ACH AND AIR TIGHTNESS TEST RESULTS IN THE CROATIAN AND HUNGARIAN BORDER REGION

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ABSTRACT

The article presents the results of our research, which was realized under a cooperation project between the University of Pécs, Hungary and the University of Osijek, Croatia. The aim was to gather 50 Pa ACH, air tightness and spontaneous ACH information of residential houses by the Croatian and Hungarian border. The budget of the project allowed approximately 50 tests for each university; these summarized results are presented together with correlations found between the results.

KEYWORDS

Blower Door; tracer gas, ACH; leakage; air tightness

1. INTRODUCTION

For determining ACH and air tightness of the buildings, we have used Blower Door tests, which have two types:

Type “A” which can serve for checking the building in use, and provides ACH information in case of 50 Pa pressure difference. In this case, the purposely made vents on the building envelope (e.g.: chimneys, ventilation shafts, etc.) are not sealed. Concerning this case there have been measurements conducted on both sides of the border.

Type “B” Blower Door, which provides information on the air tightness of the building, at standard 50 Pa pressure difference. Before the test, each of the purposely installed vents on the building envelope must be sealed. The result can be applied for qualification, according to the air tightness limits. Currently, in Hungary air tightness testing is a requirement only for passive house qualification, but in the future it is expected to be introduced also as part of the standard certification procedure for all new buildings. Type “B” tests have been conducted only on the Hungarian side of the border. This test, with a little complementation, could be suitable for exploring air tightness faults as well,: using e.g. smoke test, thermography, air velocity meter, etc.

Blower Door tests presented above are valid at 50 Pa pressure difference, which shall not provide information about actual spontaneous ACH. An interesting field of research is to examine how we can derive the spontaneous ACH number of the building from 50 Pa ACH, which can be derived for Hungary as 4 Pa for annual average pressure difference.

Another possible testing method for measuring spontaneous ACH is using tracer gas, which has an advantage as compared to Blower Door is that this test method does influences the test results to the least extent. During our research we have conducted tracer gas tests as well on the Hungarian side of the border, and we have chosen SF_6 gas for this purpose.

2. TYPE “A” BLOWER DOOR TEST REUSLT

During choosing the buildings in order to gain somewhat representative results for a certain area, we have focused only on residential houses on both sides of the border, although we have conducted some tests for a single room, or office.
As far as the construction method of the buildings concerned, residential houses belonging to a period of 100 years have been tested; therefore they included brick, adobe, panel-block, and light-weight buildings.

Table 1 presents the usual ACH rates according to the recommendation of the German Passive House Institute:

Table 1. Usual ACH rates

magnitude of n50 ACH	n50 [1/h]
old building	7..
today’s new buildings HU	5..10
today’s new buildings DE	2..6
low energy consumption house	0,17..5
passive house	0,17..0,6

The summary of test results according to table 3, as presenting Croatian results and table 4. presenting Hungarian results in a similar form. The buildings are shown in chronological order in the table, indicating their year of reconstruction (first of all referring to the change of windows and doors), and the 50 Pa type “A-type” Blower Door test results. In order to offer better overview, according to figure 1, the summarized results of the 2 countries are shown by point charts, where we have fitted trend lines on the summarized ACH results. It can be observed that there is a significant deviation for a more than one hundred years period: at 50 Pa ACH it is changing between 1 and 20. However, evaluating the trend lines, a consequent decrease can be observed in parallel with the increase of the age of the buildings; this decrease met our previous assumptions, since, as time went on construction standards became ever stricter and together with energetic requirements and more up-to-date construction technologies together resulted in the decrease of ACH.

