Analyzing air-tightness measurements using fan pressurization method on forty residential houses in Athens, Greece

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ABSTRACT

Regular air tightness and infiltration measurements were performed in forty houses, in the area of Attica, Greece. Two measurement methods were used, the tracer gas decay method and the Blower Door tests method. Blower Door measurements were done in accordance with EN ISO 13829 [1]. Ambient conditions and temperature fluctuations inside the houses were measured as well. A classification of houses examined, based on experiments' results was acted out in accordance with EN ISO 13790 [2]. The houses were classified into three air tightness categories, in regard to their air tightness in natural conditions and at a pressure difference of 50 Pa. Furthermore, the total frame length was estimated for the whole housing stock, and a correlation between the air tightness measurements at a pressure difference of 50Pa and the total frame length was examined, for the sample of buildings and for each air tightness category. A correlation between the airflow values, as they resulted from the fan pressurization method and the average infiltration rates, calculated by the tracer gas experiment results, has been extracted. Moreover, the effect of climate data including temperature and windiness and construction quality on the houses' infiltration characteristics has been investigated.

1. INTRODUCTION

Infiltration rates and therefore buildings' air tightness are important because they affect the energy use of the building and they impact the transport of pollutants so as the indoor air quality. From an energy standpoint alone it is almost always desirable to increase air tightness but indoor air quality may suffer [3].

Single-family dwellings in Greece are usually not equipped with mechanical ventilation system. When doors and windows are closed, air exchange occurs only by uncontrolled air leakage across the building envelope. The movement of air through leaks, cracks or other openings of the building envelope is known as air infiltration. High infiltration rates can cause excessive energy demand because of the need to condition the infiltrating air. At the other hand, insufficient air exchange can lead to high exposure to pollutants such as emissions from building materials, cooking, smoking or cleaning activities [4]. It is very important to estimate leakage characteristics in the housing stock in terms of construction's type and quality, buildings' age and climatic conditions, in order to control the energy demand and the pollutants' concentration.

Tens of thousands of fan pressurization measurements have been made in USA buildings. These data were collected and were analyzed in order to determine relevant leakage characteristics in the US housing stock in terms of construction type and quality, region and age [4], [5]. Very few information is available regarding infiltration of buildings in the Mediterranean area. In Italy, the issue building air tightness is still not widespread and ACH limits at 50 Pa pressure difference have not been introduced yet. However, many air tightness measurements were performed in residential buildings, last decade [6]. In France, air tightness measurement studies were performed too, in order to identify the major factors that affect the buildings' leakage area and improve the energy performance of buildings.

Tracer gas measurements were performed in order to evaluate the infiltration rates for each building. Blower door measurements were also performed but the data of this method could not be generally used to estimate airflows at natural conditions. The name comes from the fact that in the common utilization of the technology there is a fan mounted in a door [3]. Blower door data estimates airflows at a variety of pressures and mostly at a 50 Pa pressure difference. The advantage of this method is that their results are less affected by climatic conditions.

2. METHODS

2.1 Description of the residences

Regular infiltration and air-tightness measurements were performed in forty residences in the area of Attica, Greece. All forty residences are single-family buildings or double-family buildings and their entrance door is totally exposed to the exterior environment.

2.2 Measurements of ambient conditions and indoor temperature fluctuation

Ambient conditions were measured using the mobile meteorological station of Group of Environmental Studies of University of Athens. During experiments, ambient temperature, wind speed and wind direction were being traced, at 10m height and at building's average height above the ground. Outdoor dry bulb temperature at the level of the main entrance and indoor temperature in three different building zones were being traced.

2.3 Infiltration measurements using the tracer gas "decay" method

Infiltration rate was determined by using the "concentration – decay" method. The tracer gas equipment consists of a central unit that controls the gas injection and sampling, an infrared radiation detector and a gas bottle. Mixing was ensured by the use of fans. The (inert) gas indicator that was used was N_2O.

Tracer gas was injected into each of the four building zones through four separate tubes - channels, while all house openings remained closed. As soon as the inert gas – indoor air mixing was complete and N_2O concentration target value was reached, the evolution of the gas concentration in each zone was measured.

The infiltration rate, in air changes per hour (ACH), for each of the four building zones that were tested as well as for the entire building (ACH_{tg}), was calculated by using the traced concentration values.

Table 1. Average values of infiltration rate (ACH_{tg}) and air tightness (ACH_{50}) of the buildings.

House	ACHav	ACH50	House	ACHav	ACH50
1	0.71	1.87	21	0.99	7.40
2	1.21	5.72	22	2.38	6.33
3	0.97	5.4	23	0.74	2.18
4	1.14	8.52	24	0.51	8.80
5	1.56	11.3	25	1.10	7.16
6	1.14	2.22	26	0.62	3.44
7	0.35	7.51	27	1.02	2.30
8	0.33	8.5	28	0.55	10.69
9	0.83	11.12	29	0.23	7.34
10	0.99	9.58	30	0.99	7.20
11	0.86	8.86	31	0.95	10.10
12	0.62	1.98	32	1.16	13.10
13	0.59	2.44	33	0.81	5.94
14	0.71	2.69	34	0.36	5.06
15	1.38	10.49	35	0.50	8.51
16	1.46	8.29	36	0.22	5.30
17	0.49	6.39	37	0.77	10.20
18	0.32	7.68	38	0.65	3.50
19	0.90	5.94	39	0.52	2.95
20	0.40	9.3	40	0.50	4.50

Table 1 contains the average infiltration rate of the whole building, for all studied houses.

