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Trends in Airtightness of the Building Envelope

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Abstrakt The paper deals with airtightness of energy passive houses with regard to the evolution over time. Using the exploratory analysis of variables is first diagnosed state of the airtightness of energy-efficient buildings in the Czech and Slovak Republics in six recent years. The aim of the paper is to use linear regression to predict trends in the field of airtightness in the next two years.

Klíčová slova Airtightness, air permeability, passive houses, trends, linear regression

1. INTRODUCTION

Airtightness is a term used to describe the air leakage of a building. The airtightness of a building determines the uncontrolled background ventilation or leakage rate of a building which, together with purpose-provided ventilation, makes up the total ventilation rate for the building.

Untightness leads to uncontrolled air exchange and increased heat loss. Especially in areas with lots of wind and in exposed situations, this results in ventilation heat loss that could constitute up to 10% of total heat consumption.

A much greater problem happens in case of untight component joints. Humid air comes in through the cracks and condenses inside the construction. This can lead to humidity damage and favours mould growth. [1]

Revision of the standard ČSN 730540 – 2 Thermal protection of buildings - Part 2: Requirements [2] came into effect in November 2011 and incorporated stricter requirement for the thermal properties of structures. The changes also apply to the airtightness of buildings. For the first time, the standard provides two levels of recommended values of airtightness of buildings represented by n_{50}.

The paper analyses the current development of air-tightness of passive houses in the Czech and Slovak Republic in the past six years and predicts trend in the following years by using a linear regression. The predicted values for the following years are in the conclusion compared with the standards recommended values specified in ČSN 73 0540 – 2 from November 2011.

2. AIRTIGHTNESS AND BUILDING REGULATIONS

Airtightness is expressed in terms of a whole building leakage rate at an artificially induced pressure, in the Czech Republic 50 Pa is used n_{50}. Airtightness is expressed in air changes per hour with units or h-1 according to ČSN EN 13829. The standard ČSN 73 0540 – 2 recommends to fulfil the following condition:

$$n_{50} \leq n_{50,N}, \quad [h^{-1}]$$

where n_{50} is the measured total air exchange rate at 50 Pa [h^{-1}],
and $n_{50,N}$ is the recommended total air exchange rate at 50 Pa [h^{-1}].

At present, there is no rule which states the values n_{50} mandatory but only recommended to achieve values. The standardized recommended value $n_{50,N}$ is based on method of ventilation in table 2.1. For the first time, revised standard ČSN 730540-2 introduces two levels of air tightness of buildings. The values at level I are recommended to achieve all the time and the value at level II are recommended to achieve primarily. [2]

Tab. 2.1 The recommended values of n_{50} representing the airtightness of buildings.

Ventilation of buildings	Recommended values of n_{50} [h^{-1}]	
	Level I	Level II
Natural and combined ventilation	4.5	3.0
Mechanical ventilation	1.5	1.2
Mechanical ventilation with heat recovery	1.0	0.8
Mechanical ventilation with heat recovery in energy efficient buildings	0.6	0.4

Source: ČSN 73 0540-2 Thermal protection of buildings - Part 2: Requirements [2]

The last and the smallest values in the table above apply to energy passive houses. The total air exchange rate at 50 Pa must not exceed 0.6 h-1 for energy passive houses. It means that a maximum of 60 % of the complete building air volume can escape per an hour at 50 Pa.

For the first time, the standard ČSN 73 0540 – 2 recommends primarily reach the value of the total air exchange rate at 50 Pa $n_{50,N}$ = 0.4 h^{-1}. It means that only 40 % of the complete building air volume exchange per an hour.

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3. TREND OF AIRTIGHTNESS IN RECENT YEARS

In the Czech Republic, there are only recommended values airtightness of buildings. For this reason, not everyone passive energy house in the Czech Republic has a measured value of the total air exchange rate n_{50} at pressure difference 50 Pa.

Increased interest in measuring the airtightness of energy passive houses provoked The Green Savings programme of Ministry of the Environment in 2009. The Green Savings programme focuses on support for investment in energy savings in reconstructions and new buildings. The program Green Savings programme established the conditions for financial support to construction of energy passive houses. One of the many conditions is also a requirement to achieve the total air exchange rate n_{50} = 0.60 h^{-1}, as set out in TNI 73 0329 for the construction of energy passive house.

At present, the Green Savings programme is suspended for new applications progress verification and monitoring of individual applications for grants. In this situation it is possible to observe evident decline of interest in measuring airtightness of energy efficient buildings.

