INNOVATIONS IN VENTILATION TECHNOLOGY

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AIRFLOW RATE PERFORMANCE OF VARIOUS VENTILATION SYSTEMS
RESULTS OF MEASUREMENT IN A TYPICAL BELGIAN DWELLING

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1. SYNOPSIS

This paper presents the results of ventilation measurements realised in a non-occupied one-storey dwelling situated in the countryside. The measurements of the ventilation rate in the different rooms have been realised by the use of tracer gases with the constant concentration technique. Four configurations of ventilation systems have been tested successively. The ventilation systems tested consist of natural air supply and mechanical exhaust. Both 'normal' air supply grilles and self-regulating grilles have been tested. The exhaust system installed is a mechanical system without regulation.

The experiences show the importance of the ventilation in dwellings, the selection and dimensioning of effective ventilation devices as well as the correct use of the equipment installed.

2. INTRODUCTION

The first objective of the measurement campaign realised is to test various ventilation systems. Different types of natural ventilation devices dimensioned following the Belgian standard of ventilation have been installed and tested in real conditions.

The second objective is to evaluate the influence of the correct use of the devices installed on the ventilation rates. Therefore, different configurations of the same ventilation system have been successively tested.

3. THE IDEE TEST HOUSE

3.1 Description of the house

The IDEE house is a test house situated at the BBRI's research centre of Limelette, Belgium. It is a non-occupied one-storey dwelling used for research purposes. The house was built at the beginning of the 80's and is very well insulated. It is situated in a very calm environment at the countryside and is relatively exposed to the wind. We find on the ground floor two bedrooms, one living room, one kitchen, one bathroom, one toilet, a night hall and an entrance hall. The house comprises also an attic and a cellar.

Figure 1: Picture of the IDEE house View from the south-east

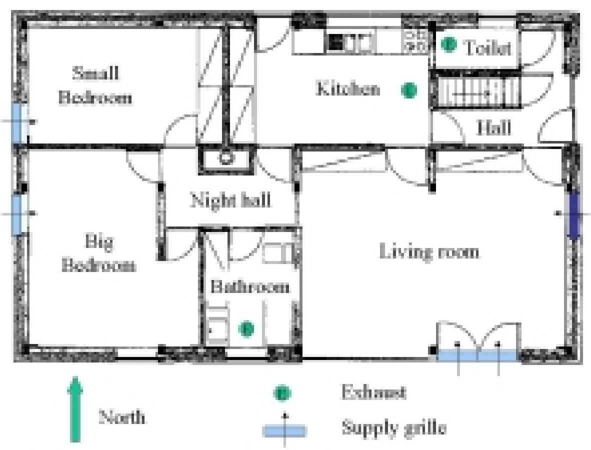


Figure 2: Ground plan of the house

This house can be equipped with all types of ventilation systems, natural or mechanical supply as well as natural or mechanical exhaust.

In the Belgian context, this house can be qualified as very tight; a pressurisation test showed a n_{50}-value of $2h^{-1}$. The equivalent leakage area at 10 Pa (ELA10) is equal to 174 cm². The envelope leakage is characterised by the following relation airflow (m³/h) – underpressure (Pa): $Q = 32\ \Delta P^{0.68}$

3.2 Dimensioning of the ventilation system following the Belgian ventilation standard

In Belgium, the standard NBN D50-001 [1] has to be applied for the dimensioning of the ventilation systems in dwellings. The general rule is to deliver a nominal airflow of 3.6 m³/h m² floor area. Minimum values and recommended maximum airflows are given in the standard. The values of the airflow rates calculated following these dimensioning rules are called "nominal airflows" and correspond to minimal values.

When the airflows are realised via natural ventilation, the ventilation devices (supply and exhaust grilles) have to be dimensioned for a pressure difference of 2Pa. The natural ventilation devices dimensioned following this rule are conform to the standard independently of the airflow really delivered in situ (that depends of the configuration of the house, the meteorological conditions, etc…). The nominal airflow of the installed ventilation devices may not exceed the double of the nominal airflow required for the room. The aperture of the natural ventilation devices must be controllable in at least 3 positions between closed and fully open.

In case of mechanical ventilation, the nominal airflows are the airflows that the installation has to be able to deliver. In practice, the airflows may be adapted to the need of the occupants by control mechanisms (manually or automatically).

Rules are also described in the standard concerning the transfer openings inside dwellings. Except for kitchens where the nominal airflow at 2Pa has to be equal to 50m³/h, the transfer openings between all the other rooms have to be dimensioned to deliver nominal airflows equal to 25m³/h.

Table 1 summarises the nominal airflows to realise in the IDEE test house in accordance with the Belgian standard.

