IMPLEMENTATION AND PERFORMANCE OF VENTILATION SYSTEMS: FIRST REVIEW OF VOLUNTARY CERTIFICATION CONTROLS IN FRANCE

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ABSTRACT

A voluntary certification for very low energy buildings has been implemented in 2013 in France, which requires among other the ventilation systems to be controlled by an independent technician. To ensure the expertise of these technicians, a certification scheme has been implemented for the airtightness measurement of ductwork. This certification will soon be required for the ventilation system controls.
From both these frames, inspection data has been collected. The purpose of this paper is to go through the ductwork airtightness tests and the visual inspections to establish a picture of the quality of the implementation of ventilation systems in low energy buildings in France.
This paper describes the diverse requirements in both regulation and voluntary certifications and describes the ventilation systems typically implemented in French low energy buildings, viewed from the data collected. The paper further discusses the ductwork airtightness performance and the visual controls collected from the database. The paper finally deals with some difficulties encountered today in implementing high quality ventilation systems.

KEYWORDS

Ventilation systems implementation quality, onsite performance, low energy buildings

1 INTRODUCTION

As a new voluntary building certification program has been implemented in France, ventilation ducts airtightness tests in this frame have become mandatory. After a few previous studies about ventilation performance in France, the database created from the ductwork airtightness tests results is a first opportunity to picture ventilation systems in low-energy buildings in France as well as to establish their performance and determine if and how achieving high performing systems is possible in the present state in France.

2 FRENCH REGULATION AND VOLUNTARY CERTIFICATIONS: TAKING DUCTWORK AIRTIGHTNESS PERFORMANCE INTO ACCOUNT IN LOW ENERGY BUILDING PERFORMANCE

2.1 Evolution of the airtightness requirements in the French Regulation and other certifications in France

For over 10 years, airtightness requirements have progressively been reinforced in the successive French energy performance (EP) regulations. If it were at first only true for building envelope airtightness, the possibilities to value performance in buildings in the EP calculation is now extended to ductwork airtightness.Today, as can be seen in Figure 1, the 2012 EP regulation takes ductwork airtightness measures into account.

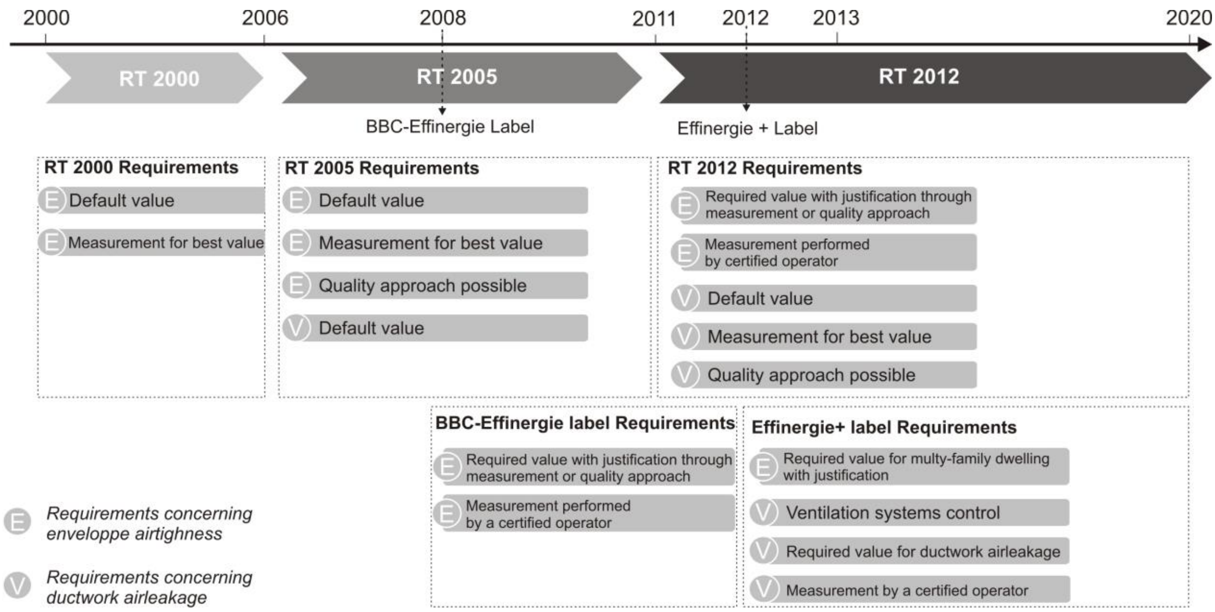

Figure 1: Evolution of French Thermal Regulation (credit : Cerema Direction Territoriale Centre-Est)

Furthermore, a voluntary building certification for very low energy buildings, Effinergie+, brought a requirement on controlling ventilation system at commissioning. A thorough inspection is required: visual control of the system as well as ductwork airtightness measurement. Without a complete inspection, a building cannot be certified Effinergie+.

