Statistical analysis of about 1,300 ductwork airtightness measurements in new French buildings: impacts of the type of ducts and ventilation systems

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ABSTRACT

This paper summarizes the most recent results of the French database of ductwork airtightness. This database was created in 2016. It is fed through measurements performed by qualified testers according to a national scheme regarding ductwork. Measurements are mainly performed in building applying for the Effinergie + label which requires class A for ductwork airtightness. Therefore, results discuss in this paper only apply to the buildings of the database and cannot be generalized to all new buildings in France. The database was enriched in 2017 by new measurements, making the total number of measurements around 1300. This enables new analyses regarding the ductwork characteristics and its impact on ductwork airtightness.
First, this paper summarizes the recent results regarding main characteristics of the buildings and ventilation systems. Then, the paper analyses the measurement results regarding ductwork airtightness classes depending on several factors, in particular building's use, type of ventilation system, targeted class and the type of ducts.
The results show that the number of measurements increases annually in both residential buildings and non-residential buildings. In particular, measurements in residential buildings are growing fast. In 2016, they represent 73% of the total measurements. Regarding ventilation system, residential buildings, are mainly equipped with single-exhaust ventilation systems (80%), whereas a large part of non-residential buildings (84%) are equipped with balanced ventilation systems.
Regarding the type of ducts, flexible ducts are widely used in single dwellings in association with single-exhaust ventilation system (89%). Rigid metallic ducts are mostly used in multi-family and non-residential buildings in association with both single-exhaust and balanced ventilation systems respectively (around 90% for both).
Regarding ductwork airtightness performance, it seems to be related to the ventilation system and especially to the type of ducts. Class A is the most frequent result for residential buildings, which are mainly equipped with single-exhaust ventilation system. However, in single dwellings where flexible ducts are mostly used, 55% of measurements achieved Class A or better, against 77% in multi-family buildings with a large part of rigid metallic ducts. In non-residential buildings mainly equipped with a balanced ventilation system and rigid metallic ducts, class B is the most frequent result, and 90% of measurements achieved Class A or better.

KEYWORDS

Ductwork airtightness, building, measurements, database, field data

1 INTRODUCTION

Recent studies on ductwork airtightness (Berthault et al., 2014) (Leprince & Carrié, 2017) have shown that a leaky ductwork can multiply by 2 the fan energy use. It also has an impact on indoor air quality if the system no longer provides required air flowrates at air terminal devices. And finally, when the air is pre-conditioned a leaky ductwork also have an impact on

heating and cooling loads. Therefore, ductwork airtightness is becoming a key issue to build low energy and healthy buildings.
In the context of the French Energy Performance (EP) regulation, the test is only required if a better value than the default value is used in the EP calculation.
However, since 2013 to get the French EP-labels "Effinergie+" and "BEPOS Effinergie 2013" (and related subside) it is required to justify by testing that the ductwork airtightness is at least Class A. In both cases the test has to be performed by a qualified tester.
According to a survey performed in the context of the Tightvent Airtightness Association Committee (TAAC) (Leprince et al., 2017), France is one of the only European country that has developed a qualification for ductwork airtightness testers (Qualibat 8721) with 82 qualified testers in 2018. Qualified ductwork airtightness testers must register every measurement data and send it to the French qualification body (Qualibat). Field data are gathered by Cerema in a common database since 2017. Currently, 1,306 measurements have been recorded in the database. It includes all the measurements that were performed by the certified testers till the end of 2017. The structure of the database is presented by (Bailly Mélois & Moujalled, 2017).
This article presents a statistical analysis of those field data regarding main characteristics of buildings, ventilation systems and ductworks.

2 DATABASE OVERVIEW

Figure 1 shows the evolution of the number of ductwork airtightness measurements and the percentage of measurements depending on the use of the building.
In 2016, the database was enriched by 696 measurements, which is 89% more than in 2015, making the total number of measurements about 1,306. For 2017, only measurements of January are yet included. The measurements are almost all performed in new buildings (98%). Residential buildings account for 67% of measurements (29% for single-family dwellings with 383 measurements, and 38% for multi-family buildings with 501 measurements), 32% of tests are performed in non-residential buildings (422 measurements). The part of measurements performed in residential buildings is significantly increasing, especially in multi-family buildings.