Room	Floor area (m²)	Nominal airflow (m³/h)
Small bedroom	12.6	45
Big bedroom	16.7	60
Living room	18.8	104
Kitchen	12.9	50
Bathroom	6.1	50
Toilet	1.9	25

Table 1: Dimensioning of the ventilation system

It can be seen that the Belgian standard doesn't impose a balance between supply and exhaust flow rates.

4. VENTILATION TESTS

4.1 Measurements realised

The first type of measurement realised concerns the ventilation rates in the rooms. Tracer gases have been used to determine the ventilation rates in the different rooms of the house. We have used the constant concentration technique, which is the more suitable for long term monitoring [2]. Two different gases have been used: the first one (N_2O) has been injected at the level of the bedrooms, the hall and the living room. The second gas (SF_6) has been injected at the level of the kitchen, the bathroom and the toilet. The set of rooms where the same gas is injected is called a "zone". It has to be underlined that inside one zone, it is impossible to determine the internal airflow rates. For instance, in the case of the supply rooms, the measured airflows correspond to fresh air coming from the outside (or from the zone 2). Airflows that would go from one bedroom to the other one would not be measured since it is already charged with tracer gas. Specialised equipment controlled by computer in parallel with a data acquisition system has been used to realise the measurements. With the configuration adopted, one measurement of the airflow was obtained each 15 minutes. The results presented in this paper are one-hour average values of the airflow rates.

The second type of measurement realised is the wind pressure on the façades of the house. Metallic plates have been fixed on façades (near the supply grilles) and the pressures have been measured at the level of these plates. The most interesting measurements to mention in the scope of this paper are the two pressure differences measured between the inside of the house (at the level of the big bedroom and of the living room) and the outside on the West and the South façades. All the system was coupled to a data acquisition system. The measurements presented in this paper correspond to 10 minutes average values of the pressure on the façades.

The last measurements registered are the meteorological data. A permanent meteo station is installed on the site of the research centre of BBRI. This station registers among other things the wind speed and direction and the external temperature (10 minutes average values have been used in the scope of this paper).

4.2 The tests

Four tests with different configurations of ventilation systems have been realised. The duration of each test was about 9 days. Table 2 summarises the characteristics of the ventilation systems tested.

Test n°	Air supply	Air exhaust
1	Natural Normal grilles open	Mechanical Constant exhaust
2	Natural Self-regulating grilles open	Mechanical Constant exhaust
3	Natural Self-regulating grilles closed	Mechanical Constant exhaust
4	Natural Self-regulating grilles closed	Mechanical exhaust OFF

Table 2: Configuration of the ventilation systems tested

Two types of supply grilles have been used during the tests:

- The first type called in this paper "Normal grille" (as opposed to the "Self-Regulating grilles") has not any self-regulating part and can only be opened or closed manually. The relation airflow – pressure difference of this type of grille can be characterised by a relation of the type $Q = C\, \Delta P^n$.
- The second type of supply grille is the Self-Regulating grille (also called in this paper SR grilles). This grille is characterised by a rubber tongue that is integrated in the grille. When a pressure difference appears between the outside and the inside, the tongue closes progressively the opening section and the airflow through the grille is limited. This regulation occurs without any intervention of the user. This relation airflow – pressure difference of this type of grille cannot be characterised by a single couple of values C, n and the complete characteristic of the grille has to be measured (see Figure 7). A separated mechanism permits to the user to manually open or close the grille.

The Figure 2 shows the exact position of the ventilation devices (supply and exhaust grilles). For the tests realised with self-regulating grilles, since the nominal airflow of these grilles is lower than the nominal airflow of the normal grilles, a third grille has been placed in the living room on the east façade.

Since the objective was not to test the impact of the transfer openings on the ventilation pattern observed in the house, the tests have been realised with all the internal doors open. In order to avoid a perfect mixing of the air inside the house, plastic sheets have been placed at the level of the internal doors and gaps of about 250cm² have been left open at the bottom of each door.

During the tests, the house has been heated at a constant temperature of about 20°C.

5. RESULTS OF THE TESTS

5.1 Test 1 – Natural air supply – mechanical exhaust

The first test of a duration of about 10 days has been realised with "Normal" adjustable supply grilles (in full open position) and a permanent mechanical exhaust. The supply grilles provide a nominal airflow equal to 85m³/h per meter length at 2Pa. No regulation is placed on the mechanical exhaust, it means that the nominal airflows are realised continuously. The Table 3 summarises the meteorological conditions during the test. Very low wind speeds have been observed.

