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DETERMINATION OF VENTILATION HEAT LOSSES THROUGH BUILDING ENVELOPE – A CASE STUDY

Abstract

In this paper the experimental procedure for the determination of ventilation heat losses across building envelopes has been shown. The alternative name for this method is Blower Door Test or Fan Pressurization method. This text is a user manual for the determination of ventilation heat losses and parameters which is used to describe the air permeability of buildings. The experiment examination was performed at the office with old and after with new windows. The results were compared, and a significant contribution of new windows was shown.

Keywords: Blower door test; Experimental determination of ventilation heat losses; air change rate

ЕКСПЕРИМЕНТАЛНА ПРОЦЕДУРА ЗА ОДРЕЂИВАЊЕ ВЕНТИЛАЦИОНИХ ГУБИТАКА У ЗГРАДАМА

Сажетак

У раду је приказана експериментална процедура за одређивање вентилационих губитака кроз грађевински омотач. Ова процедура се у пракси назива и Метода повећања притиска помоћу вентилатора. У тексту је детаљно објашњен поступак мерења, као и приказ мерне опреме. Такође је у раду приказано мерење на конкретном објекту. Мерење је извршено у две фазе. Прва фаза мерења је извршена на просторији са старом столаријом. Друга фаза мерења је извршена након промене столарије. Сврха мерења је одређивање побољшања заптивености унутар испитне просторије променом застареле столарије.

Кључне ријечи: Blower door тест, експериментално одређивање вентилационих губитака, број измена ваздуха, , ISO 9972

1. INTRODUCTION

Buildings lose heat by ventilation and infiltration. This is caused because of the movement of heated air from inside the building into its surroundings and its replacement by cold air from outside. Ventilation heat losses means the controllable air movement through windows, doors, extractor fans, mechanical ventilation systems. Infiltration heat losses refer to the air flow through gaps in the fabric of the building. The advantage of ventilation is in removing moisture in the roof space or under suspended ground floors, from kitchens, toilets, as well as to provide fresh air. It is necessary to provide ventilation in buildings, but it is required to limit heat losses to save energy and protect environment. A number of works [6-8], deals with heat loss of buildings.

Heat gains and heat losses of buildings mostly depend on the thermal and physical properties of construction elements and materials. 25% of total energy required for heating and cooling is caused by heat losses or heat gains through the building windows. For detailed engineering calculations of heating or cooling loads of building it is important to know the information of the thermal transmittance through windows and doors [1]. This type of losses is heat loss by heat transmission through the building envelope. The other group of heat losses is ventilation heat losses through gaps between leaf and frame of doors and windows, wall penetrations caused by cables, pipes, etc. This type of looses could be determined experimentally for rooms or entire buildings. The experimental procedure has been given in International Standard ISO 9972 [2]. This paper has shown a short version of this standard and it could be used as a user manual for the determination of air change rate and other engineering parameters, like as uncertainty of the blower door method.

The air change rate is a measure of air tightness quality of rooms or an entire building. This parameter could be determined using two modes: pressurization and depressurization. Similar for both methods is making a constant pressure difference between examined room and outer space. On this constant pressure difference could be measured volume flow on the fan measuring system. This volume flow is actually the air leakage rate across the building envelope area. Air leakage rate per inertial volume is the definition of air change rate.

The rulebook [3] prescribes the standards according laboratory should measure air changes. The allowed number of air changes according to JUS U.J5.100 is 2 h^{-1}, while the standard SRPS EN ISO 9972 does not prescribe this value. The reason why the European standard does not have this type of data is that each country has prescribed the number of air changes.

In this paper, the two experiments were performed at the inside door of the examined office. The first experiment was the determination of air change rate at the office with old wooden windows, then windows were replaced with new PVC windows and the second experiment was performed. The experimental procedures were performed to examine the decrease of ventilation heat losses across building envelopes.

