Ventilation performances in French dwellings : Results from field observations and measurements

Karine GUILLOT [1]* - Andrés LITVAK [1] - Marc KILBERGER [1] - Didier BOZE [2]

[1] CETE de Lyon - DVT/HTC
46, rue St Théobald BP 128
38081 L'ISLE d'ABEAU Cedex - FRANCE

[2] CETE de Lyon - Laboratoire Régional d'Autun
Boulevard de l'Industrie, Z.I. de Saint Andoche BP 141
71406 Autun Cedex - FRANCE

* *corresponding author :* tel : int/ 33 4 74 27 51 66 fax : int/ 33 4 74 27 52 52
e-mail : karine.guillot@equipement.gouv.fr

ABSTRACT

This paper presents a recent field measurement study undertaken in 1999 on 73 recent French dwellings. The study presented the opportunity to assess the conformity and the performances of the dwelling ventilation systems and to assess the impact of infiltration on airchange rates. The following aspects were analyzed : (1) the type of ventilation facilities in the dwellings ; (2) the defaults in the installed systems and in their operation ; and (3) the measured air flow rates, as compared to the French standard required levels. For each dwelling, we investigated the infiltration air exchange contribution as compared to the total air change rate. For this, on site depressurization tests were performed on each dwelling with the *« blower door »* technique. With a first measurement, we assessed the sole air leakage rate, while with a second test, we measured the total air change rate (including air flow through ventilation air inlets). Comparison of results led us to assess the infiltration air contribution into the total air exchange rates. The results of the study show a significant proportion of defaults in ventilation systems, in terms of conformity as well as in terms of global performance. Besides, airflow rate assessments reveal a significant contribution of air infiltration when compared to the total airchange rates.

Key Words

Field measurements ; Infiltration ; Ventilation ; Dwellings

1. INTRODUCTION

The present French construction standard related to ventilation, dated from 1982, requires from ventilation facilities in dwellings to permit both a permanent and a general ventilation [5] . These compulsory requirements remain the two key principles of the French standard in this field. The aim is double : to limit energy losses and, meanwhile, to achieve adequate indoor air quality. According to the number of principal rooms, specific airflow rate levels are mandatory in each service room (kitchen, bathroom, W.C.), while minimum airflow rates are set for the whole dwelling and for the kitchen. Although these requirements are mandatory, on site controls and recent studies have shown that ventilation French standard is not respected in the majority of the dwellings [3] .

1-1) Objectives

This work is part of a 18 month study that aims at improving our knowledge of the actual thermal performances of French dwellings in terms of ventilation and airtightness impacts. The overall results of this study are reported elsewhere [2]. A companion paper in the proceedings of the 21st AIVC conference presents the results related to airtightness performances of the dwellings and the experimental protocole in more details [4] .

2- METHODS

2-1) Background : French ventilation standard

French ventilation standard of March 1982 [5] contains the principle of an air changing based on air transfer from principal rooms (bedroom, living room) to service rooms (kitchen, bathroom and toilet). For this standard, air is extracted by mechanical or natural ventilation, from ventilation inlets to outlets. Furthermore, air transfer throughout dwelling has to be possible even with closed doors, with a gap under the door for example.

Q_m	Number of principal rooms						
	1	2	3	4	5	6	7
Minimal air flow rates in kitchen m^3/h	**20**	**30**	**45**	**45**	**45**	**45**	**45**
Total minimal air flow rates	**35**	**60**	**75**	**90**	**105**	**120**	**135**

Table 1 Minimal air flow rates Qm required as a function of the number of principal rooms

The standard requires minimal air flow rates Qm, see Table 1. It also specifies the specific air flow rates to be obtained (not necessary by the same time) in each service rooms, see Table 2. In Table 2, Q_M is the sum of specific air flow rates to be obtained in each service rooms. It is calculated in the case of one bathroom and one WC.

Number of principal rooms	Air flow rates required (m3/h)					
	Kitchen	Bathroom	additional bathroom	WC	additional WC	**Q_M (1)**
1	*75*	*15*	*15*	*15*	*15*	**105**
2	*90*	*15*	*15*	*15*	*15*	**120**
3	*105*	*30*	*15*	*15*	*15*	**150**
4	*120*	*30*	*15*	*15*	*15*	**180**
5 and more	*135*	*30*	*15*	*15*	*15*	**195**

Table 2 Minimal air flow rates required as a function of the number of principal rooms

2-2) Observations and measurements on ventilation facilities

To assess the conformity of ventilation facilities, the following points were checked :

- types and models of ventilation inlets and outlets
- ability to supply a general and permanent ventilation
- the set up quality of ventilation inlets / outlets
- the free air transfer throughout the dwelling
- the defects of the equipment.