2.4 Air tightness measurements using the fan pressurization method

Each building's air tightness was measured using a Blower Door in accordance with EN ISO 13829.

Blower door has a variable speed fan so that the pressure difference can be adjusted and an aluminum frame in order to seal the fan tightly into the doorjamb. The system is mounted in each house entrance door to measure the leakiness of the house. In order to measure the leakiness of the house, the blower door measures both the airflow through the fan and the pressure difference between the house inside and outside. Measurements are taken by increasing the speed of the fan until the pressure difference between the house and outside is at the desired level. Typically, testing is done between 20 and 70 Pascals (Pa). The airflow out of the house at that pressure is then recorded.

Measurements were carried out following method A – common building use – of EN ISO 13829 while also applying a pressure difference of 50Pa in order to fulfill the requirements of EN ISO 13790 [2] (former EN ISO 832). All experiments' results are acceptable as they fulfill EN ISO 13829 criteria.

Table 1 contains the calculated air changes per hour values for a 50Pa pressure differential (ACH50) and the criteria parameters values.

3. RESULTS

3.1 Classification of houses examined based on experiments' results

Tracer gas decay and pressurization test method were used in order to estimate the infiltration rate under natural conditions and the air tightness of the building respectively. According to EN ISO 13790 (former 832), house buildings can be classified into three categories in regard to their air tightness under natural conditions (infiltration) or at a pressure difference of 50Pa (ACH50) between indoor and outdoor air.

Table 2. Tightness levels for natural ventilated, non-shielded single-family buildings

Air change rate (h^{-1}) at 50Pa	Ventilation rate ((h^{-1}) for naturally ventilated single family houses	Envelope tightness level
10	1.5	Low
4 – 10	0.8	Medium
4	0.5	High

Table 2 shows the limit values (ACH_{tg}) of three air tightness levels for non shielded, naturally ventilated single family buildings with more than one exposed façade and their corresponding values when a 50 Pa pressure difference is applied between indoor and outdoor environment (ACH_{50}). Figure 1 and 2 contain the rating of each tested building, resulting from tracer gas decay and fan pressurization measurements.

3.2 Correlation between air tightness measurements and total frame length

One important factor associated with air tightness of a building is the total window frame length divided by the building's net volume. The total window frame length was estimated for each building, it divided by the net volume and the "frame length factor (FLF)" was defined.

FLF = (TFL) / (NV) (1)

where *FLF* is the frame length factor, *TFL* is the total window frame length and *NV* is the net volume of the building. Linear correlation between the air tightness measurements at a pressure difference of 50 Pa and the frame length factor FLF was performed for each one of three air tightness levels (high, medium, low).

As it can be seen at Figure 3, the linear correlation for the "high" and the "medium" air tightness levels give lower R^2 values compared with high value of R^2 = 0.88 of "low" air tightness buildings. In case of "low air tightness" houses, the most important linear correlation between FLF and air tightness measurements is noticed, while this category is mostly affected by the total window frame length.

However, the sample of buildings is small and the correlation should be further checked in many cases.

3.3 Correlation between the average infiltration rates, the "fan pressurization method" results and the Frame Length factor

A correlation between the airflow values, as they resulted from the fan pressurization method, the average infiltration rates, calculated by the tracer gas experiment results and the Frame Length Factor has been extracted.

All tested houses were classified in regard to their frame type. The most common frame types of the examined houses are those with wooden frame and those with aluminium sliding frames.

A correlation between the two method's results was investigated for each "frame type" category. The correlation between three parameters gives the best results in case of buildings with wooden frame (R^2 = 0.99), and with aluminum frame (R^2 =0.98) (Figure 4).

The effect of climatic data in air infiltration was investigated for each "window frame type" category. For the case of the wooden window frames (R^2=0.80) the effect of temperature difference and wind speed in air infiltration is bigger than in the case of sliding aluminium frames (R^2=0.75). However, the forty buildings have significant differences in their construction's quality as well as in their age, so the climatic conditions' effect is not clear. It would be desirable to measure the air infiltration for one specific building in different climatic conditions, so that we can have the appropriate results.

4. CONCLUSIONS

Air tightness of forty single-family buildings was calculated under natural conditions and under a 50 Pa pressure difference between indoor / outdoor environment. The buildings were rated according to their measured air tightness. There is no correlation between infiltration measurements at natural conditions and the total window frame length. It is necessary to study the effect of climatic conditions on these infiltration measurements. A correlation between air tightness measurements at a 50 Pa pressure difference and the total window frame length was noticed, mainly at the "low air tightness" buildings. The total frame length affects the air leakage of each house and its air tightness. Also a classification of buildings according to their window frame type was realized, and a correlation between the airflow values, as they resulted from the fan pressurization method and the average infiltration rates, calculated by the tracer gas experiment results, has been extracted for each frame type category. However, the sample of buildings is very small and a large number of experiments are required.