Wind speed (m/s)		Outside temperature (°C)	
Average speed	1.4	Average temperature	2.3
Standard deviation	0.9	Minimum	-3.6
Maximum speed observed	5.0	Maximum	9.5

Table 3: Meteorological conditions during the first test

For the rooms equipped with natural supply grilles, typical results are presented in the Figure 3. Although the airflows seem sometimes very variable, the Figure 4 shows that a very good correlation exists between the airflow measured in the room and the wind pressure on the façade.

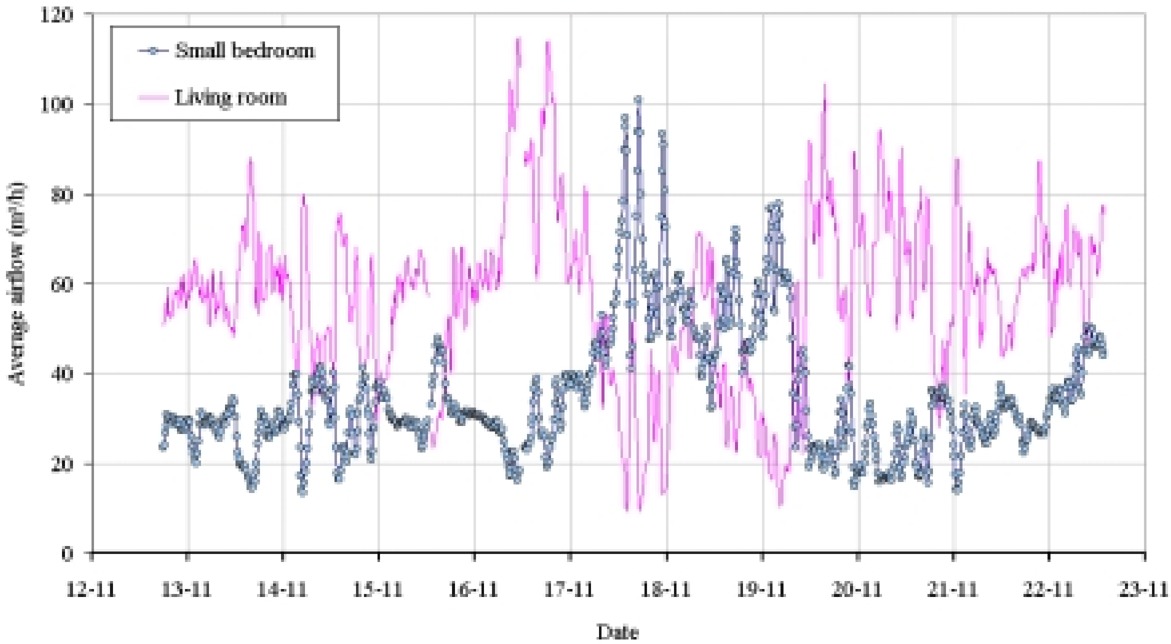


Figure 3: Airflows measured in rooms equipped with natural supply grilles

The fact that the airflow in the room is not equal to zero when the measured pressure difference is zero can be explained by the fact that the pressure reference on this figure is taken in the other bedroom about one meter below the level of the grille. Moreover the pressure reference at the outside is not taken precisely on the grille but on the façade at the height of the grille. Finally, the airflow in the bedroom is not only characterised by the pressure difference on this façade.