Airflow rates on mechanical ventilation (except for humidity controlled exhaust ventilation) and differential pressures in ventilation exhausts were measured and compared to standards and recommendations from the manufacturer.

2-3) Airtightness measurements

Two types of depressurisation tests with the "blower door" technique were performed on each dwelling. This technique is commonly used and described in the literature (see the companion paper [4]). From a first depressurization test, we assessed the air leakage rate caused by the sole enveloppe leakage defects, while with a second test, we measured the total air change rate (including air leakage rate and ventilation air flow through air inlets). The results led us to assess the ratios of the infiltration air contribution to the total airchange rates (see Figure 1).

3- RESULTS OF OBSERVATIONS ON VENTILATION FACILITIES

Different types of ventilation facilities were observed among the sample, see Figure 3. Among the 2 observed cases of "no ventilation facilities" in single family dwellings, no air inlets were installed. In one case, a natural exhaust duct was installed in the kitchen, while the other case presented air vents (grilles) in the kitchen and in the bathroom. In both cases, the observed facilities prevented the dwelling from complying with the mandatory regulation.

Among the 40 dwellings equipped with a mechanical ventilation (except humidity controlled ventilation), defects were observed in 17 cases due to installed facilities (7 cases) and/or to set up quality problems (13 cases).

More precisely, defects on facilities represent :

- lack of air inlets (3 cases)
- excess of air inlets (1 case)
- air inlet set up in service room (2 cases)
- mechanical cooker hood installed on ventilation exhaust (1 case).

Defects caused by bad set up conditions concern :

- adjustment of air flow rate which is impossible or difficult (5 cases)
- air inlets set up in the wrong way (3 cases)
- no sign for normal and specific air flow rates (3 cases)
- defaults in the exhaust duct or in the connection with the exhaust outlet (3 cases)
- wrong position of the air outlet on the wall / roof (2 cases).

