EVALUATION OF SELECTION CRITERIA OF AN AIR TIGHTNESS MEASUREMENT METHOD FOR MULTI-FAMILY BUILDINGS

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ABSTRACT

There are often practical limitations to measure the airtightness of a multifamily building as a whole as described in EN 13829. The building may be too large; the floors may not be connected with an internal airflow path; or there may be large leaks in the stairway. In such cases, the measurement is performed on a sample of apartments for compliance check purposes, which raises a number of questions especially as legal disputes may arise.
Therefore, our objective was to evaluate the limitations of several sampling methods and suggest improvements based on a field data from ten new multi-family buildings, representing 208 units. In each building, we measured a) the air tightness on the whole building, b) in each apartment, and c) in the common areas of the building. The envelope area was found to be the most reliable parameter as a selection criterion for the sampling method, i.e., it is the best parameter we found to correlate airtightness with. Our analysis also confirms that the leakage in the common areas can have a significant impact on the air permeability of the whole building, especially in the presence of with lift shaft and/or basement parking.

KEYWORDS

Airtightness measurement, multi-family buildings, sampling method.

INTRODUCTION

European standard EN 13829 [1] describes the measurement method of air permeability of buildings. This measurement is meant to be performed on the whole building. In the case of multi-family buildings, there are often practical limitations to measure the air permeability of the whole building. The main reasons we found are: the building is too large; the floors are not connected with an internal airflow path; or the stairway is very leaky, e.g. due to a lift shaft or a fire access door. For these buildings, it is common to measure the airtightness of individual apartments separately. Note that although there exist protocols to better evaluate the leakage to the outside (i.e., avoiding double-counts of leakage to interior spaces), they are seldom used in practice.
Because these measurements (if they are performed) are usually necessary for compliance checks, some organizations or regulations propose specific rules a) to choose the units that must be tested; and b) to extract the criteria that will be used. Walther and Rosenthal [2] give an overview of different sampling methods in use in Europe. In Germany, at least 20% of the

total number of apartments should be tested, with at least one tested apartment at the top floor, one at an in-between floor and one at the ground floor. In UK, zone testing should cover at least 20% of the building's envelope area. In France, 3 apartments have to be measured if the building has 30 units or less, and 6 apartments otherwise. The apartments must have the largest ratio of floors and windows length per floor area and must be located at the top, intermediate and ground floors. The French method has been included in the French application guide GA P 50-784 of EN ISO 13829 [3]. However, to our knowledge, there has not been any careful evaluation of the relevance of these rules.
The research project MININFIL has been conducted since 2008 with the support of ADEME and the French ministry of ecology in order to enhance the knowledge of professionals on the air tightness and its impact on the energy performance in buildings. Under the task 3 of the project, an extensive campaign of airtightness field measurements has been carried out in ten new multi-family buildings. In each building, the air tightness was measured for all the apartments and for the whole building. This paper presents the approach used and analyses performed to compare several airtightness assessment methods in muti-family buildings based on our field data.

METHOD

The air permeability measurements have been performed with the fan pressurization method according to the standard EN ISO 13829 [1]. The aim of the measurements was to identify separately the air permeability of each apartment, the common areas, and the whole building. Therefore, three types of air permeability measurements have been carried out in each building:

1. Individual measurements of the air leakage rate at 4 Pa "Q_{4Pa_apart}" (m^3/h) of each apartment of the building with a blowerdoor positioned on the entrance door of the apartment. The entrance door of the building is fully opened.
2. A measurement of the air leakage rate at 4 Pa "$Q_{4Pa\_whole\ building}$" of the whole building, including leakages in apartments and common areas. This measurement is realized with a blower door using a single or double fan. The blower door is located at the entrance door of the building. The doors between apartments and common areas are fully opened.
3. A measurement of the air leakage rate at 4 Pa "$Q_{4Pa\_common\ areas}$" of the common areas. This measurement is similar to the previous, but this time the doors between apartments and common areas are closed, in order to eliminate the leakage in apartments from the measurement. This requires that the doors are air-tight. Additional tightening of the doors was done if necessary.

