ASSESSMENT OF THE AIRTIGHTNESS AND AIR EXCHANGE IN POLISH DWELLINGS – MEASUREMENT EXPERIENCES AND PROBLEMS MET

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ABSTRACT

Indoor environment quality in buildings strongly depends on the proper ventilation. Still a large amount of single- and multifamily buildings are equipped with the natural ventilation system.

When the air exchange in the building is estimated, the main uncertainty concerns the air tightness of the given object. This parameter is used as the input data when the ventilation air flows in building are simulated, and therefore a reliable determination of the air tightness is essential.

The method of determining of the air tightness consists of the measurement of the air flows through the investigated flat or house for the given pressure difference. The procedure and techniques are well- known and the measurement is realized by so-called blower door.

The paper presents the course and results of experiments performed in several flats in different multifamily buildings as well as in the single-family house.

KEYWORDS

airtightness, air exchange, ventilation, blower door

INTRODUCTION

Airtightness of the building envelope is an essential parameter for assessment of the energy demand, for it determines the amount of air infiltration to the building, and therefore the amount of heat required for heating. Modern technologies and materials used in construction, allow the walls of the buildings for significant reduction of heat loss through transmition, however at the same time, due to tight windows, they limit the possibility of proper ventilation.

Large share of the housing stock in Poland are multi-family dwelling houses, ventilated by the natural duct ventilation based on the stack effect. This method of ventilation, cheap to run, results from existing regulations, which allow the system to be used in buildings up to 11 storeys. The system of natural duct ventilation is common in domestic single-family housing. More and more often passive single-family houses, as well as houses using renewable energy sources and mechanical ventilation systems are built.

Measurement of building airtightness can be used to verify the design assumptions, to allow comparisons with other buildings and to estimate the air infiltration.

The paper presents the results of the measurements of the airtightness in two types of dwelling houses: multifamily (two buildings) and single-family (one building). In addition the results of the measurement of exhausted air flow of the analysed multi-family houses and the air exchange simulation calculations on a model of one of the buildings, in which the results of previous measurements were used as an input, are presented.

POLISH REQUIREMENTS REGARDING BUILDING VENTILATION

Polish regulations are based largely on European standards, both for ventilation air flows and airtightness of buildings and flats. The selection of the ventilation method is based on Polish standard PN-83/B-03430/Az3 [1]: in buildings up to 11 storeys, both residential and public, gravitational ventilation can be used, whereas in higher buildings mechanical ventilation is required. In the case of dwelling houses, Polish standards set removed air flows on the following levels: 70 m^3/h for the kitchen, 50 m^3/h for the bathroom and 30 m^3/h for the separate lavatory. The minimum air change rate in dwellings should be 0.5 h^{-1} [2].

The airtightness of the building envelope (or the airtightness of the dwelling), measured by the n_{50} index, should be in accordance with PN-EN 12831 standard [2] (Tab. 1).

Building	**Airtightness requirement at 50 Pa pressure n_{50}, h^{-1}**		
	high airtightness	medium airtightness	low airtightness
Single family buildings	<4	4-10	>10
Multifamily dwelling houses	<2	2-5	>5

Table 1. Air change rate according to PN-EN 12831 standard

AIRTIGHTNESS AND AIR EXCHANGE MEASUREMENTS

The study aimed at: the measurement of the airtightness of the building envelope or its part, the evaluation of the ventilation air flow as well as the identification of uncontrolled air flow paths.

The measurements of the building airtightness were conducted in accordance with PN-EN 13829 standard [3], based on the fan pressurization method with the use of blower door device. The standard recommends measurements according to the method A or B. The main difference lays in the fact that heating and ventilation systems in method A are in the same condition as during regular utilization, while all intentionally made openings in the building envelope in method B should be closed. All the airtightness measurements in the research presented in this paper were carried out in accordance with method B.

Before performing the measurements of airtightness, areas were thoroughly examined in order to eliminate possible leakages, other than window leaks. All of the intentionally made openings in investigated areas were closed: windows, exterior doors, inlets of ventilation and exhaust ducts. All the interior doors were open.

Auxiliary measurements were performed prior to conducting the experiment: floor area, height and volume of the room were calculated; air temperature inside and outside the building, air pressure and wind speed were measured.