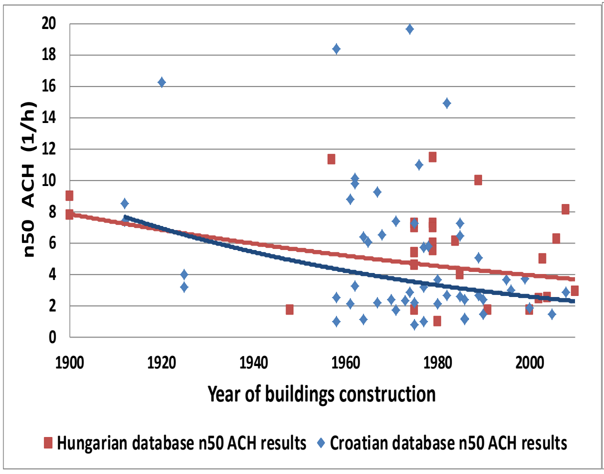


Fig 1. n50 ACH values in all tested houses

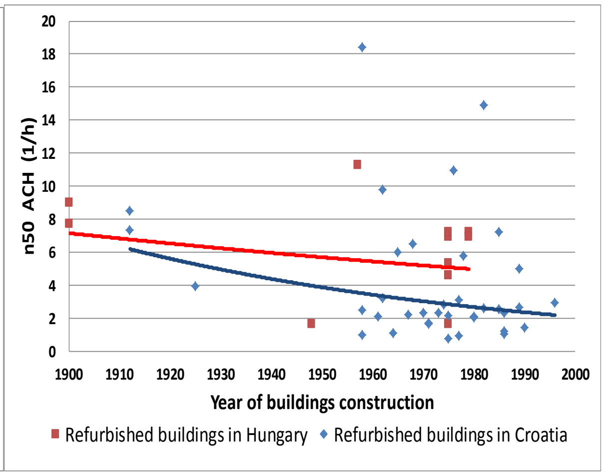


Fig 2. n50 ACH values in refurbished houses

Table 2. Croatian test results

Year of construction	NO.	Type of building	Year of construction	Year of reconstruction	ACH, n50 [1/h]	Average ACH, n50 [1/h]
Before 1945	1.1	Apartment house	1912	2007	7,35	7,84
	1.2	Apartment house	1912	2009	8,53	
	1.3	House	1920	-	16,21	
	1.4	Terraced House	1925	2006	3,94	
	1.5	House	1925	-	3,16	
1945.-1965.	2.1	Terraced House	1958	2011	2,51	6,31
	2.2	Apartment house	1958	1981	18,39	
	2.3	Apartment house	1958	2001	0,99	
	2.4	Terraced House	1961	2007	2,12	
	2.5	Terraced House	1961	-	8,77	
	2.6	House	1962	1994	3,22	
	2.7	House	1962	-	10,12	
	2.8	House	1962	1993	9,77	
	2.9	Apartment house	1964	-	6,39	
	2.10	Apartment house	1964	2004	1,13	
	2.11	Terraced House	1965	1975	6,01	
1966.-1975.	3.1	Apartment house	1967	2010	2,2	5,08
	3.2	Apartment house	1967	-	9,26	
	3.3	House	1968	2008	6,49	
	3.4	Apartment house	1970	2010	2,35	
	3.5	Apartment house	1971	2010	1,71	
	3.6	Apartment house	1971	2005	1,69	
	3.7	Apartment house	1971	-	7,35	
	3.8	Apartment house	1973	2013	2,32	
	3.9	House	1974	1998	2,86	
	3.10	Apartment house	1974	-	19,64	
	3.11	House	1975	2003	0,76	
	3.12	Apartment house	1975	-	7,23	
	3.13	House	1975	1998	2,18	
1976. - 1985.	4.1	House	1976	2010	10,95	5,24
	4.2	Apartment house	1977	2007	0,94	
	4.3	Apartment house	1977	2006	3,14	
	4.4	Apartment house	1977	-	5,73	
	4.5	Apartment house	1978	2003	5,77	
	4.6	Apartment house	1980	2002	2,13	
	4.7	Apartment house	1980	-	3,63	
	4.8	Apartment house	1980	2009	2,07	
	4.9	House	1982	2012	2,63	
	4.10	Terraced House	1982	2012	14,91	
	4.11	Terraced House	1985	1994	2,56	
	4.12	Apartment house	1985	1994	7,21	
	4.13	Apartment house	1985	-	6,41	
1986.-1995.	5.1	Apartment house	1986	2011	2,34	2,47
	5.2	Apartment house	1986	2008	1,07	
	5.3	Apartment house	1986	2004	1,2	
	5.4	Apartment house	1989	2007	2,64	
	5.5	Apartment house	1989	2007	5,02	
	5.6	House	1990	2009	1,45	
	5.7	House	1990	-	2,37	
	5.8	Apartment house	1995	-	3,63	
1996. - 2005.	6.1	Apartment house	1996	2007	2,96	2,48
	6.2	House	1999	-	3,69	
	6.3	House	2000	-	1,81	
	6.4	House	2005	-	1,45	
From 2006	7.1	House	2008	-	2,82	2,99
	7.2	House	2011	-	0,86	
	7.3	House	2011	-	3,4	
	7.4	House	2013	-	4,88	