Table 1 presents the multi-family buildings characteristics. The number of apartments per building varies between 12 and 38, and the number of the levels between 2 and 7. The volume of buildings varies between 2365 m^3 and 5704 m^3, with 2 buildings larger than 4000 m^3.

Building code	**B01**	**B02**	**B03***	**B04**	**B05***	**B06**	**B07**	**B08**	**B09**	**B10**
# of levels	4	3	2	4	3	5	5	4	7	5
# of flats	17	12	17	20	16	17	17	16	38	36
Area (m^2)	1325	956	1266	1486	1150	1455	1248	1375	2256	2246
Volume (m^3)	3280	2365	3150	3700	2893	3544	3446	3031	5704	5175

Table 1: The description of the assessed buildings.

The measurements have been done at the end of the building construction. All of the apartments were unoccupied, in order to facilitate the access to all the parts of the building. However, the global measurements of buildings B03* and B05* have been disturbed by the presence of workmen during the tests. Therefore, the global measurements for these building will not be considered in the analysis.

RESULTS

In France, the air permeability "$Q_{4Pa\text{-}Surf}$" ($m^3/h/m^2$) is calculated as the ratio between the air leakage rate at 4 Pa and the envelope area of the building except the floors area "A_{TBAT}". The new thermal regulation sets the limit value required for air permeability to 1.0 $m^3/h/m^2$ for multi-family buildings. This value is based on the French regulatory low-energy building standard (BBC-Effinergie). We present the results here with the French air permeability indicator.

The ten buildings represent a total of 208 apartments. For the individual measurements, more than half of the apartments (52%) show lower results than the limit value of 1.0 $m^3/h/m^2$. For the measurement of the whole buildings, only three buildings (over eight) are lower than the limit value. The major part of the leakage in the apartments (40%) has occurred across the fenestration (joints at window sash, window sill, and shutter box), while 30% of the leakage occurs at the joints of hatch and ducts, and 25% across the electricity plugging. The leakage across the joints between walls and slabs are negligible.

Figure 1 presents the results of the individual and whole measurements for each building. Figure 1 shows that that the individual measurements of air permeability are very heterogeneous between buildings, and between apartments in the same building in some cases. Based on our observations, the buildings can be classified into two major categories:

- Buildings B05*, B06, B07 and B08 having the whole measurement and the individual measurements globally below the required limit value (1.0 $m^3/h/m^2$). For these buildings, the individual measurements are uniform and vary in a narrow range.
- For the other buildings, both the whole measurement and the median of the individual measurements are greater than the limit value. The individual measurements in each building are very heterogeneous and vary in a wide range. In B09, the upper value of the individual measurements is almost ten times greater than the lower value.

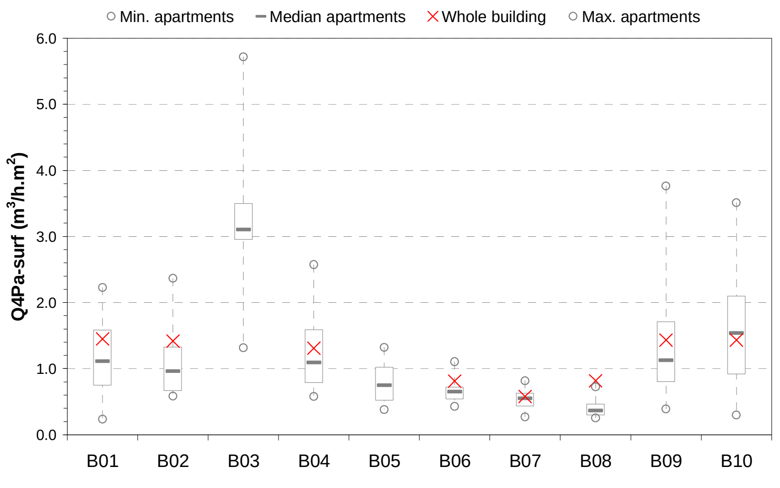

Figure 1: Box plot of the measured air permeability values in each building: the box lines indicate the statistic results of individual measurements and the red marks indicate the measurement of the whole building in each case. The whole measurements of B03* and B05*have been excluded.

