Ventilation
Information
Paper
n° 19

May 2008

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International Energy Agency
Energy Conservation in Buildings
and Community Systems Programme

Air Infiltration and Ventilation Centre

Trends in the French building ventilation market and drivers for changes

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1 Introduction

This paper presents evolutions of the French building ventilation regulations and market, with attention paid to IAQ, energy, air tightness and the assessment of innovative systems.

France[1] has 61 millions inhabitants (2006). Building stock includes[2] 30.7 millions dwellings (2005), 33% built before 1949. Main dwellings are houses (56%) and apartments (44%). Their mean surface[1] is 90 m^2 for 2.4 persons and their mean final energy consumption[2] is 208 kWh/m^2/year, 74% for heating and ventilation. Occupants are owners (56%) or tenants (38%). 402 000 new dwellings have been built in 2006[1] (57% houses, 43% apartments).

Non-residential heated buildings surface[2] is 840 millions m^2, 2/3 of them for shopping, offices and education. Their mean energy consumption[2] is 222 kWh/m^2/year, 63% for heating, ventilation and domestic hot water. Non-residential new buildings[3] built in 2007 are for offices (4.5 Mm^2), shopping (4.7 Mm^2), health care (3.4 Mm^2), culture (2.2 Mm^2), education (2 Mm^2), industry, agriculture or storage of goods (23.2 Mm^2).

[1] Source: INSEE. www.insee.fr
[2] Source : ADEME. www.ademe.fr
[3] Source : MEDAD, 2008. www.developpement-durable.gouv.fr

2 National trends in IAQ requirements and market

2.1 Requirements on ventilation of dwellings

The French regulation concerning residential buildings ventilation mainly relies on the *« Arrêté du 24 mars 1982 relatif à l'aération des logements »* [1]. This order relates to air renewal in new dwellings.

Its main requirements are :

- overall and continuous air renewal,
- air inlets (natural or mechanical) in main rooms, which can be adjustable or self-adjustable, but cannot be blocked,
- air exhausts (natural or mechanical) in kitchen, bathroom(s), toilet(s),
- ventilation system that must be able to ensure exhaust air flow rates mentioned in Table1 (simultaneously or not),
- individual adjustment devices which allow the reduction of reduce exhaust air flow rates, provided that the total (and kitchen) exhaust air flow rates remain greater than values of Table 2.

In practice, these requirements have usually been achieved by using centralised mechanical exhaust systems, with two-stages exhaust rates in kitchens and fixed exhaust rates in bathrooms and toilets. Demand controlled ventilation is usually based on humidity control systems, integrated to air outlets and possibly also to air inlets

Table 1: requirements for achievable exhaust air flow rate

Number of main rooms	Achievable exhaust air flow rate (m³/h)				
	Kitchen	Bathroom with toilet	Other bathroom	Toilet	
				First one	Others
1	75	15	15	15	15
2	90	15	15	15	15
3	105	30	15	15	15
4	120	30	15	30	15
5 and more	135	30	15	30	15

Table 2: requirements for minimum values of reduced air flow rates

Number of main rooms	Minimum values of reduced exhaust air flow rates (m³/h)		
	Without demand controlled ventilation		With demand controlled ventilation
	Total exhaust	Kitchen	Total exhaust
1	35	20	10
2	60	30	10
3	75	45	15
4	90	45	20
5	105	45	25
6	120	45	30
7	135	45	35

Table 3: Ventilation systems in residential buildings stock (source: AIR .H, 2007)

	Multifamily buildings (13.1 millions dwellings)	One-family houses (17.3 millions)	Total dwellings stock (30.4 millions)
No ventilation system	9 %	14 %	12 %
Room by room ventilation	34 %	36 %	35 %
Overall ventilation	57 %	50 %	53 %
Overall natural	*17.6 %*	*22 %*	*20 %*
Overall mechanical	*39.5 %*	*28 %*	*33 %*

The *« Règlement Sanitaire Départemental Type »* [2] (typical local health regulation), linked to the *« Code de la Santé Publique »* (Public Health Code), gives supplementary detailed requirements about the design of ventilation systems for new and existing dwellings: air inlets, air exhausts and air outlets positions, ventilation coupled with combustion appliances, …

French Standards NF P 50-410 [3] and 411 [4], also known as DTU 68.1 and 68.2, relate to design and installation requirements for new mechanical overall ventilation systems in new or existing buildings. They are used as references by insurance companies to cover the risks of damage linked to the malfunctioning of ventilation systems.

These regulations and standards have not changed in the last years but their revision could occur in the future.

2.2 Ventilation systems in residential buildings stock and market

AIR.H[4] estimated in a recent study for ADEME [6] that more than half of the French stock of residential buildings is now equipped with a ventilation system for overall dwelling (Table 3).

