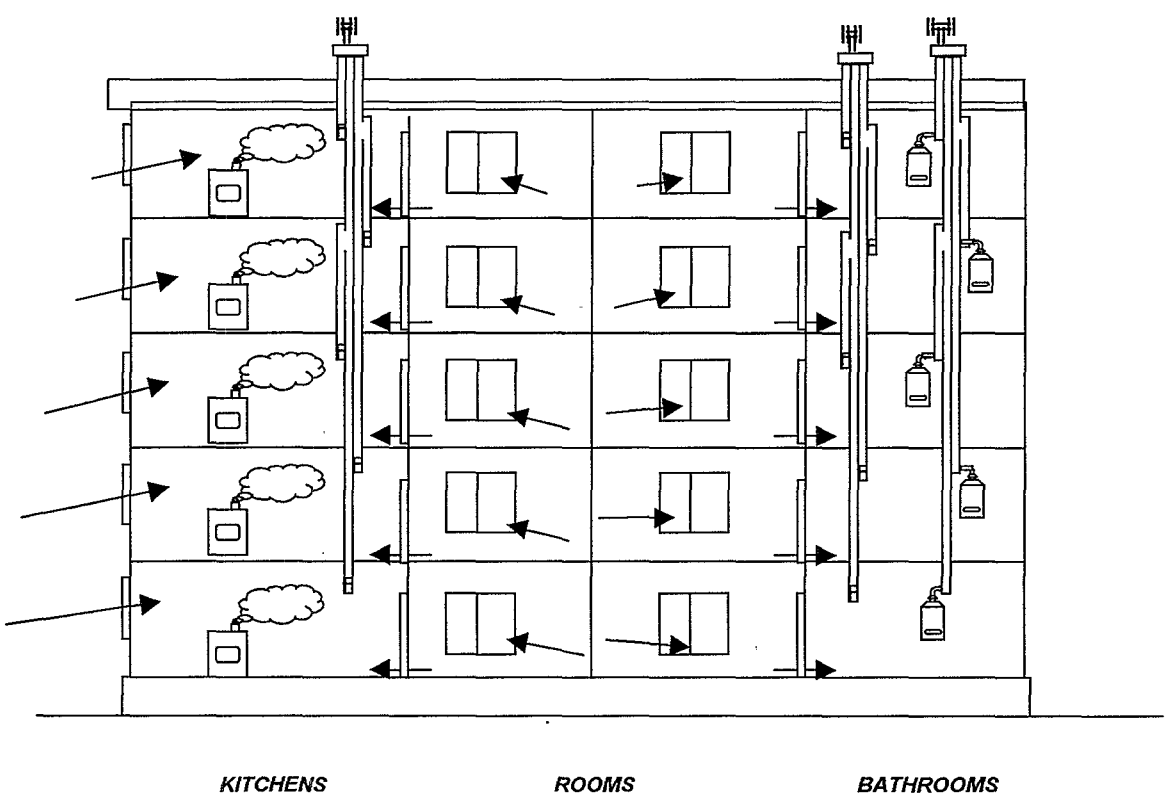

Figure 1. Scheme of stack ventilation in analysed building

In late seventies the apartments had been equipped with gas water heaters. Open fame gas appliances with flue balances had been located in bathrooms (current regulations forbid locating gas appliance in such a small volume). Lately, some energy conservation actions have taken place. Among others, window cracks have been sealed with soft rubber "o"-ring gaskets. Few occupants reported their dissatisfaction with existing situation. Also chimney-sweep service reported improper operation of ventilation and ordered improvements. Some actions connected with repairing of ventilation stacks and flues have been undertaken, but not radical improvement has been observed.

Ten apartments have been selected for the pressurisation tests. The selection has been to some extent randomised, but special attention has been paid to distribute analysed apartments in all staircases and at all floors. Inspections of apartments shown number of changes made by the users that have influence on operation of ventilation systems. In majority of apartments the openings in lower part of the bathrooms door were too small (Polish building code requires 220 cm^2). Some users installed kitchen hoods with small fans (Polish building code forbids this in apartments equipped with open gas burning and in apartments with ventilation stacks connected to more than 1 floor). Users have been interviewed during the test. Questions dealt with their opinion on operation of ventilation and gas appliance before and after the sealing of the windows.