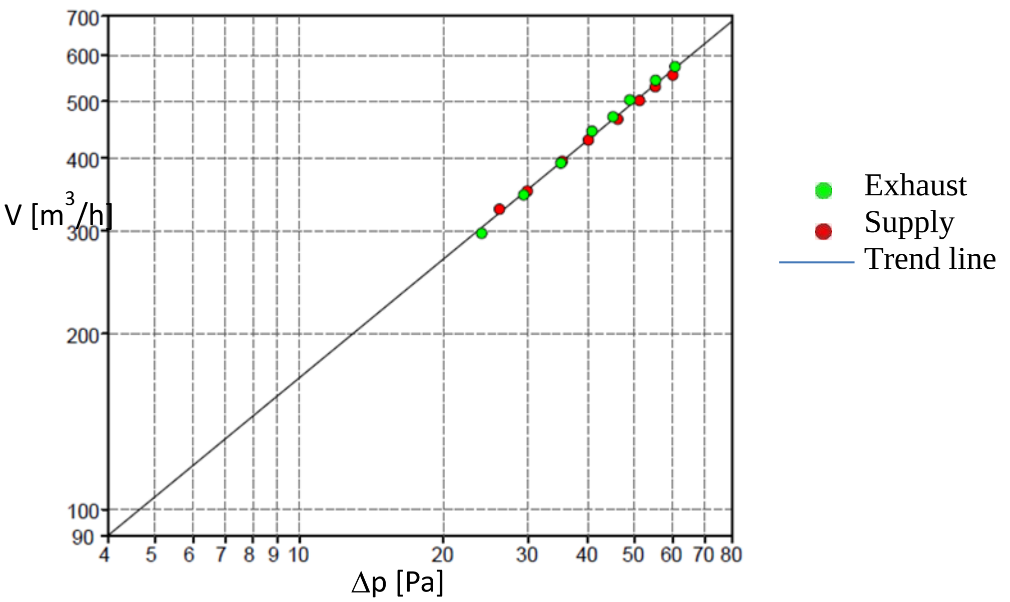
Table 3. Hungarian test results

Year of construction	NO.	Type of building	Year of construction	Year of reconstruction	ACH, n50 [1/h]	Average ACH, n50 [1/h]
before 1945	1.1	House	1900	2012	7,75	8,38
	1.2	Room	1900	2012	9	
1945. 1965.	2.1	House	1948	2012	1,68	6,49
	2.2	House	1957	1994	11,3	
1966.-1975.	3.1	Office room	1975	2008	6,94	5,16
	3.2	Office room	1975	2008	4,59	
	3.3	Office room	1975	2008	5,36	
	3.4	Library	1975	2008	1,68	
	3.5	Classroom	1975	2008	7,21	
1976. - 1985.	4.1	House	1979	-	11,42	6,02
	4.2	Room	1979	-	6	
	4.3	Room	1979	-	5,5	
	4.4	House	1979	2010	7,23	
	4.5	Room	1979	2010	6,96	
	4.6	Room	1980	-	1	
	4.7	House	1984	-	6,08	
	4.8	Flat	1985	2008	4	
1986.- 1995.	5.1	House	1989	-	10	5,84
	5.2	House	1991	2011	1,68	
1996. - 2005.	6.1	House	2000		1,68	2,89
	6.2	House	2002	-	2,41	
	6.3	House	2003	-	5	
	6.4	House	2004	-	2,48	
from 2006	7.1	House	2006	-	6,25	4,65
	7.2	House	2008	-	8,1	
	7.3	House	2010	-	2,89	
	7.4	House	2011	-	3,19	
	7.5	House	2011	-	8	
	7.6	House	2011	-	1,86	
	7.7	Room	2011	-	3,45	
	7.8	Room	2012	-	3,49	

In case of the flats where ACH is outstandingly high (over 10/h) this phenomenon is explained by the use of open-chamber furnaces or fire places, or the existence of uncontrolled ventilation shafts. At the same time, the too low ACH figures can be concerning, too (i.e. under 2/h) in case the flat did not have artificial ventilation system, but they can be considered as traditional window-ventilation buildings. According to the trend lines, as time went on the Croatian ACH results are lower than those of measured on the Hungarian side of the border, however, studying tables 2 and 3, it is clearly seen, that following the Bosnian war, nearly all of the Croatian flats were renovated, unlike the ones on the other side of the border. Therefore the interim renovation of flats can be a significant factor of influence. This uncertainty can be eliminated by limiting the results, and presenting only the results of the flats that had been renovated earlier, according to the results of figure 2. In the figure presented this way deviance can still be observed, and the results still show a decreasing tendency in favour of the Croatians. However, this statement is based on a sample of relatively small number of flats that had been renovated on the Hungarian side of the border.

