Estimating the average Air Change Rate for the heating season

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ABSTRACT

Ventilation of buildings and homes is a key issue both from comfort and energy aspects.
However to determine the average ventilation air flow or the Air Change Rate (ACH) for a heating season by tests in case of natural ventilation, involve certain difficulties.

Essential requirements when testing a physical phenomenon:

1) The test itself must not influence the tested phenomena.
2) The test must be repeatable delivering the same result each time.

Tracer gas test does not influence the tested phenomena but repeated tests do not deliver the same result due to the constantly changing ambient condition e.g. temperature and wind speed affecting the ACH tremendously.
Repeated BlowerDoor tests deliver the same result assuming that the wind speed during the tests remains below the threshold, but the ACH evinced by the test is much higher than the normal due to the higher than normal natural test pressure difference.

The aim of the research introduced by the paper was to elaborate a method to specify the average ACH for a heating season based on field tests.

Test method:

1) Testing the leakage by BlowerDoor test at +50 and -50 Pa pressure difference, and performing a series of tests at various pressure differences. Plot the correlation curve against logarithmic scale.
2) Performing a series of tests to measure the real ACH values by tracer gas technology throughout a whole heating season during various ambient conditions.
3) Searching cross correlation between the temperature difference, the wind speed and the real ACH.
4) Searching correlation between real ACH values and the BloweDoor test results.

The result of this approximation is a multivariate equation visualised as a surface chart. This equation with the parameters provides a more sophisticated method than the currently available ones to estimate the average ACH for a heating season. The method developed is suitable to estimate the average ACH for various climate zones.

KEYWORDS

Air Change Rate (ACH), Tracer gas test, BlowerDoor test, Heating season avg ACH

1 INTRODUCTION

Ventilation of buildings and homes is a key issue both from comfort and energy aspects.
However to determine the average ventilation air flow or the Air Change Rate (ACH) for a heating season by tests in case of natural ventilation, involve certain difficulties.

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2 BACKGROUND

Ventilation represents a significant proportion of the thermal energy requirement of houses and buildings. The overwhelming majority of the existing building stock has natural ventilation. When auditing a house or a building with natural ventilation the ventilation air flow is estimated that may lead to significant inaccuracy.

In order to achieve an acceptable accuracy in energy audit ventilation air flow should be measured. There is need for a procedure to specify the ventilation air flow for the heating season by a test or series of tests performed in a short period of time.

Driving forces of natural ventilation:

2.1 Stack effect

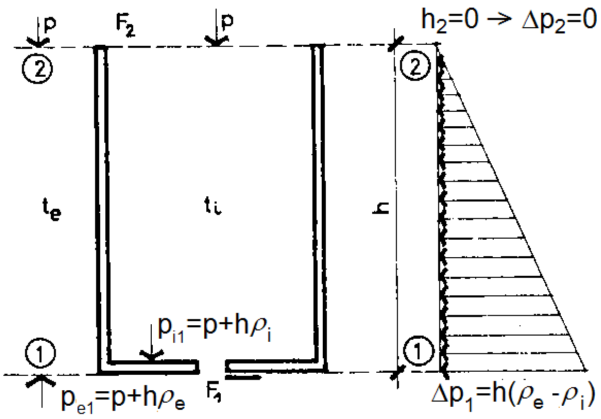

Figure 1: Pressure difference as the function of the height and the temperature difference

$$\Delta p = h \cdot g \cdot (\rho_e - \rho_i) \quad [\text{kg/(m}\cdot\text{s}^2)] \ [\text{Pa}] \qquad (1)$$

Where

h : height [m]

g : gravitational acceleration [m/s^2]

ρ : air density [kg/m^3]

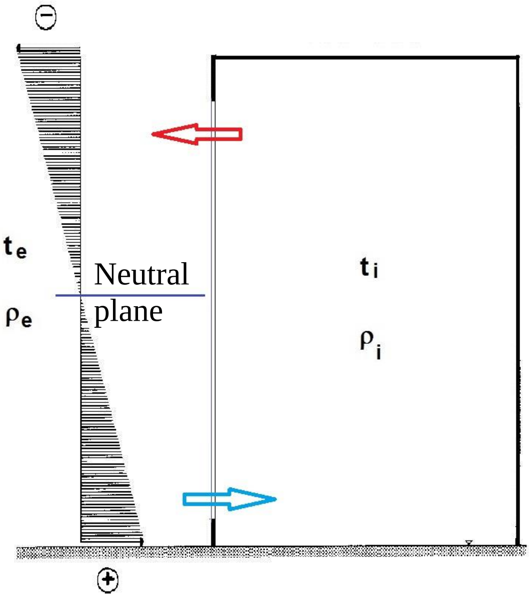

Figure 2: Pressure difference distribution in case of an opening on the facade

2.2 Wind effect

In case of obstacles airflow speed changes that results dynamic pressure. Dynamic pressure is proportional to the square of the velocity. In case the velocity drops to zero:

$$p_d = \frac{\rho}{2} \cdot v^2 \quad [\text{kg/(m} \cdot \text{s}^2)] \quad [\text{Pa}] \tag{2}$$