2. TEST APPARATUS AND TECHNICAL REQUIREMENTS OF EQUIPMENT

There are many ways to achieve positive or negative pressure inside the building or room. Figure 1. is shown the most common test apparatus which consists of the pressure-measuring device (1), temperature-measuring device (2), airflow measuring system (3), fan control (4), and fan (5). The pressure-measuring device is capable of measuring pressure difference in the range of 0 Pa to 100 Pa, with an accuracy of ±1 Pa. Temperature-measuring device should be capable of measuring temperatures to an accuracy of 0, 5 K. Air flow rate measuring device is capable of measurement with an accuracy of ±7 % of the reading.

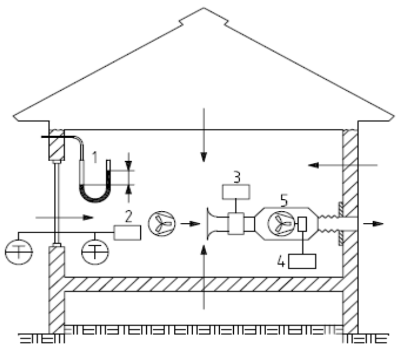

Figure 1. *Test apparatus [2]*

3. MEASUREMENT PROCEDURE

The examination exists of two measuring modes: depressurization and pressurization. With those methods, we can measure the air leakage of building envelopes. Measurement accuracy depends on several factors: ambient conditions, instrumentation, and apparatus. The results of the depressurization method are even larger than that of the pressurization method. However, when air-tightness in the building is high, the test results of both methods are almost equal. For modern buildings with PVC windows this is more often. PVC windows and doors have higher resistance to air permeability.

The proper measurement depends on meteorological conditions. These conditions could influence on zero-flow pressure difference. The zero-flow pressure difference is measured when the fan was turned off. This pressure difference is corrected on actual measured pressure during the measurement process. If the product of the indoor/outdoor air temperature difference, expressed in Kelvin, multiplied by the height (vertical position of the room), expressed in meters, of the building or measured part of the building gives a result greater than 250 mK, it is unlikely that a satisfactory zero-flow pressure difference can be obtained [2]. If the wind speed near the ground exceeds 3 m/s or the meteorological wind speed exceeds 6 m/s or reaches 3 on the Beaufort scale (used for measuring wind speed), it is unlikely that a satisfactory zero-flow pressure difference can be obtained. [2] It is the most widely used system to measure wind speed today [2], [3].

In standard [2] are defined three types of test methods depending on the purpose.

Air permeability measurement is performed inside a completely finished envelope of the building or part of the building (apartment, office). In standard [2] are defined three types of test methods depending on the purpose. There are three methods for the preparation of the building measurements.

The first method applies the test of the building in use (for example clean rooms). While using this type of method the ventilation openings for natural ventilation, openings for mechanical ventilation or air conditioning (only intermittent use), windows, doors, trapdoors in envelopes and openings not intended for ventilation should be closed, and openings for the whole building mechanical ventilation or air conditioning should be sealed.

The second method refers to the building envelope and it is used to compare different construction techniques. While using this method the ventilation openings for natural ventilation, openings for whole building mechanical ventilation or air conditioning, openings for mechanical ventilation or air conditioning (only intermittent use), openings not intended for ventilation should be sealed and windows, doors, trapdoors in envelope and openings should be closed.

The third method is used when we have the building for a specific purpose, for compliance with the air-tightness specification of a building code or standard. While using this method the ventilation openings for natural ventilation, openings for whole building mechanical ventilation or air conditioning, openings for mechanical ventilation or air conditioning (only intermittent use), openings not intended for ventilation and windows, doors, trapdoors in envelope and openings could be closed, sealed, or open as specific.

Before starting the test it is necessary to connect the air-moving equipment to the building envelope using an adequate door, window, or vent opening (to eliminate leakage).