3. DETERMINING SPONTANEOUS ACH BY TYPE "A" 50 PA BLOWER DOOR TEST

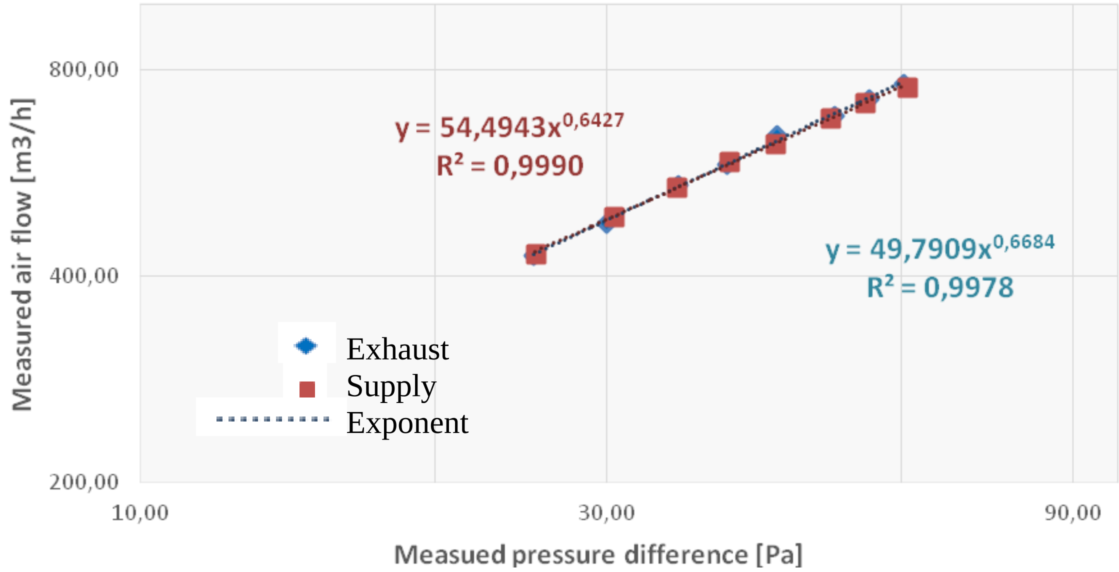
Tectitle 3.6 software provides test results together with trend line as shown in figure 3 (presenting the results of the house 7.6 in table 3.)



Averages:								
Δpn [Pa]	60	55	50	45	40	35	30	25
Δp [Pa]	60,6	55,3	51	44,7	39,9	35,4	30,2	25,3
V [m3/h]	760.8	722.3	685.5	634.5	587.0	542.4	484.1	430.7

Fig 3. Extrapolating ACH values by the trend line of the test results

The software provides both the multiplying factor and the exponent of the describing equation belonging to the trend lines created for both pressurization and depressurization, or else they can be even derived exporting the software results (measured pressure difference and the related air flow) by an excel program, such as seen in figure 4.



3. figure

Next, the values of air change number typical for the building can be calculated. The following results were yielded for the detached house tested:

- In case of overpressure (supply):
  The exponent of the descriptive equation: n=0,6427
  The multiplying factor of the describing equation: C=54,4943
  ACH for 50 Pa pressure difference: n_{50}=1,85 1/h
- In case of depression (exhaust):
  The exponent of the descriptive equation: n=0,6684
  The multiplying factor of the describing equation: C=49,7909
  ACH for 50 Pa pressure difference: n_{50}=1,87 1/h
- In case of the mean of depression (exhaust)and overpressure (supply):
  The exponent of the descriptive equation: n=0,6501
  The multiplying factor of the describing equation: C=53,1409
  ACH for 50 Pa pressure difference: n_{50}=1,86 1/h

The equation describing the results:

$$\dot{V} = C \cdot \Delta p^n \quad [m3/h] \qquad (1)$$

Where:

$\dot{V}$ - the measured air flow by the Blower Door
C – the multiplying factor of the describing equation
Δp – pressure difference at the point of testing
n - The exponent of the descriptive equation

Following the 50 Pa type “A” Blower Door test, knowing the multiplication factor and the exponent of the describing equation depending on the characteristics of the buildings, ACH can be calculated of any pressure difference. A good approximation by statistic methods achieved despite the fact that some leaks can behave quite differently in case of diverse pressure differences. The most important factors are: turbulent or laminar flow or opening pressure difference.

