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QUALITY ASSURANCE OF AN ENERGY PERFORMANCE OF BUILDINGS - AIRTIGHTNESS TESTING

Summary

International building legislation is setting more rigorous requirements for the energy performance (EP) of buildings. The EP as defined by the Energy Performance of Buildings Directive (EPBD) takes into account envelope airtightness in the calculation methods. In Croatian building regulation, maximum air change rates are defined. The infiltration losses become especially significant factor to the energy performance of the high performance buildings. This paper discusses the procedure and the practical issues of the airtightness testing using blower door method of a family house.

Key words

EPBD, Airtightness, Blower Door Test, IR Thermography, Leakages,

OSIGURANJE KVALITETE IZVOĐENJA ENERGETSKI EFIKASNE ZGRADE – ISPITIVANJE ZRAKOPROPUSNOSTI

Sažetak

Međunarodna regulativa u području zgradarstva određuje sve strože kriterije u pogledu energetske učinkovitosti i energetskog svojstva zgrada. Energetsko svojstvo zgrada, kako je definirano Direktivom o energetskom svojstvu zgrada (EPBD) uzima u obzir zrakopropusnost vanjske ovojnice zgrade. U Hrvatskom zakonodavstvu, maksimalni broj izmjena zraka u zgradi je definiran. Gubici topline infiltracijom zraka kroz vanjsku ovojnicu zgrade postaju posebno značajni kod vrlo niskoenergetskih zgrada. U ovom radu se opisuje način i problemi ispitivanja zrakopropusnosti metodom blower door.

Ključne riječi

EPBD, zrakopropusnost, blower door metoda, IC termografija, infiltracija zraka

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1. INTRODUCTION

The implementation of the Energy Performance of Buildings Directive (EPBD) [1] has caused in most of the EU Member States more severe requirements for the energy demand of buildings. In order to meet these requirements, not only buildings components with better U-values and more efficient building systems have to be used, also the ventilation losses have to be reduced. A contribution to this necessary reduction is the improvement of the building envelope airtightness, mainly the airtightness of building components and joints.

Airtightness of buildings has been proven to constitute an important factor from a variety of perspectives: it affects the infiltration rate of the building, therefore influencing both, the quality of indoor air and the need for ventilation, as well as the energy used for heating and/or cooling. Airtightness is one of the fundamental factors used for predicting the ventilation rates in buildings. Good envelope airtightness allows one to better control the ventilation airflow rates. Therefore, it makes it possible to minimize energy use while maintaining a good indoor environment.

To provide a rough idea about the energy losses, in Belgium and in Germany, it is estimated that envelope airtightness accounts for about 10% of the energy performance level. In these countries, the benefit of envelope airtightness is similar to the installation of solar collectors. In France, the impact of envelope airtightness is estimated at 2 to 5 kWh/m²/year per unit change of leakage-number (n_{50}) for the heating needs. On the other hand, in Scandinavia the impact might be around 10 kWh/m² year per unit change of n_{50} [2]. Airtightness is not only an issue in cold climates. In warm climates, while an airtight envelope may have a smaller impact on heating energy, it can reduce the cooling energy in buildings with air conditioning. Figure 1 shows the diagram of the heat losses according to the airtightness of the building envelope defined in the IEE Passnet project [3].

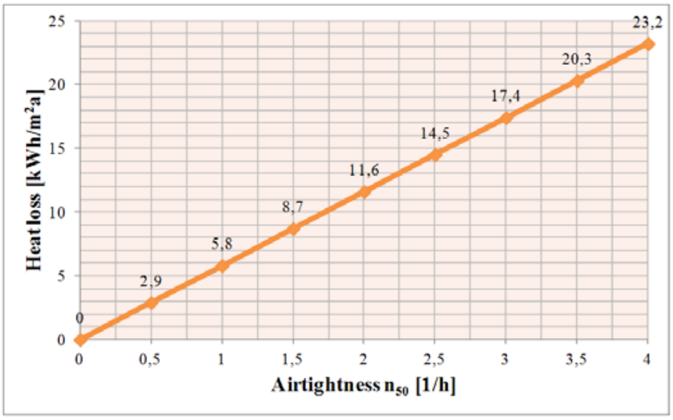

Figure 1. Heat losses regarding the airtightness of the building envelope [3]

Because of the large energy impacts of envelope and ductwork leakage, many low-energy labels (PassivHaus, Minergie-P, Effinergie, etc.) include specific requirements on these aspects, for example PassivHaus requirement is max 0.6 1/h at the pressure difference of 50 Pa between indoor and outdoor pressure (n_{50}).