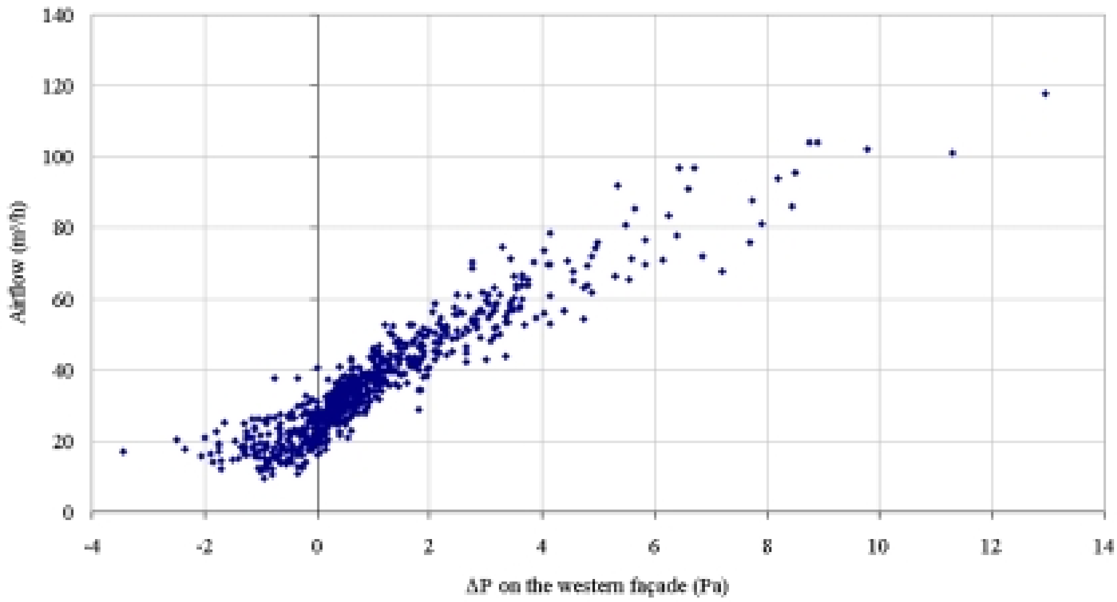


Figure 4: Correlation between airflow measured in the small bedroom and the difference of pressure on the façade where the supply grille is installed

The picture is different if we look to the rooms equipped with a permanent mechanical exhaust. The airflows are more constant. The variability observed is mainly due to infiltration, it can be observed in the kitchen where an external door and a window exist. We can see during the period where no wind is observed that the airflows in the rooms are very stable.

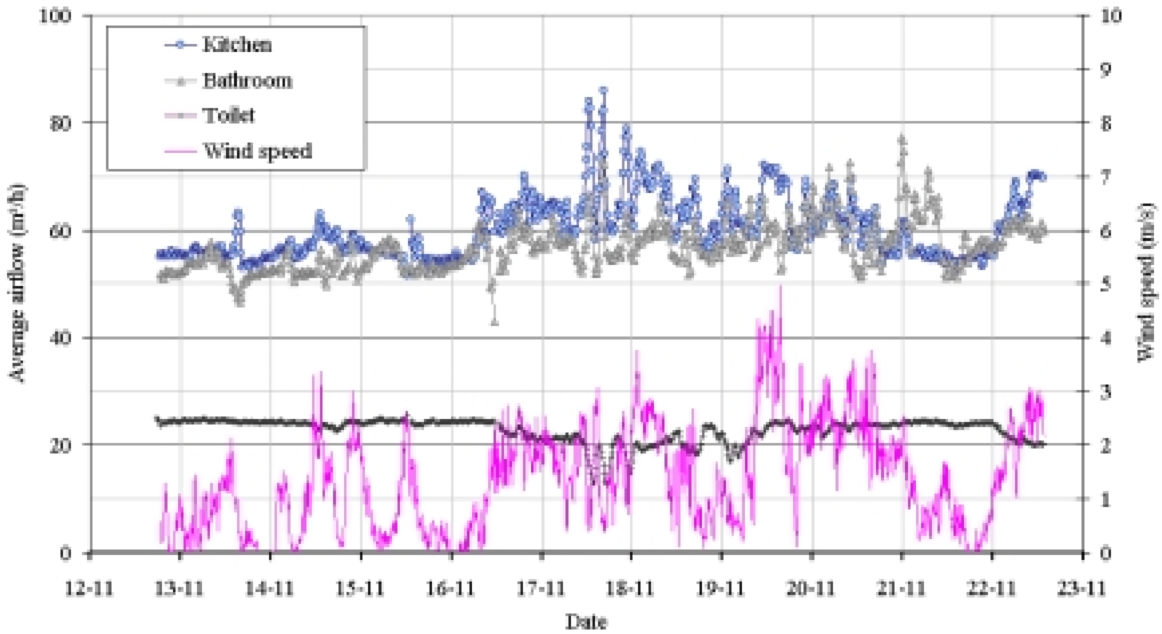
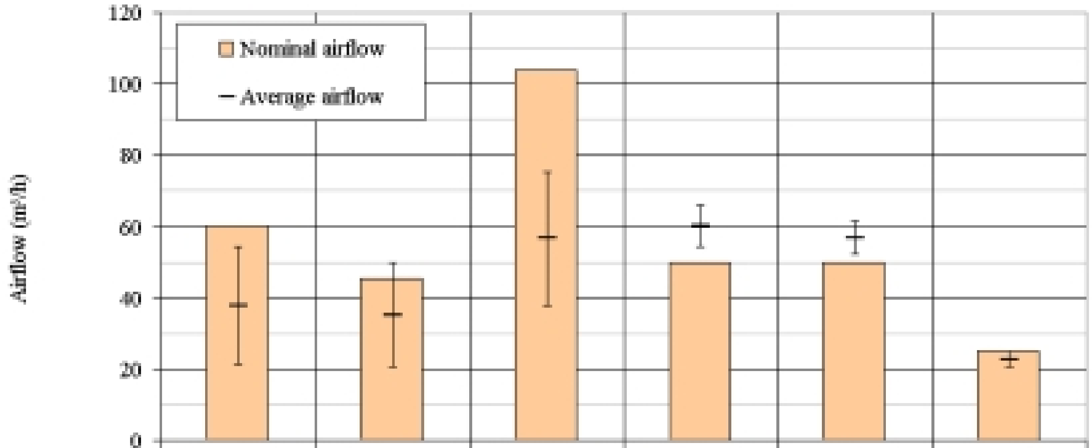