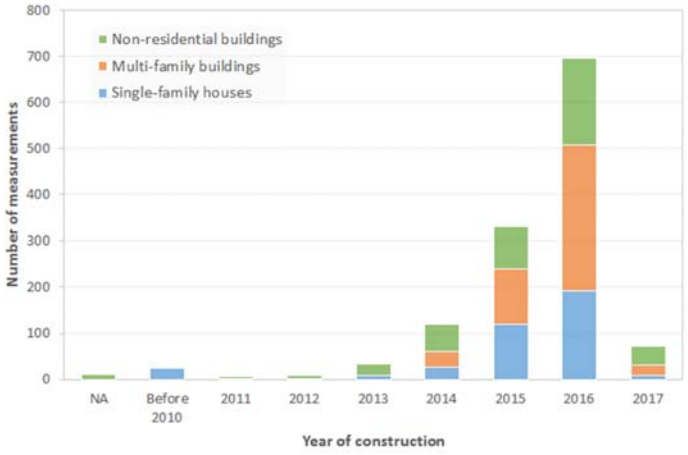

Figure 1: Number of ductworks airtightness measurements depending on the construction year and the use of the building

Figure 2 presents the distribution of the measurements number depending on the measurement time and the measured extent of ductworks. It shows that 52% of measurements are performed upon building completion, 29% upon ductworks completion (i.e. the rest of the building is still in progress but the ductwork is completed), and 14% before ductworks completion.
Contrary to building airtightness, almost half of the tests are performed before building completion. Therefore, in this database most probably a building appears twice (once before completion and once upon completion) which means that almost all building are "pre-tested" which is wise.
Concerning the measured extent of the ductworks, almost all measurements in single-family dwellings are performed on the whole ductworks (61% with extractor, and 29% without extractor). Conversely, more than half of the measurements in multi-family (52%) and non-residential buildings (64%) are carried out on a part of the ductworks. This results are in accordance with the compulsory measurement protocol which allows measurements based on a sampling method in case of ventilation system serving several dwellings or non-residential buildings (FD E51-767, 2017).

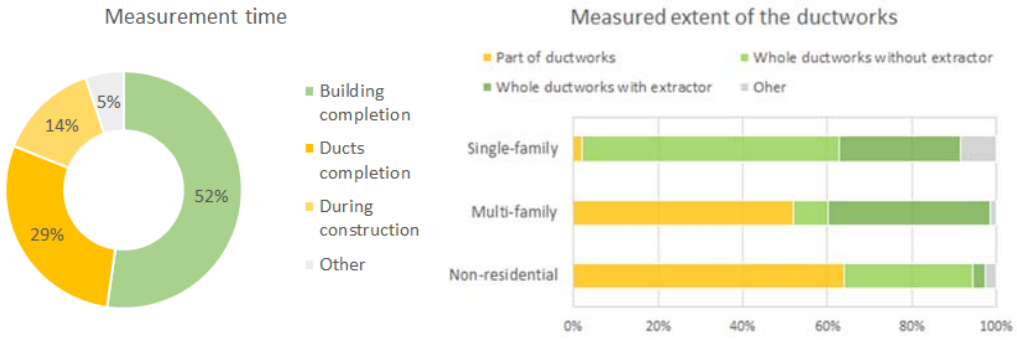

Figure 2: Number of ductworks airtightness measurements depending on the measurement time (left) and the measured extent of ductworks (right)

3 RESULTS

3.1 Main characteristics of buildings, ventilation systems and ducts

Figure 3 shows the distributions of measurements according to buildings 'use and EP-label. As mentioned before, residential buildings are the main part with almost 40% for multi-family buildings. For non-residential buildings, office buildings, schools and hospitals are the main parts with 18% (342 measurements), 8% (143 measurements) and 3% (52 measurements) respectively. Few measurements are performed in hotels, commercial or other non-residential buildings.
Almost half of residential buildings are applying to EP-label, against 25% for non-residential buildings. So the test is either performed to improve the default value in the EP calculation or for quality reasons. French EP-labels "Effinergie+" and "BEPOS Effinergie 2013" represent the main parts of EP-label with 76% and 8% respectively. As mentioned before, they require to achieve at least class A.

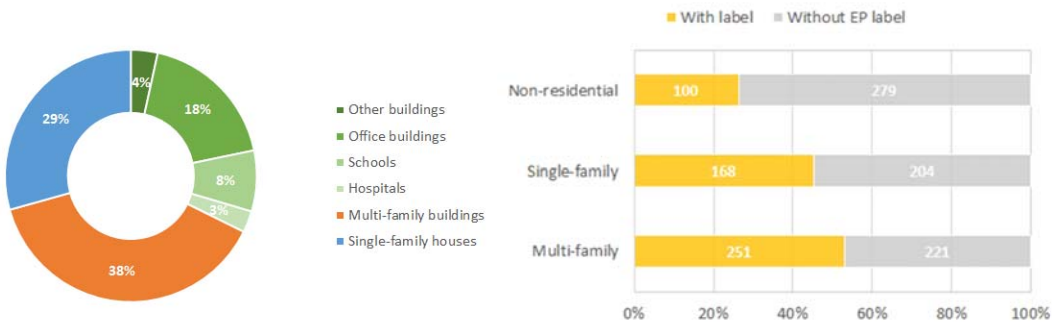

Figure 3:Distribution of buildings 'use (left) and EP-label (right)