2. DEFINITION OF AIRTIGHTNESS

Envelope airtightness can be defined as the resistance to inward or outward air leakage through unintentional leakage points in the building envelope, i.e. not through leaks in the ventilation system. This air leakage (also called ‘infiltration’) is driven by differential pressures across the building envelope due to the combined effects of stack, external wind and mechanical ventilation systems [2].

From a measurement standpoint, air tightness means measuring the flow through the building envelope as a function of the pressure across the building envelope. This relationship often fits a power law (Equation 1), which is the most common way of expressing the data. Indicators of the air flow through the building’s envelope at a given conventional pressure are weighted either by the heated building volume V (Equation 2) or by an area A (Equation 3). The area generally used is the envelope area defined in standard HRN EN 13829:2002 [4].

$$\dot{V}_{\Delta p_r} = C_L \cdot (\Delta p_r)^n \tag{1}$$

Where:

$\dot{V}_{\Delta p_r}$ - Volume airflow rate through the leakage site [m³/h]

Δp_r - Pressure difference across the building envelope reduced to the atmospheric pressure [Pa]

n - Flow exponent ($0.5 < n < 1$). Typical value is 0.66

C_L - airflow coefficient [$m^3\ h^{-1}\ Pa^{-n}$]

Airflow rate through building envelope at conventional atmospheric pressure ***Δp*** (1013 hPa) and the temperature of 20°C divided by the heated building volume ***V*** gives the number of changes of total air volume at the specific pressure difference Δp_r.

$$n_{\Delta p_r} = \frac{\dot{V}_{\Delta p_r}}{V} \tag{2}$$

Specific airflow rate $w_{\Delta pr}$ through building envelope at conventional pressure Δp_r is calculated by dividing the airflow rate through building envelope by the surface area A_e of the heated building volume.

$$w_{\Delta p_r} = \frac{\dot{V}_{\Delta p_r}}{A_e} \tag{3}$$

According to the HRN EN 13829:2002 the above values should be calculated for the pressure difference of 50 Pa and presented as n_{50} and w_{50}.

3. BLOWER DOOR AND THE DIAGNOSTIC PROTOCOL

The Blower Door (Figure 2) is used to create an artificial pressure difference between the interior of the structure and outside of the building. For diagnostic purposes, the interior is depressurized or over pressurized with reference to the outside. The standard differential pressure for residential diagnostics is 50 Pa (overpressure or underpressure), which is equivalent to a 35 km/h wind blowing against all sides of the structure simultaneously. 50 Pa is high enough to overpower pressure noise and zero drifts caused by wind or stack effects. Thus it is reasonably precise and therefore reproducible.

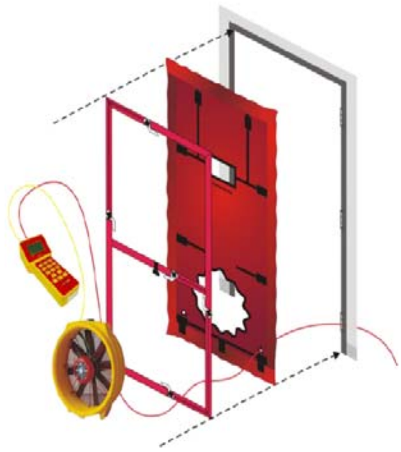

Figure 2: The breakdown of a typical Blower Door fan system

The pressure difference forces air to leak through all of the discontinuities (gaps, cracks and holes) in the exterior envelope of the building envelope and cools (or heats) the interior. The amount of air that is required to maintain a constant pressure difference is equal to the amount of air that is leaking from the enclosure. A specially designed gauge is then used to measure the amount of air flowing through the fan, and the pressure difference, which can be used to determine the total size of all those leaks and calculate the indicators, as shown by equations 2 and 3.

The key advantage of the n_{50} is that it can be easily used as an input in an airflow simulation tool in which the volume is usually necessary to evaluate the dynamic behaviour of contaminants. However, this is not the case in thermal simulation tools that do not require the building volume as an input to calculate the energy use. In such tools, the surface area of cold walls is usually known, which explains why some countries use the q_{50} in their regulation. On the other hand, the rationale behind the w_{50} metric lies in the ease to have access or calculate the floor area of the building.

One common problem of these indicators is that, although they are specified in the standard, there remains some variation between countries or even regions or technicians in their precise definition. For example, standard HRN EN 13829:2002 states that the floor area used to calculate w_{50} is calculated according to national regulations. In some countries, the cold wall surface area used to derive q_{50} includes the lower floor whereas this area is excluded in others. Finally, because building shapes are often complex, the volume calculation may differ between operators [5].