Figure 5: Airflows measured in rooms equipped with permanent mechanical exhaust

It is interesting to observe that higher airflows in the kitchen seems to correspond to lower airflows in the toilet. This is due to a transfer of air going from the kitchen to the toilet. As already explained in this paper, the same tracer gas is used to measure the airflows in the kitchen and in the toilet. At this particular time, a part of the air going to the toilet comes from the kitchen; since this air is already charged with tracer gas (SF_6), this airflow cannot be detected and lower values of the airflow are calculated. This is inherent to the principle of measurement. Several punctual injections of CO_2 in different rooms (bedrooms, living room, and kitchen) have shown that this phenomenon (air transfer inside the same zone) occurs rarely so the results presented here can be considered as valid.

The summary of the results obtained in the different rooms is given in the Figure 6.



	Big bedroom	Small bedroom	Living-room	Kitchen	Bathroom	Toilet
Nominal airflow	60	45	104	50	50	25
Average airflow	38	35	57	60	57	23
Standard deviation	17	15	19	6	5	2
	Equipped with supply grilles			Equipped with mechanical exhaust		

Figure 6: Summary of the results obtained in the different rooms

The average airflows are compared with the nominal airflows. The chart indicates also the standard deviation of the airflow. The results are very different following the type of ventilation device present in the rooms. In the rooms equipped with natural supply grilles, the airflows are variable and the nominal airflow is in general not reached. This is explained by the average pressure difference observed on the façade, which is lower than 2 Pa during this particular period. The rooms equipped with mechanical exhaust show much more stable airflows, which correspond well with the nominal airflows required.

5.2 Test 2 – Natural air supply by self-regulating grilles – mechanical exhaust

The ventilation system tested during the second test is natural air supply realised via SR grilles with a permanent mechanical exhaust. No regulation is placed on the exhaust. The meteorological conditions during the test are described in the Table 4.

Wind speed (m/s)		Outside temperature (°C)	
Average speed	4.0	Average temperature	6.5
Standard deviation	2.0	Minimum	0.3
Maximum speed observed	9.8	Maximum	11

Table 4: Meteorological conditions during the second test

A comparison between the type of self-regulating grille used and a comparable normal grille is made on Figure 7. The arrow shows the difference for a given pressure difference between the airflows realised by the two types of supply grilles. Note that this characteristic can be noticeable variable from one grille to another one. The phenomenon of hysteresis is not shown here.

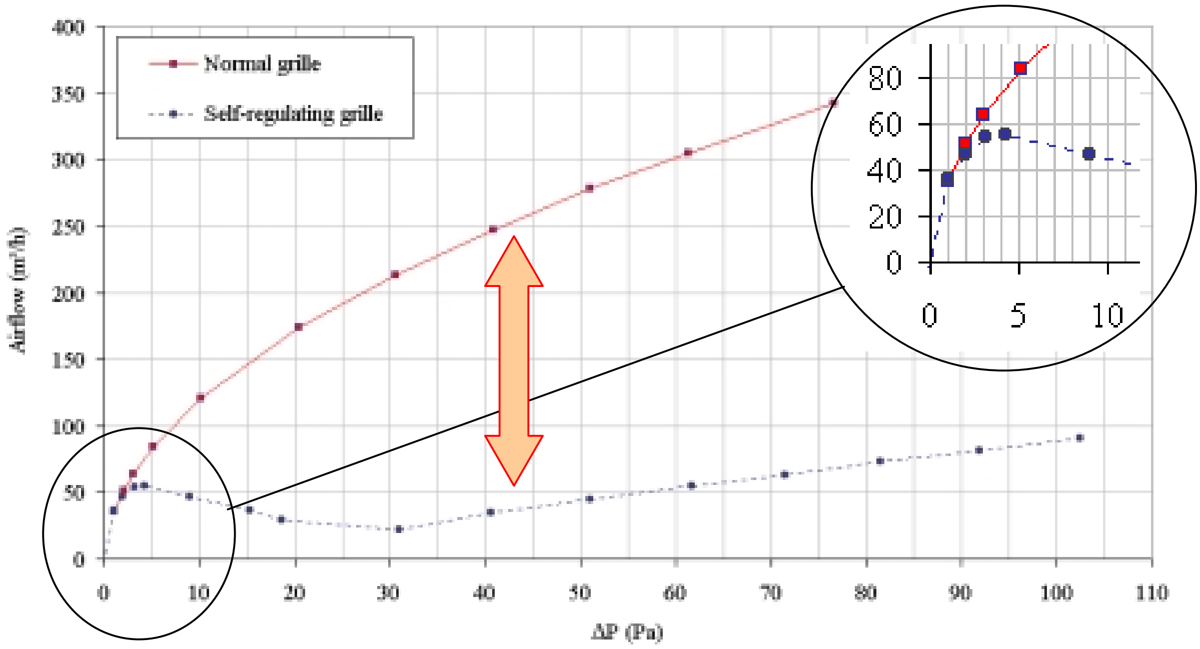


Figure 7: Measured characteristic of the self-regulating grille used per meter length