2.2 Taking ductwork airtightness into account in low energy building performance

Ventilation ducts airtightness is taken into account in the energy consumption calculation of the French regulation, which is described in the Th-BCE 2012 calculation method (CSTB, 2013). Indeed, leaks have an impact on the heating and cooling calculation as well as on the energy consumption of the air handling units. Focusing on the heating and cooling energy consumption, the air leakage flow rate is proportionate to the airtightness class of the ventilation ductwork.

$$q_v = 3600 \cdot Kres \cdot A \cdot dP^{0.667} \quad (1)$$

Where qv is the air leakage flow rate, Kres a coefficient depending on the class of the ductwork, A a conventional surface area of the ductwork and dP a conventional pressure difference.

If no specific airtightness class is input in the calculation process, a default value is used. This value equals 0,0675 $m^3/s/m^2$, which is almost 3 times as leaky as a class A at 1Pa. It is however possible to voluntarily justify a better airtightness class in the energy consumption calculation, up to class C. It is possible to justify one airtightness value per ventilation zone, which can result into several measurements in one building.When it is the case, the French regulation requires a measurement by an independent technician.

2.3 Effinergie+ certification: guarantees of the quality of a ductwork airtightness measurement

The Effinergie+ certification program sets several requirements to guarantee the quality and the homogeneity of measurements. The program requires aspecifically qualified technician to fulfill the airtightness measurements of the ventilation ductwork when commissioning a newly built building.

First, technicians must have undergone a specific training, which program and contents is supervised by the Effinergie association. Secondly, to standardize the measurements procedure and adapt European norms to the French landscape, the association Effinergiehas published a measurement protocol that sets further requirements on the measurements than norms NF EN 12237, NF EN 1507, NF EN 13403, NF EN 12599 and French FD E51-767. The use and application of this protocol is mandatory to have a building certified.

Finally, technicians will soon have to fulfill a second requirement: a Qualibat qualification on measuring ductwork airtightness. To undergo the qualification, technicians have to provide proof of their experience by giving the results of at least ten measurements. Their skills are then analyzed and the quality of their reports is controlled.

3 A PICTURE OF VENTILATION SYSTEMS IN FRENCH LOW ENERGY BUILDINGS

3.1 Data collection

In the frame of the Qualibat qualification, all candidates provide proof of a sufficient and pertinent experience of at least ten measurements in different buildings by filling in a predetermined document called tests register, summarizing their results.

So far, several technicians have undergone or are still undergoing the qualification. All their measurement results have been collected from their tests register and allowed us to build a small database about which the paper further deals. Seeing the requirements set by Qualibat for the qualification, it is expected that all technicians have a homogeneous quality expertise in ductwork airtightness measurements. Therefore, it is expected that even if the data is collected from 5 different technicians, the results can be combined and compared to statistic aim.

3.2 Characteristics of the collected data

As stated in Table 1 page 4, this database contains ductwork airtightness data of 33 buildings, which is the work of 5 technicians. There are 113 test results representing 93 unique ducts. From all these buildings, 2 are certified Passivhaus and 13 have another certification.

Table 1: Characteristics of the database

Number of unique buildings in the database	33
Number of technicians who contributed	5
Number of unique tests performed	113
Number of unique ducts tested	93
Number of buildings under certification	15
Total duct surface area tested	4757,87 m²
Mean duct surface area tested	42,11 m²

The buildings in the database are quite recent: 15 have been built in 2013or after, 9 in 2012, 3 in 2011 and only 4 in 2010 or before. Most of these buildings could therefore be considered as recent low-energy buildings.