For testing spontaneous ACH the annual natural pressure difference should be known which is quite dependent on the weather conditions, such as actual indoor and outdoor temperature difference or the prevailing wind force. In Hungary, the annual average pressure difference is 4 Pa, and taking it into account when using the equation (1) we could get quite accurate results for spontaneous ACH. Regarding the initial example, substituting the data:

With 4 Pa spontaneous pressure difference, the filtration ACH is:

$$\dot{V}_{4Pa} = C_L \cdot \Delta p^n = 53{,}14 \cdot 4^{0,65} = 130{,}8 \quad [m3/h]$$

With 4 Pa spontaneous pressure difference, ACH value is:

$$n_4 = \frac{\dot{V}_4}{V} = \frac{130{,}8}{363{,}2} = 0{,}36 \quad [1/h]$$

Completing the data of table 3 by the 4 Pa ACH calculated for brickwork houses:

Table 4. ACH values of traditional brickwork houses

No.	**Year of construction**	**Type of building**	**C**	**n**	**n50**	**n4**
			-	**-**	**[1/h]**	**[1/h]**
1	1900	House	96,9	0,563	7,75	1,87
2	1979	House	150,4	0,569	11,42	2,71
3	1979	House	243,9	0,595	7,23	1,61
4	1980	Room	6	0,632	1,10	0,23
5	1984	House	135,9	0,59	6,08	1,37
6	1985	Flat	87,5	0,649	4,85	0,94
7	1989	House	471,7	0,596	10,00	2,22
8	2002	House	24,5	0,596	2,41	0,54
9	2003	House	192,5	0,609	5,02	1,08
10	2004	House	64,1	0,664	2,48	0,46
11	2006	House	89,1	0,566	6,25	1,49
12	2008	House	162,9	0,601	8,10	1,52
13	2010	House	75,3	0,591	2,89	0,65
14	2011	House	57,7	0,636	3,19	0,64
15	2011	House	171,7	0,689	8,28	1,45
16	2011	House	53,1	0,65	1,86	0,36
17	2012	Room	15	0,628	3,49	0,72

It could be important to know that the expected 4 Pa spontaneous ACH can be determined quite precisely from the result of type “A” 50 Pa Blower Door ACH test results without forming any functions. For this, as shown in figure 5. using the results of table 4, imaging the measured 50 Pa and calculated 4 Pa pairs of figures, whereby a trend line is fitted indicating the equation describing the function concerned. Using this equation, any the 4 Pa spontaneous ACH can be determined from the relevant 50 Pa ACH result. The high standard deviation figure, R^2=0,9819 suggests that the results can be considered reliable. In order to provide better illustration the results are also shown by a bar chart by figure 6, compared to the calculated 4 Pa results, and the 4 Pa results calculated by the describing equation of figure 5. It can be seen in figure 6 that 4 Pa ACH can be calculated by approximately 90% accuracy.