Subsequently, the device producing, depending on the flow direction, underpressure or overpressure in examined room, was installed in the door opening (Fig. 1). Airtightness of the joints in door opening was inspected, then the device measuring air pressure and the computer with an appropriate software were installed.

The measurements of the air flow and the air pressure difference between the zone and the environment at intervals of 10 Pa and in the range of $30 \div 70$ Pa, were performed after the device initiating movement of the air was turned on.

Figure. 1. The test stand for the measurement of the apartment airtightness in multifamily house

The main result of the study was a flat or building leakage curve (separately for pressurization and depressurization) in the form of the formula:

$$\dot{V} = C \cdot \Delta p^{n} \quad (1)$$

where:

$\dot{V}$ – leakage air flow rate, m^3/h
C – flow coefficient, $m^3/h \cdot Pa^n$
Δp – pressure difference induced by ventilator, Pa
n – exponent.

Additionally, the air flow V_{50} and the air change rate n_{50} for the air pressure difference of 50 Pa, were obtained.

Prior to airtightness tests in every analysed apartment in multifamily houses, the flows of the air blown out through ventilation ducts were measured with the use of barometer. Moreover, meteorological data, according to the local weather station, for the day and hour were recorded.

Multifamily dwelling houses

The measurements were performed in two multifamily dwelling houses: 5 and 11 storeys, equipped with gravitational natural ventilation. The buildings were built several decades ago. Gravity pipes are located in kitchens, bathrooms and separate lavatories in the case of 2-storey building (in each case one exhaust grille). There are several types of windows in buildings, both: relatively new, quite tight PVC windows with seals, as well as wooden windows made several decades ago. None of the windows is equipped with air inlets.

There are leaks in the form of cracks in building construction and poorly sealed verticals of central heating in apartments (Fig. 2). Serious leakages into the corridor in the place where gas pipes pierce to counters were noticed in some apartments of 11-storey building.

Figure. 2. The examples of leakages in the walls and ceiling of the apartments

In the 5-storey building, the measurements concerned three apartments: two on the 2nd storey (M1 and M3) and one on the 5th storey (M15). The selection was random and depended on the consent of the tenants to carry out measurements. Similar situation occurred in the case of 11-storey building, where the measurements were performed in apartments on the groundfloor (M4) and one on the 10th storey (M55).

It was necessary to seal some components of the electrical installation, as well as culverts of central heating verticals and culverts of gas installation. Grilles' outlets were also plugged. Large and hard-to-reach openings, caused by the culverts for exhaust pipes to the individual gas water heaters, were detected in bathrooms in 11-storey building. Due to the fact that bathrooms are interior rooms, without windows and external walls, they were isolated by sealing the door for the period of measurements (Fig. 3). Hereby, problems with all leakiness in these rooms were avoided.

The results of pressurization tests are presented in Table 2. Knowing the length of the window leakages and a flow coefficient *C* generated by the program, window airtightness factor *a* was calculated.

Figure. 3. Method of sealing of bathroom's door in the flat of the 11-storey building

The value of an index generated by the program should be about 0.67. If it is different, much lower than 0.67, it may indicate the presence of uncontrolled air flows through the envelope of a zone.

Unfortunately, during the study, it was not possible to seal the zones enough to obtain a desired value of *n*, therefore, to calculate airtightness factor *a*, the index of a flow characteristics (*n*) was corrected to a value of 0.67. With the use of spreadsheet, corrected values of flow coefficient *C* were obtained. Dividing the flow coefficient *C* by the length of the window cracks, the values of airtightness coefficients a were obtained and summarized in Table 2.

Building	Flat	Type of window	V_{50}, m³/h	n_{50}, h⁻¹	Airtightness factor *a*, m³/m·h·Pa^0,67	Air flow measured in air outlets (required air flow), m³/h
5-kond.	M1 (2st storey)	old	**415**	**3.3**	1.16	32 (120)
	M2 (2st storey)	new	**232**	**1.5**	0.54	92 (150)
	M15 (5th storey)	old/new	**715**	**3.8**	1.37	105 (150)
11-kond.	M4 (1st storey)	old/new	**320**	**2.7**	0.57	15 (120)
	M55 (10th storey)	new	**132**	**1.5**	0.32	10 (120)

Table 2. The results of the measurements of the airtightness and ventilation air flow

Single family building

Figure 4. The example of leakiness in the building

The measurements were performed in 2-storey building with a cubage of 570 m3. The building is equipped with a mechanical ventilation system providing required ventilation air flow. All windows are in very good condition, relatively new and tight.