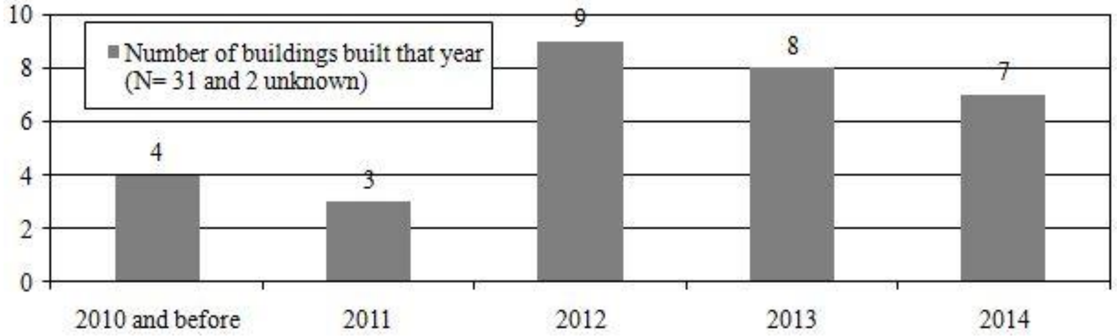

Figure 2: Year of construction (N=31 and 2 unknown year of construction)

As can be seen in Figure 3, the buildings of the database are mostly single-family dwellings, multi-family dwellings, office buildings and the remaining buildings are either education buildings, sports buildings or other/unknown.

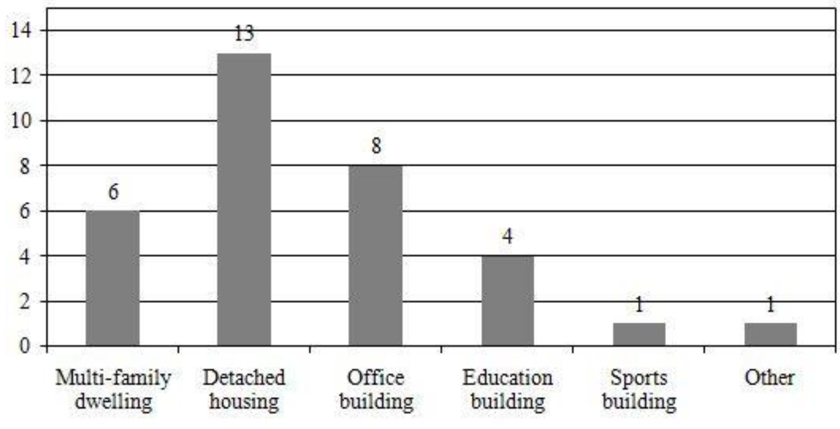

Figure 3: Type of building in the database (N=33)

31% of these buildings are located in South-East France and 61% in the East of France. This is in a certain measure a bias in the database. Indeed, newly built buildings in southern France are less dependent on energy gains through efficient ventilation than average. And on the contrary, buildings in eastern France are much more dependent on energy gains from ventilation than average in France. From this point of view, the buildings of the database collected so far can only be held representative for a part of France buildings.

3.3 Strategies in ventilation to achieve low energy buildings in France

As stated before, the data collected gives in a certain measure a picture of ventilation systems in low energy buildings in France. This section will only deal with detached housing, multi-family dwelling and office buildings for the rest of the buildings cannot be considered as representative.

Overall in the buildings of this sample, mechanical exhaust ventilation systems is used: 73% with mechanical ventilation and 18% with mechanical exhaust ventilation and natural air inlet. The other ducts tested were either non mechanical ventilation ducts or earth cooling tubes.

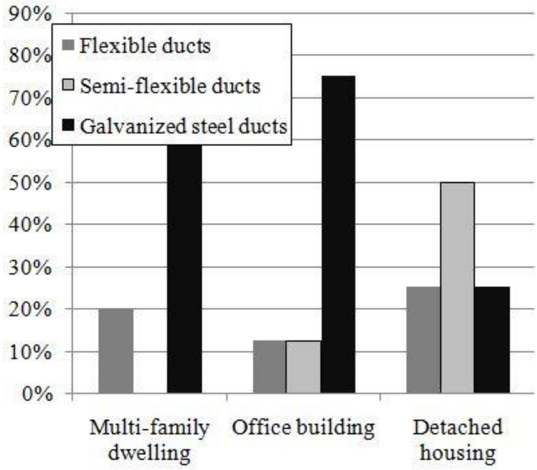

Figure 4: Ducts per building type (N=25 and 8 unknown)

As shown in Figure 4, flexible ducts, semi-flexible ducts and galvanized steel ducts are the three types of ducts used in the buildings of the database. Flexible ducts are mainly found in single family dwellings. As for galvanized steel ducts they are mainly found in office buildings but are also found in detached housing and multi-family dwellings.