The most interesting result is the relation between the airflow and the pressure of the wind on the façade where the supply grille is installed. The Figure 8 illustrates this relation for the big bedroom. In addition, the results of the first test with the normal supply grilles are also presented in this figure.

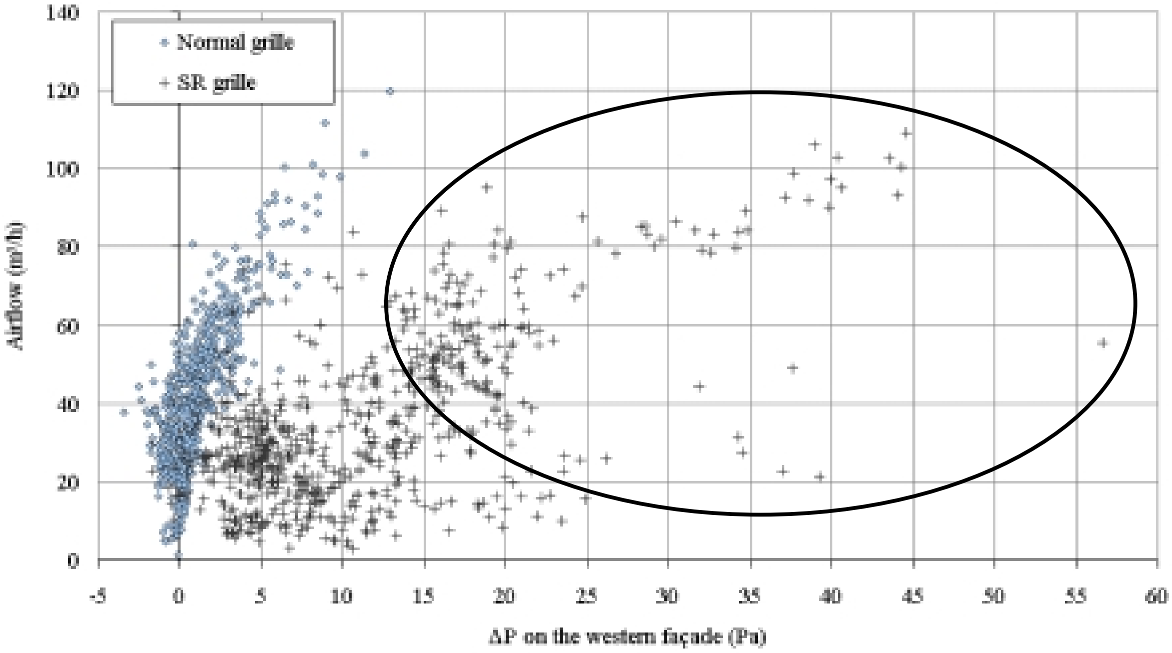
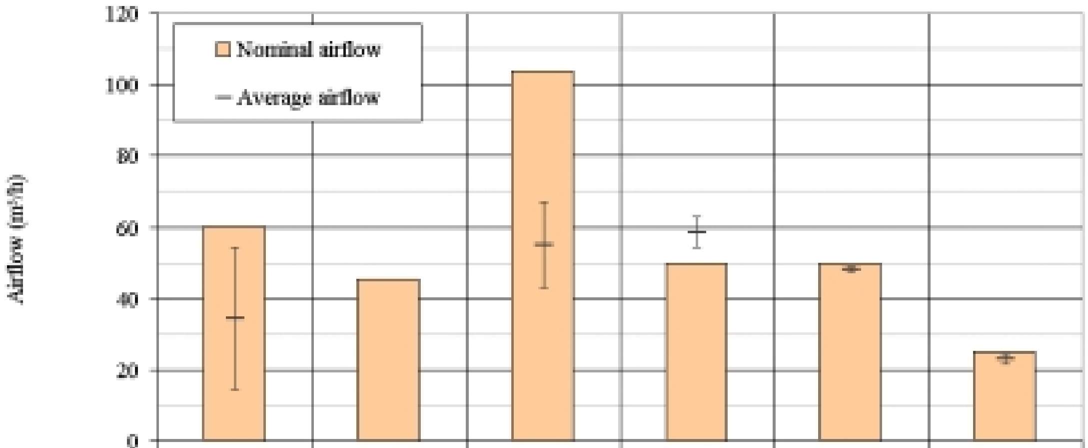


Figure 8: Comparison of the relation Q– ΔP for the normal and the SR grille in the big bedroom

The area indicated on the chart represents the interest of the self-regulating grilles. For such pressures on the façade (15-60Pa), the airflow rates were restricted. This is favourable to limit the draught problems and can have important energetic consequences when ventilation is synonym with energetic losses (during the winter).