Where

ρ : air density [kg/m^3]

v : velocity [m/s]

3 DISCUSSION

Since the driving force of the natural air flow is the function of both the temperature difference as well as the wind speed the natural air flow (or ACH) can be characterised by bivariate function:

$$n = a \cdot \Delta T + b \cdot v^2 + c \quad [1/h] \tag{3}$$

Where

n: ACH

ΔT : temperature difference [K]

v : wind speed [m/s]

c = 0

Search for the minimum of the function by Least Squares method i.e. minimize the sum of squared deviations:

$$F(a,b,c) = \sum_{i=1}^{N} (a \cdot \Delta T[i] + b \cdot v^2[i] + c - n[i])^2 \tag{4}$$

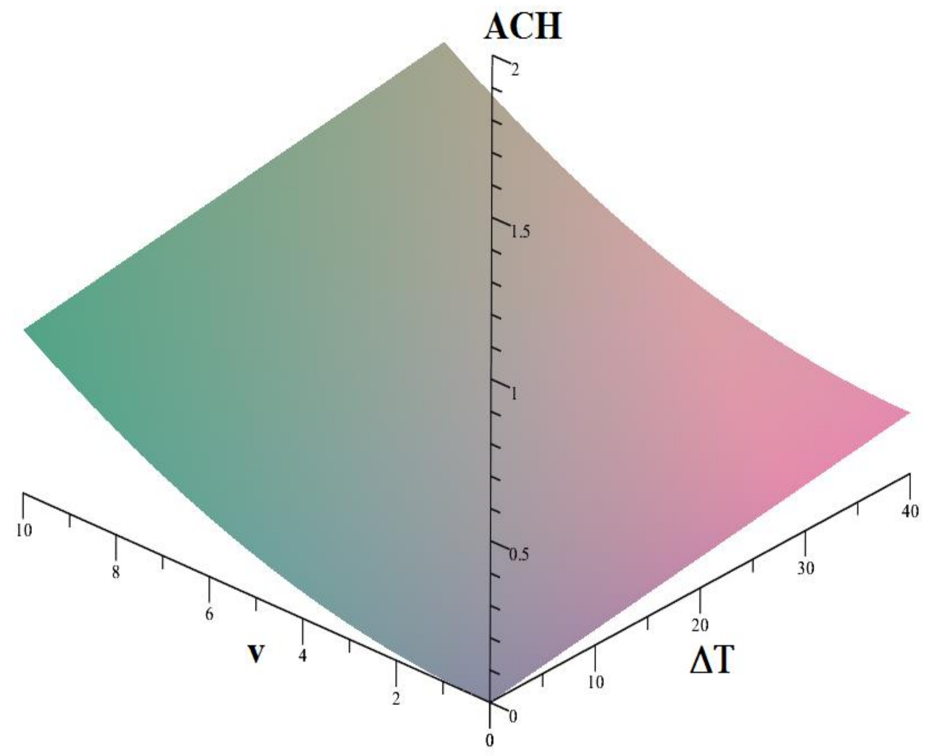

Figure 3: ACH as the function of the wind speed (v) and the temperature difference between the room and the ambient (ΔT)

4 TEST METHOD

Test method:

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5 TEST RESULTS

5.1 BlowerDoor test results

The test room leakage is shown in Fig.4. as a function of the pressure difference between inside and outside.

$$\dot{V} = C \cdot \Delta p^n \quad [m^3/h] \tag{5}$$

Where

$\dot{V}$: air leakage at given pressure difference [m^3/h]
Δp : pressure difference [Pa]
C : Constant