4. INPUT DATA

The calculation and estimate of the development airtightness is based on the sample, which contains 84 reference energy passive houses. The total air exchange rate at 50 Pa and year of construction are known for these houses. The source of sample data set on the airtightness of energy passive houses is taken from [2]. The sample is supplemented by houses of trusted and year of construction are known for these houses. The source of sample data set on the airtightness of energy passive houses is taken from [2]. The sample is supplemented by houses of trusted and relevant sources. A figure below (Fig. 4.1) illustrates the total air exchange rate n_{50} at 50 Pa from 2004 to 2011 and also takes into account the type of construction.

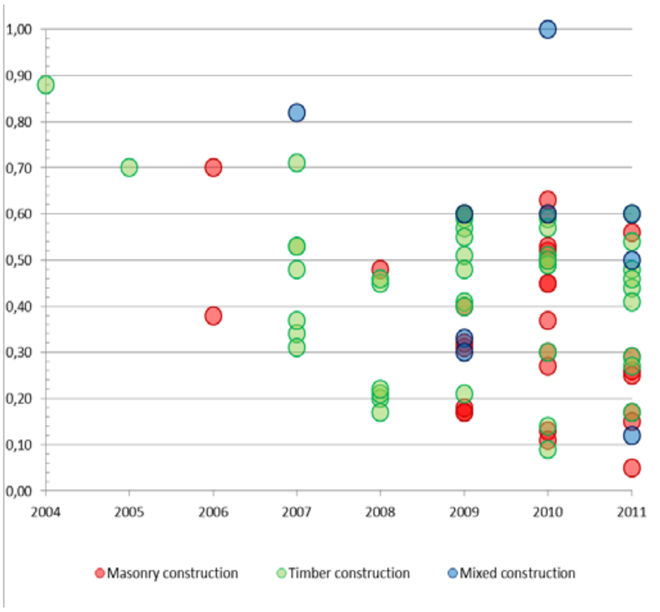

Fig. 4.1 Sample analysis grouped by years

Due to low values frequency from 2004 to 2008, these years were merged of the above years into one category. Otherwise, analysis of individual years probably would have been less valid and representative.

4.1 Exploratory data analysis for sample grouped by time

The basic statistical research – exploratory data analysis is performed by using spreadsheet Microsoft Excel 2010 [4] and analytics software IBM SPSS Statistic 19 [5]. Table 4.1 shows the exploratory characteristic for whole sample and also for each year.

Tab. 4.1 Descriptive of characteristic n_{50} grouped by years

	Sample	Pre 2008	2009	2010	2011
Mean	0.4232	0.4705	0.4238	0.4433	0.3535
St. error	0.0208	0.0488	0.0350	0.0418	0.0384
Median	0.4550	0.4600	0.4100	0.4950	0.3500
Modus	0.6000	0.7000	0.6000	0.5000	0.2900
St. deviation	0.1903	0.2129	0.1603	0.2049	0.1716
Variance	0.0362	0.0453	0.0257	0.0420	0.0295
Kurtosis	0.0358	-0.7348	-1.3730	1.2751	-1.2775
Skewness	0.2186	0.3940	-0.3277	0.2354	-0.1253
Range	0.9500	0.7100	0.4300	0.9100	0.5500
Minimum	0.0500	0.1700	0.1700	0.0900	0.0500
Maximum	1.0000	0.8800	0.6000	1.0000	0.6000
Sum	35.5500	8.9400	8.90000	10.6400	7.0700
Frequency	84.0000	19.0000	21.0000	24.0000	20.0000

Interpretation of the exploratory characteristics is implemented in the conclusion, because it is not a key element of the paper. The Exploratory data analysis provides the input data used to calculate the linear regression and determination of trends.

5. STATISTICAL ESTIMATION OF AIRTIGHTNESS

The future values for the prediction of the expected development of airtightness of energy passive houses can be generated by using spreadsheet Microsoft Office Excel 2010. The Forecast function of Microsoft Excel 2010 returns the predicted value of the dependent variable for the specific value, x, of the independent variable by using a best fit least squares linear regression to predict y values from x values.

The Forecast function is defined by the following expression:

$$FORECAST\ (x, known\_x's, known\_y's),$$

where x is the data point for which we want to predict a value,
known_y's is the dependent array or range of data,
and known_x's is the independent array or range of data. [4]

In our case, the values x are years 2012 and 2013 for forecast the total air exchange rate at 50 Pa. The dependent array of data known_y's is values of the total air exchange rate at 50 Pa from 2008 to 2011. The independent array of data known_x's is years from 2008 to 2011.