It is quite unusual to find that galvanized steel ducts are found in 25% of detached housing whereas flexible ducts are actually widely used in this type of buildings. Plus, semi-flexible ducts are also found in 50% of detached housing. Since the database is constituted of tests in buildings where owners were willing to have their system controlled, we can safely assume that their goal was higher performance than basic regulation requirements. Hence we can understand that in order to achieve higher performance, craftsmen tend to use more reliable systems like galvanized and semi-flexible ducts, which are less likely to be damaged by simple manipulation and during implementation.

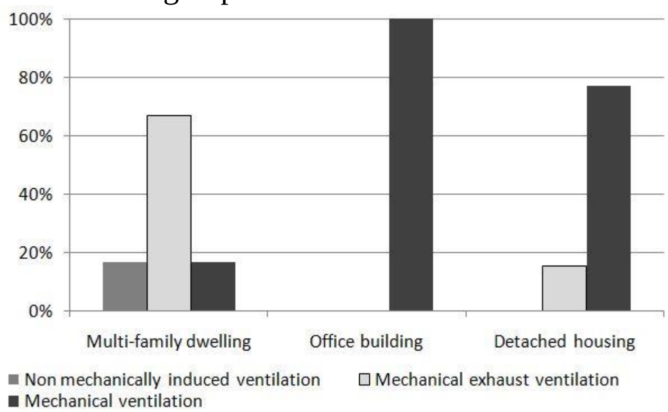

Figure 5: Type of ventilation system per type of building (1 unknown among detached housing)

Figure 5 is mostly interesting for the distribution of mechanical exhaust ventilation and total mechanical ventilation among the different types of buildings. Where mechanical exhaust ventilation is very widely used in French residential buildings (between 85 and 95% see (Promotelec,2012)), buildings in the database collected show more systems combining mechanical air inlet and mechanic outlet. Here again, this could be considered as a trend in very-low energy housing, especially when specific attention is brought to achieve performing ventilation.

3.4 Ductwork airtightness performance

As mentioned earlier, the database collects 113 tests in 36 unique buildings. When only taking into account tests that have been made at 80Pa or more in absolute, there are **103 valid tests**. The rest of the data is not taken into account and concerns tests at very low pressure because the measurement device used was not able to induce higher airflow rates. Two are measured at 20 Pa regarding a non mechanical ventilation duct which is designed to work at 20 Pa.

From Table 2 can be inferred that ducts and ducts samples achieve rather performing classes. 75 % achieve a class A or better and more than a quarter achieve a class C or D.

Table 2: Airtightness classes achieved all tests included (N=103)

Class D	Class C	Class B	Class A	3xClass A	Higher than 3xClass A
4 %	25 %	29 %	17 %	19 %	6 %
4 %	29 %	58 %	75 %	94 %	100 %

However, when put in perspective, it appears that some buildings have undergone many tests: because airtightness of all in- and outlet ducts in the buildings were measured or because the technician made many samples. Plus, some tests have been performed during construction work and is not representative of the ventilation ductwork at commissioning. This results in multiplying good results whereas most of the buildings perform rather poorly as can be seen in Figure 6.

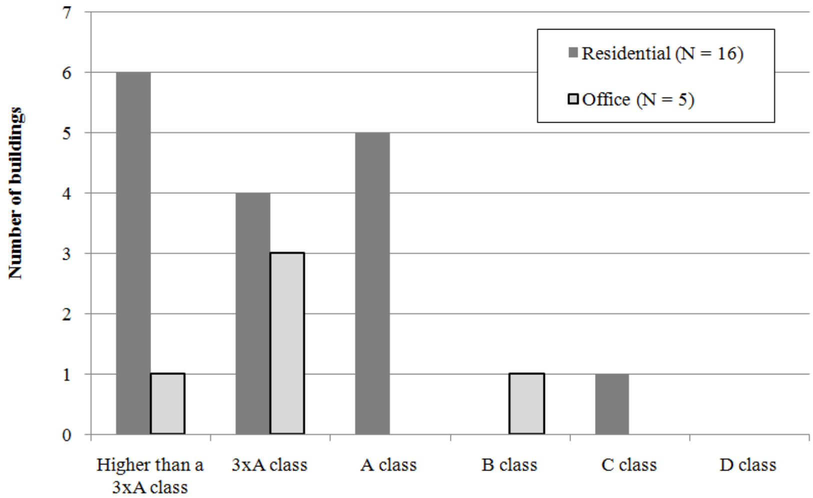

Figure 6: Final performance of residential and office buildings in the database at commissioning (N=21 buildings tested exactly at commissioning in the database)