It is recommended that indoor/outdoor pressure difference shell be measured at the lowest floor level of the building envelope. It is necessary to pay attention that the air moving equipment does not influence interior and exterior pressure taps. We must pay special attention to the exterior pressure tap, because of the influence of the effect of dynamic pressure. This problem can be solved by fitting a T-pipe or connecting it to a perforated box. During sunny days we need to protect the tubing from the large temperature differences if we want to pressure measuring to be valid.

4. MEASUREMENT PROCESS

It is recommended to make two types of measurements: pressurization and depressurization. In the beginning, it is necessary to record the wind speed or force by Beaufort scale based on observation. Afterward, it is needed to determine the zero-flow pressure difference. For the zero-flow pressure difference, the reference value is outside. At the beginning of the test temporarily cover the opening of the air moving equipment and connect pressure measuring device to measure inside-outside pressure difference. [2] Minimum 10 values should be recorded throughout for over at least 30 s. After collecting the data it is necessary to calculate the average of the positive values of zero-flow pressure difference (Δp_{01+}), the average of the negative values of zero-flow pressure difference (Δp_{01-}), and the average of all values of zero-flow pressure difference (Δp_{01}). This procedure shall be repeated at the end of the test and calculate Δp_{02+}, Δp_{02-}, Δp_{02}. If the absolute value of Δp_{01+}, Δp_{01-}, Δp_{02+}, Δp_{02-} is higher than 5 Pa, the test shall be declared not valid.

Pressure difference measurement starts with turning on the air-moving equipment. Measurement of airflow rate and indoor and outdoor pressure difference is obtained. Pressure difference shall be increased no more than 10 Pa. The value for the lowest pressure difference shall be 10 ± 3 Pa, or five times the value of the zero-flow pressure difference (Δp_0), whichever is greater. For the highest pressure difference, it is recommended the value of 50 Pa, but it would be best to achieve pressure difference from 100 Pa.

5. TECHNICAL DESCRIPTION OF USED BLOWER DOOR EQUIPMENT

For experimental analysis of room, air permeability is used MINNEAPOLIS BLOWER DOOR [5]. The Blower door consists of a nylon door panel which is mounted on an adjustable aluminum door frame. The Blower Door Fan is an axial fan and it is consist of a pressure difference device and flow rings. The fan could be controlled manually using frequency regulation of motor speed. Depending on the volume of a room, the size of the flow ring shall be chosen. When the testing room is with higher volume it is necessary to use larger rings (example ring A in Figure 2). An adequate ring is that one that can measure pressure difference in measuring intervals of 10Pa to 100 Pa.

The first step of measuring is to maintain a constant pressure difference of 50Pa with one installed ring. If this pressure difference is not possible, an additional ring is necessary. The next figure is shown an axial fan with flow rings. On the top of the fan shall be installed pressure difference gauge. In these experiments are used DG 700 Pressure Difference gauge, Figure 2, and figure on the right side. This gauge measures pressure difference in the inlet of the axial fan, Figure 3. Pressure gauge calculates volume flow depends on pressure difference and used flow rings.