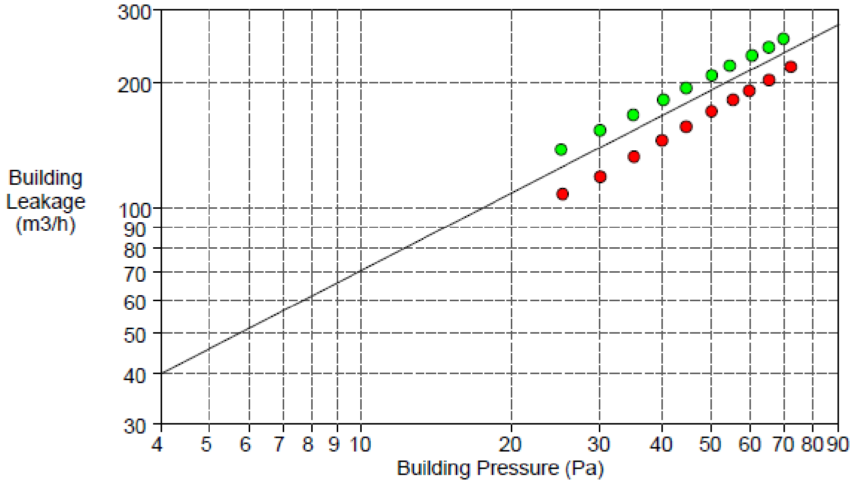

Figure 4: Test room leakage as a function of the pressure difference

5.2 Tracer Gas test results

The method used: Concentration Decay

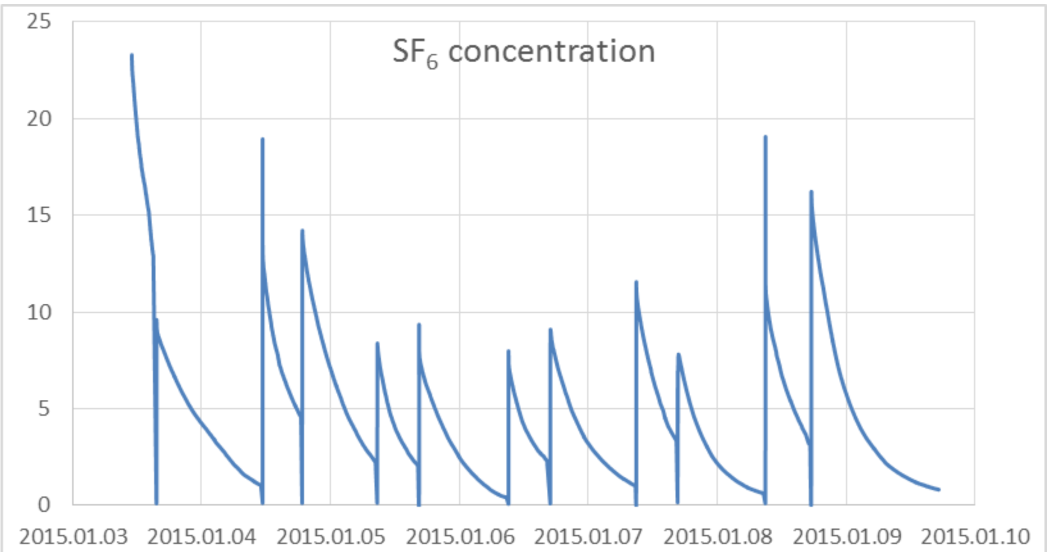

Figure 5: Example of Tracer Gas tests

Evaluation of the Concentration Decay test results:

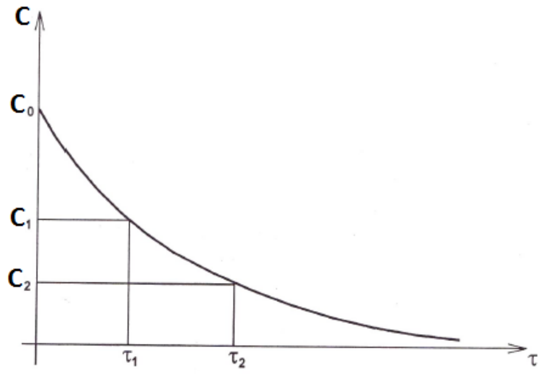

Figure 6: Evaluation of Tracer Gas Concentration Decay test results

$$n = \frac{\ln(C_{r1}) - \ln(C_{r2})}{\Delta\tau} \left[\frac{1}{h}\right] \quad (6)$$

Where

n: ACH [1/h]

τ: Time

$C\tau$: Concentration at time τ [ppm]