APPENDIX A. Figures

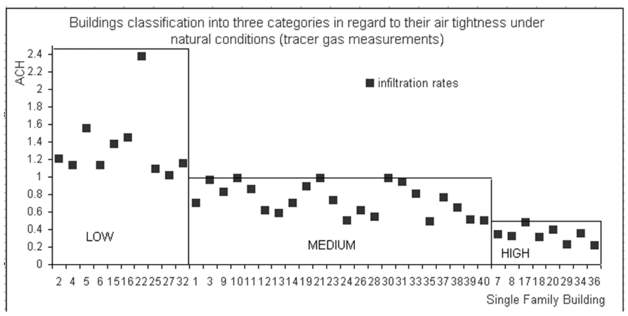


Figure 1. Building classification into three categories in regard to their infiltration under natural conditions (measurements with tracer gas "decay" method)

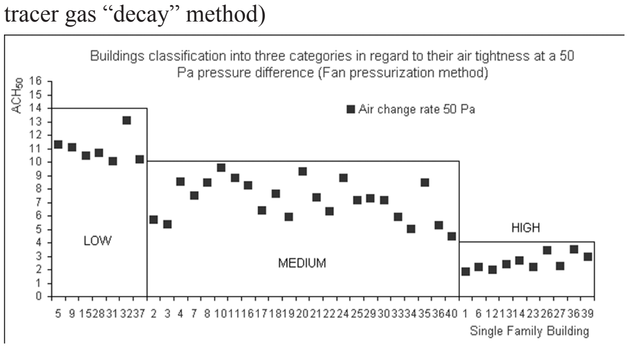


Figure 2. Building classification into three categories in regard to their air tightness at a 50 Pa pressure difference (Fan pressurization method)

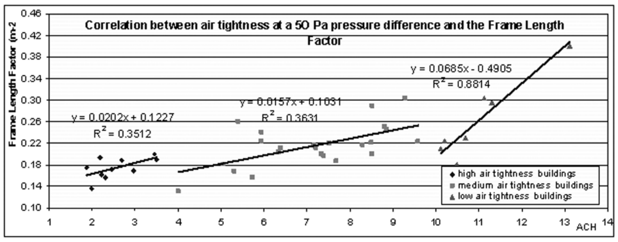
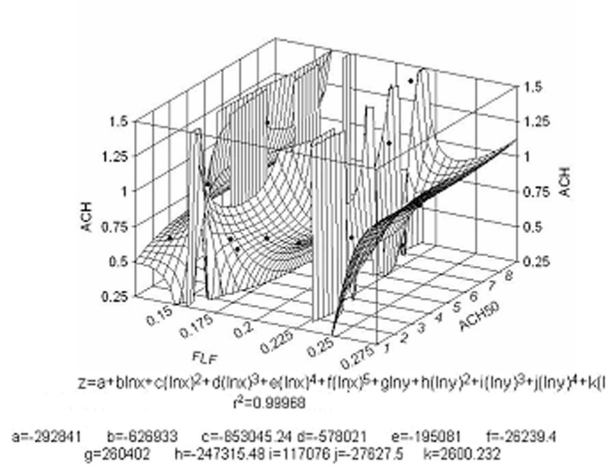
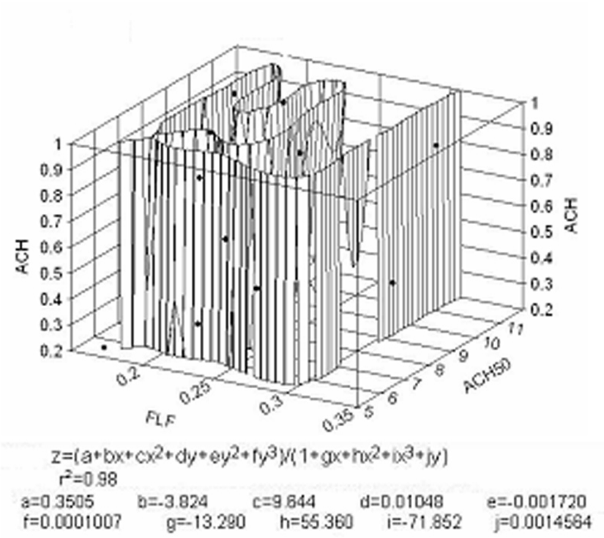


Figure 3. Linear correlation between air tightness at 50 Pa pressure difference and the total frame length factor for three air tightness categories



Buildings with wooden window frame



Buildings with aluminum window frame

Figure 4. Correlation between infiltration rates (ACH), air tightness at 50 Pa pressure difference (ACH_{50}) and the total frame length factor (FLF) for each frame type category.

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