As a summary, Figure 7 shows the number of tests for all 33 buildings (3 naturally ventilated buildings excluded)for both ductwork sample and final airtightness performance of the ventilation ducts. Some buildings have several separated ducts, which explains the 41 ducts classed.

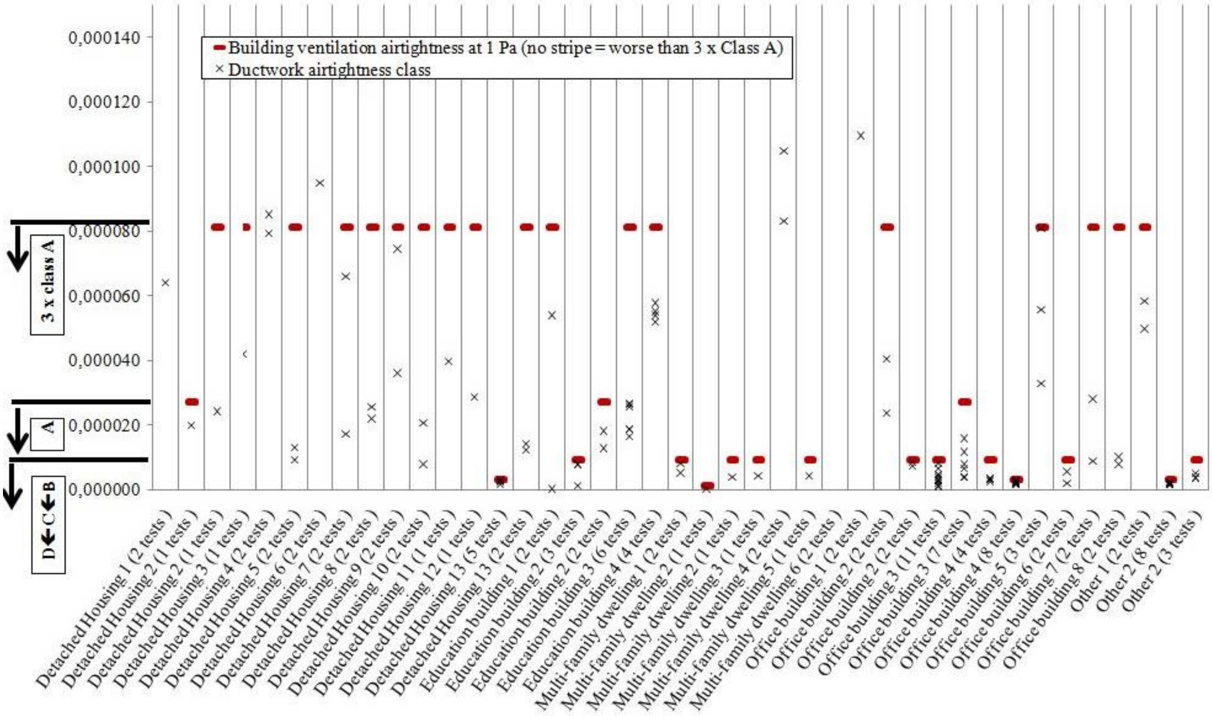

Figure 7: Ductwork airtightness at 1Pa and final building ventilation airtightness at 1Pa ($N_{buildings}$=33 for 41 ductwork performance calculated)

As stated in 2.2, the default value in the EP calculation is almost equal to 3 times a class A, a value that can be considered as a reference. Figure 6 and Figure 7show therefore that more than half of the ducts perform worse than the default value in the EP calculation.

Furthermore, only 17 out of 41 ducts perform at a class A or better, which should be at least the reference now in very low energy construction, if not the classes B or better.

4 DISCUSSION AROUND THE IMPLEMENTATION QUALITY OF DUCTWORK

4.1 Comparison to past and present French studies results

The results acquired from the collected data show a picture of ductwork airtightness performance. These results, as representative as they can be considered, show in a certain measure the performance of ventilation ducts in low-energy newly built construction in France.