5.3 Summary of the test results

Table 1: Summary Table of the Test Results

#	ACH [1/h]	Δt [°C]	v [m/s]	t_i [°C]	t_e [°C]	ρ_e [kg/m3]	p_{din} [Pa]	ρ_i [kg/m3]	Stack Effect [Pa]	Δp TOTAL [Pa]
1	0,139	14,8	0,45	23,54	8,71	1,253	0,126	1,19	1,659	1,785
2	0,093	16,9	0,41	23,61	6,74	1,262	0,107	1,19	1,9	2,007
3	0,136	16,6	1,45	23,81	7,21	1,26	1,318	1,189	1,865	3,183
4	0,127	20,4	1,17	23,98	3,62	1,276	0,874	1,189	2,316	3,19
5	0,19	19,7	1,41	24,01	4,36	1,273	1,266	1,188	2,229	3,495
6	0,142	20	0,99	24,13	4,1	1,274	0,62	1,188	2,273	2,893
7	0,176	20,2	1,66	23,75	3,57	1,276	1,76	1,19	2,298	4,057
8	0,14	22,3	0,57	24,19	1,89	1,284	0,212	1,188	2,551	2,763
9	0,118	24,3	0,76	25,22	0,93	1,289	0,375	1,184	2,779	3,154
10	0,146	21,4	0,41	25,02	3,63	1,276	0,106	1,184	2,424	2,53
11	0,144	21,6	0,58	24,58	2,99	1,279	0,215	1,186	2,457	2,671
12	0,151	6,6	0,39	24,97	18,39	1,211	0,092	1,185	0,708	0,8
13	0,127	9,5	1,01	25,37	15,86	1,222	0,618	1,183	1,031	1,649
14	0,076	4,5	0,29	24,32	19,82	1,205	0,049	1,187	0,483	0,532
15	0,238	12,5	2,78	25,69	13,14	1,234	4,773	1,182	1,371	6,144
16	0,149	13,3	1,41	24,98	11,7	1,24	1,227	1,185	1,462	2,69
17	0,173	11	0,69	25,37	14,42	1,228	0,29	1,183	1,193	1,483

18	0,149	7,5	0,53	24,97	17,43	1,215	0,172	1,185	0,815	0,987
19	0,235	11,5	0,68	25,76	14,26	1,229	0,281	1,182	1,252	1,533
20	0,193	13,1	2,26	23,6	10,52	1,245	3,172	1,19	1,454	4,625
21	0,135	10,2	0,77	23,52	13,32	1,233	0,364	1,19	1,123	1,488
AVG:	**0,151**	**15,14**	**0,98**	**24,49**	**9,36**	**1,251**	**0,858**	**1,187**	**1,697**	**2,555**

5.4 Results of the regression analysis

$$\text{ACH} = n = a \cdot \Delta T + b \cdot v^2 + c \quad [1/h] \tag{3}$$

Constants of the regression analysis:

$$ACH = 0{,}009461005 \cdot \Delta\, \text{T} + 0{,}010126854 \cdot \text{v}^2 + 0 \tag{7}$$

The equation above provide an acceptable approximation for the test results but not yet validated against a large number of test at various sites.

6 CONCERNS

The spread of the data is too large the method to be proved with full confidence.

Possible reasons:

1) The BlowerDoor set of equipment was installed in the door. As a consequence the air leakage through the gaps of the door is not included in the BlowerDoor test, but is in the Tracer Gas tests. The only other opening is the window.
2) Wind direction is not recorded, assumed that it is perpendicular to the surface. There any many turbulences around the test façade.
3) The properties of the air flow through the gaps might change as a consequence of the variation of the air speed. Might be turbulent at high speed during BloerDoor test but laminar during normal conditions.
4) The properties of the air gaps might change (become wider or narrower) as a consequence of the higher than normal pressure.

7 CONCLUSIONS

The overall aim of the research has been fulfilled: to elaborate a method to calculate the natural ACH based on BlowerDoor test by taking the temperature difference and the wind speed into the account. Applying the method the average ACH can be specified on the basis of the average ambient temperature and the average wind speed of the region for certain period of time e.g. heating season. This method is simple but reasonably refined. The ACH derived by the method increases the reliability of the energy balance calculations.

However the parameters and constants are not finalised yet. Further tests are required to achieve more reliable values.

8 ACKNOWLEDGEMENTS

Acknowledgement for Dr. Hámori Ildikó Perjésiné associate professor, Head of Mathematics Department, Faculty of Engineering and Information Technology, University of Pécs, HU for her support in mathematics and Maple.

Acknowledgement for László Budulski, engineer, HVAC Department, Faculty of Engineering and Information Technology, University of Pécs, HU for his contribution in testing and data processing.

Acknowledgement for EU Hungary-Croatia IPA (Instrument for Pre-Accession Assistance) Cross-border Co-operation Programme for funding the equipment procurements.

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