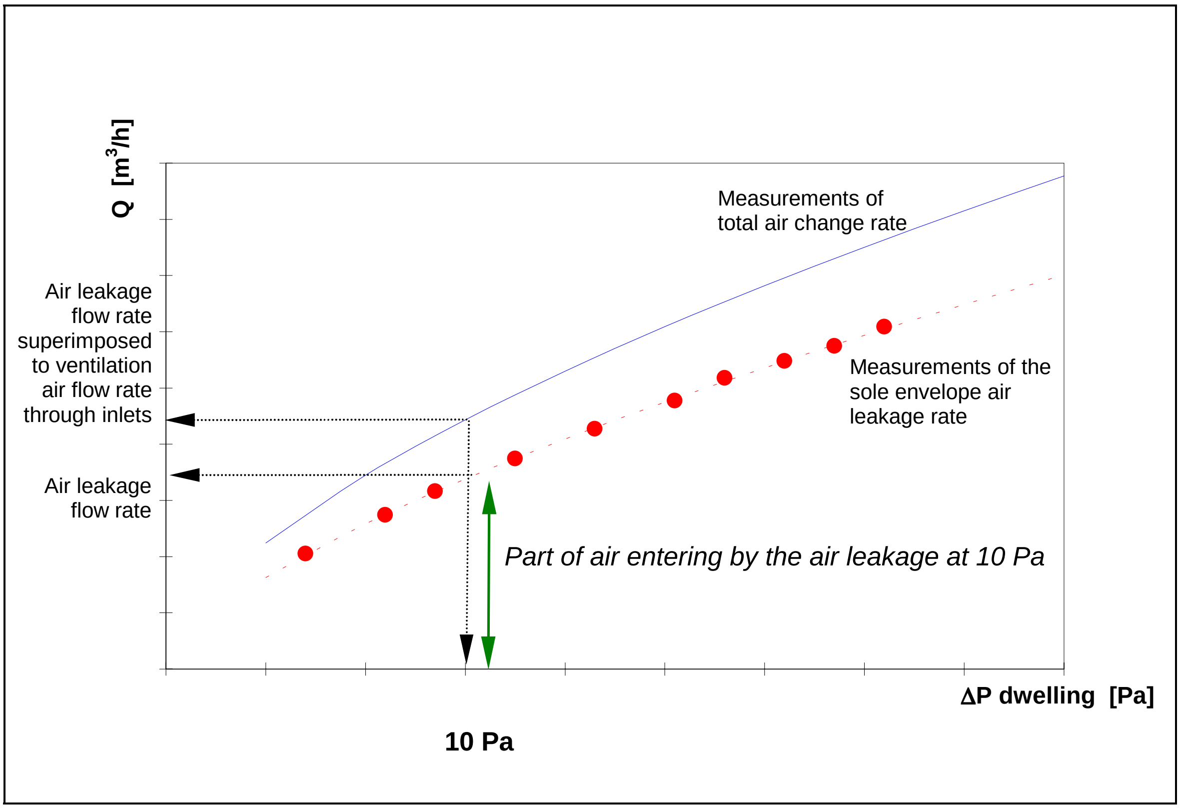

Figure 1 Superposition of airflow rates as a function of the differential pressure : infiltration contribution and total (ventilation and infiltration) contribution.

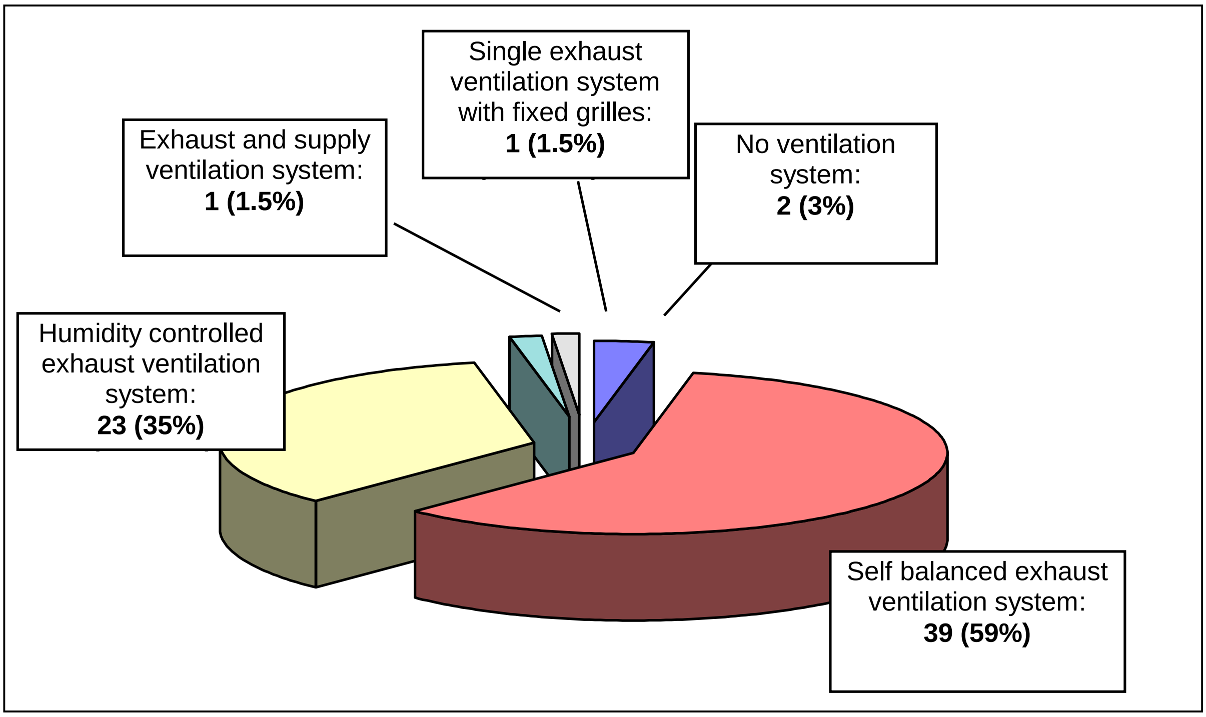

Figure 2 Distribution of the different types of ventilation equipements.

Among the 23 dwellings equipped with humidity controlled exhaust mechanical ventilation, defaults were observed in 6 cases. Causes of defaults are due to the installed facilities (5 cases) and/or to bad set up conditions (3 cases).

Regarding the ventilation system operation, more than 1/3 of the systems investigated (23 cases out of 64, except the 2 cases without ventilation system) have defaults linked to conception (bad choice for air inlets) or to inadapted set up.