RESULTS

Pressurisation tests were carried out using "Minneapolis Blower Door model 3" produced by The Energy Conservatory. Apartments were only overpressured. This allowed researchers to perform the test with sealed ventilation grilles and to avoid potential pollution of apartments with dust and black from dirty stacks.

Blower door has been mounted in the apartments entrance front door. All windows in analysed apartment have been closed while doors to rooms, kitchen and bathroom have been opened. Measurements tried to follow instructions of standard ISO 9972 [2], which is not obligatory in Poland. Unfortunately small volume of tested apartment resulted in some inconveniences. Even with reduction rings mounted on the fans inlet it has not been possible to reach the air volume less than 600-700 m^3/h, and as a result minimal pressure the difference has risen to 20 – 30 Pa. The leaks through the analysed apartment have been described by the power law equation.

$$Q = c \cdot (\Delta P)^n \qquad \ldots.(1)$$

where: Q is the air volume flow rate, c is the flow coefficient of the pressurised volume, ΔP is the pressure difference and n is flow exponent.

One apartment has been pressurised several times to investigate the influence of air sealing of windows on their infiltration coefficient. Additional tests were performed with ventilation grilles and gas flue sealed and partly removed gasket (0.98 m, 1.96 m and 3.77 m). The results are presented at figure 2.

Table 2. The comparison of pressure characteristics of tested apartments.

Staircase - apartment number	Floor	Apartment volume	Ventilation grilles and flue from gas water heater opened		Ventilation grilles and flue from gas water heater sealed	
			c	n	c	n
-	-	m^3	m^3/h at 1 Pa	-	m^3/h at 1 Pa	-
A 1	1	107.9	124.3	0.555	111.4	0.480
A 2	1	97.65	114.5	0.565	100.7	0.506
A 7	3	107.9	157.0	0.510	114.0	0.495
A 14	5	97.65	105.4	0.610	116.7	0.471
B 6	2	107.9	147.6	0.533	88.6	0.559
B 15	5	107.9	125.6	0.548	103.0	0.509
C 4	2	107.9	115.4	0.579	82.9	0.555
C 5	2	97.65	97.3	0.567	123.4	0.459
C 9	3	107.9	162.3	0.535	108.1	0.510
C 10	4	107.9	128.2	0.557	104.4	0.527
		Mean	127.8	0.556	105.3	0.507
		SD	21.6	0.028	12.4	0.033