Figure 2. *Axial Fan with flow rings and pressure difference gauge [5]*

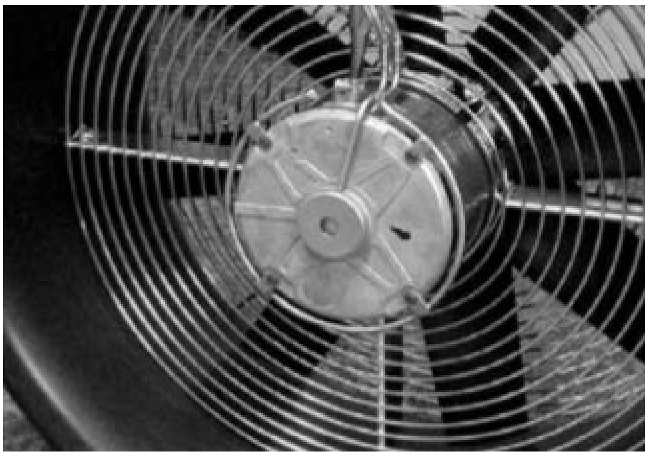

Figure 3. *Flow sensor [5]*

6. EXPERIMENTAL RESULTS OF BLOWER DOOR TEST

This chapter shows the results of air permeability tests of the office when old, wooden windows were replaced with new, PVC windows, and new PVC windows. The tested office has dimensions 4.5 x 2.47 x 3.75m. The calculated volume of the office is 41.7 m^3. The height of the room is 5m (second floor of the building). First measurement was done in the office with old wooden windows. After that, new PVC windows were installed in place of the old ones. Second measurement was done thereafter setting-up new windows.

Before replacement windows, on the envelope of the room were installed wooden windows and two doors. PVC door is the outside door, while wooden door is the inside door of the office. The air conditioning system is sealed and heating was turned off. Tests are performed in pressure difference range between -10 Pa to -100 Pa (depressurization mode). For measuring was chosen warm day with low wind speed. Wind speed and the outside temperature were measured by a hot-wire device. Outside temperature was 303 K, the wind speed was less than 3m/s, and volume flow was not corrected by wind speed corrections. Office temperature was constant at 297 K.

Tests were performed on the flow ring C, and ten measuring points were taken. Before air permeability examination was performed measuring of zero pressure difference. The bias pressure of the room was about -4Pa. In the next table are shown measured data.

Table 1.Experimental data of office with wooden windows

Δp_m $[Pa]$	10.2	19.9	30.2	40.2	50.1	60.0	70.0	80.3	90.0	100.2
q_r $[m^3h^{-1}]$	122.0	181.0	205.0	247.0	281.0	305.0	345.0	367.0	406.0	425.0

All of the data in table 1 are plotted in Figure 4. The equation on the figure is determined using the trend line option in *Microsoft Excel*. This equation is useful for designers of HVAC systems, to determine ventilation losses across building envelopes. The most useful information of air permeability across building envelope is air change rate at a reference pressure of 50Pa. The calculated airflow across the building envelope is 294.2m^3/h. Air change rate at a reference pressure difference of 50Pa is 7.05h^{-1}.