AIR.H also estimates that the market for different ventilation systems is shared- as shown in Tab.4 for new buildings on the in 2000-2004.

The compliance to the requirements of the regulations and standards contributed to the improvement of actual indoor air quality in dwellings by establishing minimum air flow rates requirements and increasing the number of residential buildings equipped with a demand controlled ventilation system.

[1] The objectives of AIR.H are to promote mechanical ventilation for health and comfort residential and non residential buildings, to contribute to the improvement of the quality of installed systems, to act as a privileged spokesman of the government for the future revision of the regulation. Members of AIR.H Association are 5 ventilation systems manufacturers (AERECO, ALDES, ANJOS, FRANCE AIR, UNELVENT) and 2 organisations (CETIAT, UNICLIMA).

Table 4: Market share for new residential buildings 2000-2004 (source: AIR .H, 2007)

	Multifamily buildings (653 000 dwellings)	One-family houses (1.04 millions)
No ventilation system		1 %
Room by room natural		4 %
Room by room mechanical		3 %
Overall natural	3 %	1 %
Overall mechanical	98 %	91 %
Exhaust only without demand control of air flow rates	*53 %*	*54 %*
Exhaust only with demand control of air flow rates	*44 %*	*36 %*
Balanced systems	*1 %*	*2 %*

Nevertheless, on-site checks in new residential buildings operated by CETEs (Centres Techniques de l'Equipement) show [5] that 40 to 50% of the checked dwellings do not comply to the regulation for minimum or maximum exhaust air flow rates.

This figure emphasises the need for improved training of installers, increased quality in the construction process as well as commissioning of systems after their installation.

2.3 Requirements on ventilation of non residential buildings

The French regulation about commercial buildings ventilation mainly relies on the « *Code du Travail* » (Work Code) [7] for buildings occupied by workers and on the « *Règlement Sanitaire Départemental Type* » [2] (typical local health regulation, known as RSDT), linked to the *« Code de la Santé Publique »* (Public Health Code), for buildings receiving public .

These two regulations (RSDT and *« Code du Travail »*) define air renewal flow rates in new or existing buildings, according to their destination and use.

RSDT (for building receiving public) covers buildings or rooms such as : education buildings, dormitories, offices receiving public, libraries, banks, post offices, meeting rooms, cinemas, churches, shops, supermarkets, restaurants, swimming pools, sports buildings,… It also applies to rooms with specific air pollution sources: bathrooms, showers, toilets, laundry, commercial kitchens,…

As an example, the minimum required fresh air flow rate for cinemas is 18 m^3/h/occupant. For kitchens serving less than 150 meals simultaneously, the requirement is 25 m^3/h/meal.

Work Code (for buildings occupied by workers) requires minimum fresh air flow rates for rooms such as offices, restaurants, shops, meeting rooms, workshops.

Minimum fresh air required in offices is for example 25 m^3/h/occupant, as it is up to 60 m^3/h/occupant for workshops.

Other requirements of RSDT concern:

- position of air inlets far from outdoor pollution sources (8 m),
- position of air outlets far from windows or air inlets (8 m),
- air filtration with mechanical systems,
- air circulation patterns from rooms without specific pollution source to others, air recycling.

2.4 Ventilation systems in non residential buildings stock and market

AIR.H estimated in a recent study for ADEME [6] that more than 57% of the square meter surface of the French stock of commercial buildings (Table 5) is now equipped with an overall ventilation system or air handling unit.

About half of offices, shops and education buildings have as yet no ventilation system.

Table 5: Ventilation systems in commercial buildings stock (source: AIR .H, 2007)

	Offices	Shops	Education buildings	Health care buildings	Leisure buildings	Hotels	Total
Stock (thousands square meters)	3 026	3 732	1 747	1 700	1 666	821	12 692
No ventilation system	50 %	40 %	60 %		10 %	5 %	34 %
Overall natural						9 %	1 %
Room by room mechanical	10 %	10 %		15 %	20 %		10 %
Overall mechanical	20 %		39 %	50 %		85 %	22 %
Exhaust only without demand control of air flow rates	*9 %*		*20 %*	*25 %*		*75 %*	*13 %*
Exhaust only with demand control of air flow rates	*1 %*						*0.2 %*
Balanced systems	*10 %*		*19 %*	*25 %*		*10 %*	*9 %*
Air handling unit	20 %	50 %	1 %	35 %	70 %	1 %	34 %

3 National trends in energy requirements and market

3.1 Requirements on ventilation

Energy requirements for ventilation are mainly covered by the RT 2005 buildings energy regulation [8], [9]. It is an evolution of the previous regulation RT 2000[10]. It aims to improve the energy efficiency and the summer comfort of new buildings, based on:

- the compliance to "minimum" requirements for building and components characteristics
- a calculated Cep coefficient (primary energy in kWh/m^2/year) which must be less than a reference coefficient Cep $_{ref}$. This reference coefficient is obtained by replacing in the calculation the actual planned building components by reference ones. The calculation method takes into account ventilation, as well as heating, cooling, domestic hot water production and lighting.
- the calculation of the maximum operative temperature in summer for a reference day Tic. This calculation follows the same logic as the Cep calculation. Tic is also compared to a Tic $_{ref}$ as a reference.