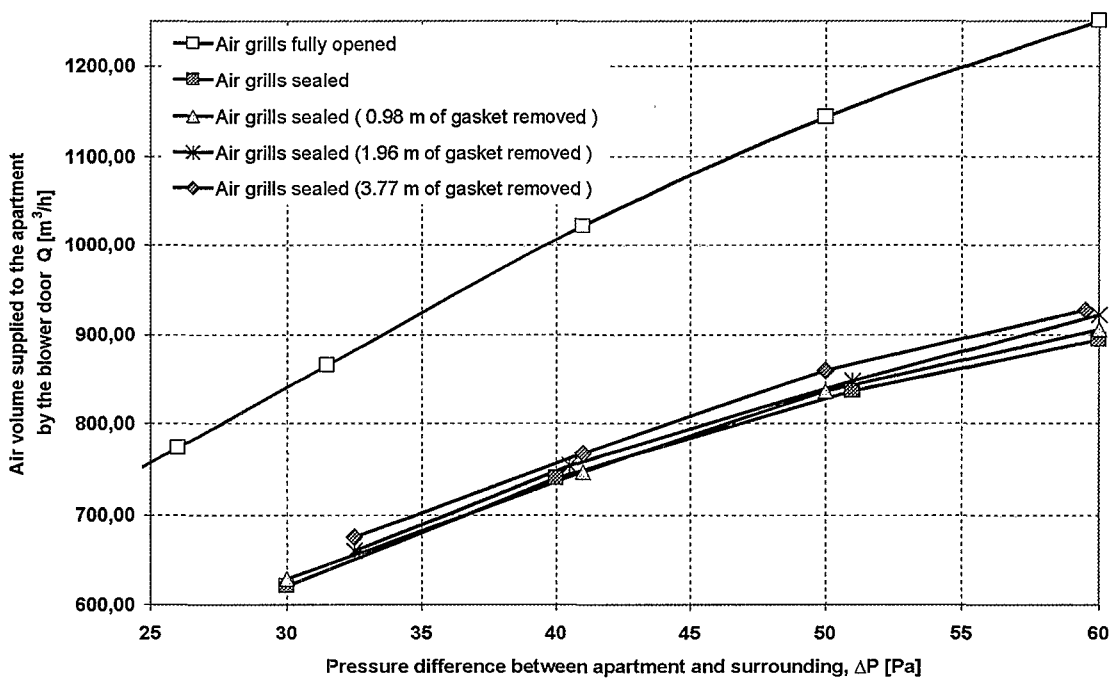

Figure 2. Influence of length of removed gasket on pressure characteristics

DISCUSSION

Air change rates at 50 Pa in analysed apartments have values from 9.3 to 12.4 h^{-1} (mean 10.8 h^{-1}). According to AIVC Technical Note 44 [3] for similar buildings in Western European and AIVC countries average value of N_{50} equals 12 h^{-1}.

Precise estimation of windows' airtightness using results of pressurisation tests is impossible. Air supplied to the apartment during the test (when ventilation grilles and gas flue are sealed) may exfiltrate to other apartments through cracks around water and sewage pipes, electrical and telephone wires etc. Level of air sealing of these airflow paths in each apartment has been different. However on a base of inspections and reference data it has been assumed that 50% - 70 % of air volume is leaking through windows. For assumed 50% ratio of air volume leaking through windows to total leakage, the estimated values of infiltration coefficients for windows equal 0.41 – 0.71 $m^3/h \cdot m \cdot$(at 10 Pa), with mean 0.54 $m^3/h \cdot m \cdot$(at 10 Pa). Similar values for assumed 70% ratio rise to 0.57 – 1.0 $m^3/h \cdot m \cdot$(at 10 Pa), with mean 0.75 $m^3/h \cdot m \cdot$(at 10 Pa).

According to Polish building code [4] and Polish Standard PN-91/B-02020, "Thermal protection of buildings. Requirements and calculations." [5] infiltration coefficient of windows in rooms without air vents should be within the range 0.5-1.0 $m^3/h \cdot m \cdot$(at 10 Pa). Pressurisation tests indicated that level of windows' airtightness fulfilled the requirement. It should be pointed out that the code assumes that, in rooms not equipped with air vents, windows are able to provide enough outside only when they are partly opened or occupants use de-sealing option.

Changes of pressure characteristics indicated (fig 2) that in tested apartment simple air-sealing of windows with "o"-ring gaskets decreased infiltration coefficient of windows by approximately 0.2 $m^3/h \cdot m$ at 10 Pa (reference pressure in Poland). Estimation results can not be generalised for whole building. Probably the more leaky windows were the bigger improvement was made.

Polish Standard PN-83/B-03430 "Ventilation in dwellings and public utility buildings, Specifications" [6] states that air volume removed by grilles should not be less than 70 m^3/h from kitchen and 50 m^3/h from bathrooms. As intensity of natural ventilation changes with meteorological conditions estimation has to be done for standardised conditions (t_e = +12 °C), no wind, windows closed.