Figure 4 shows the distributions of measurements according to the type of ventilation system and building's use. Residential buildings are mainly equipped with single-exhaust ventilation system (78% for single-family houses and 85% multi-family buildings). Conversely, non-residential buildings are mainly equipped with balanced ventilation system (85%).
The proportion of balanced ventilation system in this database is globally higher than its proportion compared to all new buildings in France. According to the building airtightness database (which includes more than 200,000 buildings), only 50 % of non-residential buildings have balanced ventilation, and less than 5% in residential buildings. It makes sense to test more balanced ventilation systems because of the higher impact of ductworks leaks on heat/cooling loads.

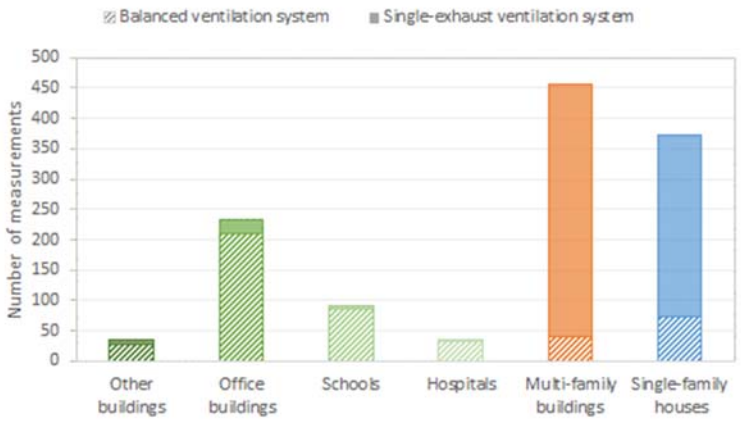

Figure 4: Type of ventilation system depending on buildings' use

Figure 5 presents the distributions of measurements regarding the type of ducts. Table 1 presents the distribution of the type of ductwork depending on the building's use and the type of ventilation system.
Three different types of ducts are mainly used: rigid metallic ducts, semi-rigid ducts, and flexible ducts with either cylindrical or rectangular section. Rigid metallic ducts represent the main part with 61% followed by flexible ducts with 27%. The ducts are mostly circular (79%). The 8% of rectangular ducts are sheet metal ducts.

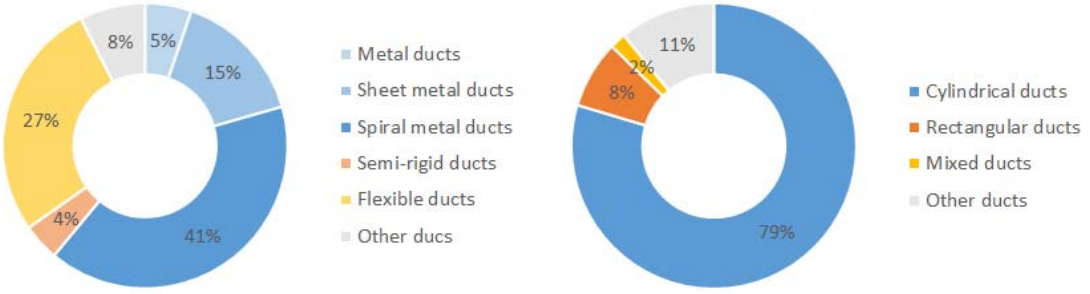

Figure 5:Distribution of type of ducts

For balanced ventilation systems, metal ducts are mainly used especially in non-residential buildings. For single-exhaust ventilation system, metal ducts are widely used both in non-residential buildings and multi-family buildings, and flexible ducts in single-family houses. According to (Bailly Mélois & Moujalled, 2017), this practice is consistent with the type of ducts generally implemented in all buildings in France, as it corresponds to the French standards and professional recommendations.

