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ESTIMATION OF AIR LEAKAGE RATE OF WOOD-BASED RESIDENTIAL BUILDINGS CONSTRUCTED IN THE CZECH REPUBLIC IN THE YEARS 2006-2014 USING BLOWER DOOR TEST

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ABSTRACT

The article analyses the air leakage rate in 203 newly constructed low-energy and passive wood-based residential buildings in the Czech Republic. The most frequent air leakage points were analysed in the buildings measured, and the development of the air leakage rate in the period monitored (2006-2014) was evaluated. A significant decrease in air leakage rate values was found out in low-energy buildings, while the results for passive buildings were more or less steady within the period in question. Further, airtightness of envelopes of low-energy buildings not equipped with a mechanical ventilation system with heat recovery reached, in some cases, values indicating that recommended values of the overall air leakage required by hygienic regulations are not ensured.

KEYWORDS: Air leakage rate, air change rate, air tightness, blower door test, ventilation.

INTRODUCTION

After a long dominance of heavy and energy-intensive materials, the number of wood-based structures has been increasing in the Czech Republic. This trend is visible especially in the family house development sector where the share of newly constructed wood-bases houses increased from 2 % in 2002, to over 12 % in 2012 (Czech Statistical Office). The majority of realised wooden houses is characterised by very good thermal-technical parameters. With the developing construction of low-energy and passive buildings, a more and more frequently discussed issue is the quality of realisation. Due to a stronger pressure on the energy efficiency of buildings, mechanical ventilation in the interior was gradually introduced, with the use of heat recovered from waste air taken outside the building. Together with mechanical ventilation systems, very good air tightness of structures, including the introduction of accurate diagnostic methods, became necessary. Among the most frequently used diagnostic methods is the Blower Door Test (BDT). Using this test the quality of the air tightening layer is checked and points with air infiltration are searched for (Gadsby 1981, Paleček 2012). With overpressure and under pressure of 50 kPa, a value regularly used for measuring in the EU, it is possible to detect defective points of the structure where water condensation may occur, which subsequently leads to damages to the supporting wooden elements as well as thermal insulation materials. The lifetime period of wooden structures may be multiplied by repairing these critical points. Another reason why such critical points should be detected and repaired is a significant energy saving (Erhorn-Kluttig et al. 2009, Caillou and van Orshoven 2010).

The biggest problem of the previous generations of residential buildings in terms of air tightness was poorly sealing windows and doors. On the one hand untightness provided spontaneous ventilation and drainage of humidity which could cause increased contamination of the interior by various dirt (Park et al. 2008), but on the other hand it was the cause of significant energy losses without the possibility of being regulated. Currently, attention is paid especially to the envelope as a whole (Shermanand and Chan 2004). Besides reduced energy consumption, the purpose of decreasing air tightness is primarily proper functioning of the building envelope with all air-tightening devices and layers. The building air tightness is also an important factor influencing the inner environment quality and energy consumption in the building (Kim et al. 2013).

MATERIAL AND METHODS

The BDT air tightness test is performed according to a procedure described in the Czech standard ČSN EN 13 829: 2001 (Thermal performance of buildings – Determination of air permeability of buildings – Fan pressurization method). A blower located in a suitable opening in a perimeter wall (door, window, etc.) creates a pressure difference inside the building (under pressure or over pressure). By measuring the volume flow rate at the blower an evaluation unit for the average value of n_{50} is calculated – the ratio of the air leakage rate at 50 Pa to the volume of the test zone (hour^{-1}).

$$n_{50} = \frac{V_{50}}{V}$$

where: n_{50} - air change rate at 50 Pa (hour^{-1}),
V_{50} - air leakage rate at 50 Pa (m^3.hour^{-1}),
V - internal volume (m^3).