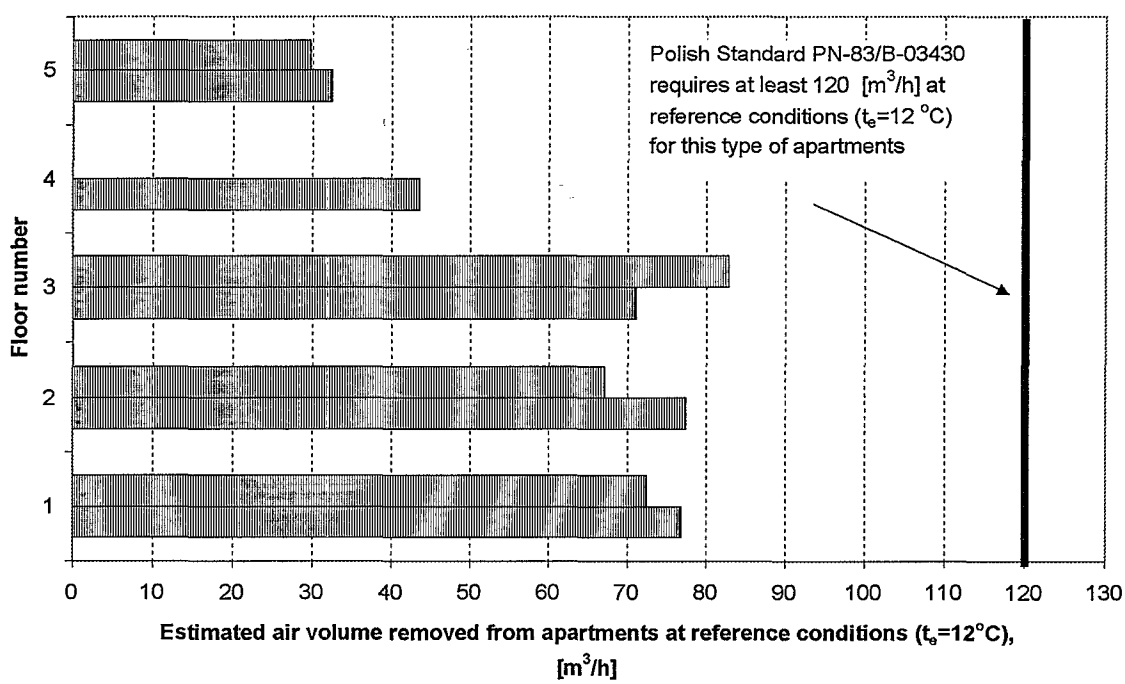

Figure 3. Estimated air volume vs. requirements of Polish standards

Air volumes in all tested buildings are less than minimum required by building codes and standards (from 24.7% to 69% of requirements). Moreover, air volume exhausted by the stacks from apartments at 4 and 5 floors is much lower than from apartments located at floor 1 to 3 (figure 3). This indicates that cross sections of ventilation stack are not dependent on magnitude of driving forces decreasing, off course, with floor number.

Pretty tight windows are not the only one reason of too low air change rates. Additional calculations have been performed for the reference temperature (t_e = 12 °C) and the case when windows are ajar (there is no pressure drop during outside air supply). Estimated air volumes removed by stacks from different apartments vary from 29.0% to 95.8 % of volumes required by the Polish Standards. It indicated that existing stacks do not perform well.

CONCLUSIONS

The analysis of natural ventilation performed in typical Polish multi-family building shown number of faults, deviations from requirements of Polish building code and Polish Standards. Unfortunately, it seems that inadequate ventilation of small apartments equipped with gas kitchens and water heaters creates really serious risk to health and life. Number of specialists regards this situation as the biggest problem related to indoor air quality in Poland.

Thus, the development of standardised measurement techniques related to natural ventilation is very important for Poland. Inspection of apartment followed by pressurisation test and further simple calculations based on single zone model may provide number of inserting information related to air tightness of building components and ventilation intensity. Of course, these rather rough measurements, lot of assumptions and simple models used for calculations, result in quite big error margin. In future the database of measurement results collected for Polish buildings and cross verification with other measurement techniques will probably improve quality of these estimations.

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