Table 1: Type of implemented ducts depending on building's use and type of ventilation system

Type of ventilation	Type of ducts	Office buildings	Schools	Hospitals	Multi-family buildings	Single-family houses
Balanced ventilation	Metal ducts	**79% (146)**	**83% (77)**	**83% (26)**	4% (18)	8% (32)
	Semi-rigid ducts	5% (10)	2% (2)	6% (2)	1% (6)	4% (17)
	Flexible ducts	3% (6)	6% (6)	0% (0)	2% (13)	5% (19)
Single-exhaust ventilation	Metal ducts	11% (21)	7% (7)	6% (2)	**80% (360)**	5% (20)
	Semi-rigid ducts	0% (1)	0% (0)	0% (0)	1% (6)	3% (11)
	Flexible ducts	0% (0)	0% (0)	3% (1)	10% (46)	**72% (265)**

3.2 Results of measured ductwork airtightness

Figure 6 presents the distribution of ductwork airtightness measured classes depending on target classes. The class "2.5*A" is the default value of the French EP-regulation. It can be used in the EP calculation without any justification.

More than half of the measurements (56%) are performed without any target class (">2.5*A"). When a target class is selected, class A is the most frequent (19%). This is logical since the class A (or higher) is the class to reach for the EP-labels. It is followed by the class "2.5*A" (16%). Target Classes B and C are less frequent with 6% and 2% respectively.

Target classes "A" and "2.5*A" are mostly chosen for residential buildings (almost 90%). Whereas most target classes B and C (90%) are chosen for non-residential buildings.

As shown in Figure 6, the distribution of the specific ductwork airtightness measured class depends on the chosen target class:

- For the target class C, only 55% of measured ductworks achieve class C (mainly offices and hospitals). 23% of measurements achieve class B, and 19% are two classes lower at class A.
- For the target class B, the result is slighter better with 63% of measured ductworks achieving class B or higher. 28% of measurements achieve class A, and 8% are at least two classes lower than class B.

- For the target class A, most measured ductworks achieve class A (90%), and 25% achieve a better class. Only 10% do not achieve class A.
- For measured ductworks with “no target class” (>2.5*A), the results are quite good as 69% of the measured ductwork reach class A or better. It means that, even with no target class, good results can be achieved thanks to the commitment to a measurement procedure encouraging a careful implementation of ductworks. However, this result only applies to the database and cannot be generalized to all new buildings in France.

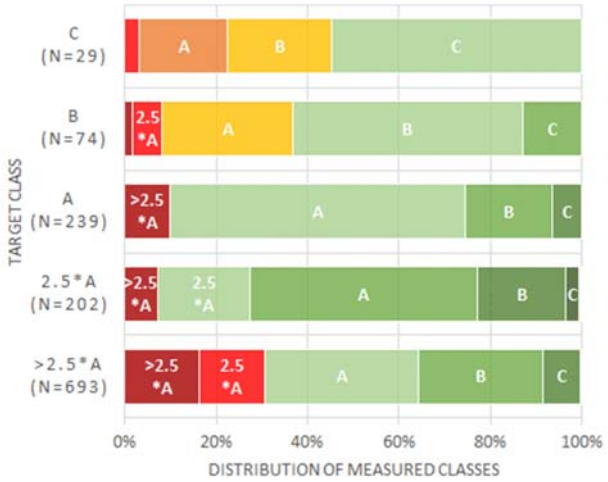

Figure 6: Distribution of ductwork airtightness measured classes depending on target classes

Figure 7 presents the results of ductwork airtightness measured class in residential and non-residential buildings. For residential buildings, most measured ductworks achieve class A (46% for single-family houses and 48% for multi-family buildings). In multi-family buildings, 23% of measured ductworks achieved a better class (mainly B), against 11% in single-family houses.

For non-residential buildings, most measured ductworks achieve class B in particular office buildings (55%) and hospitals (44%). Also 15% of measured ductworks in non-residential buildings achieve class C (against 5% in residential buildings). Ductworks in non-residential buildings are overall tighter than in residential buildings. This result is consistent with the target classes of non-residential-buildings where classes B and C are the most targeted.

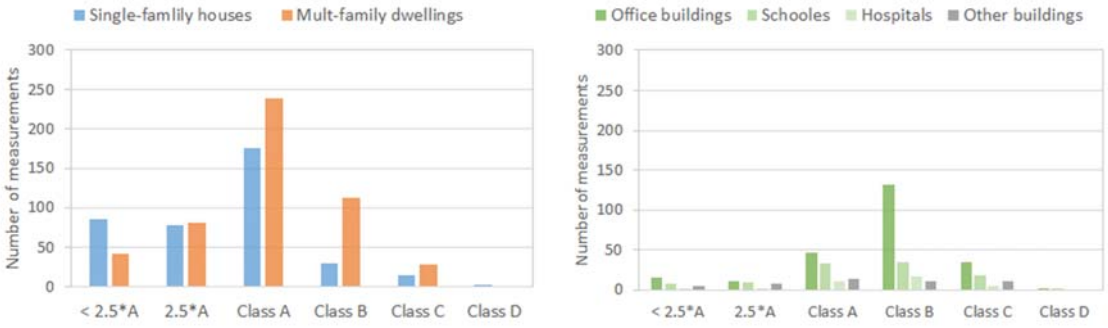

Figure 7: Distribution of ductwork airtightness measured classes in residential buildings (left) and non-residential buildings (right)