4. RESULTS OF OBSERVATIONS ON AIR FLOW RATES AND DIFFERENTIAL PRESSURES OF VENTILATION FACILITIES

4.1) Analysis of depressions in ventilation exhausts

Among the sample, 15 cases out of 35 measured (43 %) have major defaults related to the measured depression in the ventilation exhausts, namely :

- 12 cases show a too weak depression according to manufacturers recommendations (10 humidity controlled exhaust ventilation systems and 2 self balanced exhaust ventilation system);
- 3 cases show a too large depression (2 self balanced exhaust ventilation systems and 1 humidity controlled exhaust ventilation system).

The most common observed default is an insufficient depression at the ventilation exhaust. Humidity controlled exhaust ventilation systems seem to be more often defective on this point (a ratio of 10 out of 16).

Regarding depression, 9 multi-family dwellings out of 22 exploitable measurements and 6 single-familly dwellings out of only 8 exploitable measurements have apparent defaults. The measurements of depression in ventilation exhaust in single-family dwellings are often unexploitable because their systems of ventilation are in kit form and do not mention the necessary data to do analysis. The measured depressions were often very weak (about 1 Pa).

4.2) Analysis of extracted air flow rates

From our sample, 29 out of 33 dwellings (except humidity controlled ventilation system) have defaults : 19 cases out of 19 in single-family dwellings and 10 cases out of 14 in multi-family dwellings.

Three types of defaults are observed :
- 5 systems (*15%*) do not reach minimal air flow rates required (in kitchen or the total air flow rate). This situation can cause a risk of the absence of ventilation in these dwellings.
- 16 systems (*48%*) do not comply with the air flow rates required in one or several service rooms.
- 11 systems (*33%*) can be considered as over-ventilated (air flow rates are larger than the sum of air flow rates required in each service room, given in the standard of 1982).

5. ANALYSIS OF THE EFFECT OF AIRTIGHTNESS ON AIR CHANGE RATES

We analyzed the effect of airtightness on the total air change rates. For that we compared the leakage airflow rate under 10 Pa, as measured in the first depressurization test (testing the sole envelope leakage defects), to the total airflow rate under 10 Pa, as measured in the second depressurization test. Althought the choice of the dwelling depression level at 10 Pa is arbitrary, it appears to be adequate to represent the actual average situation in a typical French dwelling, specifically in terms of depression.

For multi-family dwellings, there is systematically at least 1/3 of the incoming air which originates from air infiltration. The median value of the ratios $Q_{infiltration}/Q_{total}$ was measured to be 50% for 21 dwellings analysed. Furthermore, for ¼ of multi-family dwellings, we show that ¾ of the entering air comes from infiltration air leakage. For single-family dwellings, there is at least 2/3 of entering air which comes from air leakage. The median value of $Q_{infiltration}/Q_{total}$ was assessed to be larger than 80% for 23 dwelling analyzed.

One should notice that this values do not account for wind effect but give valuable information on the relative impact of infiltration on the ventilation airchange rates. A more realistic method should account for wind fluctuations and occupant behaviour. The measurement were done for wind velocity inferior to 2 m/s : in these conditions, we consider that wind has a negligible effect on depression. In presence of wind, part of air leakage in air change will be different.

Although the calculated proportions do not reflect real conditions, they show that airtightness effect is significant. Moreover, the air leakage distribution can afffect dramatically airflow patterns within the dwellings, for example, by preventing adequate air transfers from principal rooms to service rooms, which is the main principle of dwelling ventilation in the French stan dard, see Figure 3 and Figure 4. For example, the configuration on the latter figure show an example of how air transfer can prevent a correct dwelling ventilation, following the principle of the present French standard.