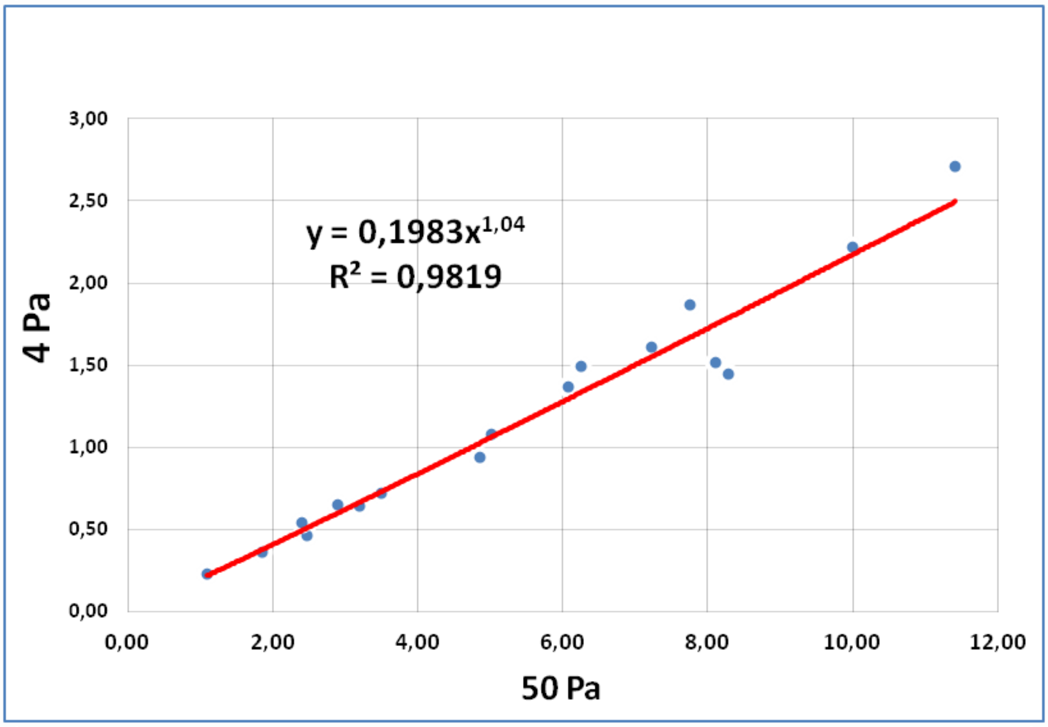


Figure 5. n4 ACH values as a function of n50 values

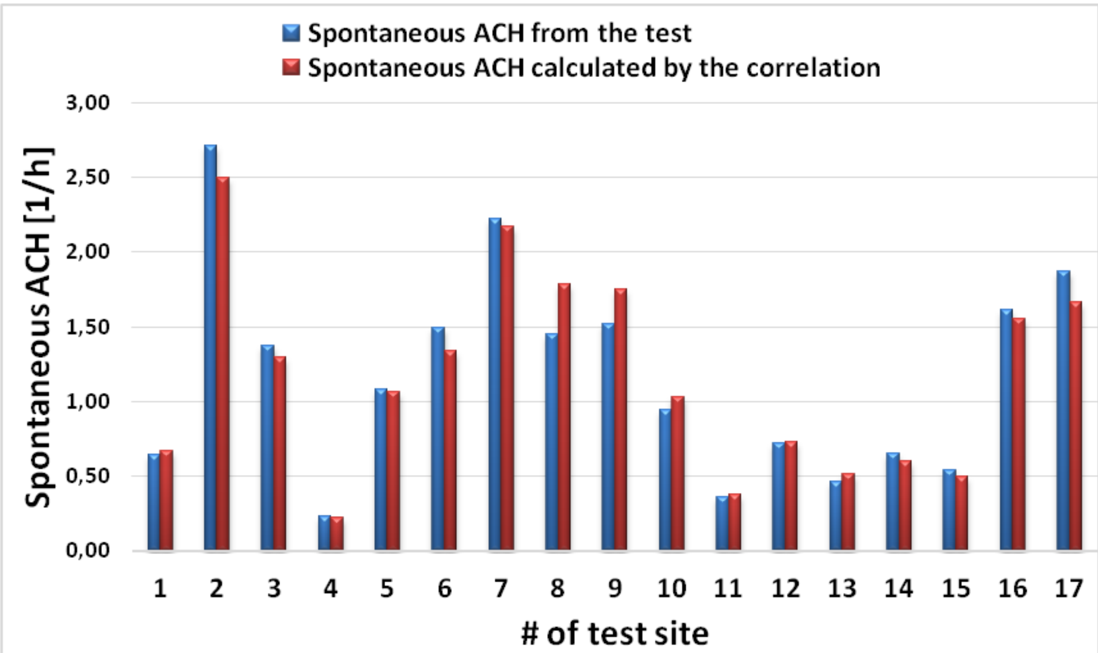


Fig 4. Comparison of test results and calculated ACH values

4. DETERMINING SPONTANEOUS ACH BY TRACER GAS:

For carrying out the tests, we used an INNOVA 1412i Photoacoustic Gas Monitor sold by LumaSense Technologies. The gas chosen for the tests is Sulphur-hexafluorid (SF6). A specific characteristic of the test is that it is hard to apply for measuring the ACH of multi-space buildings due to the lack of appropriate mixture of air, however, it is perfectly suitable for measuring the spontaneous ACH of only one space. SF_6 gas is approximately 5 times heavier than air, therefore during the test the appropriate mixture of the gas inserted should be provided by a fan. The test cycles as a function of time and their evaluation is presented in figure 7.