The ventilation system used as a reference can be described as follows [9]:

- for residential buildings : an exhaust only system, with a fan of an electrical power equal to 0.25 W/m^3/h (or 0.40 W/m^3/h with filters), with demand controlled air flow rates allowing to decrease energy losses
- due to air renewal by 10% (or by 25% for dwellings with direct electrical heating) ;
- in practice, such decrease can be achieved with humidity controlled systems ;
- for non residential buildings : balanced system without heat recovery, with blowing and exhaust fans of electrical power equal to 0.30 W/m^3/h (or 0.45 W/m^3/h with filters).

Minimum requirements for ventilation system relate for example to:

- thermal insulation of air ducts in some cases,
- the need to use separate ventilation systems for different zones of non-residential buildings having different occupations, uses or pollutants emissions,
- the capacity of mechanical ventilation systems in non-residential buildings to operate at minimum air flow rate when they are not occupied,
- …

For the installation or replacement of ventilation systems in existing residential buildings, the regulation [11] specifies that the electrical consumption of each ventilation fan must not exceed 0.25 W/m^3/h (or 0.40 W/m^3/h with filters F5-F9). For non-residential buildings, the same approach applies with values of 0.30 and 0.45 W/m^3/h. These values can be majored of 0.05 W/m^3/h until 30 June 2009. Regulation also requires an automatic control of air flow rates for occupied and non-occupied building greater than 400 m^2.

These regulations and their recent changes are a strong driver for ventilation systems leading to less energy consumption, either by control of air flow rates or by limitation of electrical consumption of fans. Future revisions of these building energy regulations will continue to strengthen the requirements.

3.2 Energy savings certificates

Another driver for the improvement of energy performance of buildings through ventilation could be the energy savings certificates scheme (sometimes called « white » certificates or tradable certificates for energy savings).

This system relies on energy savings targets fixed by the government for energy suppliers. The target can be reached by the energy supplier by getting from the government energy savings certificates [12], providing a guarantee that a certain amount of energy savings has been achieved by the energy supplier itself or by its clients. If the total of the energy savings certificates is not sufficient to reach the target, additional certificates can be bought by other parties.

Standard eligible measures to get energy savings certificates [13] have been identified and are covered by a list of 139 standard operations. Each of them is described with the conditions for its eligibility, and the conventional figure of energy savings is given.

Several standard energy savings operations concern the installation of ventilation systems in non-ventilated buildings, ventilation systems with demand controlled air flow rates, balanced ventilation systems with heat recovery, … In each case, an energy savings figure is given for the whole life of the system and used by the government when establishing energy savings certificates.

4 National trends in air tightness requirements and market

Requirements for building envelope or ventilation network air tightness in new buildings are covered by the RT 2005 buildings energy regulation [8], [9].

The reference air tightness of building envelope under 4 Pa is defined as follows [9]:

- for one-family houses: 0.8 $m^3/h/m^2$ of envelope area,
- for other residential buildings, offices, hotels, restaurants, education buildings, health care buildings : 1.2 $m^3/h/m^2$,
- for other buildings : 2.5 $m^3/h/m^2$.

The air leakage of the network of the reference ventilation system is fixed at 5% of the exhaust air flow rate.

These regulations and their recent changes are a strong driver for ventilation systems leading to less energy consumption, either by control of air flow rates or by limitation of electrical consumption of fans. It is announced that the future revisions of these building energy regulations will continue to strengthen the requirements.

On-site checks operated by CETE de Lyon [14] and [15] show that the actual air tightness of building envelopes is not good. Results on 215 one-family houses, 23 dwellings, hotels, education and health care buildings and 25 other building show that:

- the mean air tightness of one-family houses under 50 Pa is about 3 vol/h,
- the mean air tightness of other checked buildings under 50 Pa is greater than 6 vol/h,
- less than 5% of checked buildings have an air tightness lower than 1 vo/h.

Nevertheless, recent measurements of CETE de Lyon on real pilot buildings have shown [14] and [15] that better values can be achieved:

- 80% of the dwellings of a multifamily building have an air tightness lower than 1 vol/h under 50 Pa,
- an air tightness of 0.9 vol/h was achieved for a renovation of an office building.