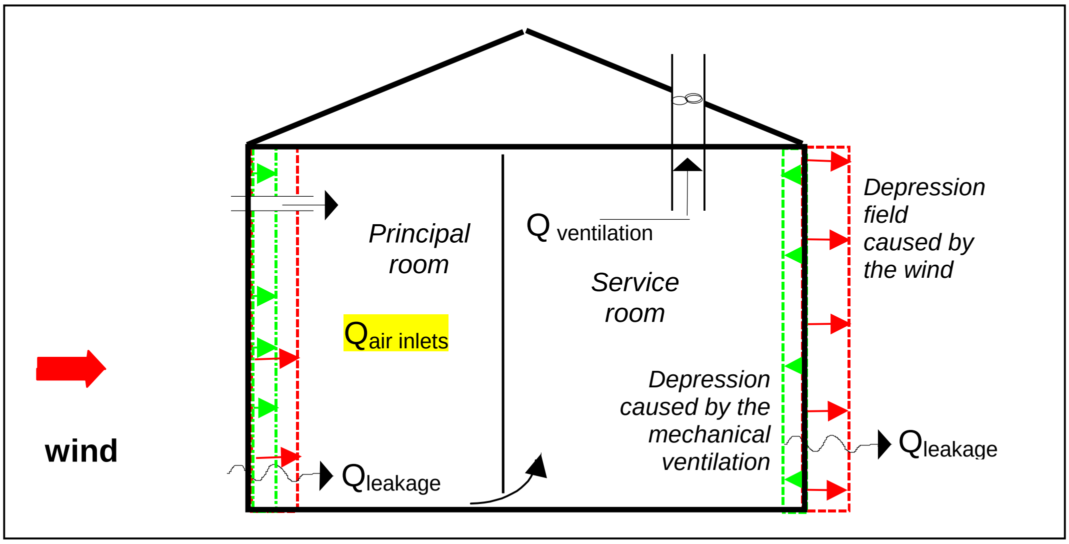

Figure 3 Illustration of the phenomena of infiltration air flow superposed to mechanical ventilation exhaust air flow (case of a principal room exposed to wind)

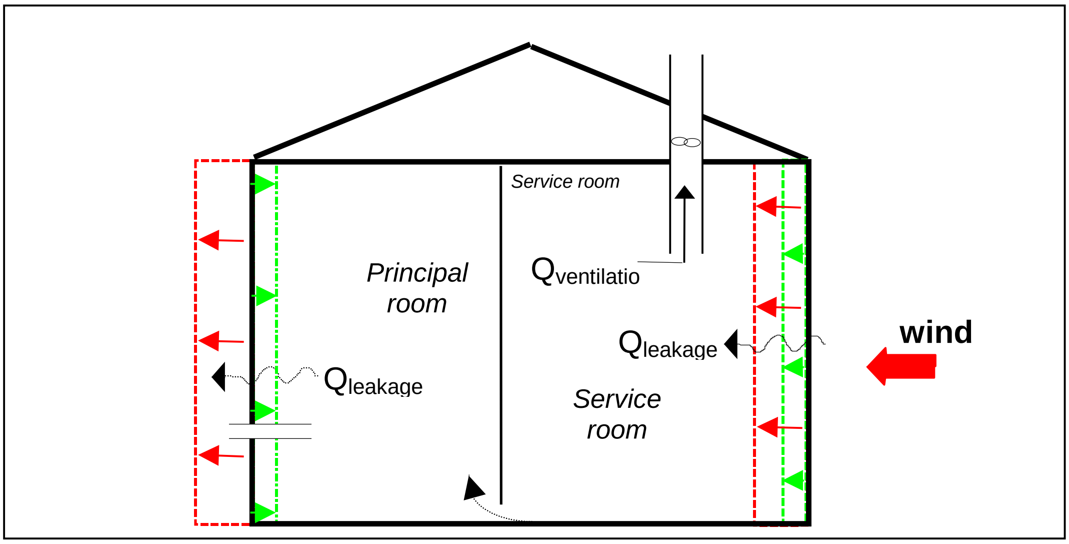

Figure 4 Illustration of the phenomena of infiltration air flow superposed to mechanical ventilation exhaust air flow (case of a service room exposed to wind)

The standard XP P 50-410 [1] recommends minimal air leakage flow rates as they are used in calculation of air inlets size (see Table 3). These theoretical air flow rates given at 20 Pa are compared to the measured air leakage flow rates in the tested dwellings under 20 Pa.

Figure 5 et Figure 6 show the distribution of the ratios between the measured and the recommended airflow rates under 20 Pa. The difference appear to be dramatic, especially for single-family dwellings. Globally, we show that the ratios between the measured airflow rates and the theoretical airflow rates vary principally in the range 1,5 to 4 for multi-family dwellings, and in the range 4 to 8 for single-family dwellings.