HRN EN 13829 describes two methods to perform a pressurisation test named methods A and B (the new version of ISO 9972: 2006 mentions 3 methods). The key difference between the methods lies in the openings in the buildings envelope that are sealed for testing.

- Method A applies for the airtightness measurement of the building in use, with the building envelope representing the conditions during the season in which heating or cooling systems are used.
- Method B applies for measurement of the airtightness of the building envelope. In this case, any intentional opening in the building envelope is closed or sealed.

Of course, the choice of method A or B may lead to major differences in the measured airtightness, for instance, if a fireplace damper is sealed, closed, or left open. There may be good reasons for using either method. For example, if the energy performance calculation includes the effect of a given opening, it is relevant to seal it for the test to use the measured airtightness as an input. However, this information is often not available to technicians who perform tests.

The HRN EN 13829:2002 recommends carrying out two sets of measurements, for pressurisation (P+) and depressurisation (P-), but this is only a recommendation.

Because, the deviation between both results can be large, the deviation (%) between the air leakage rate in P- and the average between P- and P+ is shown in figure 3.

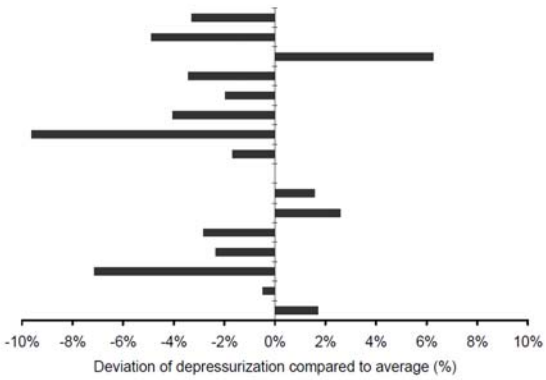

Figure 3: Deviation between pressurisation and depressurisation [6]

For the same sample of tests made on 20 different buildings, the deviation between P+ and P- is higher than 2% for most of the tested buildings (2 % is the average random error), and reached even much higher than 10% (not shown in the figure) in certain buildings [6]. This deviation can be partly due to the physical difference between the two sets of measurements. Some leaks are probably asymmetric, such as leaks in the form of valves, such as the exhaust vents of certain kitchen hoods. It is thus required in the framework of the EPBD regulation to always carry out both sets of measurements.

It is recommendable to carry out the airtightness measurements before the envelope of the building to be tested has been completed. An early measurement, which is a test before cladding and panelling the air barrier, frequently allows for easier and more cost-efficient rework and sealing of leakages than it would be possible after the completion of the entire building envelope. This is particularly true for passive houses. Such early testing allows for quality assurance during construction. The leakages through the building envelope can be localised (detected) by use of an air velocity meter, by fogging or the use of infrared thermography, figure 4.

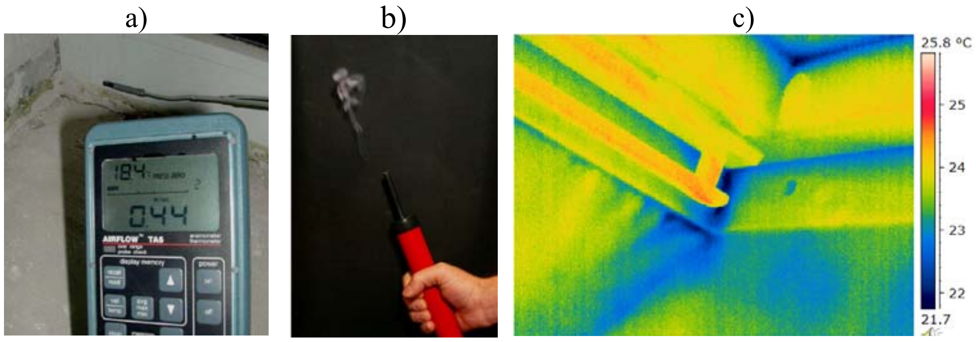

Figure 4: Visualisation techniques of the leakages: b) air velocity meter, b) fogging, c) IR thermography

4. APPLICATION OF BLOWER DOOR MEASUREMENT ON THE EXAMPLE OF THE FAMILY HOUSE

The measurements were performed on the example of the single family house located near Zagreb, Croatia, the house has the ground floor and the heated loft, the garage is within the main volume of the house but is not heated, figure 5.