Two methods of measurement are described in the above-mentioned standard. The first of them is method B referred to as preparatory measuring. Its purpose is to search for leakages in the building envelope and to eliminate them gradually during the completion of construction works. The structure must be at the stage of a completed vapour barrier layer, but without interior cladding, to enable potential leakages to be repaired. Doors and windows must be installed and sealed. The second method is certificatory measuring referred to as method A. This procedure determines the air tightness value of the building, i.e. the overall intensity of air change. The parameter identified is then stated in the certificate issued. Within this measuring no additional sealing may be carried out. The structure must be at its final stage, ready to use. The result of this measuring may serve for performing follow-up calculations of thermal losses of the building and for elaborating the building energy label.

With the combination of measurements at under pressure and overpressure, points of air leakages may be identified in wooden structures. Under pressure methods include air flow rate measuring with an anemometer, searching for cooled-through areas with a thermal imaging camera (ČSN EN 13 187: 1999), or simple manual examination. Overpressure methods are usually based on the penetration of smoke into the building. The smoke is generated mainly by a smoke tube and it shows exact points where air penetrates the structure. By comparing the values of under pressure and overpressure measurements various ways of air penetrating the structure may be identified. For example insufficient pasting-over of film-type vapour barriers is usually shown at under pressure when two layers of the film move away from each other, but they are pressed towards each other at overpressure, resting against the surrounding structure (Penc et al. 2011).

Measured structures

The BDT air tightness test was performed in the total of 203 newly constructed low-energy and passive frame-structure wooden houses in 2006-2014. This was method B measuring. The measurements were performed throughout the Czech Republic, the buildings were constructed by 43 various companies. For the purpose of this study the measurements were performed with the blow test 3000 device made by LTM Lüftungstechnik GmbH.

The structures measured were divided into three groups for the subsequent analyses: low-energy houses with natural or combined ventilation (BDT 4.5), low-energy houses with mechanical ventilation with heat recovery (BDT 1), and passive houses with mechanical ventilation with heat recovery for buildings with particularly energy-low heating (BDT 0.6). The numbers given in brackets are recommended air leakage values (hour-1) according to hygienic regulations (Recommended n_{50}, N values with regard to building ventilation according to the Czech standard ČSN EN 73 0540: 2011 Thermal protection of buildings, Part 2: Requirements). The basic data on the houses measured are given in Tab. 1.

Tab. 1: Basic data on measured structures.

Group	Number of houses measured	Floor area (m^2)	Building volume (m^3)	Envelope area (m^2)	Mean n_{50} ($hour^{-1}$)
BDT 4.5	87	109.04 (39.63)	377.15 (34.85)	280.70 (39.49)	1.48 (74.20)
BDT 1	64	126.21 (51.23)	451.58 (47.19)	360.38 (53.37)	1.22 (52.70)
BDT 0.6	52	89.67 (34.17)	386.86 (22.06)	310.45 (29.53)	0.43 (23.02)

Mean values of the basic data are given, the number in brackets is the coefficient of variation (%).

RESULTS AND DISCUSSION

During the trial measuring leakages in the envelope were searched for, the occurrence of which is strongly influenced by the structure type, method of execution, materials used, etc. The main leakage sources detected in the houses measured are shown in Fig. 1.

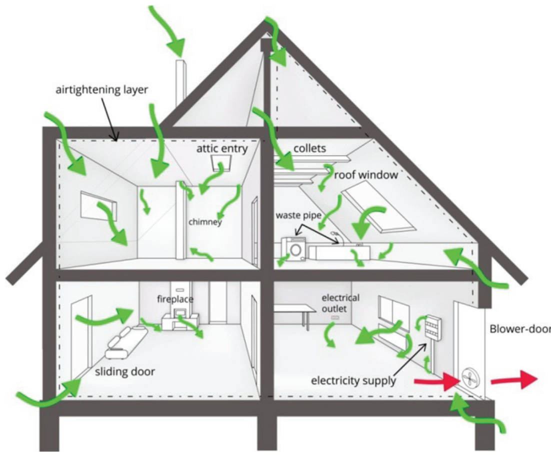

Fig. 1: Most frequent points of leakage.