Finally, Figure 8 shows the distributions of ductwork airtightness measured classes depending on type of ventilation systems and implemented ducts. The distribution of the specific ductwork airtightness measured class is clearly depending on the type of ventilation system and especially on the type of ducts:

- For single-exhaust ventilation systems that are widely used in residential buildings, 55% of measured flexible ducts achieve class A or better, against 80% for spiral metal ducts and 70% for sheet metal ducts. Flexible ducts are widely used in single-family houses with single-exhaust ventilation, whereas metal ducts are the most used in multi-family buildings. The wide use of flexible ducts in single-family houses could explain the difference in results between single-family houses and multi-family buildings in Figure 7.
- For balanced ventilation system, ductworks are clearly tighter than for single-exhaust ventilation system, especially metal ducts: 68% of flexible ducts achieve class A or better, 87% for spiral metal ducts, and 81% for sheet metal ducts. Balanced ventilation systems are mainly used in non-residential buildings where classes B and C are the most targeted as mentioned before. This is can help to explain the better results in non-residential buildings.

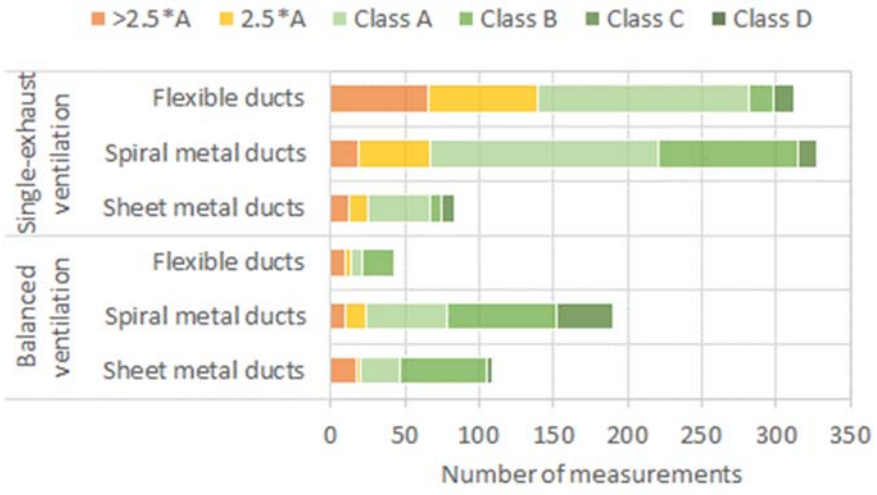

Figure 8: Distribution of ductwork airtightness measured classes depending on type of ventilation systems and implemented ducts

4 CONCLUSIONS

The French database of ductwork airtightness has been created nearly two years ago as part of the qualification scheme for ductwork airtightness testers. It now includes almost 1,300 measurements. Although the number of measurements is still low compared to the building airtightness database, the number of ductwork airtightness measurements that are performed by qualified testers continues to increase annually in both residential buildings and non-residential buildings. In particular, measurements in residential buildings are growing fast. In 2016, they represent 73% of the total measurements. Regarding ventilation system, residential buildings, are mainly equipped with single-exhaust ventilation systems (80%), whereas a large part of non-residential buildings (85%) are equipped with balanced ventilation systems.
Regarding the type of ducts, flexible ducts are widely used in single dwellings in association with single-exhaust ventilation system (89%). Rigid metallic ducts are mostly used in multi-

family and non-residential buildings in association with both single-exhaust and balanced ventilation systems respectively.
Regarding ductwork airtightness performance, it seems to be related to the ventilation system and especially to the type of ducts. Class A is the most frequent result for residential buildings, which are mainly equipped with single-exhaust ventilation system. However, in single dwellings where flexible ducts are mostly used, 57% of measurements achieved Class A or better, against 76% in multi-family buildings with a large part of rigid metallic ducts. In non-residential buildings mainly equipped with a balanced ventilation system and rigid metallic ducts, class B is the most frequent result, and 86% of measurements achieved Class A or better.
All measurements in the database were performed according to specific and not common demands. Thus, all results presented in this paper only apply to the buildings of the database and cannot be generalized to all new buildings in France.

5 ACKNOWLEDGEMENTS

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