Figure 5: The photograph of tested family house

The total measured and calculated surface area of the building envelope it is A_e=342.66 m^2, the total heated floor area of the house is 173.63 m^2 and the volume of the heated area of the house is equal to V=420.03 m^3. The outside temperature was 14°C and without wind during the testing.

The house was pressurised and depressurised in the testing procedure as described in chapter 3 of this paper, the results are shown in table 1.

In order to put the results in perspective, the equivalent leakage area (ELA) was calculated. ELA is the area of a sharp-edged orifice with a unity discharge coefficient which would provide a similar response to the flow versus applied pressure differential curves of the sum of unintentional openings in the structure [7]. In other words, it can be defined as the area that would have the same flow rate at the specified reference pressure. ELA can be a useful guide, but it is only an aerodynamic equivalent area based on a sharp edged orifice and should therefore be regarded only as approximate.

The flow rate of air can be expressed by equation 4 [8]:

$$Q_{\Delta p_{env}} = C_d \cdot A \cdot \left(\frac{2 \cdot \Delta p_{env}}{\rho_s} \right)^n \tag{4}$$

Where the discharge coefficient, $\boldsymbol{C_d}$ for a sharp edged orifice can be taken as 0.61, standard air density $\boldsymbol{\rho_s}$ is taken as 1.20 kg/m^3, $\boldsymbol{n}$ can be taken as 0.5, the test pressure is 50 Pa, and $\boldsymbol{Q_{50}}$ is in m^3/s, which then allows the calculation of ELA, table 1:

Table 1. Blower door measurement results

	Depressurised	**Pressurised**
Volume airflow rate at Δp=50 Pa [m^3/h]	1259	1170
n_{50} [1/h]	3.00	2.78
w_{50} [m^3/hm^2]	3.674	3.414
ELA [cm^2]	628	583
ELA as % of the building envelope area	0.018	0.017

The leakages were identified by using the fog generator and IR camera. Fog generator technique proved to be more efficient in pinpointing the leakage, while the IR camera is more useful to define the problematic area, few decimetres square, and record the test results. Depressurisation was proven to be more convenient technique for the thermographic imaging, because the leakages could be determined more precisely.

The defects identified as leakages are mainly the air infiltrations through leaking outlet boxes, gaskets on the entrance doors and sliding doors, the connection of a window panel to the wall and cladding, figures 6 - 9.

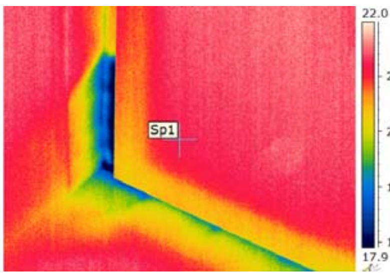

Figure 6: Poor gasket on the entrance doors

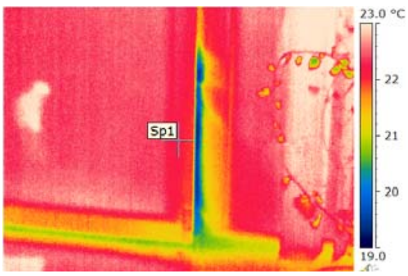

Figure 7: Poor gasket on the sliding doors

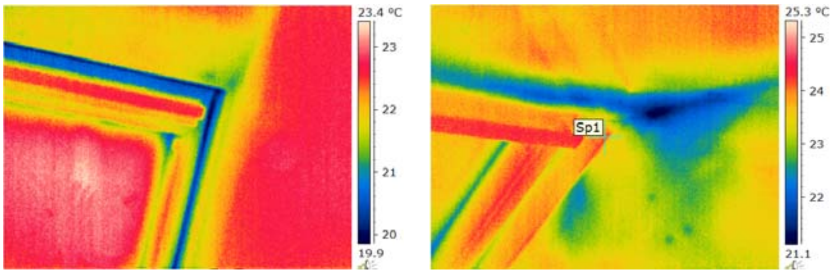

Figure 8: Connection of the roof window panel to the cladding before (left) and during (right) the blower door test

5. CONCLUSIONS

Infiltration losses have a significant influence on the energy use of buildings. The relative influence becomes bigger when the total energy use is lower, e.g. in high performance buildings, thus awareness should be raised among prescribers, designers, and craftsmen about the importance of air infiltration in the buildings performance.

Airtightness should be designed, thus avoiding all unnecessary penetrations of the air barrier. At all gasket joints and penetrations a detailed plan with defined materials and methods should be worked out in order to assure that the craftsmen are able to build in this way.

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