Before the measurements, the inspection of rooms was conducted to search and seal potential leakages. Air intake and exhaust air device, as well as fireplace doors were detached (Fig. 4). The results of pressure tests are: V_{50}=983 m^3/h, n_{50}=1.73. Analysed building is tight, obtained factor n_{50} describes the building with high degree of envelope tightness in terms of PN-EN 12831 [2] standard. In the case of the building with mechanical ventilation, this coefficient can be considered as satisfactory.

ASSESSMENT OF THE AIR INFILTRATION

One of the goals of the study was to estimate of the air change rate in the analysed buildings. Knowledge of the characteristics of airtightness and the total length of the leakages in the windows made it possible to calculate the rate of air infiltration.

In addition to measurements related to building ventilation, numerical simulations of ventilation air flow on the model of the analysed 5-storey building were carried out. Each flat and corridor was modelled as a separate zone, resulting in a total of 30 zones. Calculations were performed using the CONTAM [4] software for the meteorological data recorded by the local weather station. The air infiltration coefficients, calculated on the base of airtightness measurements, were used with the assumption of their repeatability in the same type of windows in other flats in the building. Air flow simulations were carried out for the period of the heating season. Fig. 5 presents the course of air infiltration variability on the day of measurements in three analysed apartments. Fair compatibility of the results of measurements of the air flows exhausted from two apartments with an air infiltration can be noticed. Differences do not exceed 12%. In the case the 3rd apartment, large (3-fold) difference may result from substantial contamination of the ventilation grille, so that the air flows largely through apartment's door to the staircase, which is not included in the measurement.

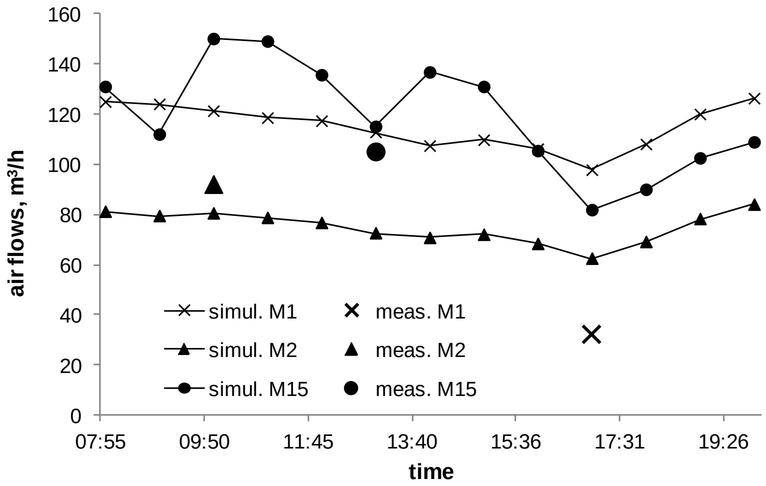

Figure. 5. Air infiltration in analysed flats – simulation versus measurement

CONCLUSIONS

The obtained results of measurements of airtightness are within the ranges specified in the standards. The measurements indicate high airtightness of apartments with new PVC windows. The value of n_{50} does not exceed 2 h^{-1}.

The study confirmed that many uncontrolled leakages, which impede measurements and increase their uncertainty, exist in old multifamily houses. Uncertainty as to the results may also result from the fact that the measurements were performed in completely random houses, not including possible connections to the neighbouring houses.

Ventilation air flow, measured directly in the exhaust grille, is small and substantially deviates from the Polish Standard (with one kitchen and one bathroom required air flow is 120 m^3/h). The maximum measured air flow for this type of housing was 32 m^3/h. The ventilation air flow decreases with increasing storey. Unfortunately, the amount of gravitational ducts on the highest storeys of the buildings has not been increased. However, it should be noted, that the given air flow was measured only in the exhaust grilles, without taking into account the air flow through the apartments doors to the building staircase.

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