Concerning air tightness of ventilation network, a field study by CETE de Lyon and ENTPE, partly funded by ADEME, gave results [16] for a sample of 9 duct systems in multifamily buildings (4 to 5 storeys), 8 in schools, 2 in a day-care centre and 3 in office buildings. Significant deficiencies were observed, leading to high air leakage well above the Class A level of EN 12237 ($K < 0.027 \cdot 10^{-3}$ m s^{-1} $Pa^{-0.65}$).

Table 6: Air leakage of ventilation networks (source: CETE de Lyon, ENTPE - 1996)

	Average air leakage coefficient K ($m^3 . s^{-1} . m^{-2} . Pa^{-0.65}$)
Multifamily buildings (9)	$0.125 . 10^{-3}$
Non residential buildings (13)	$0.066 . 10^{-3}$

Recent on-site measurements by CETIAT [17] for 3 networks with joints showed that class A, B (3 times less air leakage than class A) or C (3 times less air leakage than class B) of EN 12237 [18] were achievable with these components equipped with joints, according to the way they are installed.

Default values used by the calculation of the buildings energy regulation [9] is taken as $K=0.0675 . 10^{-3}$ (or $K=0.027 . 10^{-3}$ when rigid ducts of class C are used).

Ducts and network accessories with joints are not used much although they give a bonus in energy calculations. Apart from cost considerations, reasons for this low market share are not well identified.

5 National trends in innovative systems and market

The buildings energy regulation [9] describes how innovative systems can be taken into account.

If the energy calculation method is not applicable to an innovative system, an application for approval of the method for justification of using this innovative system must be sent to the Ministry of construction and housing.

This application is accompanied by a description of the system and of its energy performance (test reports, measurement results), input data for the parts of the calculation method which are applicable and a detailed description of the reasons that make other parts of the calculation method non applicable. The applicant may also submit a proposal to adapt the calculation method.

The Minister of Construction and Housing approves the proposal after taking the opinion of an Experts Committee established for that purpose.

6 Other points of attention or trends

Buildings acoustics regulation also concern ventilation systems.

Its main requirements for residential buildings [19] are as follows:

- Sound pressure level inside building rooms $L_{n\ AT}$ due to the ventilation system at reduced flow rate must remain lower than 30 dB(A) in the main rooms and 35 dB(A) in the kitchen.
- Sound insulation between outside and inside $D_{n\ T,Atr}$, i.e. the insulation of the facade including its air inlets, must be higher than 30 dB.
- Sound insulation between two dwellings Dn T,A must remain higher than 50 dB for bathrooms and kitchens. This applies in particular to air exhausts and ventilation network which must not transmit too much noise from one dwelling to the other.

Ventilation components are designed according to these requirements, and tested to make sure that these requirements will be fulfilled when they are installed an used.

This type of requirement also exist for hotels [20], schools [21] and health care buildings [22]. Requirements concern sound pressure levels in rooms, as well as sound insulation between outside and inside and between rooms.

Ventilation is also concerned by regulations about fire risks for residential or public buildings [23], [24].

Finally [25], smoking is now prohibited in all closed or covered public places - except in well ventilated enclosures especially dedicated to smoking - as well as in uncovered spaces in schools.

7 Conclusions

Building ventilation is well covered by French regulations. They cover general design of ventilation systems, air flow rates, energy consumption due to air renewal and fans, air tightness of building envelope and ventilation ducts, noise, fire risks.

These regulations have been drivers for changes: type of ventilation systems used, market share between systems, percentage of ventilated buildings, components performance in terms of air flows, energy consumption, noise.

Their future evolutions will create new drivers for change, together with the recently introduced energy savings certificates.

There exists a great need for improved information and training of all the actors in the construction process, in order to increase buildings quality in the framework of this changing regulations landscape.

8 References

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9 Acknowledgements

This paper has been reviewed and amended with comments from: Pierre Deroubaix (ADEME), Anne-Marie Bernard (ALLIE'AIR), Rémi Carrié (CETE de Lyon), Gérard Guarracino (ENTPE), François Bessac (CETIAT), Laure Schwenzfeier (CETIAT).

This information paper is one of the outcomes of the workshop 'Trends in national building ventilation markets and drivers for change', held in Ghent (Belgium) on March 18 and 19 2008. This workshop was an initiative of AIVC, organized by INIVE EEIG, in collaboration with REHVA and with the European SAVE-ASIEPI and SAVE Building Advent Projects. The workshop was supported by the EPBD Buildings Platform.

The Air Infiltration and Ventilation Centre was inaugurated through the International Energy Agency and is funded by the following countries: Belgium, Czech Republic, Denmark, France, Greece, Japan, Republic of Korea, Netherlands, Norway and United States of America.

The Air Infiltration and Ventilation Centre provides technical support in air infiltration and ventilation research and application. The aim is to promote the understanding of the complex behaviour of the air flow in buildings and to advance the effective application of associated energy saving measures in the design of new buildings and the improvement of the existing building stock.