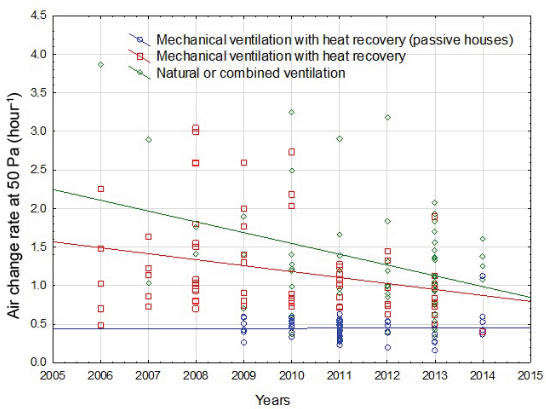

Fig. 2: Dependence of air change rate on the year of construction and ventilation type.

The following areas were detected as the most frequent leakage points in structures:

- Disrupted compactness of the air tightening layer due to assembly, or caused later by craftsmen,
- Improperly/insufficiently joined individual parts of the air tightening layer (board joints not pasted over, film strips not pasted under),
- Non-tight connection of the vapour barrier and the base slab,
- Insufficiently sealed passages (air-conditioning system, wiring, beams, etc.),
- Poorly installed vapour barrier at the connection of the wall and ceiling structure,

- Insufficient connection of the vapour barrier to doors and windows,
- Non-sealed chimney openings (air leaking between the liner and chimney wall).

Upon the analysis of measurements performed it may be stated that in all buildings equipped with plastic tilt-hinged windows untightness of the top hinge was detected, where the hardware is placed above the sealing which, thus, cannot fulfil its function. Other problematic points include the glazing joint of skylights and vast majority of brick chimneys made of multilayer blocks with leaking flues. The level of untightness and the quality of construction strongly depend on the building company.

In order to determine the development of air change values at a given pressure difference in the period monitored (2006-2014), a regression analysis was performed. Results of the regression analysis are shown in Fig. 2. Calculated regression equations for individual groups are given below.

n_{50} BDT 0.6 (h^{-1}) = -3.7742+0.0021*x
n_{50} BDT 1 (h^{-1}) = 156.817 - 0.0774*x
n_{50} BDT 4.5 (h^{-1}) = 282.8813-0.14*x

The regression analysis results show a significant decreasing trend of air change values due to a leaking building envelope in low-energy houses. Improving the airtight performance of current buildings is also confirmed by the studies of other authors (Novák and Paleček 2010; Pan 2010). This trend is positive in terms of energy efficiency of buildings and it may be stated that the construction of new frame-structure wooden houses in the Czech Republic goes in the right direction. Comparing to the international context, the air tightness of buildings reported in this paper was superior to that in some other countries, (Alfano et al. 2012; Chen et al. 2012).

For passive houses, the air change rate values were almost steady in the period monitored. This was probably due to rather strict requirements of the standard and, at the same time, financial demands on the construction. The worsened results in 2014 may be caused by the launch of the Green Savings subsidy programme, or by increased demand and, thus, increased number of construction companies. In that year, especially houses constructed by companies with less experience in building passive houses were measured and showed worsened results of air change rate and an increased number of leakages.

CONCLUSIONS

With regard to hygienic regulations it must be pointed out that the Czech standard ČSN EN 15 665: 2009 requires the minimum air leakage to be ensured, i.e. the minimum quantity of air to be changed to ensure healthy usage of buildings. At present, this change of a certain quantity of air is not ensured, particularly in low-energy houses with natural or combined ventilation. At the same time it should also be pointed out that building air leakage (n) should not be interchanged with air change rate (n_{50}). The requirement on the air leakage is determined by ČSN EN 73 0540: 2011 in given climatic conditions. However, the value of the air change rate measured by BDT is calculated from mean values at overpressure and underpressure of 50 Pa, which are values that almost do not occur in normal usage of a building.

Thus, if the decreasing trend of air change is to further continue, it is appropriate to provide mechanical ventilation in low-energy buildings. Constructional leakages and untightness of windows and doors cannot ensure sufficient air leakage for healthy usage of buildings.

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