Earlier studies had shown that ventilation ducts airtightness performance in France was quite poor in comparison to other countries. For example the 1999 Save-ductstudy from AIVC (1999) showed that among 21 buildings in France, 60 % performed 3 x class A, 10 % a class A, 5% a class B and the 25% left worse than 3 x class A.

The 2009 French PREBAT Performance study showed the benefits of an integrated quality approach before and during construction with multi-family dwellings performing a class B while a second building which had not fully integrated their quality management system performed worse than 3 times the class A.

In comparison, it is obvious that the ventilation ducts in newly built buildings currently in France do not perform much better than 15 years ago according to the Save-duct project. With only a third of buildings at commissioning performing at class A or better, ductwork performance is not easily achieved.

4.2 Visual inspection for air leakage

If the Effinergie + certification program requires a detailed visual inspection including basic checks on the air handling unit, on the air inlet and outlet grids or on the state of the ducts themselves, the buildings of the database have not undergone any visual inspection. However, an air leakage inspection has been fulfilled on some of the buildings of the database and the results are described hereunder.

Ductwork air leakage in the buildings of the database can be dissociated into two types: leakage inherent to the ductwork system itself and leakage due to the implementation. In the first category, leaks inherent to the ductwork elements themselves, air leakage was found all around flexible ducts because of very small perforations of the ducts.

In the second category, leaks due to implementation and therefore manipulation are mainly found at the connection between two ducts or between a duct and an element. In these cases, leakage was found where the airtightness treatment was poorly managed. In particular, leaks were found at the junction between two different types of ducts or elements, like between flexible and galvanized steel ducts, or between flexible ducts and the plastic sleeve joining the flexible duct and the air in- or outlet grid. Leaks were also found at the connection between rectangular galvanized steel ducts.

4.3 Achieving high performance in ventilation airtightness today

As stated in 3.3, some configurations found in the buildings of the database were quite unusual. We suspected a tendency among craftsmen for the use of particular systems or type of ducts to achieve high performance. The results of the airtightness measurements of the database corroborate the idea in a certain measure.

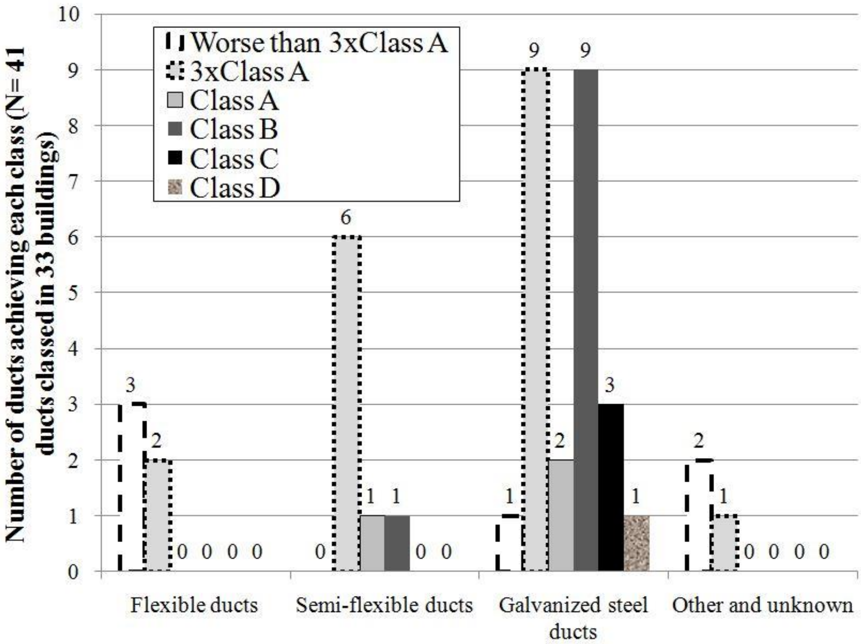

Figure 8: Class achieved by the 41 ducts tested (33 buildings)

Figure 8 shows the classes achieved by the ducts tested. Admittedly, the amount of ducts tested is not statistically representative but it shows a certain tendency. The flexible ducts did not achieve better than three times a class A. Semi-flexible ducts achieved higher performances with at least three times a class A. Galvanized steel ducts achieved the highest performances with more than a half of the ducts achieving a class A or better.