Figure 9 summarises the results of this test.



	Big bedroom	Small bedroom	Living-room	Kitchen	Bathroom	Toilet
Nominal airflow	60	45	104	50	50	25
Average airflow	34	n.a.	55	59	48	23
Standard deviation	20	n.a.	12	4	1	1
	Equipped with supply grilles			Equipped with mechanical exhaust		

Figure 9: Summary of the results observed with self-regulating grilles

Although more wind has been registered during this test, the airflows stay limited and the variability of the airflows is totally comparable to what was observed with normal supply grilles.

5.3 Test 3 : ventilation grilles closed

A situation that can be encountered in the reality is that the supply grilles are manually closed, for instance because of the wind, and that they are kept closed. The mechanical exhaust is still working. The meteorological conditions during the test are given in the Table 5.

Wind speed (m/s)		Outside temperature (°C)	
Average speed	3.1	Average temperature	4
Standard deviation	2.1	Minimum	-3.3
Maximum speed observed	11.3	Maximum	11.3

Table 5: Meteorological conditions during the third test

All the airflows are now remarkably stable. In particular, the airflows observed in the rooms equipped with natural supply grilles are very stable compared with the previous results. The average airflows are lower.

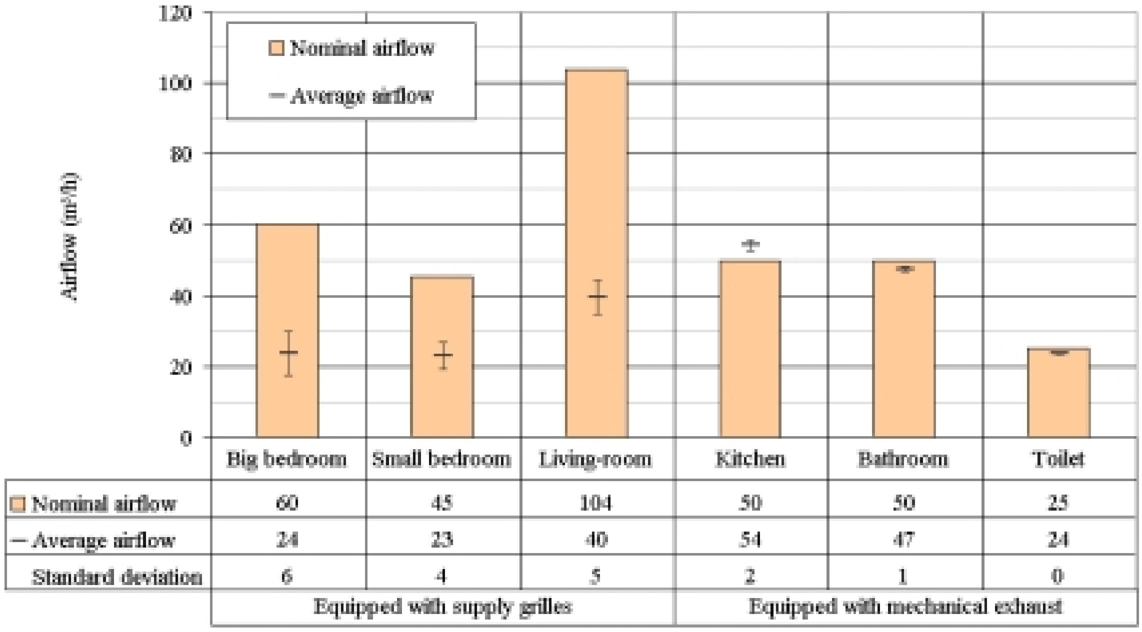


Figure 10: Summary of the airflows measured with the supply grilles closed

5.4 Test 4 : No ventilation system used

For this test, a ventilation system is installed but is not used: the self-regulating grilles installed in the house have been manually closed but not sealed and the fan has been switched off.

The meteorological conditions are given in the Table 6.