Number of principal rooms	Air leakage flow rate *Qf* (m3/h) at 20 Pa	
	MULTI-FAMILY DWELLINGS	SINGLE-FAMILY DWELLINGS
1	*20*	*30*
2	*30*	*45*
3	*40*	*60*
4	*50*	*75*
5	*60*	*90*
6	*70*	*105*
7	*80*	*120*

Table 3 *Extract from DTU 68.1 : minimal air leakage flow rate recommended for calculation of the number of air inlets.*

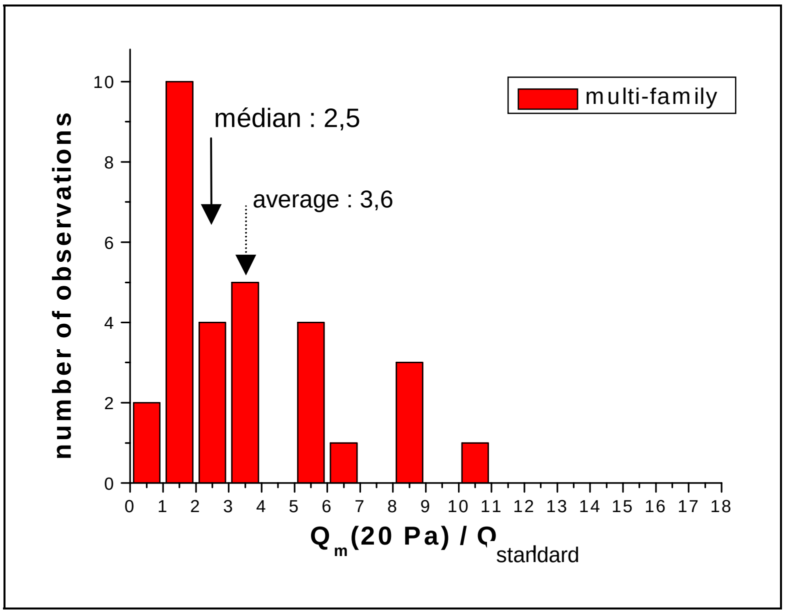

Figure 5 Ratio histogram between leakage air flow rate at 20 Pa and theorical leakage air flow rate proposed by standard (multi-family dwellings).

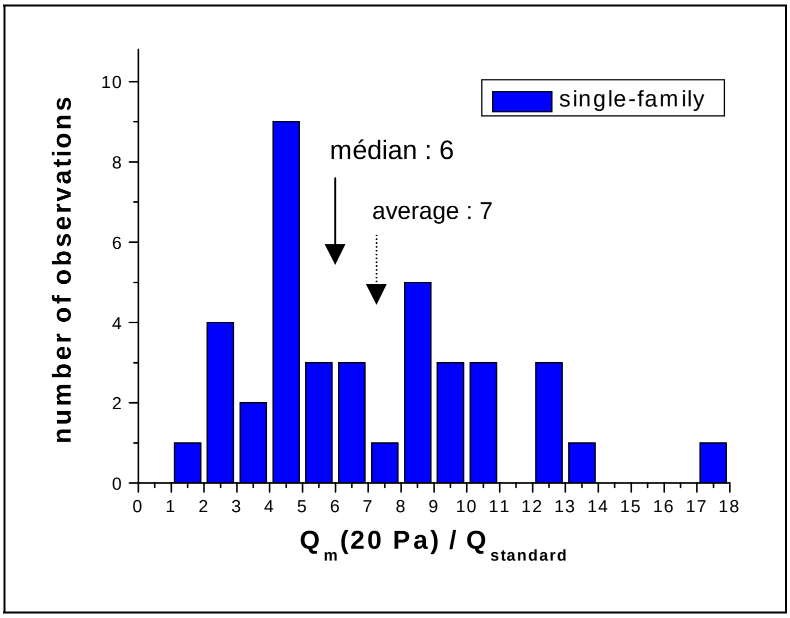

Figure 6 Ratio histogram between leakage air flow rate at 20 Pa and theorical leakage air flow rate proposed by standard (single-family dwellings).

6. CONCLUSION

This study shows that more than 30% of the dwellings of the studied sample do not comply with the French standard. Globally, the main defaults noticed are linked to :

- air inlets (problem of number or type of this inlets)
- airflow rates extracted by ventilation system, which are either excessive or insufficient
- depressions in ventilation exhausts, which do not correspond to the values recommended by manufacturers

Besides, the impact of infiltration airchange rates appears to be significant as compared to the to total airchange rates, when simulating real conditions with a dwelling depression of 10 Pa. We show that the recommended dimensions for ventilation inlets are not adapted to the actual observed levels.

Finally, the results of this study illustrate through a relatively modest sample, the overall problems that ventilation and airtightness defaults can cause on buildings, namely :

- inadequate indoor air quality due to insufficient air change and building preservation, namely with condensation risks;
- higher energy costs due to excessive infiltration airchange rate;
- acoustical discomfort such as noise produced by a bad working ventilation system;
- thermal discomfort caused by inadequate air transfer

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