The table 5.1 illustrates the predicted values calculated by using function FORECAST. The calculation is performed for the basic characteristics of the exploratory data analysis in Chapter 4.

The predicted value of the minimum total air exchange rate at 50 Pa n_{50} (*) for 2013 is negative and therefore not real. It is not possible to reach a negative value of total air exchange rate at 50 Pa both theoretically and practically.

Tab. 5.1 The predicted values by using a linear regression

	Mean	Median	Modus	Minimum	Maximum
2008	0.47053	0.46000	0.70000	0.17000	0.88000
2009	0.42381	0.01000	0.60000	0.17000	0.60000
2010	0.44333	0.49500	0.50000	0.09000	1.00000
2011	0.35350	0.35000	0.29000	0.05000	0.60000
2012	**0.33990**	**0.36750**	**0.19000**	**0.01000**	**0.66000**
2013	**0.30475**	**0.33750**	**0.03500**	**-0.05000***	**0.66000**

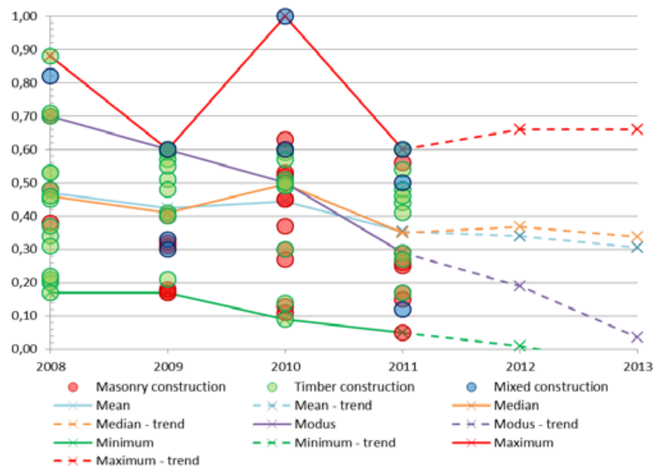

Fig. 5.1 The trends of the exploratory data characteristics

6. CONCLUSION

The statistical survey of the data set provided the basic exploratory characteristics of energy passive houses in six recent years. It may be stated that the trend of airtightness of passive energy houses is still reducing the value of the total air exchange rate n_{50}. While in 2010 the mean value n_{50} is 0.44 h^{-1}, in 2011 is only 0.35 h^{-1}. It means a reduction of over 20 per cents.

The larger decrease of the total air exchange rate at 50 Pa can be observed at the most numerous values, i.e. mode. While the mode was 0.70 h^{-1} to 2008, in 2009 is 0.60 h^{-1}, in 2010 is 0.50 h^{-1} and in 2011 is only 0.29 h^{-1}.

While the minimum value of the total air exchange rate at 50 Pa was 0.17 to 2009, in last year the value equals 0.05 h^{-1} was measured for masonry construction in Veltrusy in the Middle Bohemia. This represents a reduction of the total air exchange rate at 50 Pa over 50%.

Using by the linear regression in the spreadsheet Microsoft Office Excel 2010 is predicted the future trends of airtightness of energy passive houses for two next years. The predicted value of Median for 2012 (0.35 h^{-1}) and 2013 (0.30 h^{-1}) means that the half measured values will be lower or equals these values. The Fig. 5.1 demonstrates the most frequently measured values, i.e. modus is lower for 2012 and 2013. From the facts above, it can be concluded the most frequently measured values of the total air exchange rate at 50 Pa in 2013 will be lower than the minimum value measured in 2011.

By comparing calculated trends for 2012 and 2013 with the standard ČSN 73 0540-2 Thermal protection of buildings - Part 2: Requirements, it can be concluded that in the during next two years, more than half measured values of the total air exchange rate at 50 Pa will be comply with the recommended values of the level II, i.e. $n_{50,N} = 0.4\ h^{-1}$.

Finally, it must be stated the predictions of the analysed parameters above are limited by the number of input data. It is possible to confirm the decreasing trends of air permeability from the logical - deductive point of the view, as can be expected the reduction of the energy performance of buildings in the future. In the present, the costs associated with the energy performance of buildings will not decrease, but only increase. About the future attributes supporting the willingness to invest into energy efficient houses it can be only speculate.

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