Wind speed (m/s)		Outside temperature (°C)	
Average speed	2.5	Average temperature	4.7
Standard deviation	1.7	Minimum	0.3
Maximum speed observed	8	Maximum	9.0

Table 6: Meteorological conditions during the second test

The summary of the results shows that all the average airflows are lower or equal to 10 m³/h. Airflows of 5 m³/h are observed in the bedrooms. These results show if needed that in very tight houses, only the installation of a ventilation system is not sufficient, the use of the equipment is also a requirement to insure sufficient IAQ.

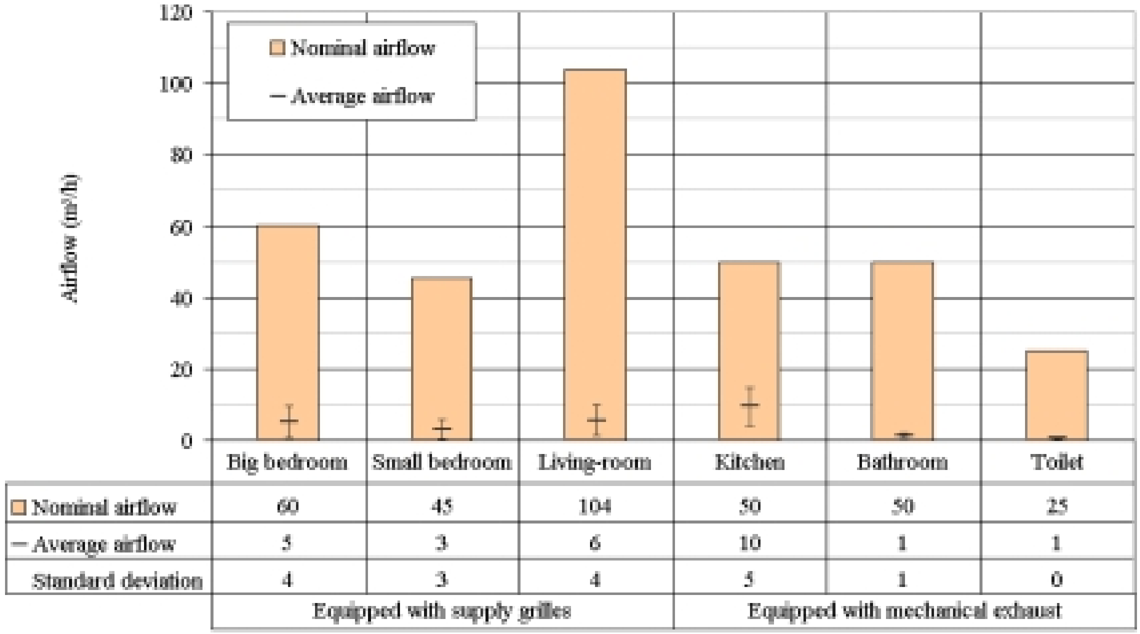


Figure 11: Airflows observed when no ventilation system is used

Based on these data, we have calculated the infiltration rate observed during this test (n= $0.06h^{-1}$). The results are compared with the ventilation rate n_{50} calculated by the pressurisation test of the house ($n_{50} = 2.04\ h^{-1}$). The factor 'a' indicates the relation between the n_{50} and the infiltration rate ($n = n_{50} / a$). It is used to estimate the infiltration rate due to natural ventilation during the heating season. This factor has generally a value varying between 10 and 30 depending on the exposure to the wind.

It has to be noted that the factor calculated here is based on 9 days of measurements and that the corresponding meteorological conditions are not necessarily equal to the average conditions observed during the heating season. In this case, the factor is equal to 36.1.

6. CONCLUSIONS

According to the Belgian standard of ventilation, when natural ventilation is used, the ventilation devices have to be dimensioned for a pressure difference of 2Pa. During these tests, with the meteorological conditions observed, the nominal airflows are not reached in the rooms ventilated by natural ventilation. This fact is observed with normal grilles as well as with self-regulating grilles. This result is valid for the period of time considered and no conclusions about the relevance of the Belgian approach can be extrapolated from these results. The ventilation rates observed are variable in the time but are very well correlated with the meteorological conditions observed during the tests.

Self-regulating grilles are able to limit the over-ventilation and therefore to avoid draught problems and to reduce the ventilation losses during the heating season. The airflows observed are also more stable with self-regulating grilles than with normal grilles, even when higher wind speeds are observed.

The rooms equipped with mechanical ventilation presents much more stable airflows. The requirements of the standard are fulfilled for all the configurations of the ventilation system tested where the fan is working. The part of infiltration in these rooms can clearly be identified from the results.

The last test realised has shown if needed the importance of the ventilation system. It appears that to install a system is not sufficient, the correct use of it is at least as important as the installation of the system itself.

7. ACKOWLEDGEMENTS

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8. REFERENCES

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