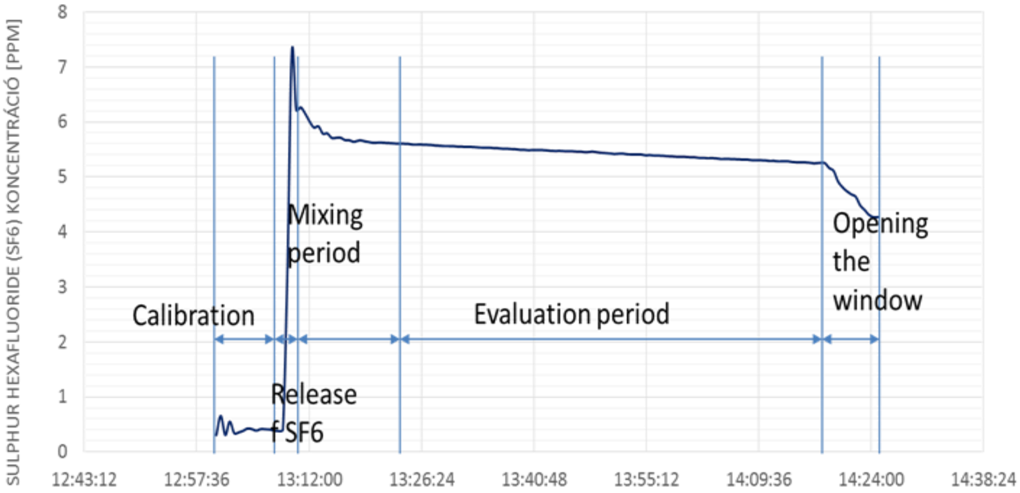


Fig 7. Procedure of tracer gas test

The evaluable period of the change of gas concentration is seen by the enlarged figure 8.

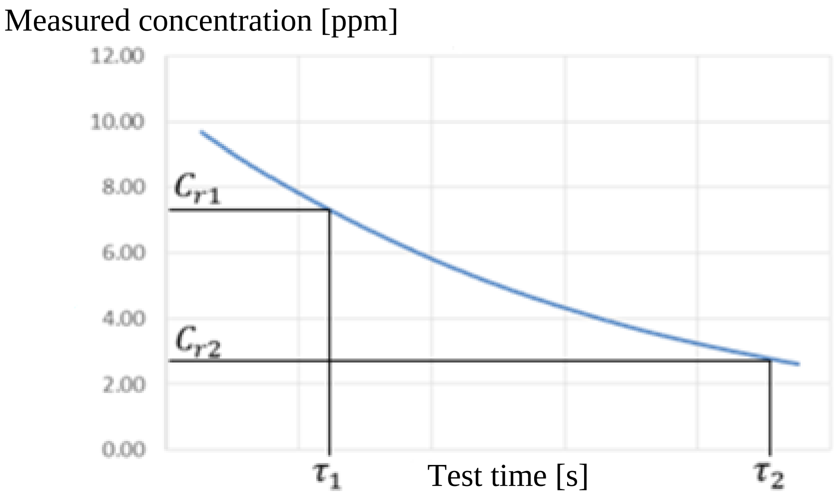


Fig 8. Concentration decay test method

The spontaneous ACH can be calculated if concentration decline is divided by the time elapsed:

$$n = \frac{\ln(C_{r1}) - \ln(C_{r2})}{\Delta\tau}\left[\frac{1}{h}\right] \qquad (2)$$

Where:

Cr1: is the concentration at the beginning of the phase suitable for evaluation
Cr2: a is the concentration at the end of the phase suitable for evaluation
Δτ: is the time elapsed in between

5. CORELATION BETWEEN BLOWER DOOR TYPE “A” 50 PA AND BLOWER DOOR TYPE “B” 50 PA

Blower Door Tests of both type “A” and “B” have been completed only in Hungary. The summarized results concerned are included in table 5 and figure 9.

Table 5. Comparison of A-type and B-type test results

no	Year of Construction	Type of building	A-type Blower Door n50 ACH [1/h]	B-type Blower Door n50 Air tightness [1/h]
1	1900	room	9,28	9,28
2	1979	house	11,42	10,11
3	1979	room	5,5	5,5
4	1979	room	6	6
5	1979	room	6,96	6,96
6	1980	room	1,1	1,1
7	1984	house	6,08	5,31
8	1984	flat	8,91	7,14
9	1989	house	10	10
10	2002	house	2,41	1,45
11	2004	house	2,48	2,4
12	2006	house	6,25	5,25
13	2008	house	8,1	6,92
14	2011	house	3,19	2,75
15	2011	house	1,86	1,38
16	2011	room	3,45	3,45
17	2012	room	3,49	3,49

Evaluating the results of the above table, it can be seen that if air tightness or ACH measures were completed only for one room, generally the results show no differences. The reason for this lies in the fact that in case of traditional window-ventilation spaces usually there are not further artificial leaks on the envelope of the building which should be sealed according to the requirements of air-tightness tests, and which would show changes in the results. This occurs in every such a case even in case of complete house test where there no artificial leaks on the building envelope that should be sealed. Limiting the data of table 5 focusing only the figures which show differences between type “A” and “B” test results, we have presented these pair of data in a graph in figure 10 where, by means of curve fitting, we have determined the equation describing the trend line. Since the deviation R^2=0.9893 is high, the equation can be considered reliable, thus, we have found a quasi correlation between the “A” and “B” ACH tests at 50 Pa. However, it is important to point out that there are several factors which can influence the outcome of the results e.g. the shape and size of the leak can result in significant differences as compared to their determined equation.