The results from the airtightness tests in Figure 8 and from the leakage analysis in caption 4.2 might therefore indicate that the use of flexible ducts is a risk for airtightness of the system. On the contrary, we can assume that it is less risky to use galvanized steel ducts, combined of course with the adaptedjunction and connection systems, in order to achieve good airtightness of ductwork.

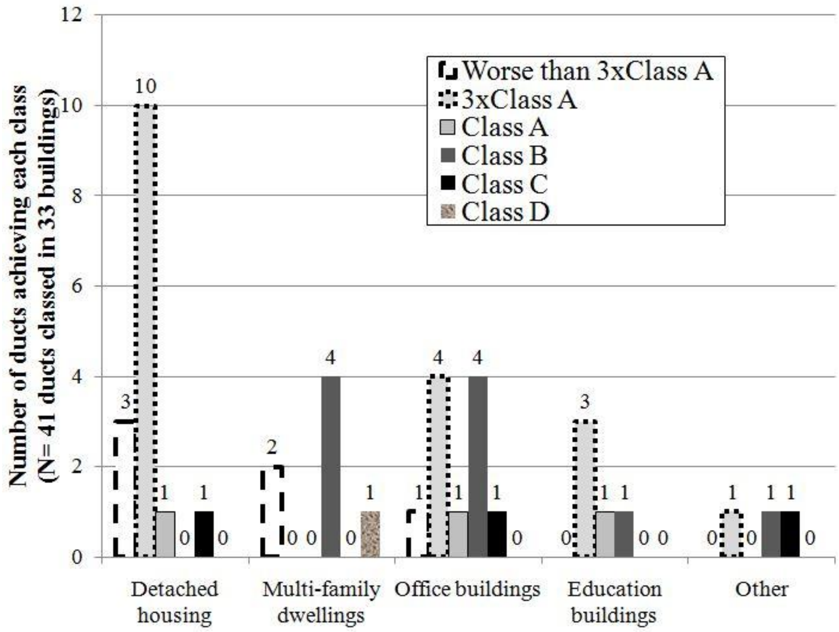

Figure 9: Class achieved for each type of buildings

Figure 9pictures the classes achieved for each type of buildings: detached housing, multi-family dwelling, office building or education building. It is clear that detached housing dos not perform as well as multi-family dwellings or office buildings. This confirms the lack in France of real craftsmanship for ventilation, particularly in detached housing. Most of the time, the ventilation system is implemented by the plumber, the electrician or the plasterer. In this frame, the lack of knowledge, training and practice is highly probable and results into various problems on site regarding the quality of the implementation of ventilation systems. These results underline once again the need for the rise of an expert craftsmanship.

4.4 Discussion on the sample representativeness for French low-energy buildings

The database collected cannot quite be considered as a perfectly representative sample of new constructions in France. First because the amount of data is not large enough to draw reliable conclusions. Also because it is issued from ductwork airtightness data, which unsurprisingly requires ventilation ducts in a building. So the database does not account for naturally ventilated building which might be used in very-low energy buildings today. Plus, building owners probably order tests more oftenfor fully mechanical ventilation than for mechanical exhaust ventilation, which is today largely used in France. If we can surely define trends, it is not possible to draw definite conclusions yet.

5 CONCLUSIONS

The database issues from the collection of data from technicians undergoing a Qualibat qualification, which only a few underwent today. However this number is expected to drastically rise which means that a larger amount of data will enrich the database and allow exploiting it with a better statistical significance and accuracy.

Exploiting these tests still showed valuable results on both the picture of low-energy buildings today and airtightness performance of ventilation ducts in these buildings. If the amount of data does not allow definite conclusions, it shows quite concerning trends in the performance achieved today in France, which is not much better than 5 or 15 years ago, according to previous studies. There is therefore reasonable doubt about the air renewal achieved in buildings where ventilation systems are indeed not properly implemented.

This is a serious concern because in the meantime, the 2012 French Energy Performance Regulation has set a high requirement on the airtightness of the envelope of residential buildings. All of them undergo an airtightness test at commissioning and have to perform better than 0,6 $m^3/h/m^2$ at 4 Pa. At this level of airtightness, it is required to guarantee a good air quality by a performing ventilation system and therefore avoid sick building syndromes in newly-built buildings. There is today an urgent need in creating an expertise area around ventilation craftsmanship and around control technicians to check the performance at commissioning.

6 ACKNOWLEDGEMENTS

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