Analysis of the selection criteria

GA P50-784 evaluates the air permeability of the whole building through the weighted average of the sample of apartments. Besides it does not impose any requirement on the individual measurements. However, it requires compliance of the sample to a selection criterion meant to avoid samples heavily biased towards favourable units. This criterion is based on the ratio of the length of floor and windows per unit of floor area "(PVl+Pl)/Shl". The method requires the selection of apartments with the largest value of this ratio, as they are considered to be potentially the leakiest apartments.

Figure 2 shows on the left hand-side the variation of the air leakage rates at 4 Pa versus this ratio. It shows no significant correlation between these two parameters (r^2=0.02); in fact, if anything, the air leakage rate seems to decrease with this ratio. Consequently, this criterion "(PVl+Pl)/Shl" seems inappropriate to select the leakiest apartments. We have analysed the correlation with a number of parameters with the help of "principal components analysis". In turn, we found that the correlation was more significant (r^2=0.20) although it remained weak with the envelope area "A_{TBAT}" (see right hand-side of Figure 2). This suggests that although not ideal, the envelope area is more relevant as a selection criterion than the ratio of the length of floor and windows per unit of floor area.

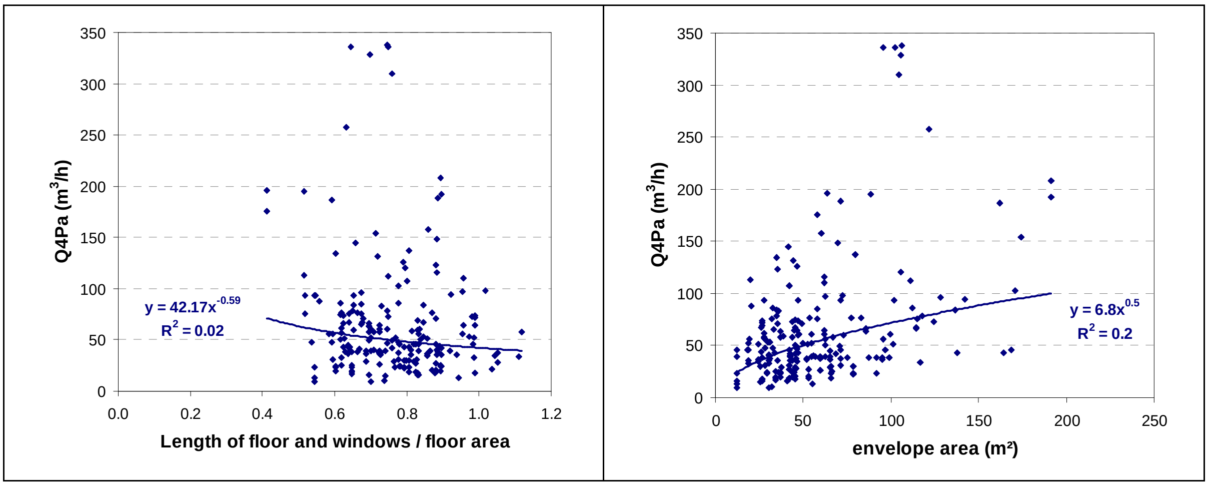

Figure 2: The variation of the measured air leakage rates at 4 Pa as a function of the sampling criteria (the GA P50-784 sampling criteria on the left panel and the envelope area excluding floor on the right panel).

Comparison of the GA P50-784 sampling method against the measurements

GA P50-784 method based on a sample of units has been compared to the results of the measurements on all units. The left panel of Figure 3 presents a comparison between the weighted average air permeability of the sample of apartments and the weighted average of all the apartments for each building. For the buildings with uniform individual measurements lower than the limit value (B05*, B06, B07, and B08), the results of the samples are very close to those obtained with all the apartments. For the other buildings, the difference is more significant.