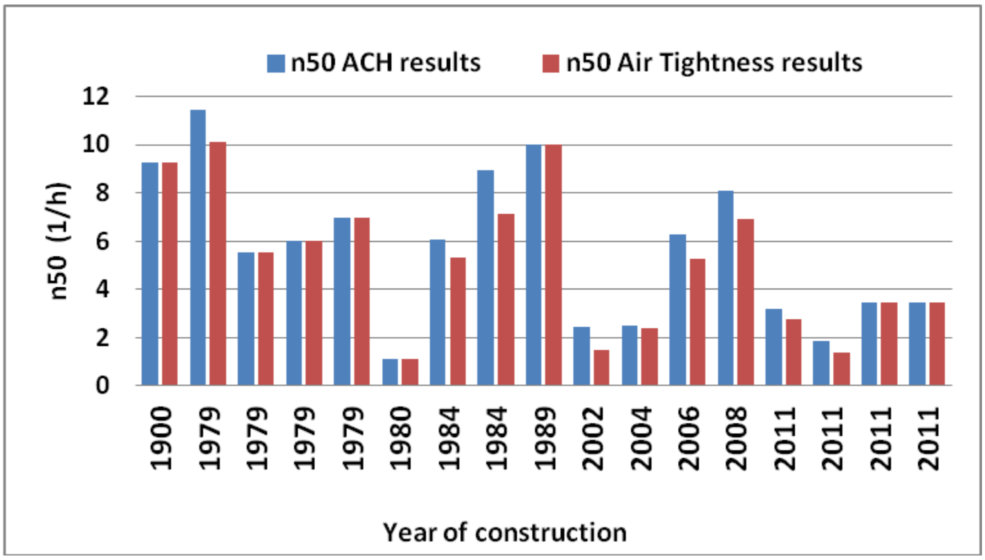


Fig 9. Comparison of A-type and B-type test results

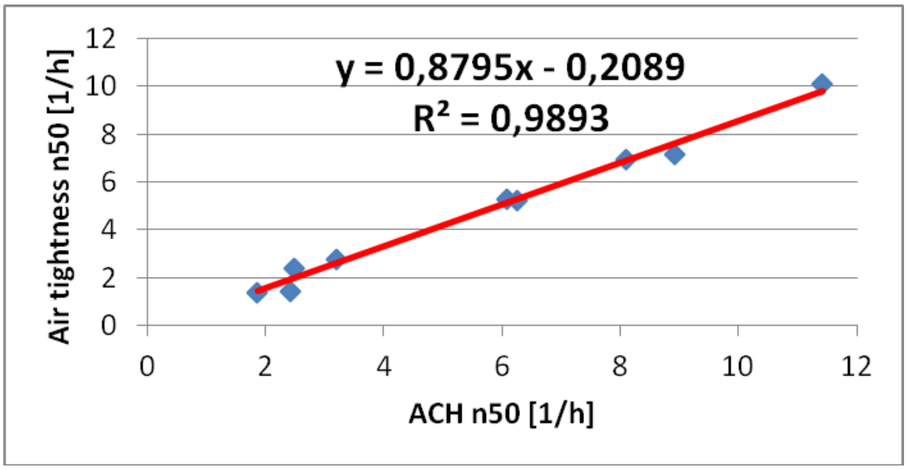


Fig 10. Comparison of A-type (ACH) and B-type (air tightness) test results

6. CONCLUSION

Results of air tightness and ACH tests in Hungary and in Croatia presented. The project was supported by the EU IPA cooperation project. Correlations found between the spontaneous ACH and Blower Door type “A” 50 Pa ACH results.

Correlations found between the results Blower Door type “A” 50 Pa and Blower Door type “B” 50 Pa tests. The research and results presented could be helpful for conducting measurements and evaluating their results.

Furthermore the tracer gas concentration decay test method is presented which is most suitable to determine spontaneous ACH. This method does not influence the tested parameters. However it cannot be applied to measure complex spaces simultaneously and it is especially sensitive to the changes of the external conditions.

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