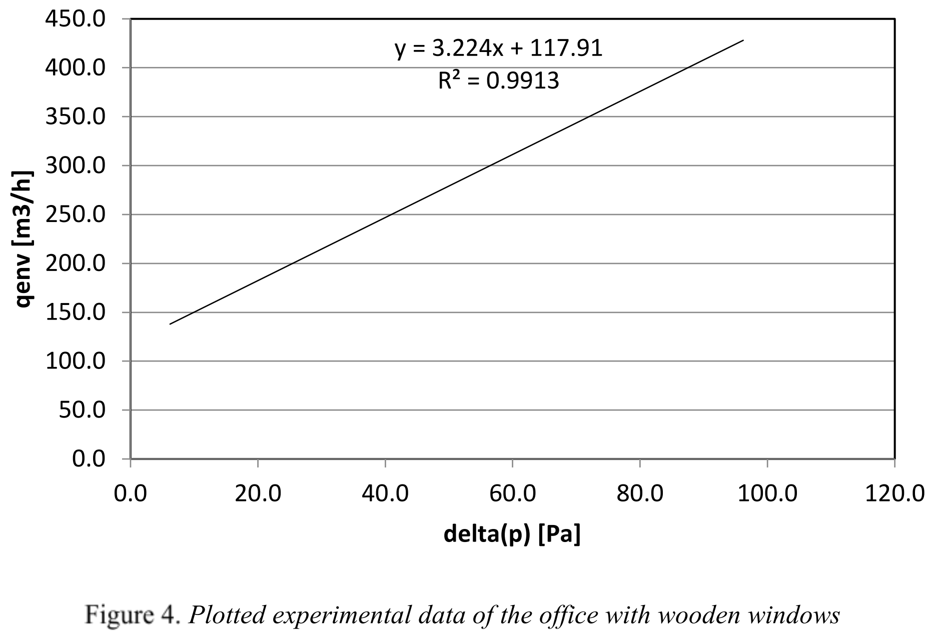

Figure 4. *Plotted experimental data of the office with wooden windows*

The second measurement was done after replacing wooden with PVC windows. These tests were performed because it is necessary to check the thermal improvement of the office. On the envelope of the room are installed PVC windows and two doors. PVC door is the outside door, while wooden door is the inside door of the office. The procedure was identical to the previous examination. Outside temperature was 305 K, wind speed was less than 2 m/s, and volume flow was not corrected by wind speed corrections. Office temperature was constant at 298 K.

Tests were performed on the flow ring C, and ten measuring points were taken. Before air permeability examination was performed measuring of zero pressure difference. The bias pressure of the room was about -3 Pa. In the next table are shown measured data.

Table 2.Experimental data of office with PVC windows

Δp_m $[Pa]$	10.4	20.0	30.5	40.2	49.9	59.9	69.9	80.5	89.8	100.3
q_r $[m^3h^{-1}]$	61.0	110.0	147.0	180.0	208.0	240.0	269.0	300.0	332.0	352.0

All of the data in table 1 are plotted in Figure 4. The equation on the figure is determined using the trend line option in *Microsoft Excel*. This equation is useful for designers of HVAC systems, to determine ventilation losses across building envelopes. The most useful information of air permeability across building envelope is air change rate at a reference pressure of 50 Pa. The calculated airflow across the building envelope is 217.3 m^3/h. Air change rate at a reference pressure difference of 50 Pa is 5.21 h^{-1}.

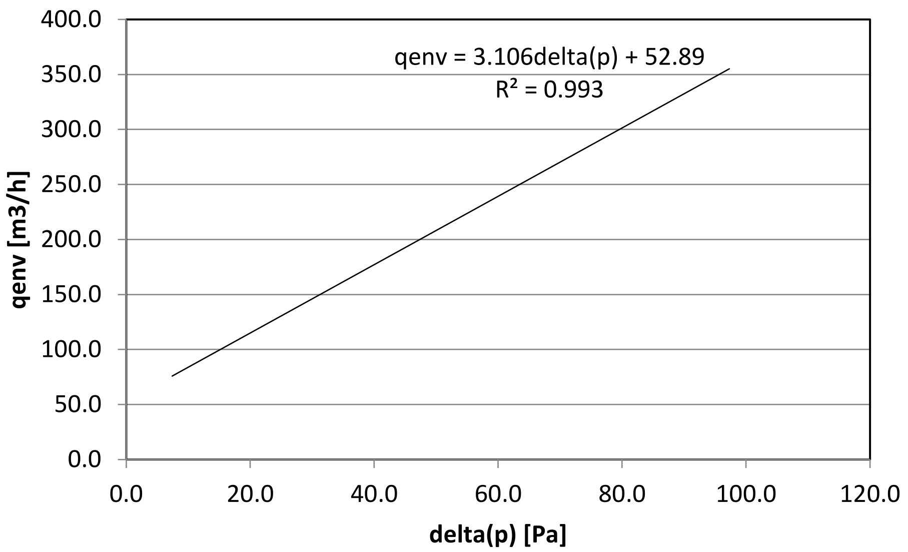

Figure 5. *Plotted experimental data of the office with PVC windows*

7. DISCUSSION AND CONCLUSION

In this paper, experimental procedure for the determination of air permeability in buildings was shown. This procedure has to be performed to determine ventilation heat losses across building envelopes before and after reparation of windows and doors. Quality of room air tightness is the air change rate at a reference pressure. Using windows and doors with higher thermal performance could decrease the cost of heating and cooling. The experimental procedure was performed on the same room with old and after, with new windows. The experiment has shown that ventilation heat losses were reduced by more than 25%.

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