The right panel of Figure 3 presents the comparison of the weighted average air permeability of the samples of apartments (both the sample of GA P50-784 method, and the sample of all the apartments) against the measurement of the whole building. For both samples, the weighted average air permeability of apartments is always lower than the air permeability of the whole building as it doesn't account for the leakage in the common areas caused by the lift shaft, the parking basement and other shafts and hatches. The greatest difference was found in the case of buildings B08, B09 and B10 with lift shaft and basement parking in the common areas.

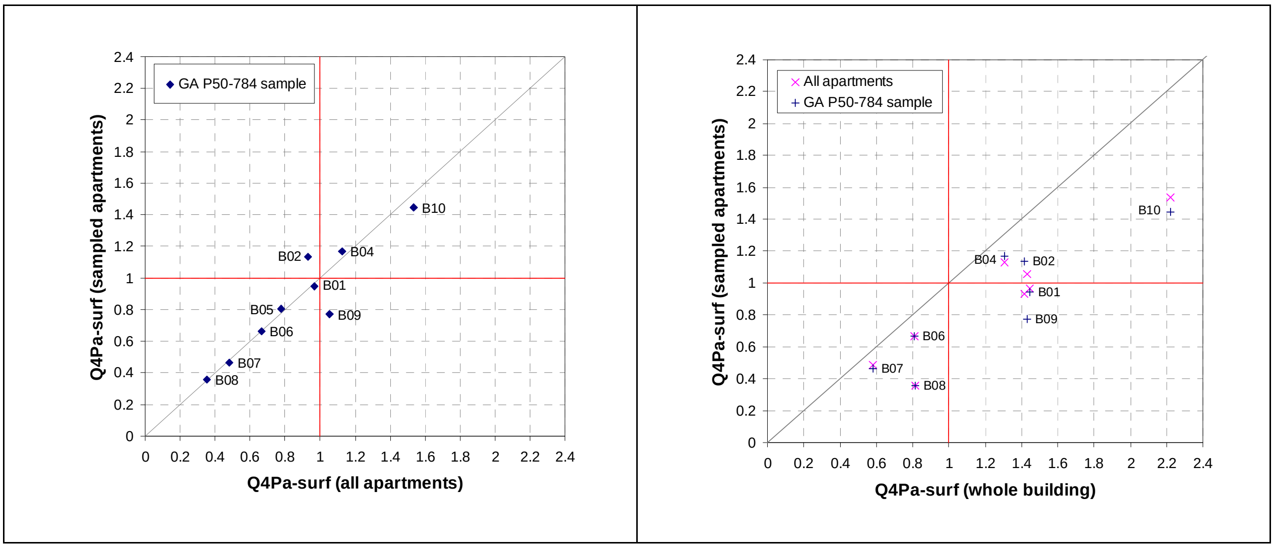

Figure 3: Comparison of the weighted average air permeability of the samples against the weighted average of all the apartments on the left panel, and against the whole building measurement on the right panel.

Analysis of the air leakage in the common areas

In order to evaluate the airtightness of the common areas, we have realised a whole building measurement with the Blower Door positioned on the entrance door of the building. The doors between the apartments and the common areas were all closed and airtight, except for the building B09 where the doors were very leaky at the moment of measurement (the results of this building will be excluded from the analysis).

The measured air flow rate accounts for all the leakages in the common areas. It may include parasitical flow through leaks to adjacent apartments of the common areas. The part of the parasitical flow depends on the airtightness of the walls separating the apartments and the common areas.

The left panel of the figure 4 presents for each building a comparison between the measured air leakage rate of the whole building (including the apartments and the common areas) against the sum of the measured air leakage rate for each apartment and the measured air leakage rate of the common areas.

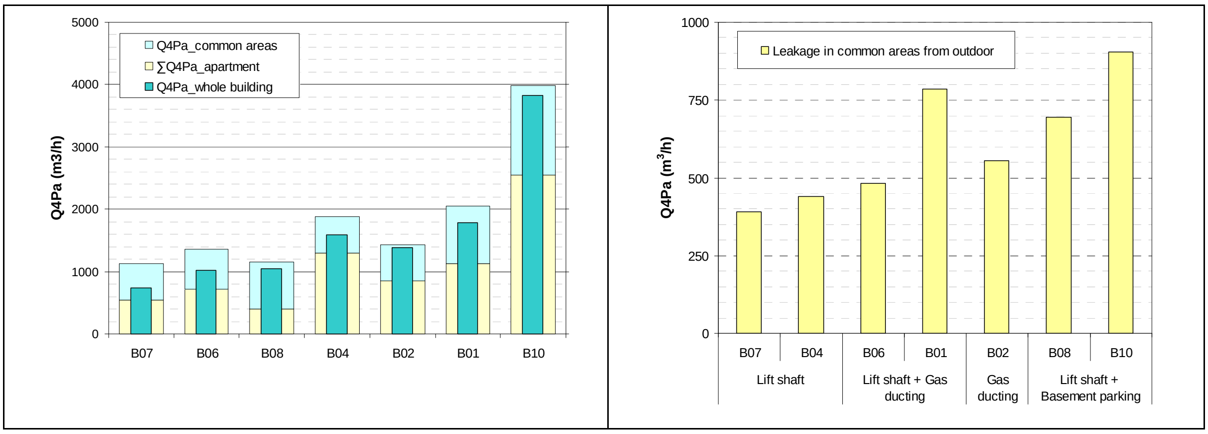

Figure 4: Comparison between the measured air leakage rate of the whole building and the sum of the measured air leakage rate of the apartments and the common areas (left panel). Air leakage in the common areas from the outdoor (right panel).

Ideally if there were no leaks between the apartments and the common areas, the air leakage of the whole buildings should be equal to the sum of the air leakage of the apartments and the common areas. As we can see on the figure, it is always lower than the sum of the apartments and the common areas air leakages. This is due to the air flow through leaks between the apartments and the common areas, which is accounted twice in the apartments and the common areas measurements. Hence, the air leakage of the whole building can be written as in equation 1, where “$Q_{4Pa\_common/apart}$” is the air flow through leaks between the apartments and the common areas. The air leakage in the common areas can also be written as the sum of two parts : the air flow from the apartments “$Q_{4Pa\_common/apart}$” and the airflow from the outdoor “$Q_{4Pa\_common/outdoor}$” (equation 2). From these two equations, we can calculate the air leakage in the common areas from the outdoor where “$Q_{4Pa\_whole\ building}$”, “Q_{4Pa_apart}”, and “$Q_{4Pa\_common\ area}$” are measured values.

$$Q_{4Pa\_whole\ building} = \Sigma Q_{4Pa\_apart} + Q_{4Pa\_common\ areas} - 2 * Q_{4Pa\_common/apart} \quad (1)$$

$$Q_{4Pa\_common\ area} = Q_{4Pa\_common/apart} + Q_{4Pa\_common/outdoor} \quad (2)$$

The results of the calculation are given on the right panel of figure 4. The amount of the air leakage at 4 Pa through lift shaft or gas ducting in the common areas is about 500 m^3/h. In the case of lift shaft with basement parking, it becomes more important (between 700 and 900 m^3/h). The air leakage in the common areas represents 24% up to 67% of the air leakage of the whole building.

CONCLUSION

A detailed campaign of air permeability measurements has been carried out in ten multi-family buildings in France. For each building, the air permeability of individual apartments and the whole building have been measured. This represents a total of 208 units on which sampling method of the implementation guide GA P50-784 has been evaluated. The results show that the sampling method gives good results only in the case of buildings with uniform individual measurements. Moreover, the selection criterion of the GA P50-784 sampling method does not identify the apartments with greatest risk of leakage. The use of another criterion based on the envelope area appears more relevant. The results have shown that the leakage in the common areas are significant and can have an important impact on the air permeability of the whole building in the case of common areas with lift shaft and basement parking. These leakages should be considered in the measurement method if it extrapolates the individual measurements to the whole buildings.

ACKNOWLEDGEMENTS

This work has been conducted under the task 3 of the research project MININFIL that is financed by the French Mininstry of Housing and the French Agency for the Energy Efficiency and the Environment ADEME.

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